Cooperative Institute for Marine and Atmospheric Studies

Third Annual Report

NOAA Cooperative Agreement NA10OAR4320143

July 1, 2012 – June 30, 2013

Peter B. Ortner, Director
David Die, Associate Director

UNIVERSITY OF MIAMI
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 encompasses seven inter-related Research Themes which are linked to NOAA's Strategic Science Goals. These mandatory Research Themes were specified and defined 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) under the present Cooperative Agreement (CA) during this reporting period was $17.1M. Task I which includes not only Administration but also Research Infrastructure (shiptime, computing resource access etc.), Education and Outreach was ca. $1.6M. The University of Miami contributed an additional $.24M towards Administration. Task II, which supports CIMAS employees conducting research off- campus was ca. $ 8.9M.

Research project funding (Tasks III and IV) totaled ca. $6.7M. 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 69%. The smallest portions were in Themes (4, 5 and 7) Ocean Modeling, Ecosystem Modeling & Forecasting and Protection and Restoration of Resources which together account for only 9%. 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 (Tasks II, III or IV) refer only to those under the new CA initiated October 2010. They do not include continuing expenditures during these same time period under prior agreements with CIMAS (the last of the so-called Shadow Awards).

During this reporting period a total of 126 individuals at UM were directly provided salary support through CIMAS. Of these, 106 received over 50% of their support through CIMAS. Of the 106 research employees who received over 50% NOAA support, 68 worked with AOML, 34 with SEFSC, 3 with RSMAS and one with the NHC. Twenty seven of these employees were

Research Scientists including 4 part time former NOAA employees. The employees in the Research Associate and Research Scientist ranks have a diverse demographic profile. The population is 56% female. Foreign-born individuals make up 53% of the personnel. Of these, Hispanics make up 20% of the ranks; Asian and Pacific Islander, 19%. 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 the same to last year's demographic profile.

During this last year there were 96 peer-reviewed publications and another 14 non-peer reviewed technical reports or other publications resulting from CIMAS research. Partial 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. An attempt was made to avoid highlighting continuing projects highlighted in the two prior annual reports. 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 Research Themes or for individual competitive program awards made to CIMAS investigators under the new CI competitive award policy in an Appendix to be made available on the CIMAS website. That Appendix will contain abstracts from the most recent progress reports furnished to the NOAA competitive program offices that funded those projects.

Research, educational and outreach activities conducted by CIMAS during the twelve months summarized herein but related to prior Cooperative Agreements through Shadow Awards 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*:** The Western Boundary Time Series (WBTS) project maintains one of the longest time series of water mass and transport observations of key components of the global meridional overturning circulation (MOC). During this last year project personnel have found important connections between Florida Current variations and direct wind forcing (Frajka-Williams et al., *Geophys. Res. Lett.*, 40, 349-353, 2013) and intriguing potential connections between the deep flows on either side of the Mid-Atlantic Ridge associated with the MOC (Meinen et al., *Deep-Sea Res.*, 85, 154-158. 2013).

***Coral Health and Monitoring Program (CHAMP)*:**

- **Predicting effects of climate change on coral reefs:** Novel analysis of data from state of the art climate models has shown that coral reefs in the western tropical Pacific Ocean are likely to be among the first to perish due to climate change induced bleaching, whereas coral reefs in other places, such as near the high-latitude limits of their range may represent temporary refugia from temperature stress but may see the biggest impacts of ocean acidification.
- **Refugia from ocean acidification in The Florida Reef Tract** Seagrasses likely caused a net draw-down of CO_2 at inshore sites in the upper Keys and coral reefs in this area may therefore be buffered from the deleterious effects of OA.

***Southwest Atlantic Meridional Overturning Circulation ("SAM") Project*:** Despite significant uncertainty about the path of the lower limb of the MOC in the South Atlantic (as opposed to the better understood North Atlantic pathway), the observed time variability of the Deep Western Boundary Current transport in the South Atlantic is equal in magnitude to that observed in the North (Meinen et al., *Ocean Sci.*, 8, 1041-1054, 2012).

***OSSE Evaluation of Targeted Airborne Ocean Observing Strategies in the Gulf of Mexico*:** Successful validation of the first ocean OSSE system demonstrates the potential to provide important feedback to NOAA and other agencies regarding the impacts upon forecast uncertainty of alternative regional and global ocean observing systems that will permit cost-effective optimization of observing system design.

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

***Ensemble-based high-resolution, vortex-scale data assimilation for hurricane model initialization*:** The Hurricane Ensemble Data Assimilation System (HEDAS) was developed to assimilate high-resolution, vortex-scale observations collected during the field program run by the Hurricane Research Division. HEDAS was shown to more realistically represent initial hurricane vortex structure. As a result, HWRF forecasts initialized with HEDAS analyses have been found to be superior both in track and intensity to the currently operational HWRF.

***Multi-model Ensembles for Hurricane Forecasts*:** Results obtained demonstrate much improved hurricane track and intensity forecasts out to day five using a multi-model super-ensemble.

***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 satellite-derived isotherm depths and OHC products relying upon the SMARTS climatology. A derived operational product was provided which includes assessments of the quality of the OHC product using all available in-situ data from floats, XBT transects, moorings and ships.

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

***Development of a Towed Camera System for Assessing Demersal Fish Stocks: C-BASS (Camera-Based Assessment Survey System)*:** The rapid, precise and credible assessment system developed will improve science understanding and ultimately the management of reef fish populations such as red snapper, groupers, amberjack, porgy and other reef-dependent species not only in the Gulf of Mexico but anywhere hard bottom reefs limit the utility of traditional sampling gears.

***Ocean Conditions in the Gulf of Mexico*:** **S**ignificant progress has been made in understanding the circulation of waters in the Gulf of Mexico using satellite data: ocean color, infrared and satellite altimeters. Findings suggest that the position and strength of anticyclonic mesoscale features in the GOM define the most favorable spawning habitats for these species.

***Investigation of the Movement of Adult Billfish in Potential Spawning Areas*:** Progressive warming leads to shoaling of the available habitat by about 1 m yr^{-1}, which concentrates both predator and prey in progressively shallower surface areas. Moreover the documented decline in dissolved oxygen is estimated to have resulted since 1960 in about a 15% habitat loss for tropical tuna and billfish.

***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*:** Juvenile oceanic developmental and foraging habitats are not been defined for any federally protected sea turtle species. This project is providing among the first satellite tracks of oceanic stage sea turtles in the Gulf of Mexico allowing preliminary definition of the foraging habitat.

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 through Tasks III and IV described below.

The remaining research in CIMAS is carried out under Tasks III and Task IV. These Tasks provide funding to university faculty and CIMAS 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 and are consistent with the CIMAS Themes but are funded by other federal (non-NOAA), state or private funding sources. All funding provided by NOAA to University Partners other than UM is 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 130 persons were associated with CIMAS in various capacities. Of these, 106 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 106 who received over 50% NOAA support, 68 are associated with AOML, 34 with SEFSC, 3 at RSMAS and one with NHC. Two of these work out of state. All but two were research personnel.

Table 1: CIMAS Research Personnel 2012 – 2013

Category	Number	BS	MS	Ph.D
Research Associate/Scientist	68	16	24	28
Part Time Research Associate/Scientist	9	3	2	4
Postdoctoral Fellow	9			9
Research Support Staff	20	1	0	
Total (> 50% NOAA support)	**106**	**20**	**26**	**41**
Full Time Administrative Staff	5			2
Task I Undergraduate Students	10			
Task I Graduate Students	5			
Visiting Scientist	4			
NOAA Association	68-AOML 34-SEFSC 3-RSMAS 1-NHC			
Obtained NOAA employment within the last year	0			

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 9 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 two such employees but we expect this category to continue to grow.

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 CIMAS employees 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 therein 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 a list of the 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 all 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 29 CIMAS Fellows. 6 CIMAS Fellows are from RSMAS, 8 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.

Demographics of CIMAS Employees

The CIMAS population is 56% female. Foreign-born individuals make up 53% of the personnel; of these Hispanics make up 20% of the ranks; Asian and Pacific Islanders, 19%. Only 4% 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 54. 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 5 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 10 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. $17.1 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	12,074,759
Year 2	3,269,557	7,880,380	6,236,972	2,012,573	19,399,482
Year 3	1,634,929	8,941,974	5,854,265	698,591	17,129,759
TOTALS	**6,646,943**	**24,746,444**	**13,674,809**	**3,535,804**	**48,604,000**

The sources of that funding are shown in Table 2. The major source of funding continued to be OAR which provided 54% of the total. NMFS, NESDIS, NOS and NWS were second at 25%, 12%, 4% and 3% respectively. Of the total OAR funding most originated from the Climate Program Office (CPO). The other major source NOAA funding was associated with the implementation of the NOAA Hurricane Forecast Improvement Program (HFIP) program. "Other" sources of funding include awards from NSF, NASA and private industry as well as a sub-contractual award from FIU.

Table 2: Funding by Source

1 July 2012 - 30 June 2013		
Source	**Funding $M**	**% Total**
NESDIS	2.00	12%
NMFS	4.37	25%
NOS	0.64	4%
NWS	0.45	3%
OAR/AOML	7.84	46%
OAR/CPO	0.79	5%
OAR/OER	0.60	3%
Other	0.44	2%
GRAND TOTAL	17.13	**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 55%) 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 $ 1.63M, of which $0.67M was for the Administration component and the remainder for Research Infrastructure, Education and Outreach. The numbers reported last year were higher due to advance funding of Task I for this reporting period. The distribution of NOAA Task 1 expenditures is shown in Figure 1.

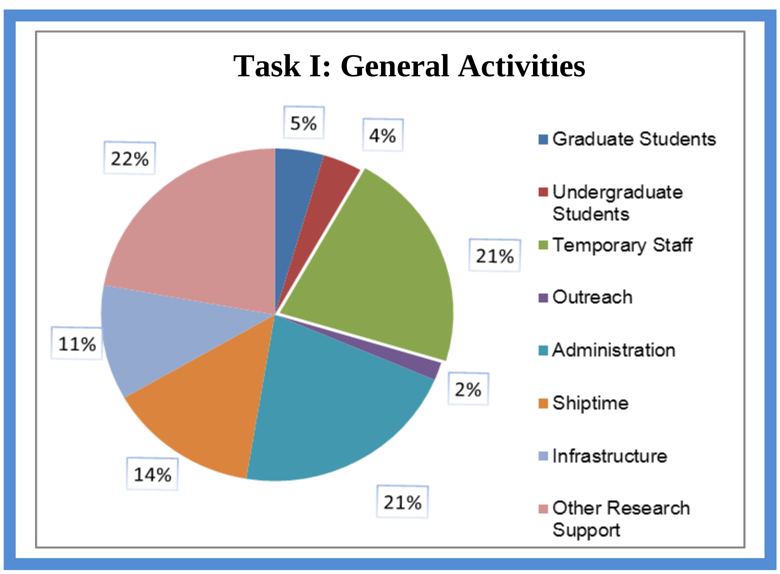

Figure 1: Distribution of Task 1Funding

The total NOAA-supported Task 1 budget was $ 1.63M. The category "Administration" 21% 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" 22% includes: travel for students, visiting scientists and temporary staff in support of research activities, consulting agreements, other supplies (minor equipment, peripherals, etc.). Research ship-time accounts for 14% of the total. Temporary Staff (21%) covers persons hired on a temporary basis to support research. Infrastructure accounts for 11% of total budget, this category allowed the purchase of N-Wave connection and access to high performance computing or other university owned research facilities as well as the acquisition of moorings.

The funding provided for Task II employees totaled $8.9M over the past twelve months. The distribution of these funds by employee category is depicted in Figure 2.

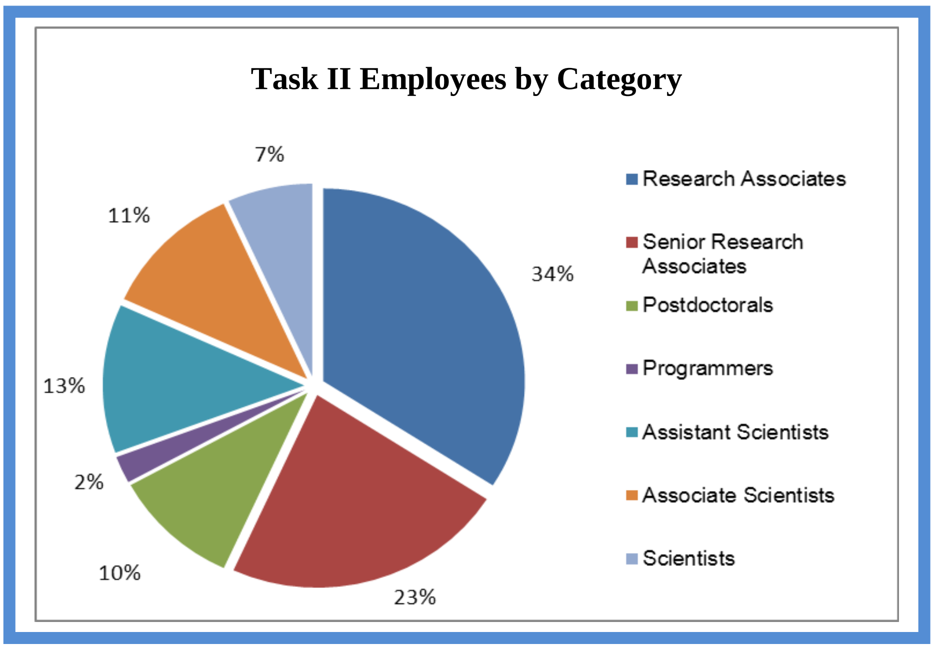

Figure 2: Distribution of Task 2: Funds by Employee Category

Funding By Theme

Project specific research funding (Tasks III and IV) under the new CA totaled ca. $6.6M 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 continues to account for the largest portion of the funding - 46%. The smallest portion of funding was in Theme 4: Ocean Modeling – 1%.

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. Moreover 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 projects that necessarily fall within these same Themes. While the salary of those personnel is paid through CIMAS all the other costs for those research projects are budgeted directly within NOAA and no specific project proposal was submitted through CIMAS to obtain the requisite funding.

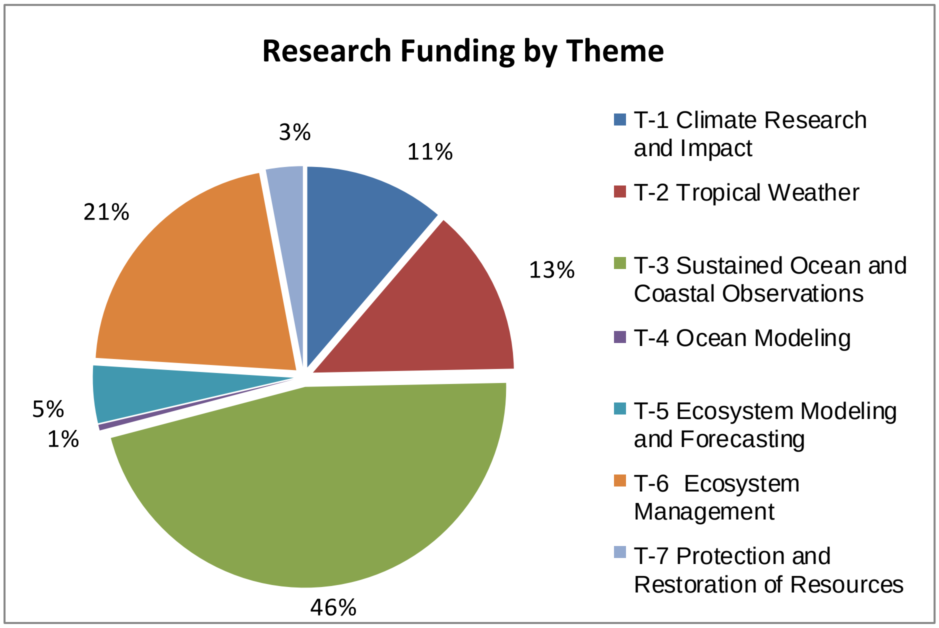

Figure 3: Percentage of Task 3 and Task 4 (Research) funding in the CIMAS Themes

Table 3 below tabulates NOAA current funding received by CIMAS under the present Cooperative Agreement as well as its immediate predecessors. For example, note that the Shadow Award continued to be operative; it was in its final year during the present reporting period although those expenditures are not reported herein.

Table 3: Recent NOAA Funding Directly to CIMAS

NOAA Award Number	Award Period	Total Funds
NA10OAR4320143	09/01/10 - 8/31/15	$ 43,077,176
NA08OAR4320889 Shadow	07/01/08 - 06/30/13	$ 3,068,262
NA10OAR4310120	09/01/10 - 8/31/15	$ 457,924
NA11OAR4310207	09/01/11 - 08/31/13	$ 71,964
NA11NOS4780045	09/01/11 - 08/31/16	$ 1,515,182
NA11OAR4310077	09/01/11 - 08/31/14	$ 307,600
NANA12OAR4310105	08/01/12 - 07/31/14	$ 190,000
NANA12OAR4310089	08/01/12 - 07/31/14	$ 130,000
NANA12OAR4310083	08/01/12 - 07/31/16	$ 10,000
NANA12OAR4310073	08/01/12 - 07/31/16	$ 10,000

Funding distributed through CIMAS to the Partner Universities during the present reporting period was $1.7M or 29% of Task III (Partner Universities are only eligible for Task III funding through CIMAS).

Awards to CIMAS during this last reporting period under the new CI award policy whereby those projects get assigned a different accounting code (although they are "associated" with the overall Cooperative Agreement) are listed in the following table.

Table 4: Task III Projects Linked to CIMAS

PI	Funding Source	Project Title
Dunion, J	NWS	Development of a Probabilistic Tropical Cyclone Genesis Prediction
Cowen, R	NOS	Population Connectivity of the Pulley Ridge - South Florida Coral Reef Ecosystems: Processes to Decision-support Tools
Chen, S	NWS	Convective Structure and Environmental Conditions in the MJO Initiation over the Indian Ocean
Criales, M	OAR/CPO	Integrated Models for Evaluating Climate Change, Population Growth, & Water Management (i.e. CERP) Effects on South Florida Coastal Marine and Estuarine Ecosystems (iMODEC)
Soden, B	OAR/CPO	Development of a Long-term Homogenized Upper Tropospheric Water Vapor Data Set from Satellite Microwave Radiances
Kirtman, B	OAR/CPO	A. U.S. National Multi-Model Ensemble ISI Prediction System
Lee, s	OAR/CPO	Toward Developing a Seasonal Outlook for the Occurrence of major US Tornado Outbreaks
Kamenkovich, I	OAR/CPO	Mesoscale variability in the Gulf of Mexico and its importance in climate extremes over North America

Conclusion

In our funding summary we report only expenditures during the twelve months project period under the new Cooperative Agreement or associated with it under the new CI Policy with respect to competitive NOAA program awards. There were also a few additional CIMAS expenditures that either just missed the deadline (or represented continuations of pre-existing awards – see Table 3) which were also not included herein. Specifically, due to this year's budget uncertainty, some awards normally made during this project period (typically during April or May) were deferred until June/July. Last, there is a substantial number of research and educational activities that are carried out by university faculty at both UM and the Partner Universities that complement and contribute to the NOAA-supported CIMAS-linked programs but are not directly associated with CIMAS. That leveraging 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 specified and explicitly 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 *secondary* and *tertiary* themes.

RESEARCH REPORTS

THEME 1: Climate Research and Impact

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

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

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To investigate the mechanisms underlying 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 (*Primary*)
***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 Units: 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 model-data differences in the seasonal variations of the meridional overturning circulation (MOC) and meridional heat transport (MHT) in the South Atlantic, and to investigate the causes for those differences. Temperature and salinity climatology from Argo profiling floats and from GFDL models are used to estimate the MOC/MHT at 34S. On the time-mean the MOC from model T/S fields show strong transport in the ocean interior region, but weaker eastern boundary transport, compared to the estimated from Argo T/S fields and from XBT measurements (Figure 1). 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. 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. Previous studies in the North Atlantic suggested that the wind stress curl forcing in the eastern boundary forces the seasonal variations in the MOC through Rossby Wave propagation. The missing seasonal variations in the geostrophic transport in the model may be due to the mis-representation of the winds in the eastern boundary. Also interesting is that the density field as well as estimated velocity from observations show strong vertical coherent variations, which is not shown in the model field. This missing vertical coherent variation may also contribute to the difference in the seasonal variations in geostrophic transport. We also noticed that the zonal wind stress in the model shows a strong seasonal variations resulting in strong seasonal cycle in the Ekman transports.

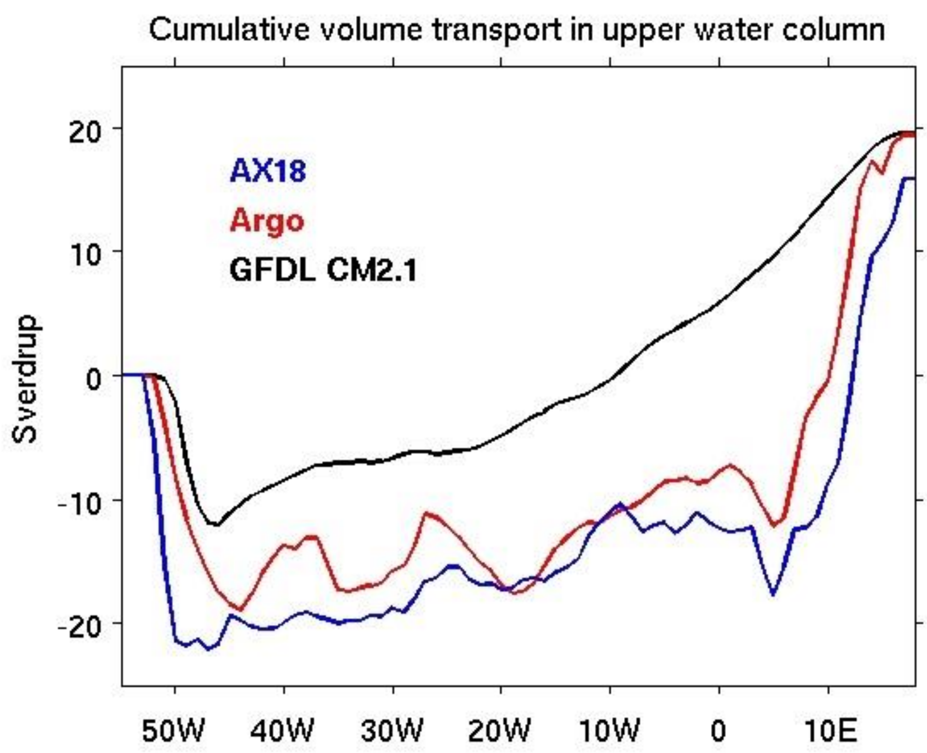

Figure 1: Cumulative volume transports from west to east in the upper water column estimated from Argo (red) and XBT (blue) measurements and that from GFDL CM2.1 model (black).

(2) Analysis of CMIP5 climate models:

Our analysis of the 20th Century historical simulations in CMIP5 models demonstrates that the SAMOC in all 20 available models exhibits variations on decadal and longer time scales (Figure 2), although the long-term mean SAMOC varies over a large range and the specific time scale of the variations differ among these 20 models. Out of these 20 models, 8 including two GFDL models and CCSM4 give a mean MOC value consistent with observational based estimates of 17.9 ± 2.2 Sv. The variations in SAMOC and the Southern Hemisphere westerlies show different relationship in different models. Among the 20 models investigated 9 display a statistically significant positive correlation between the winds and the MOC with the winds leading the MOC by ~4 years. No significant correlations between the two were found in 6 models, consistent with the results from fine-resolution models in which wind-driven Ekman transport is compensated by eddy-driven transport. Interestingly, the other 5 models show a negative correlation between the MOC and the winds, suggesting that the MOC decreases with enhanced Southern Hemisphere westerlies. What causes the discrepancy among CMIP5 models and how the different eddy parameterization schemes used in each model contribute to these discrepancies need further investigation.

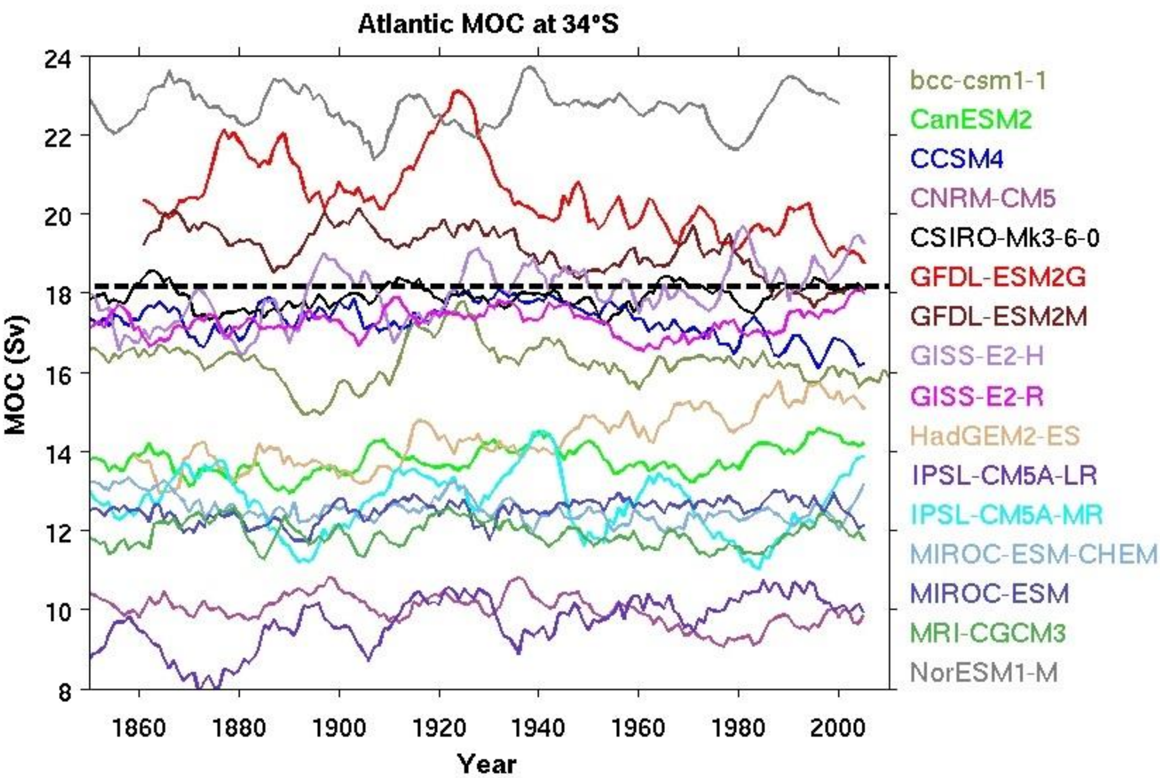

Figure 2: Time series of the South Atlantic MOC at 34°S from 20th Century historical simulations in CMIP5 models. A five-year running mean is applied to show MOC variations on decadal and longer time series. Corresponding models are listed in the legend.

Research Performance Measure: Quantitative comparison of the differences between models and observations with respect to seasonal variation in the SAMOC. This objective was realized and the initial results obtained were presented at the AMOC annual PI meeting, August 2012 in Boulder, CO.

Coral Health and Monitoring Program (CHAMP)

Project Personnel: R. Carlton, I.C. Enochs, L.J. Gramer, S. Hariharan, K.P. Helmle, R. van Hooidonk, M. Jankulak and D.P. Manzello (UM/CIMAS); T. Burton, D. Graham and L. Olinger (UM undergraduate)
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 variation 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 information to management on small-scale geographic variations in thermal stress, based on an improved understanding of the physical environment of reefs; provide data archiving and artificial intelligence tools to facilitate the acquisition and integration of high-quality data from these and other reef areas worldwide. Utilize an integrated analysis of coral growth records, bioerosion monitoring units, settlement plates, as well as 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 1*:** Climate Research and Impact (*Primary*)
***Theme 6*:** Ecosystem Management (*Secondary*)
***Theme 3*:** Sustained Ocean and Coastal Observations (*Secondary*)
***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* (*Primary*)
***Goal 3*:** Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems* (*Secondary*)

NOAA Funding Units: OAR/AOML, NOS/CRCP, OAR/OAP
NOAA Technical Contact: Alan Leonardi

Research Summary:
In the past year the Coral Health and Monitoring Program (CHAMP) team conducted field operations at Coral Reef Early Warning System (CREWS) stations in Puerto Rico, the Cayman Islands, and Saipan. The Puerto Rico station was upgraded with new sensors, new programming and

a new satellite transmitter. The Little Cayman CREWS station received a detailed evaluation after damage caused by Hurricane Sandy and plans are underway for the deployment of replacement infrastructure. The Saipan station was refurbished following a power failure in mid-2012 and is once again operational (Figure 1).

Figure 1: Mike Jankulak (CIMAS) and Gordon Walker (PacIOOS) install instrumentation on the Saipan CREWS station.

The Saipan CREWS station was refurbished concurrently with site surveys for the potential installation of a MApCO2 (Moored Autonomous pCO2) buoy, in accordance with the priorities of the Coral Reef Conservation Program's (CRCP) new National Coral Reef Monitoring Plan (NCRMP). Existing MaPCO2, pH logging, and light sensing assets at the Atlantic Ocean Acidification Test-bed (AOAT) site at Cheeca Rocks, Florida Keys, were maintained. Seasonal process-based studies were conducted at the AOAT site along with collaborators from URI, WHOI, and UM. Seawater samples were collected from the AOAT site and from locations throughout the Florida Keys. Samples were analyzed for Dissolved Inorganic Carbon (DIC) and alkalinity. Derek Manzello and Ian Enochs used these data to characterize spatio-temperal variability in carbonate chemistry and identify potential ocean acidification refugia (Figure 2).

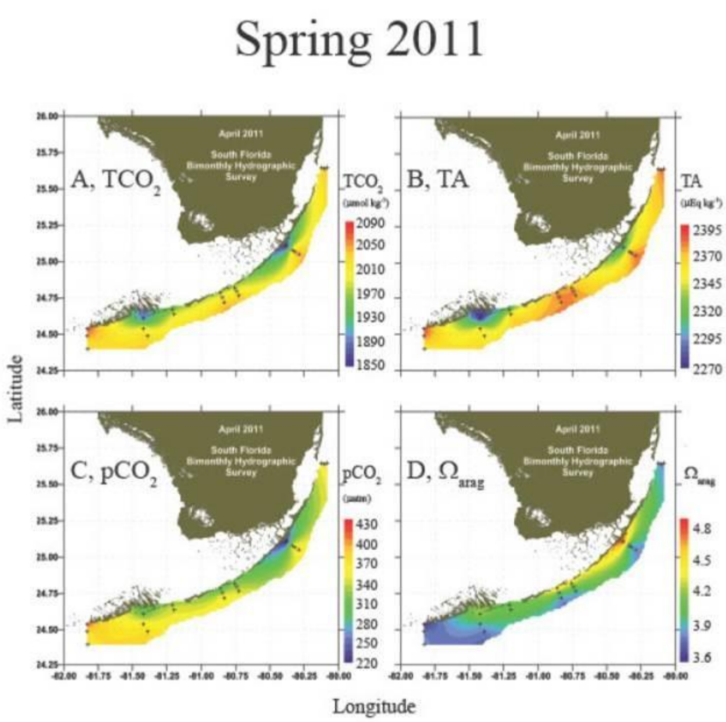

Figure 2: (A) Total CO_2 (TCO_2), (B) Total Alkalinity (TA), (C) partial pressure of CO_2 (pCO_2), and (D) aragonite saturation state ((Ω_{arag}) from April 2011 for the Florida Reef Tract.

Ian Enochs, Derek Manzello, Renee Carlton, and Ruben van Hooidonk, along with RSMAS/MBF graduate student Sean Bignami conducted experiments to assess the effects of elevated pCO2 on benthic-reef dwelling invertebrates (*Acropora cervicornis,* Figure 3; clionaid sponges; octocorals) and fishes (Cobia, Figure 4).

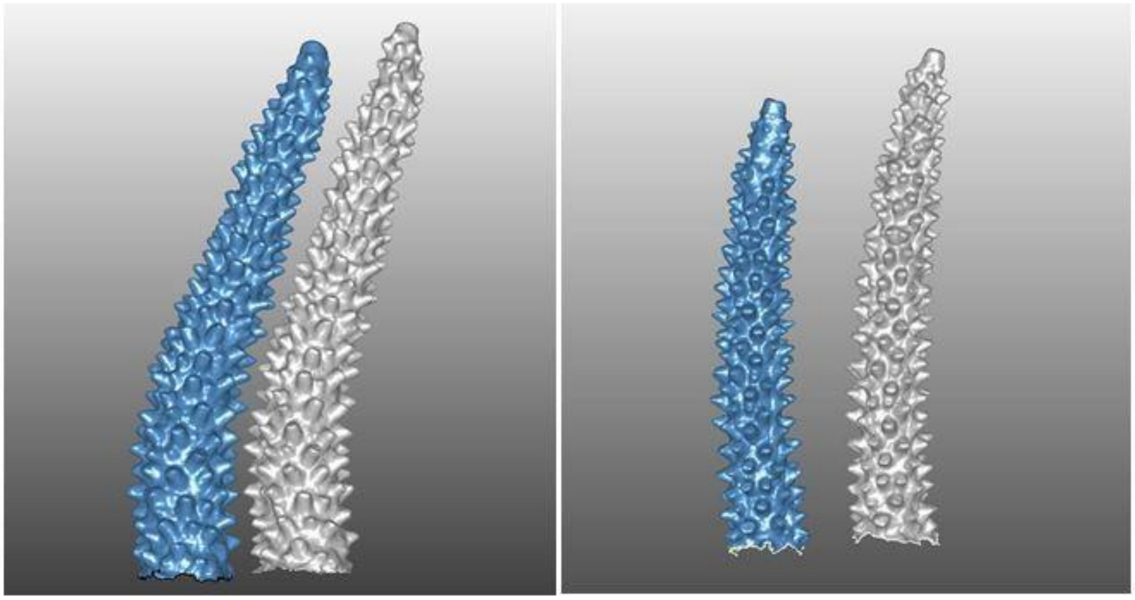

Figure 3: 3D scans of two branches of ESA-listed *Acropora cervicornis*, showing growth over several weeks in experimental aquaria.

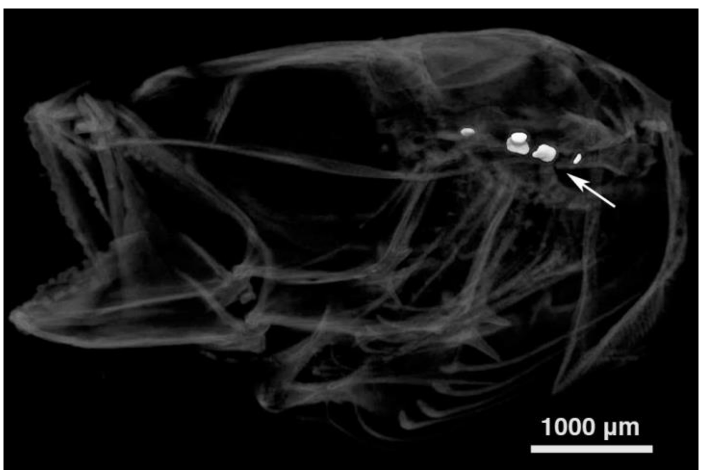

Figure 4: Micro-CT image of the skull and ear bones of larval Cobia (*Rachycentron canadum).*

Lewis J. Gramer, in collaboration with scientists from RSMAS, JCU, and NOAA, published research on the dynamics that drive sea-temperature variability on coral reefs of the Florida Keys National Marine Sanctuary. The reef heat budget model initially constructed in 2011-2012 was refined and expanded upon. Data from previous studies in the Keys were analyzed to demonstrate the characteristics and operation of a physical process previously unreported in Florida coral reefs, horizontal convection (Figures 5).

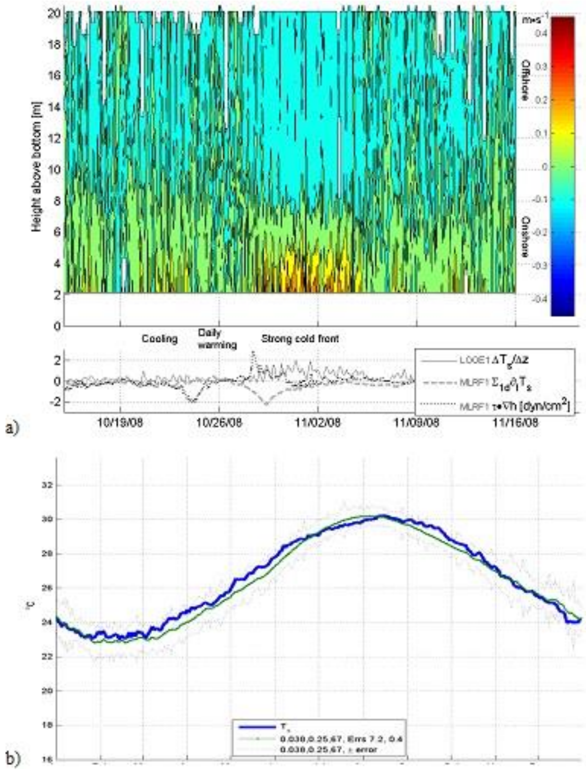

Figure 5: (a) The operation of horizontal convection, a frequent mechanism of cross-shore heat exchange on Keys reefs, not previously reported. HC may also play a significant role in cross-reef exchange of nutrients and other tracers. Ocean currents data courtesy of Looe Key mooring, AOML's South Florida Program. (b) Climatological mean (1993-2012) sea temperature and reef heat budget result, including horizontal convection, at Fowey Rocks Lighthouse station.

Ruben van Hooidonk utilized state of the art global fully coupled climate models from the 5th Intergovernmental Panel on Climate Change Assessment Report (AR5) to project both temperature stress and ocean acidification impacts on coral reefs in the coming century under four different carbon dioxide emission scenarios. Changes in coral calcification globally were forecast by relating changes in aragonite saturation state to observed rates of change found in a meta-analysis of ocean acidification literature. Results are made available to managers in a Google Earth tool (Figure 6).

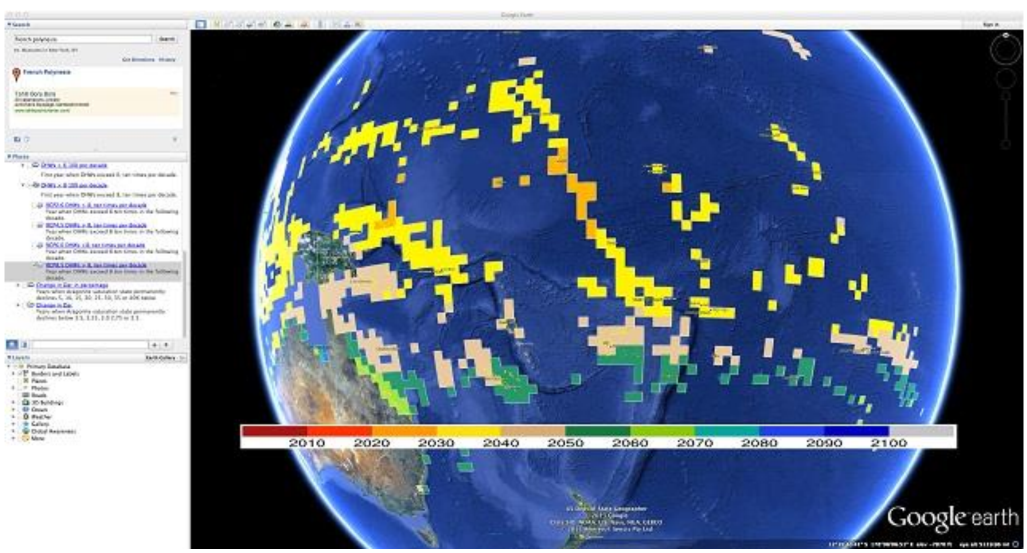

Figure 6: Screenshot of a Google Earth tool showing one of 71 available information layers on temperature stress and ocean acidification on coral reefs. Here the year when Degree Heating Weeks are projected to surpass 8 annually, indicating severe bleaching every year is shown.

CIMAS scientist Kevin Helmle along with NSU graduate student Elizabeth Mullikin determined relationships between coral size, age, and growth rate of the reef corals *Monstastraea faveolata* and *Diploria labyrinthiformis*. The coral height and age relationship derived from colony measurements and density band records of more than 70 corals indicates that coral age estimates based on size and average growth rates underestimate the actual age of the colony by up to 10 years or more.

Coral sclerochronology was also used to reconstruct historical records of coral growth and calcification as they varied with environmental conditions such as sea surface temperature and seawater pH. Kevin Helmle and NSU graduate student Darren Marshall have collected growth data spanning a period from 1748 to 2009 from 10 corals. Derek Manzello, Ian Enochs, and Renee Carlton collected hundreds of small coral cores (~10 years of growth data) from sites throughout the Pacific and Florida Keys.

Research Performance Measure: The CHAMP project addressed and met the defined objectives during 2012-2013 through a suite of research components that included ongoing data gathering from the latest CREWS system in Saipan as well as maintenance, data processing, and data delivery of existing CREWS stations throughout the Caribbean. Additionally, biogeochemistry and oceanographic process studies and autonomous data-gathering were ongoing at the Cheeca Rocks AOAT and throughout the Florida Keys. These *in situ* measurements continue to drive field-based and laboratory research including studies of net ecosystem calcification, net community productivity, and benthic community composition. Coral growth records and bioerosion monitoring units have been collected and analyzed using x-ray and micro CT technologies in order to address baseline values, spatial gradients related to carbonate chemistry, as well as variability over time. Coral colony measurements and density band records have been used to assess coral age and size relationships. Finally, reef heat budget modeling efforts were constructed to clarify sub-regional-scale thermal variability and cross-reef circulation.

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Western Boundary Time Series Project

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

Long Term Research Objectives and Strategy to Achieve Theme:
Objective**:** 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 Science Goals:

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

NOAA Funding Units: OAR/AOML and OAR/CPO

N**OAA 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. More than 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).

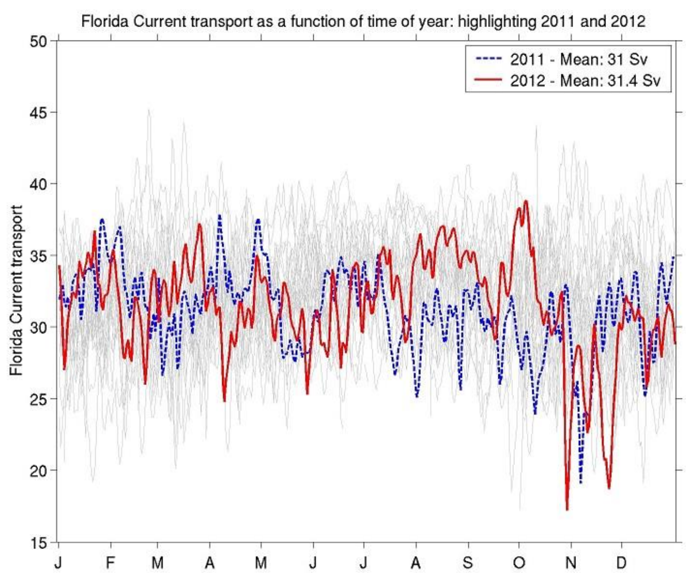

Figure 1: Volume transport of the Florida Current at 27ºN. The two most recent years are highlighted in color.

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. During the year we have reduce the number of Florida Current sections due to shortfall in charter funds. We continue to achieve our major objectives – to maintain the continuity of this long term data set and to continually improve the calibration of the data obtained.

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Southwest Atlantic Meridional Overturning Circulation ("SAM") Project

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

Long Term Research Objectives and Strategy to Achieve Theme:
***Objectives*:** To sustain time series measurement system for the South Atlantic 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 Units: 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 Circulation (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 South Atlantic near 34.5°S since 2009 via the 'Southwest Atlantic MOC', or 'SAM', project. 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 NOAA moored instruments near the western boundary at 34.5°S. During 2009-2010, collaborators from France had a pair of moored instruments deployed along the same line of latitude off the western coast of South Africa, providing an initial opportunity to simultaneously observe 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. Towards this goal, colleagues from Brazil deployed new instruments augmenting the western boundary array in December 2012, and participants from South Africa and France will deploy instruments on the eastern side in late 2013.

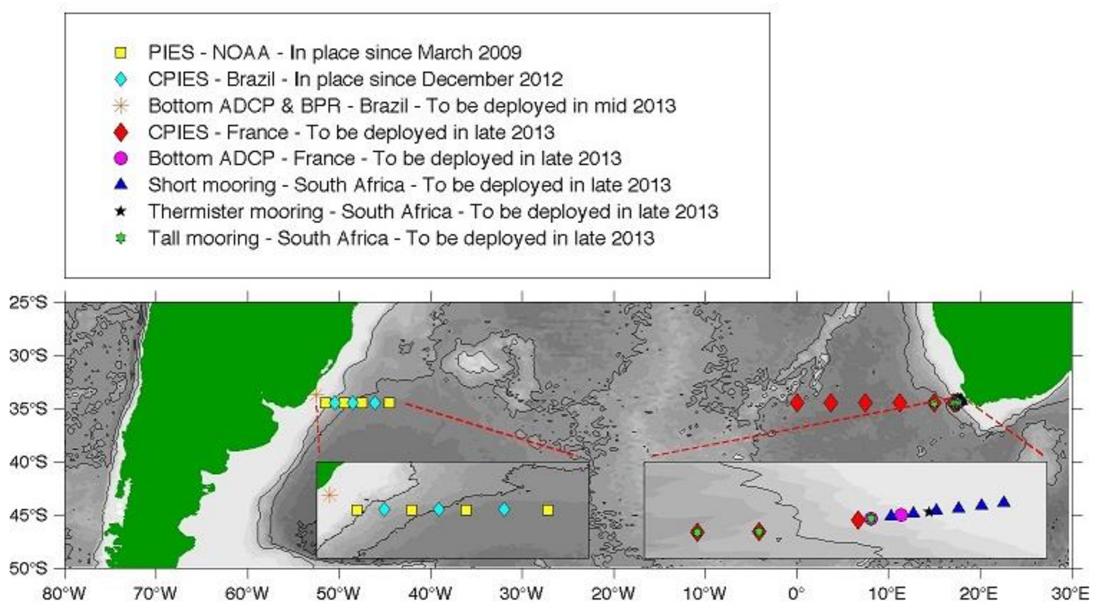

Figure 1: Map indicating the location of the four NOAA PIES making up the SAM array. Also shown are the new and planned additions to the experiment working towards the goal of the trans-basin array.

Research Performance Measure: Most research goals were met during the last year. An international workshop was hosted by CIMAS and AOML personnel in January 2013 at AOML to design future array augmentations, processing methodology, data sharing policies, and collaboration procedures. One data-download cruise was canceled due to a shortfall in charter funds. Nevertheless, the primary goals of the program are advancing. Results from the study were presented at the U.S. AMOC Meeting in Boulder, CO in August 2012. Perhaps the most exciting new achievement was the deployment of additional moored instruments in the array via a collaborative cruise with Brazilian partners.

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NOAA Climate Test Bed (CTB) National Multi-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 address 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* (*Primary*)

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

NOAA Funding Unit: 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.

RSMAS CCSM Forecasts: We are in 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. CCSM4 has significant improvements in the simulation of tropical variability relative to CCSM3.0. The initialization procedure differs from CCSM3 in that we will use the operational CFSR ocean, land and atmospheric states to initialize CCSM4 as opposed to ocean only initialization using optimal interpolation from GFDL. We have begun testing the CFSR ocean states in CCSM4 hindcast experiments, and Fig. 1 shows the hindcast SSTA correlation for a parallel set of experiments using CCSM3 with the original GFDL ocean states (bottom panel) and using the CFSR ocean states (top panel). The correlation is noteable larger with CCSM4 using CFSR ocean states. We separately examined the impact of the model changes (i.e., CCSM3 vs. CCSM4) and the changes associated with the different ocean state. Both changes contribute to the increases in the correlation, but are dominated by the model changes. We have also developed procedures for using CFSR data for the atmosphere and land initial states (e.g., Paolino et al. 2012).

NMME Skill Assessment: One of the important motivating factors for the NMME project is to understand the complementary sources of skill among the models. Essentially, we seek to understand the “where and why” in how the multi-model approach improves forecast quality. Here we show the first step in this process – simply documenting how the multi-model compares to any single model. For example, Figure 2 shows the difference in the between the grand NMME SSTA correlation and the same correlation for a set of forecasts with CFSv2. We have sub-sampled the NMME ensemble to: (i) not include CFSv2 and (ii) to only use exactly the same ensemble size for the NMME system. Regions where the NMME system improves on CFSv2 are positive and regions where the CFSv2 improves the NMME system have negative values. Figure 3 show a similar result except for rainfall forecast over North America.

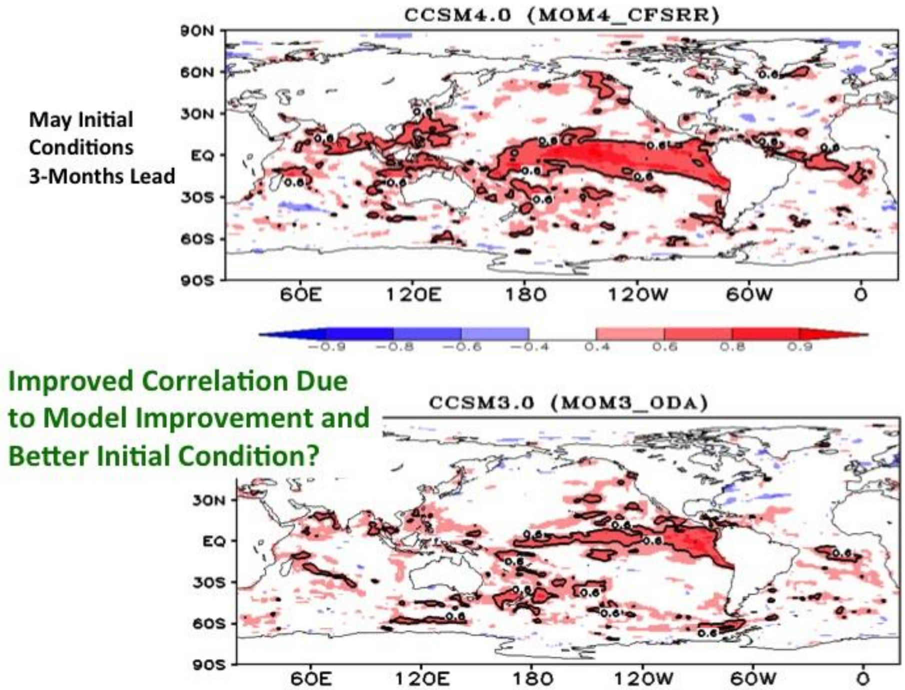

Figure 1: SSTA hindcast correlation with observational estimates for May start dates (1982-1999) verifying for the following November. For these testing experiments there is only one ensemble member.

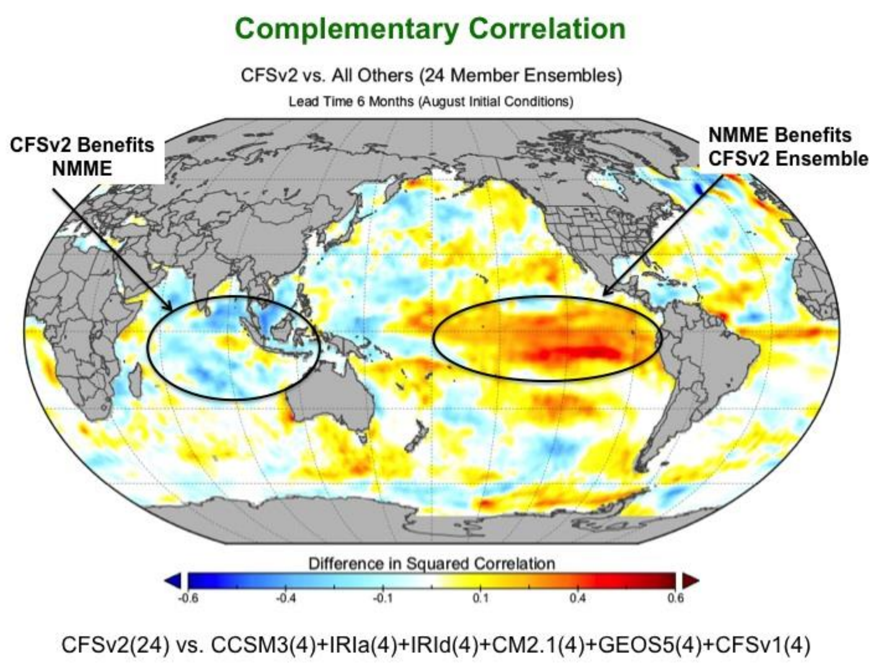

Figure 2: NMME SSTA correlation vs CFSv2. Positive values indicate NMME has larger correlation than CFSv2 and negative values indicate that CFSv2 has larger correlation.

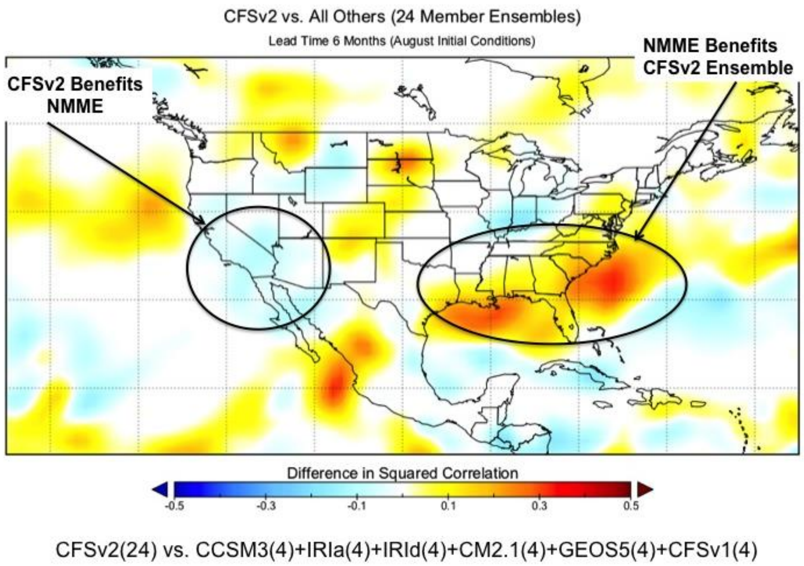

Figure 3: NMME North American rainfall correlation vs CFSv2. Positive values indicate NMME has larger correlation than CFSv2 and negative values indicate that CFSv2 has larger correlation.

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.

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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/AOML)

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 ocean acidification 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, physiological response, settlement success and behavior, and post-settlement growth of several species of Caribbean coral larvae (*Acropora palmata*, *Montastraea faveolata* and *Diploria strigosa*) under projected climate change conditions. 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 Units: AOML and OAR/OAP
NOAA Technical Contact: Alan Leonardi

Research Summary:

1. Effects of ocean acidification and increased temperature on coral early life history stages.

Experiments were carried out following the strategy from the 2011 spawning season. In 2012, no *Acropora* or *Diploria* larvae were collected so the research focused on the larvae of *Montastraea faveolata* as the subject of the experiments. All of the experiments contained four treatments which was a control treatment (29 °C/390 ppm), an elevated temperature treatment (31 °C/390 ppm), an elevated CO_2 treatment (29 °C/900 ppm), and a elevated CO_2 and temperature treatment (31 °C/900 ppm).

Larval survivorship was quantified for the first four days post spawning. Survivorship was highest in the control treatment with 85 ± 8 % (Avg. ± SE) surviving after four days at treatment conditions. Survivorship was lowest in the 31 °C/900 ppm treatment at 64 ± 5 %. The other two treatments (31 °C/390 ppm, and 29 °C/900) showed intermediate values of 76 ± 7 % and 73 ± 7 %.

To gain insight into the physiological cost of ocean acidification and increased temperature respiration experiments were performed on two day old larvae. Respiration was significantly increased under high temperature as well as high CO_2 levels when compared to the control treatment. The combination treatment of both high temperature and CO_2 showed a slight increase but not as much as in the single stressor treatments. The increased metabolic cost of dealing with increasing temperature and OA could have major implications for larval dispersal as broadcast larvae are unable to feed during the dispersal period and rely on lipid stores for energy. Thus there is a finite amount of energy available to these larvae, which is declined more rapidly under OA and increased temperature. This could limit potential dispersal distances and global recovery potential. Experiments this year will focus on quantifying lipid decrease alongside respiration to further support out findings.

Batch settlement assays were carried out under control conditions with settlement tiles conditioned for three months under either ambient (390 ppm) or elevated (900 ppm) CO_2 conditions. Settlement on the upper surface of the tiles was much greater on the tiles conditioned at 390 ppm with an average of 13.6 ± 2.1 larvae settling per cm^2 (n=18, avg. ± SE) as compared to the tiles conditioned at 900 where only 1.42 ± .34 larvae per cm^2 settled (n=17). This is most likely a factor of the absence of positive settlement cues, such as crustose coralline algae (CCA), on the tiles conditioned at high CO_2 as well as a potential increase of negative settlement cues, such as dense turf algae.

Following the batch settlement experiments, the newly settled larvae were separated into the four treatment conditions and held under those conditions for a month and a half. Pictures were taken under the microscope every two weeks and analyzed using ImageJ, software designed by NIH for picture analysis. Average growth rates were calculated for the individuals in each treatment from the 2-D area obtained from successive pictures. The results are displayed in Figure 1. The highest average growth rates were observed in the high temperature treatment (0.0026 ± .0027 $mm^2day^{-1}polyp^{-1}$), followed by the control treatment (0.00072 ± .0013 $mm^2day^{-1}polyp^{-1}$). The 29 °C, 900 ppm treatment was the only treatment that exhibited negative growth (-0.0011 ± .0011 $mm^2day^{-1}polyp^{-1}$). These results illustrate the fact that OA can limit and even reverse the growth of juvenile coral greatly hindering the potential for these new recruits to grow into adult reef building coral. In this species however, slightly elevated temperatures (1-2 °C above ambient maximum summer temperatures) can actually increase growth and may aid in mitigating the negative effects of OA.

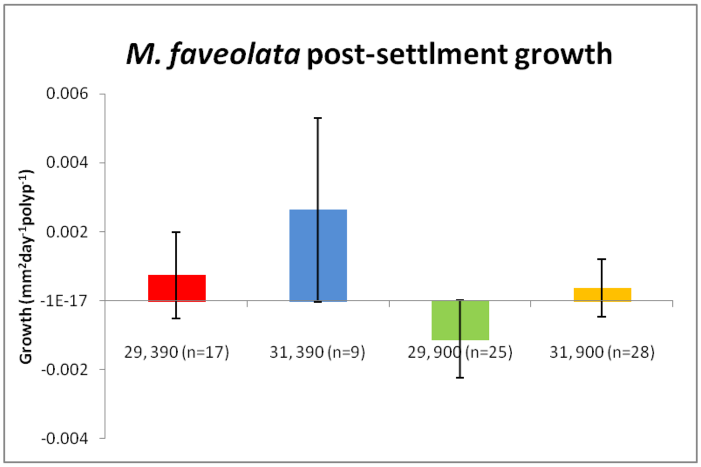

Figure 1: Montastraea faveolata post-settlement growth. Gametes were collected from Sand Island Reef, Key Largo, FL on 9/06/12. Batch settlement was carried out near the site of collection in Key Largo, FL and the tiles were brought to RSMAS on 9/27/12. T_0 measurements were conducted on 10/15/12 following a two week acclimation to the NSF tank conditions (light, salinity, ect.) at 29 C, 390 ppm. On 10/18/12 tiles were randomly distributed between the treatments. Settled juveniles were fed weekly and growth was quantified bi-weekly for a month and a half. Pictures were taken under the microscope of individuals and later analyzed using ImageJ. Data is displayed as average growth rates calculated from the slope of the regression line through the areal measurements obtained from the picture analysis. Only those regression lines with an r^2 value > 0.5 were included. Sample size next to treatment labels represents the number of individuals quantified in each treatment. Error bars represent standard error.

2. Field measurements of macroalgae and benthic algae productivity

The permit from FKNMS (#FKNMS-2013-034) has been extended for three years, for the work that is being conducted on a patch reef near 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 have been accumulating a benthic algal community and even some coral recruits. In the coming year, 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, there has already been a year worth of sampling on the reef of the two major species found during every sampling season (winter, spring, summer and fall), *Halimeda tuna* (green calcifying alga) and *Dictyota sp.* (brown alga). Other species of algae have been measured, but have not been found at every season so seasonal changes cannot be computed. *Dictyota spp.* exhibited much greater net photosynthesis rates as compared to *H. tuna* in every season (~10X more in June and August and 25-30 X more in Nov and Feb). This is due to the fact that *H. tuna* is a calcifying macroalgae so a lot of energy is devoted to this process. Calcification measurements of *H. tuna* were also obtained but are still in the process of analysis. Photosynthesis was highest for both species in August which correlated to the highest SST. Respiration measurements have also been initialized to gain a further understanding of the balance of algal photosynthesis to respiration in the overall carbon budget of coral reefs. Ocean acidification experiment are also being planned and will be carried out in the *in-situ* metabolic chambers to investigate if photosynthesis is stimulated by increased CO_2 levels, potentially hindering the ability of corals to outcompete as the prominent reef builder.

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

Is There An Optimal ENSO Pattern That Enhances Large-scale Atmospheric Processes Conducive to Major Tornado Outbreaks in the U.S.?

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

Long Term Research Objectives and Strategy to Achieve Theme:
***Objectives*:** To understand the impact of ENSO on U.S. tornadoes.
***Strategy*:** To perform composite analysis of key atmospheric variables for U.S. tornado activity.

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

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 Units: AOML and CPO
NOAA Technical Contact: Alan Leonardi

Research Summary:
The record-breaking U.S. tornado outbreaks in the spring of 2011 caused unprecedented destruction and raised a question as to whether such destructive events are linked to a specific large-scale climate pattern, which may possibly serve as a predictor before the season begins. Our research shows that a repeating pattern of tropical Pacific sea surface temperature (SST) anomalies appearing most notably during the transitional phase of the El Niño-Southern Oscillation (ENSO) in spring may be one such climate pattern. This pattern, known as the positive phase Trans-Niño, is characterized by colder-than-normal SSTs in the central tropical Pacific and/or warmer-than-normal SSTs in the eastern tropical Pacific. The study looked at the ten worst tornado outbreak years in April and May during 1950-2010 and found that seven of those ten years were strongly positive phase Trans-Niño years. Consistent with this finding, the number of intense tornadoes, those rated as F3 to F5 on the Fujita scale, in April and May is nearly doubled from neutral Trans-Niño years to positive phase Trans-Niño years (Figure 1).

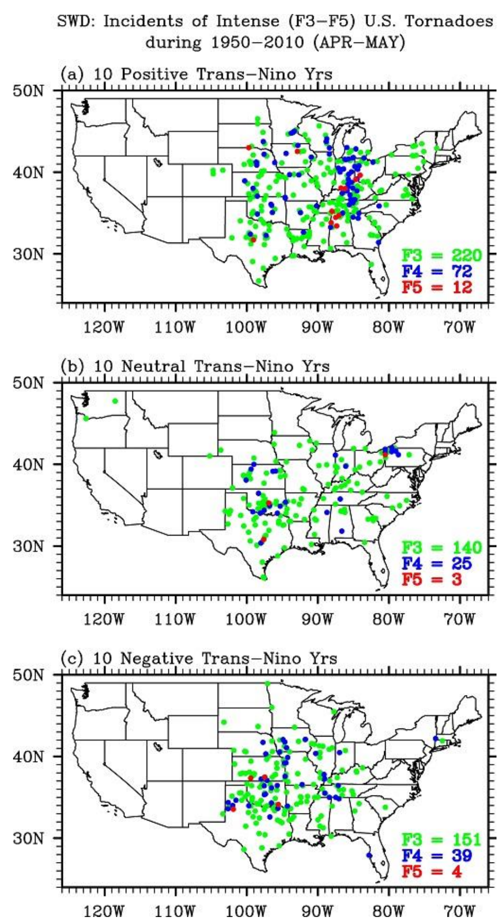

Figure 1: Incidents of intense U.S. tornadoes in April - May for (a) the top ten positive phase Trans-Niño years, and (b) ten neutral Trans-Niño years during 1950-2010 obtained from Severe Weather Database. Green color is for F3, blue color for F4 and red color for F5 tornadoes**.**

Modeling experiments suggest that the spatial pattern of tropical Pacific SST anomalies associated with the positive phase Trans-Niño forces a strong and persistent atmospheric teleconnection pattern that increases both the upper-level westerly and lower-level southeasterly over the central and eastern U.S. These anomalous winds bring more cold and dry upper-level air from the high-latitudes and more warm and moist lower-level air from the Gulf of Mexico converging into the east of the Rockies, and also increase both the lower-tropospheric (0 ~ 6 km) and lower-level (0 ~ 1 km) vertical wind shear values therein, thus providing large-scale atmospheric conditions conducive to intense tornado outbreaks over the U.S. A practical implication of the new results is that a seasonal outlook for extreme U.S. tornado outbreaks may be achievable if a seasonal forecasting system has significant skill in predicating the Trans-Niño and associated teleconnections to the U.S. However, there remain many fundamental scientific questions and various issues with the tornado database to be addressed before we can achieve such a goal.

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

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

Project Personnel: S.-K. Lee, L. Zhang, D.B. Enfield and Z. Song (UM/CIMAS)
NOAA Collaborators: 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: AOML **NOAA Technical Contact:** Alan Leonardi

Research Summary:
Recent studies have indicated that the multidecadal variations of the Atlantic Warm Pool (AWP) can induce a significant freshwater change in the tropical North Atlantic Ocean. In this study, the potential effect of the AWP-induced freshwater flux on the Atlantic Meridional Overturning Circulation (AMOC) is studied by running a series of ocean-sea ice model experiments. Our model

experiments demonstrate that ocean response to the anomalous AWP-induced freshwater flux is primarily dominated by the basin-scale gyre circulation adjustments with a time scale of about two decades. The positive (negative) freshwater anomaly leads to an anticyclonic (cyclonic) circulation overlapping the subtropical gyre. This strengthens (weakens) the Gulf Stream and the recirculation in the interior ocean, thus increases warm (cold) water advection to the north and decreases cold (warm) water advection to the south, producing an upper ocean temperature dipole in the midlatitude. As the freshwater (salty water) is advected to the North Atlantic deep convection region, the AMOC and its associated northward heat transport gradually decreases (increases), which in turn leads to an inter-hemispheric SST seesaw. In the equilibrium state, a comma-shaped SST anomaly pattern develops in the extratropical region, with the largest amplitude over the subpolar region and an extension along the east side of the basin and into the subtropical North Atlantic. Based on our model experiments, we argue that the multidecadal AWP-induced freshwater flux can affect the AMOC without air-sea feedbacks, which plays a negative feedback role that acts to recover the AMOC after it is weakened or strengthened. The sensitivity of AMOC response to the AWP-induced freshwater forcing amplitude is also examined and discussed.

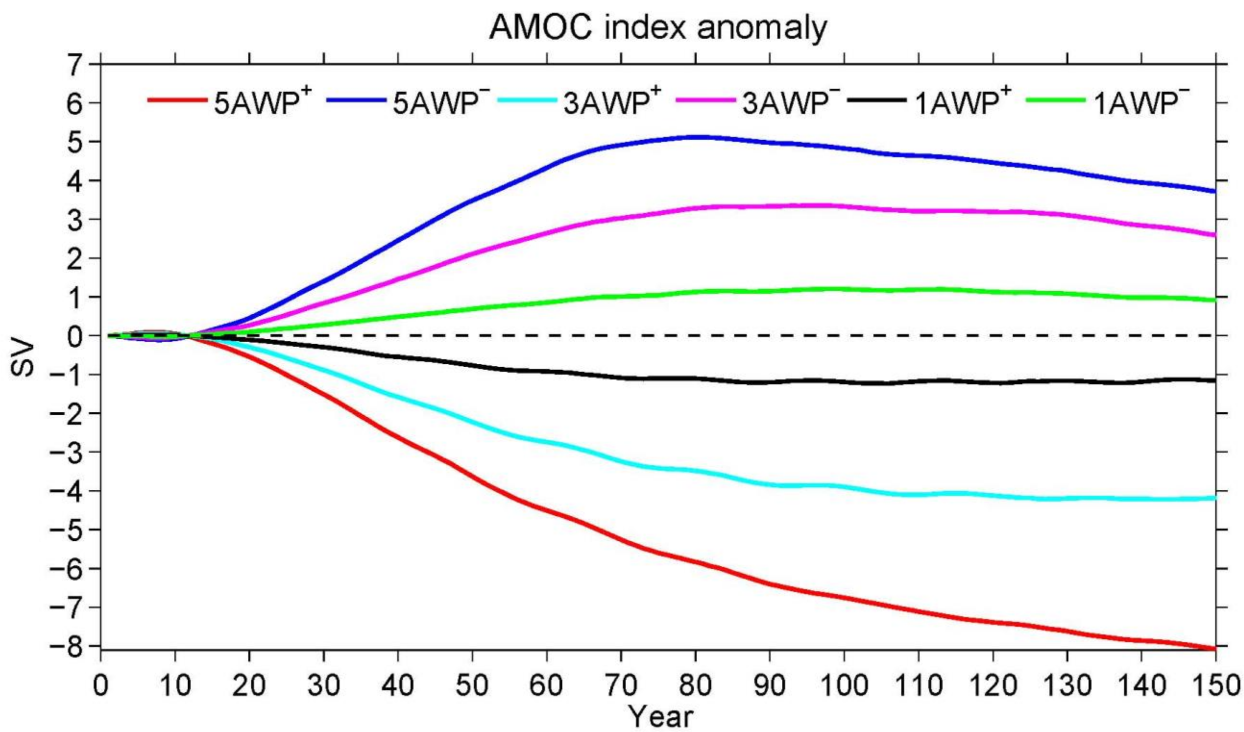

Figure 1: Time evolution of the AMOC index for 6 ocean model experiments forced by the large and small AWP-induced freshwater forcing amplified fivefold (red and dark blue lines), threefold (light blue and pink lines) and one fold (black and green lines), respectively.

Research Performance Measure: We achieved our second year work plan: to run the ocean model and analyze its output associated with the AWP.

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 Impacts

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/Climate Test Bed
NOAA Technical Contact: Fiona Horsfall

Research Summary:

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

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

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

Procedures

Our main goal is to evaluate the impact of climate variability and prediction on agricultural production. In this study we 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.

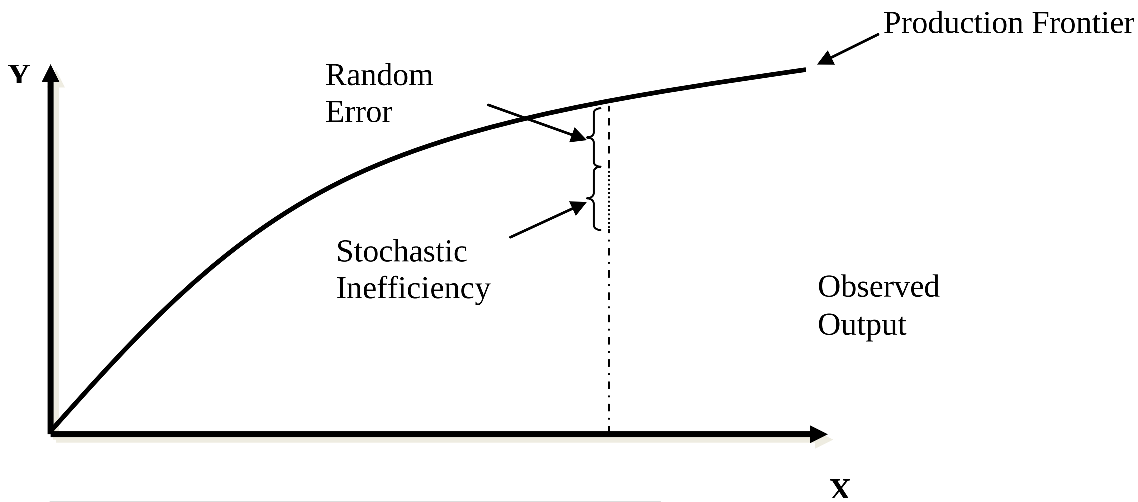

Figure 1: Stochastic Production Frontier

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.

Emperical Model

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

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

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

To control for regional differences in land quality and labor we 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^*):

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

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.

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

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Measuring the Value of Climate Variability on the Agricultural Sector: Climate Prediction Applications Science Workshop

Project Personnel: D. Letson (UM/RSMAS
Other Collaborators: M. Timofeyeva (NOAA/NWS)

Long Term Research Objectives and Strategy to Achieve Them:

***Objective*:** NOAA sponsors an annual Climate Prediction Applications Science Workshop (CPASW) that brings together climate information users, tool developers, researchers and providers. The objective of these meetings is to identify state-of the-art use of climate information and gaps in services.

***Strategy*:** To build a community of climate practitioners, discover user needs, assess impacts of climate forecasts on environmental-societal interactions, identify the science potential for meeting these needs, and provide feedback to producers on the usability of existing climate products.

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

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: NWS
NOAA Technical Contact: Marina Timofeyeva

Research Summary:
The 10th annual Climate Prediction Applications Workshop convened in Miami, FL, on March 13–15, 2012, around the integrated theme of "*Climate Services for National Security Challenges*". The workshop highlighted national and global uses of data and outlooks from seasonal to decadal scales in applications for a broad array of national security issues: state stability (including border security), international treaties, environmental regulation, resilience of coastal communities, security of natural resources, transportation, health, energy, and food, including agriculture and fisheries.

Permafrost in cold regions creates engineering and mobility challenges. Where ice within permafrost melts, these challenges are exaggerated. Temperature increases already observed in Alaska have disrupted structures and transportation, and these temperature increases (and attendant permafrost melting) are projected to accelerate in the future.

One speaker at the workshop described challenges that permafrost processes pose to infrastructure in Alaska and how these challenges grow in importance as infrastructure such as pipelines expands and as climate continues to change in Alaska. She recommended that NOAA work with national security agencies to develop new forecast products to support infrastructure management and to warn of impending conditions that could disrupt infrastructure, transportation, and communication.

Thawing permafrost could increase repair costs for public infrastructure by billions of dollars. Active layer thickness (ALT) affects engineering stability and varies with the ground temperature regime. Multiple factors affect ALT, including soil type, thickness, and moisture content; slope azimuth and declivity; cloudiness; and vegetative cover. Physically based geographically detailed models can calculate the multiple controls on ALT and other relevant parameters.

Figure 1: Permafrost damage to Copper River and Northwestern Railway in Alaska. Source: http://earthdata.nasa.gov/sites/default/files/styles/large/public/2005_permafrost_copper.jpg

Forecasts of ALT up to 1 year in advance using an existing permafrost model would represent a new product and could serve multiple user communities, including the national security community. Such a system might be implemented by the Army Corps. NOAA would provide results from existing forecast systems and work with the Army Corps to make sure climate forecasts are applied correctly.

Forewarning of the extent of melting of the active layer can allow those who must respond to infrastructure damage an opportunity to plan response, position resources, and prepare for action. Such forewarning can also allow those planning mobile operations to foresee and avert risks. Advance notice of potential disruptions in oil pipeline systems may allow stockpiling reserves so that refinery operations are not interrupted. Increased awareness, operational integration, and success will foster further opportunities to prepare for greater challenges from permafrost changes under climate change throughout the Arctic and beyond.

Research Performance Measure: Participants in the workshop reported multiple climate services relevant to the national security community and identified barriers and opportunities for better cooperation.

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Variability and Predictability of the Atlantic Warm Pool and Its Impacts on Extreme Events in North America

Project Personnel: S.-K. Lee, H. Liu, and D.B. Enfield (UM/CIMAS)
NOAA Collaborators: 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 to develop an experimental forecasting system using NCAR's 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:
This study investigates Atlantic Warm Pool (AWP) variability in the historical run of 19 coupled general circulation models (CGCMs) submitted to phase five of the Coupled Model Intercomparison Project (CMIP5). As with the CGCMs in CMIP3, most models suffer from the cold SST bias in the AWP region, and also show very weak AWP variability represented by AWP area index. However, for the seasonal cycle the AWP SST bias of model ensemble and model sensitivities are decreased

compared with CMIP3, indicating that the CGCMs are improved. The origin of the cold SST bias in the AWP region remains unknown, but among the CGCMs in CMIP5 excess (insufficient) high-level clouds simulation deceases (enhances) the cold SST bias in the AWP region through the warming effect of the high-level clouds radiative forcing. Thus the AWP SST bias in CMIP5 is more modulated by an erroneous radiation balance due to misrepresentation of high-level clouds rather than low-level clouds as in CMIP3. AWP variability is assessed as in our previous study in the aspects of spectral analysis, interannual variability, multidecadal variability and comparison of the remote connections with ENSO and the NAO against observations. In observations the maximum influences of the NAO and ENSO on the AWP take place in boreal spring. For some CGCMs these influences erroneously last to late summer. The effect of this overestimated remote forcing can be seen in the variability statistics as shown in the rotated EOF patterns from the models (Figure 1). We conclude that NCAR-CCSM4, GISS-E2H and GISS-E2R are the best three models of CMIP5 in simulating AWP variability.

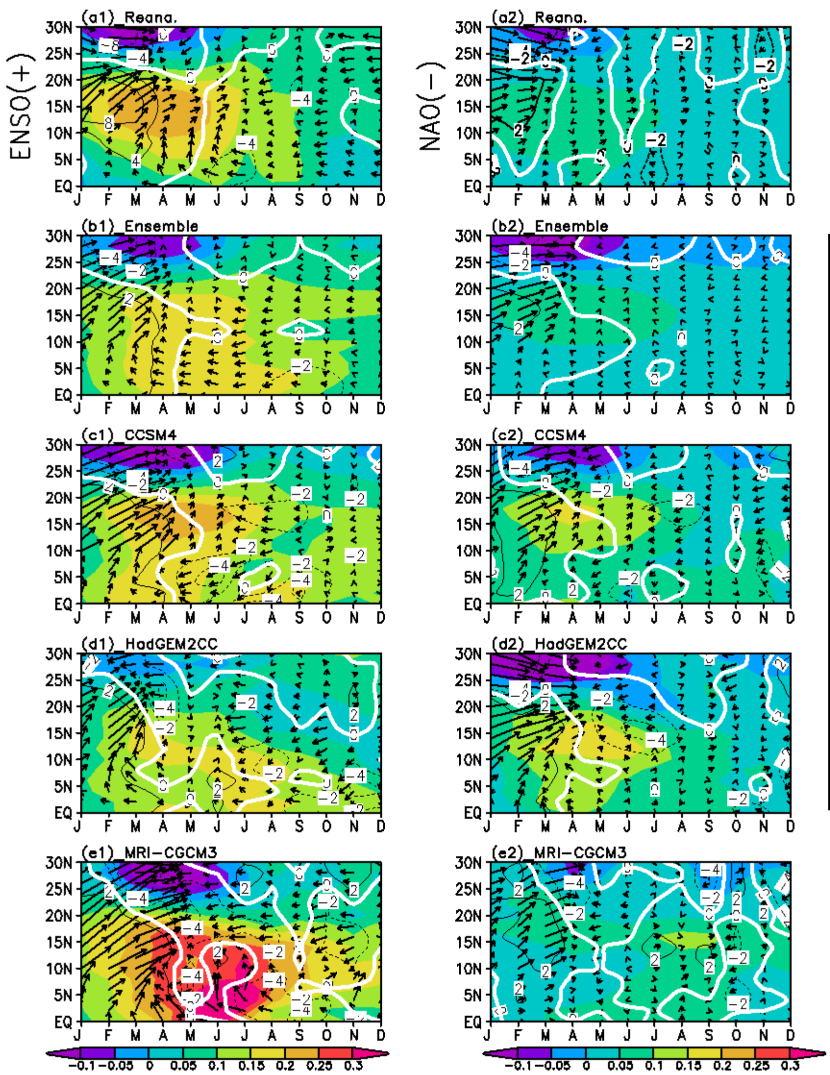


Figure 1: Regression map of surface wind stress (vector, N/m^2), net surface heat flux (positive into the ocean with solid contour line, W/m^2), and SST (shading contour, ^oC) averaged in longitude onto Niño-3 Index (DJF) and onto negative NAO index (DJFM). Shown are (a1) regression map onto Niño-3 Index for observations, (a2) regression map onto negative NAO Index for observations, (b1) regression map onto Niño-3 Index for ensemble of 19 models, (b2) regression map onto negative NAO Index for ensemble, (c), (d) and (e) are the same as (b) for selected 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.

Predicting the Effects of Natural and Forced Climate Change on the Gulf of Mexico Using Downscaled Climate Models

Project Personnel: Y. Liu, S.-K. Lee, B. Muhling and D. Enfield (UM/CIMAS)
NOAA Collaborators: J. Lamkin, W. Ingram and M. Schirripa (NOAA/SEFSC); 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 Science 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 (Muhling, B.A., S.-K. Lee, J.T. Lamkin and Y. Liu, 2011, Predicting the Effects of Climate Change on Bluefin Tuna (*Thunnus thynnus*) Spawning habitat in the Gulf of Mexico. *ICES Journal of Marine Science*, 68 (6), 1051-1062, doi:10.1093/icesjms/fsr008).

BFTs are therefore likely to be vulnerable to climate change, suggesting that there is potential for significant changes in their spawning and migration behaviors. According to our previous study (Liu et al. 2012), the volume transport by the Loop Current (LC) can be reduced by 20 - 25% at the end of 21st century. The reduced LC and the associated weakening of the warm LC eddy may have a large cooling impact in the GoM, particularly in the northern basin, and thus have strong impacts on the marine ecosystem in the GoM. Here, we further confirmed our conclusion using a high-resolution ocean model constrained with the surface forcing fields, initial and boundary conditions obtained from the CMIP5 model simulations under RCP4.5 and RCP8.5 scenarios (Figure 1 and 2). The downscaled model results indicate that the GoM is warmed everywhere, but the spatial pattern of the warming is quite different from that of the CMIP5 models (Figure 1a and 2a). In particular, the SST increase in the high-resolution model (Figure 1b) is much less especially in the northern GoM. A potential cause for this difference may be the weakening of the LC and the associated reduction in the warm water transport through the Yucatan Channel, which are not well simulated in the CMIP5 models. The downscaling CMIP5 climate models show that YC transport will be reduced during 21st century (under both RCP4.5 and RCP8.5 scenarios, see Figure 1c and 2c), consistent with a similar rate of reduction in the Atlantic meridional overturning circulation (AMOC). Figure 1d and 2d show clearly the weakening of the main branch of LC, an anomalous cyclonic ring formed in the central and northern GoM. The reduced LC and the associated weakening of the warm LC eddy have a cooling impact in the northern GoM. Due to this cooling influence, the northern GoM is characterized as the region of minimal warming. The reduced warming in the northern GoM will have important implications for marine ecosystems, including the spawning of Bluefin tuna. These results are consistent with the results using CMIP3 forcing.

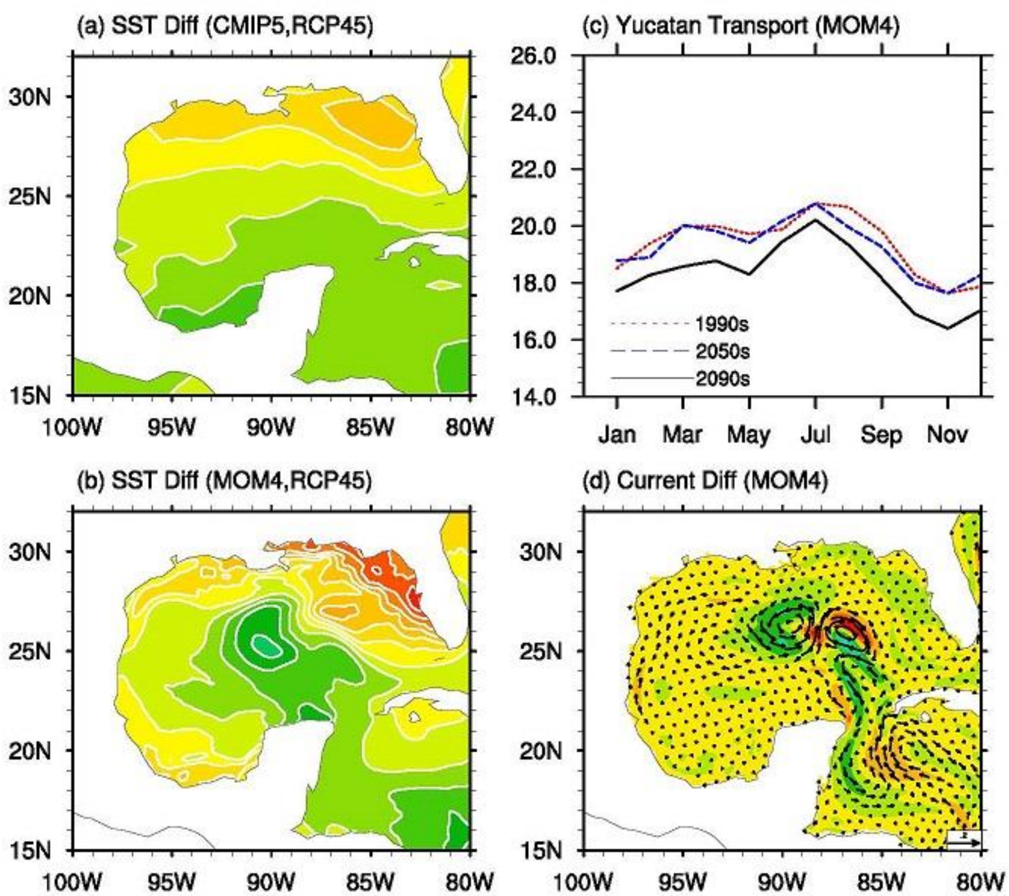


Figure 1: SST difference between the late 21st century and late 20th century for the AMJ spawning season obtained from (a) CMIP5 models (low resolution) under the RCP4.5 scenario and (b) high-resolution MOM4 model output under the RCP4.5 scenario forcing. (c) Seasonal transport through the Yucatan Channel for the three different periods (late-20th century, mid 21st century and late 21st century) from the high-resolution MOM4 model output. (d) Surface current (vectors) and current speed difference (colors) between the late 21st century and late 20th century for AMJ season from the high-resolution MOM4 model output under the RCP4.5 scenario.

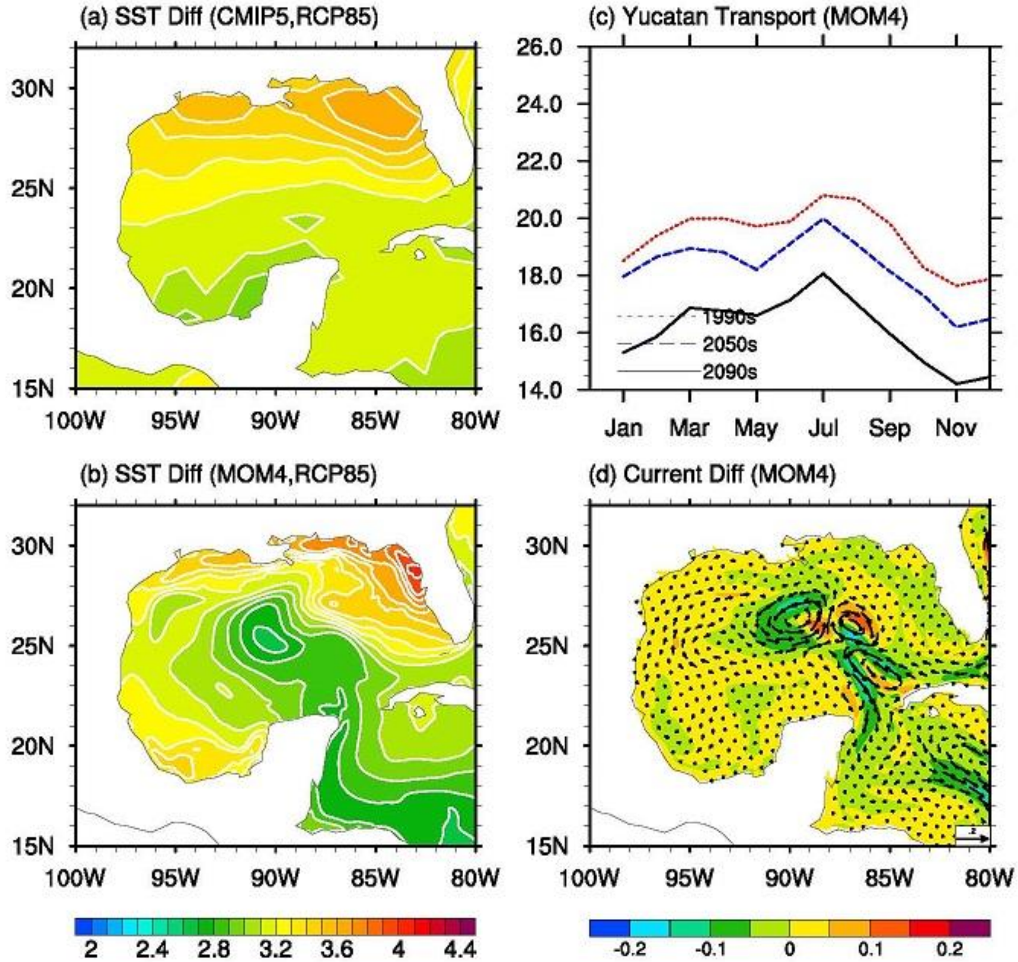


Figure 2: Same as Fig. 1, except that the differences are from the CMIP5 under the RCP8.5 scenario. The color bar is different with that in Fig.1. SST increase is more severe under RCP8.5 scenario.

The downscaled ocean model results indicate that the sea surface temperature in the GoM may increase by more than 1.5°C at the end of the 21st century. 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°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 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. Figure 3 shows the monthly wind stress and wind stress curl (WSC) regressed onto the AMO index from 1871 to 2008. As clearly shown in Figure 3, 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. Our analysis of the ocean reanalysis simulation reveals 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.

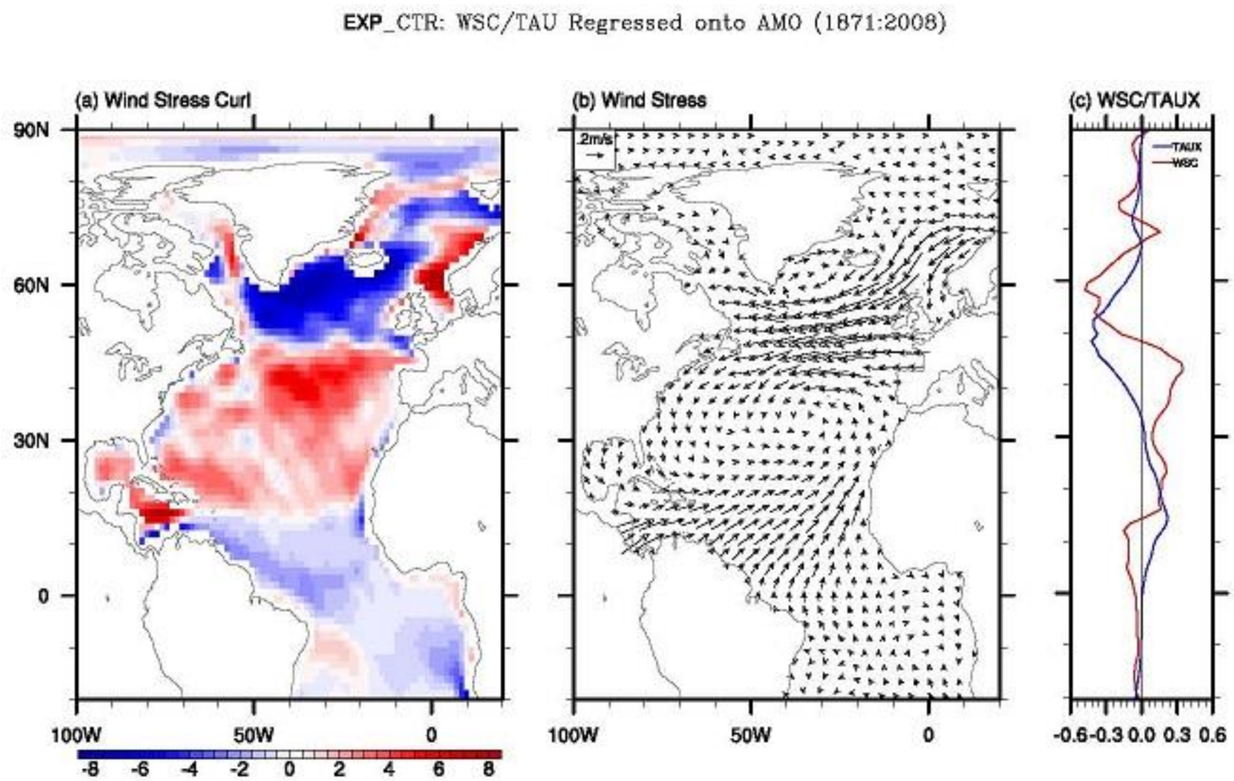


Figure 3: Regression of (a) monthly wind stress curl and (b) wind stress component on the AMO index from 1871 to 2008 obtained from CCSM_POP. (c) Zonal averaged wind stress (blue) and wind stress curl (red) for 1871–2008 period, obtained from the CCSM_POP.

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.

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

Project Personnel: X. Wang (UM/CIMAS)
NOAA Collaborators: C. Wang (NOAA/AOML)
Other Collaborators: T. Shinoda (Naval Research Laboratory); 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: AOML **NOAA Technical Contact:** Alan Leonardi

Research Summary:
Based on their opposite influences on rainfall in southern China during boreal fall, El Niño Modoki is classified into two groups: El Niño Modoki I and II, which show different origins and patterns of SST anomalies. The warm SST anomalies originate in the equatorial central Pacific and subtropical northeastern Pacific for El Niño Modoki I and II, respectively. Thus, El Niño Modoki I shows a symmetric SST anomaly distribution about the equator with the maximum warming in the equatorial central Pacific, whereas El Niño Modoki II displays an asymmetric distribution with the warm SST anomalies extending from the northeastern Pacific to the equatorial central Pacific. Additionally, the warm SST anomalies in the equatorial central Pacific extend farther westward for El Niño Modoki II than for El Niño Modoki I. Similar to the canonical El Niño, El Niño Modoki I is associated with an anomalous anticyclone in the Philippine Sea that induces southwesterly wind anomalies along the south coast of China and carries the moisture for increasing rainfall in southern China. For El Niño Modoki II, an anomalous cyclone resides east of the Philippines, associated with northerly wind anomalies and a decrease in rainfall in southern China. The canonical El Niño and El Niño Modoki I are associated with a westward extension of the western North Pacific subtropical high (WNPSH), whereas El Niño Modoki II shifts the WNPSH eastward. Differing from canonical El Niño and El Niño Modoki I, El Niño Modoki II corresponds to northwesterly anomalies of the typhoon steering flow, which are unfavorable for typhoons to make landfall in China.

Research Performance Measure: Complete analysis of the the variations of rainfall in southern China and the typhoon tracks during boreal fall associated with El Niño Modoki I and II.

RESEARCH REPORTS

THEME 2: Tropical Weather

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

Project Personnel: A. Aksoy and K. Sellwood (UM/CIMAS)
NOAA Collaborators: S.D. Aberson and T. Vukicevic (NOAA/AOML)

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: 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, *Monthly Weather Review*, 140, 1843-1862).

(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 is published in Monthly Weather Review (Aksoy 2012).

(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 published in Monthly Weather Review (Aksoy et al. 2012b, Assimilation of high-resolution tropical cyclone observations with an ensemble Kalman filter using NOAA/AOML/HRD's HEDAS: Evaluation of the 2008-2011 vortex-scale analyses. *Monthly Weather Review*, accepted and available for early online viewing).

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.

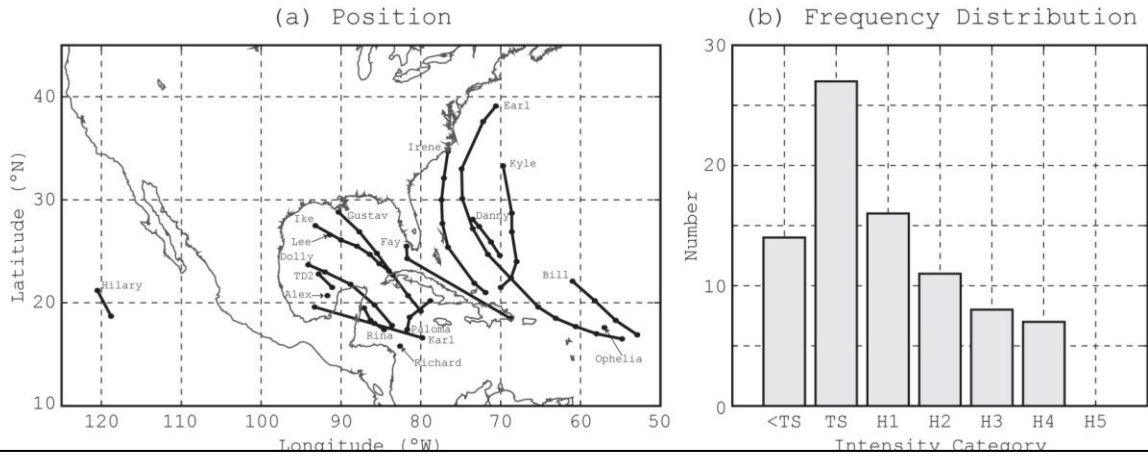


Figure 1: (a) Geographical distribution of the case position as observed in the best track dataset. (b) Frequency distribution of the case intensity category as observed in the best track dataset. Cases that do not exist in the best track database are assigned "<TS" category. "TS" and "H" stand for tropical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

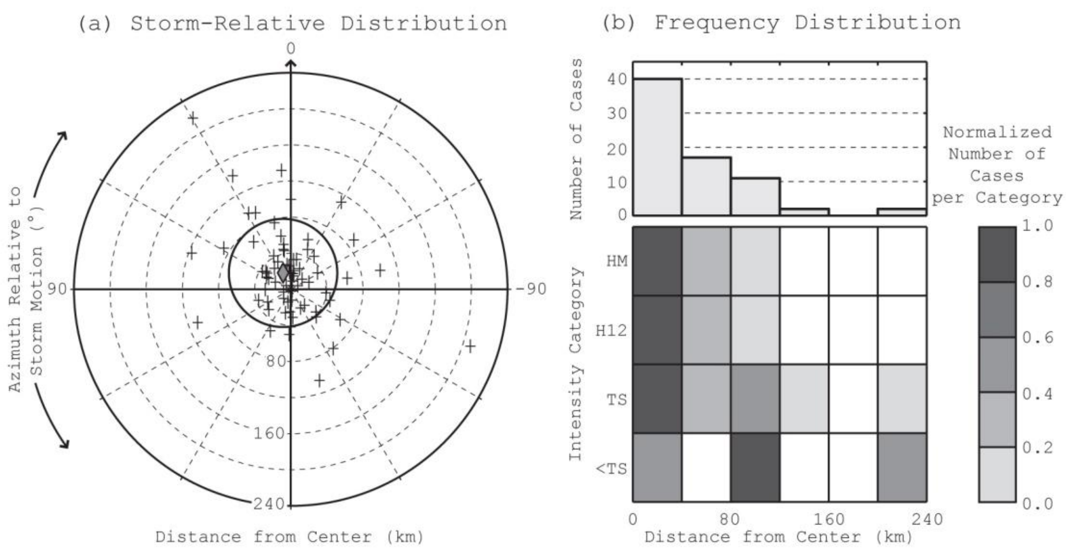
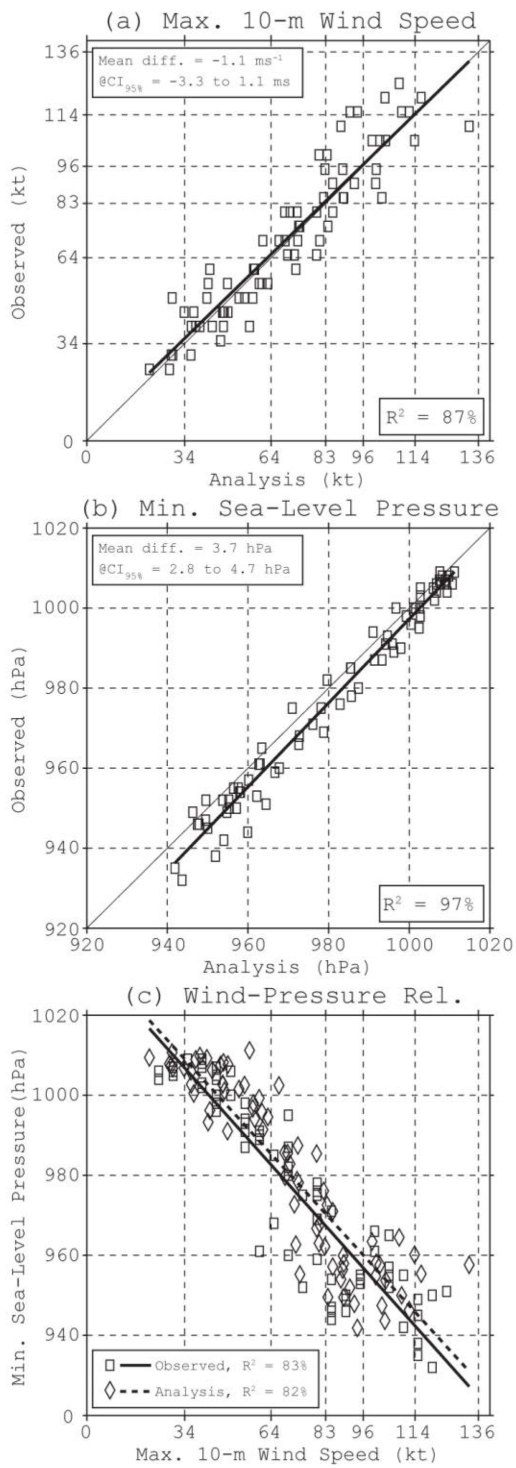


Figure 2: Position error in the final analysis as compared to the best track. (a) Analysis storm centers (plus markers) relative to the best track. Azimuth is measured relative to observed storm motion where 0° represents the direction of storm motion. Radial distance is measured from the best track 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.



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).

Impact of forecast model deficiencies on the HEDAS analyses is investigated in Vukicevic et al. 2012 (Joint impact of forecast tendency and state error biases in ensemble Kalman filter data assimilation of inner-core tropical cyclone observations. *Monthly Weather Review*, accepted and available for early online viewing). It is found that some of the systematic analysis errors in HEDAS were related to the model error in the planetary boundary layer (PBL) parameterization of HWRF. These findings contributed to the improvements in the PBL parameterization of the later versions of NOAA's operational HWRF model.

(4) HEDAS has 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

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.

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. Vortex-scale analyses from HEDAS are then provided as the initial conditions to the HWRF model to produce 126-h forecasts. The performance of these forecast runs is summarized in Aberson et al. (2013), which is currently in internal review and will be submitted to Monthly Weather Review for publication.

Figure 4 summarizes the performance of the short-range (up to 72-h) forecasts initialized with HEDAS analyses as compared to operational HWRF for the 2012 hurricane season and all cases with aircraft data. It is evident that assimilation of aircraft data in HEDAS leads to improvements in the forecast of both track (by ~10 nm, Fig. 4a) and intensity (by ~3 kt, Fig. 4b) over the operational model. These demonstrations have led to the assimilation of inner-core aircraft data to become a part of the operational HWRF data assimilation system starting with the 2013 hurricane season.

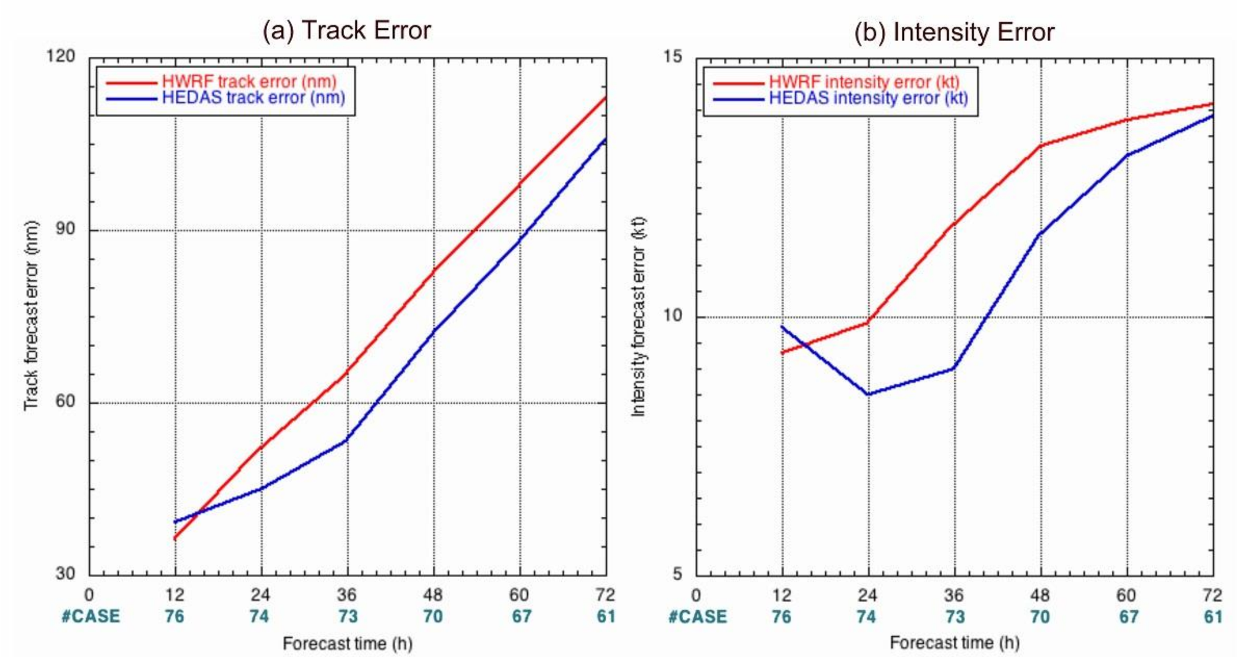


Figure 4: Comparison of the forecast error between HWRF forecasts initialized with HEDAS analyses and operational HWRF forecasts. (a) Track forecast errors (nm). (b) Intensity forecast errors (kt).

(5) 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.

Investigation of HWRF Model Errors Associated with Surface-Layer and boundary-Layer Parameterizations To Improve Vortex-Scale, Ensemble-Based Data Assimilation Using HEDAS

Project Personnel: A. Aksoy, J. Zhang and B. Klotz (UM/CIMAS)
NOAA Collaborators: E. Uhlhorn and J. Cione (NOAA/AOML/HRD)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** Improve NOAA's HWRF hurricane forecast model by addressing the sources of error in its parameterization of the surface and boundary layers.

***Strategy*:** Combine an idealized HWRF environment, observed and composited steady-state hurricane structure, and HEDAS ensemble environments to comparatively investigate model sensitivities to initial vortex structure, hurricane environment, and the parameterization of the surface and boundary layers.

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/NWSPO/JHT **NOAA Technical Contact:** Daniel Melendez

Research Summary:

Two major accomplishments of this project to date are:

(1) Observation-based, composite, axisymmetric vortex fields of tangential and radial wind speed, temperature, moisture, and pressure are constructed for initialization and comparison. The observation-based thermodynamic analyses (pressure, temperature, moisture) are developed from a weighted combination of historical radius-height cross sections and GPS dropwindsondes from multiple aircraft, both low- and high-altitude. The historical analyses serve as a low-weight background and are particularly useful where significant dropsonde data gaps exist. As part of the NOAA/AOML/HRD dropsonde database development effort, each dropsonde is associated with several storm-specific parameters, including intensity, radius of maximum wind, environmental shear vector. Each of these parameters is used to develop specific composite analyses representative of a TC of interest. A general Gaussian weighting function with Barnes-type successive correction is applied for interpolation purposes, and scaling parameters are chosen by trial-and-error. Horizontal wind (radial and tangential component) analyses are developed based on a combination of NOAA P-3 Doppler radar composite analyses and dropwindsonde observations. The Doppler analyses rarely extend beyond ~5 maximum wind radii from the storm center and higher than ~14 km due to weak precipitation scattering. Relatively little in situ observational data exist at greater altitude, which presents a challenge for resolving the upper-tropospheric outflow. To fill this important, but data-void, region, several analyses from the Hurricane Ensemble Data Assimilation System (HEDAS, developed by the P.I.) for Hurricane Earl (2010) are used a low-weight background. Interpolation procedures are the same as used for the thermodynamic fields. In Fig. 1, the axisymmetric tangential and radial horizontal wind and temperature perturbation fields of the observation-based vortex are shown.

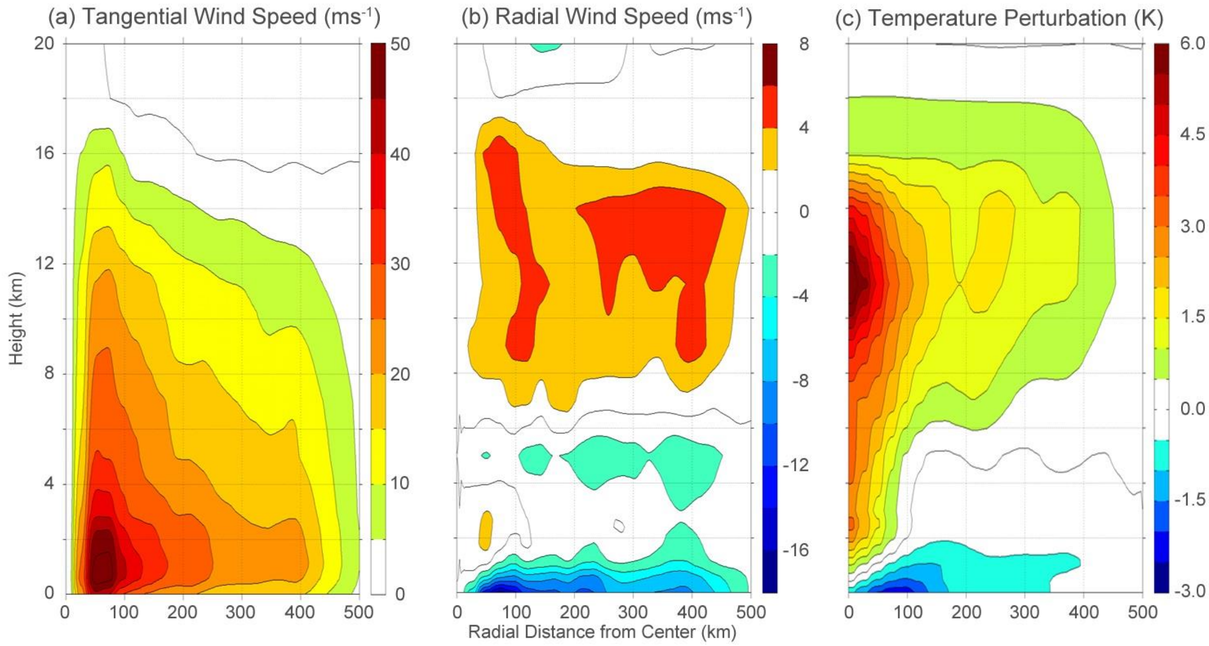


Figure 1: Axisymmetric fields from the composite, observation-based vortex. (a) Tangential wind speed (ms^{-1}). (b) Radial wind speed (ms^{-1}, positive denotes outflow). (c) Temperature perturbation from the environment (K).

(2) An idealized end-to-end HWRF system is developed with the following components: (a) The capability to initialize within any environmental profile where the boundary conditions remain consistent with the initial specified profile throughout the run. (b) The capability to specify a zonal vertical shear profile within any two vertical levels. A mass balancing constraint is also implemented to allow for meridional mass adjustment to balance the specified zonal shear. (c) The capability to control the overall storm speed through vertical mass integration of the winds. (d) A full coupling with a one-dimensional column ocean model developed within NOAA/AOML (George Halliwell, NOAA/AOML/PhOD) and the capability to initialize with any specified ocean profile of temperature and salinity. (e) The capability to control ocean-relative storm motion either through a moving atmosphere or a moving ocean. (f) The capability to initialize with any axisymmetric vortex structure, including the observationally based composite vortex as explained above.

The simulation that is initialized with the observed vortex and 8 ms^{-1} vertical (850-200 hPa) wind shear in the zonal direction is deemed the "control". Some of the features of this 5-day simulation are summarized in Figure 2. Figure 2a demonstrates that the environmental conditions remain generally steady throughout the simulation, which implies that the evolution of the vortex structure is generally the result of internal vortex dynamics and not the adjustment process to a changing environment. In Figure 2b, the steady-state nature of the simulation is demonstrated. The intensity (maximum 10-m wind speed) and minimum sea-level pressure MSLP in the steady-state regime are very close to those observed for the type of hurricane in question. The realistic response of sea surface temperature (SST) and specific humidity (SSQ) to the ocean coupling is demonstrated in Figures 2c and 2d. Finally, the simulation also depicts realistic air-sea contrast structures as can be seen in Figs. 2e and 2f. Diagnostics such as these are unique in that modeled structures can be directly compared to observed structures in high detail thanks to HRD's existing observational databases.

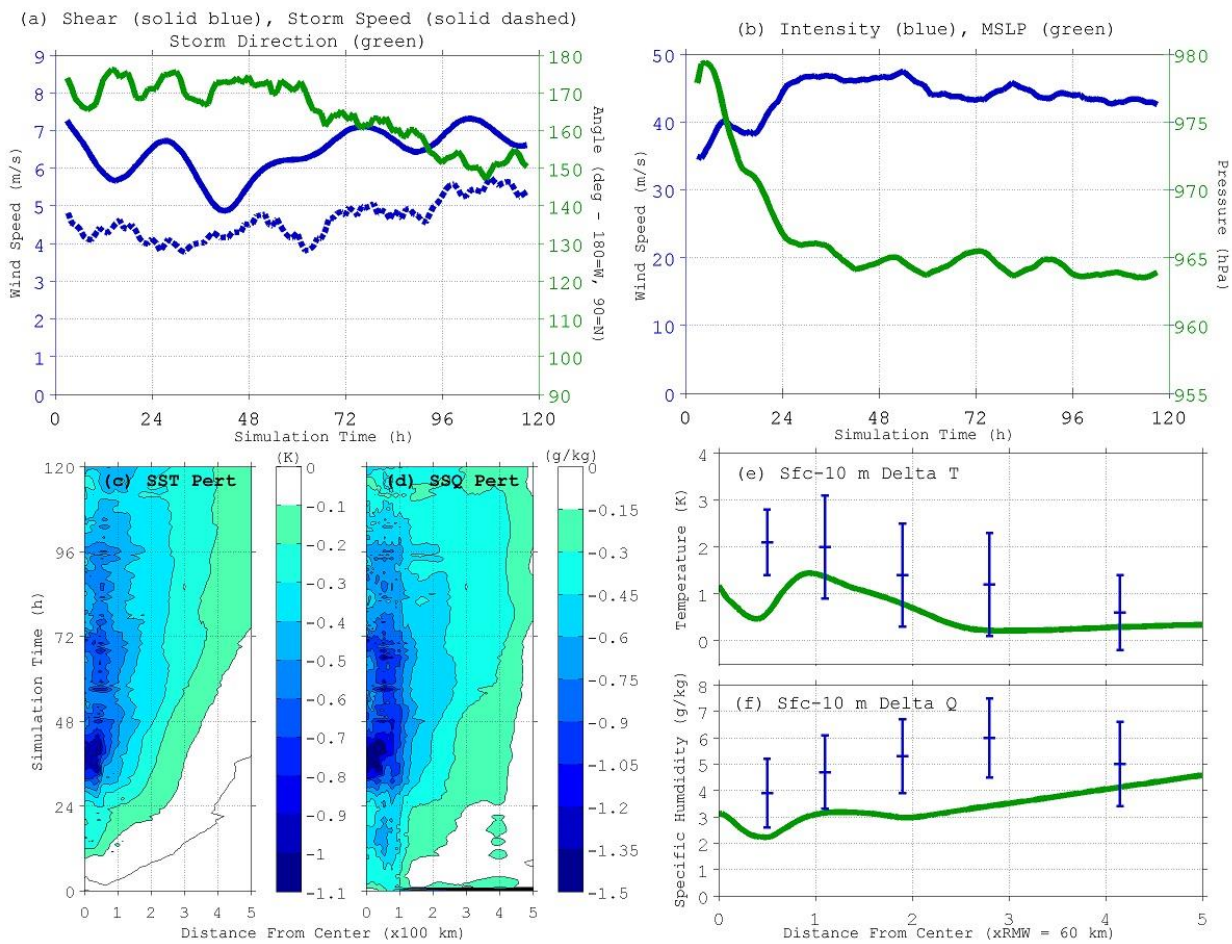


Figure 2: Various diagnostics from a realistic idealized HWRF simulation. (a) Evolution of environmental 850-200 hPa vertical wind shear (solid blue), storm speed (dashed blue), and storm motion direction (green). (b) Evolution of intensity (blue) and MSLP (green). (c) Time-radial distance plot of SST perturbation from initial constant SST of 29 C. (d) Time-radial distance plot of SSQ perturbation from initial (variable due to pressure change with radial distance). (e) Temperature contrast between the ocean surface and 10 m atmosphere at 72 h of simulation (green) compared to composite observations in similar conditions (blue). (f) As in (f) but for specific humidity.

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

Software Support for the Execution of Atmospheric Observing System Simulation Experiments

Project Personnel: A. Aksoy, B. Annane, L. Bucci and J. Delgado (UM/CIMAS)
NOAA Collaborators: R. Atlas, S. Gopalakrishnan, F. Marks, T. Vukicevic and X. Zhang (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To develop software to facilitate running of Observing System Simulation Experiments (OSSEs); to address technical, software-related issues with the components used to run these experiments.

***Strategy*:** Details of the experiments to be carried out will be discussed during weekly meetings and software will be created to integrate the existing software components needed for the experiments. Issues with existing software will be addressed as they arise.

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 OSSE experiments being conducted consist of assimilating various observation data. Each experiment consists of running an *ensemble* of multiple weather forecast simulation *members* with perturbed initial and boundary conditions for several *cycles*. We use the Hurricane Weather Research and Forecasting (HWRF) model to perform the weather simulations and the Gridpoint Statistical Interpolator (GSI) software for the data assimilation.

J. Delgado has developed UNIX scripts that run data assimilation cycles for individual members. The scripts provide flexibility in terms of the observation data that is used, the duration of the forecasts, the frequency between cycles, etc. They are optimized to reduce the required execution time and disk space, while ensuring enough data is available for proper post-processing. He has also developed a system for running an ensemble of members. This system is currently being modified to allow more flexibility in terms of the parameters of the experiments.

J. Delgado has also worked on software issues that have presented themselves in the process of designing and running experiments. For example, to be effective, OSSEs require weather simulations to be performed at relatively high spatial resolutions across relatively large sections of land. Due to the large computational requirements of these simulations, a balance must be made between resolution and execution time. J. Delgado was responsible for configuring the simulation environment such that these large experiments could be run. He also inspected the model source code to try and find issues with the code that prevented it from running certain large weather simulations, and determining the computational requirements of different experiments. Relatedly, it is possible to use the concept of "nesting" higher resolution domains that focus on regions of interest inside of larger, coarser domains. He addressed technical issues that were necessary to enable these kinds of simulations to be run with HWRF in order to work with the OSSEs.

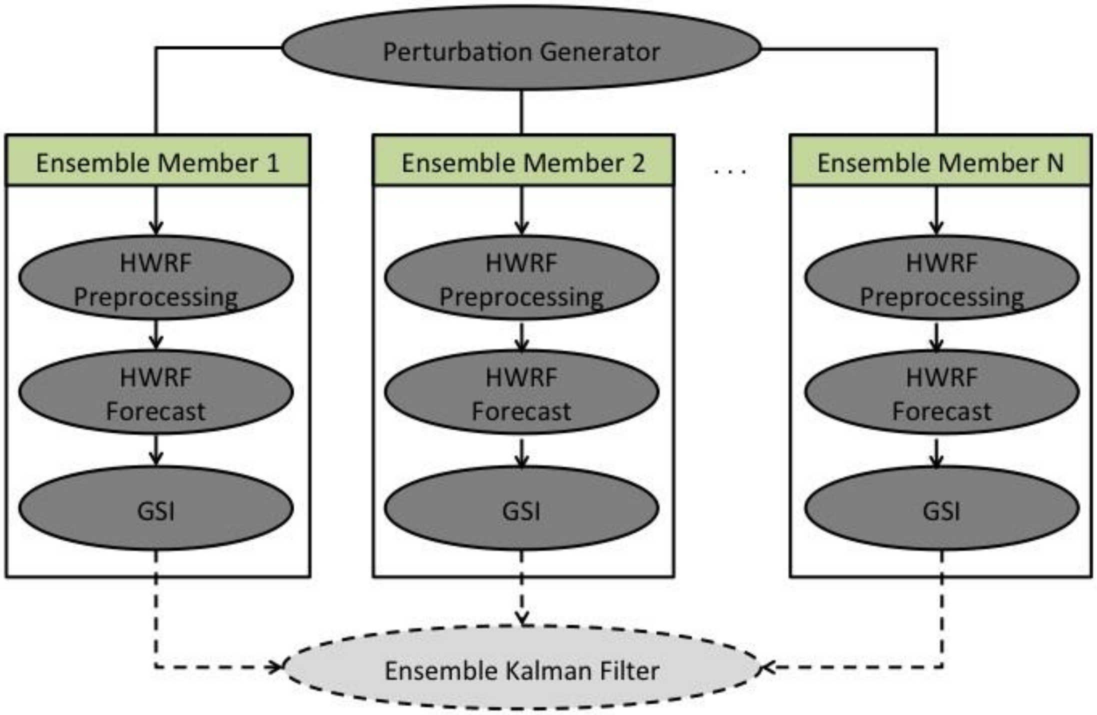


Figure 1: This figure depicts the interaction among different components of the OSSE system. We are presently developing the software that automates the workflow, so that a wide range of experiments can be conducted seamlessly. We are still evaluating our options for the Ensemble Kalman Filter component, hence the dashed lines. Note that the cycling is not illustrated in this figure.

Research Performance Measure: The software currently works satisfactorily with the current single-member experiments being run, although the experiments will change as new data is received. The program for running ensembles will be modified to accommodate changes in the experiments.

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Development of an Objective Scheme for Predicting Tropical Cyclone Genesis

Project Personnel: J.P. Dunion (UM/CIMAS)
NOAA Collaborators: J. Kaplan (NOAA/AOML/HRD); M. DeMaria (NOAA/NESDIS)
Other Collaborators: A. Schumacher (CSU); J. Cossuth (FSU)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To develop and objective scheme for predicting the likelihood of tropical cyclone genesis in the North Atlantic for both the 0-48 and 0-120 hr timeframes. Design this scheme to be a real-time tool for forecasters at the NOAA National Hurricane Center (NHC).

***Strategy*:** To continue development and real-time development of this scheme, the Tropical Cyclone Genesis Index (TCGI), and begin a real-time demonstration during the 2013 Atlantic hurricane season.

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/JHT **NOAA Technical Contact:** Christopher Landsea

Research Summary:
Tropical cyclone (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. Additionally, there are limited objective resources available to NHC forecasters tasked with diagnosing the potential for TC genesis in the 0-48-hr and 0-120-hr time frames. The main goal of this project is to develop a disturbance-following TC genesis index (TCGI) to provide forecasters with an objective tool for identifying the 0-48hr and 0-120hr probability of TC genesis in the North Atlantic basin. Sixty predictors from a variety of satellite and model-based sources were tested for potential integration into this new scheme and real-time testing will begin during the summer of 2013. The final TCGI predictors and their relative importance for 0-48 and 0-120 hr genesis forecasts are shown in Figure 1.

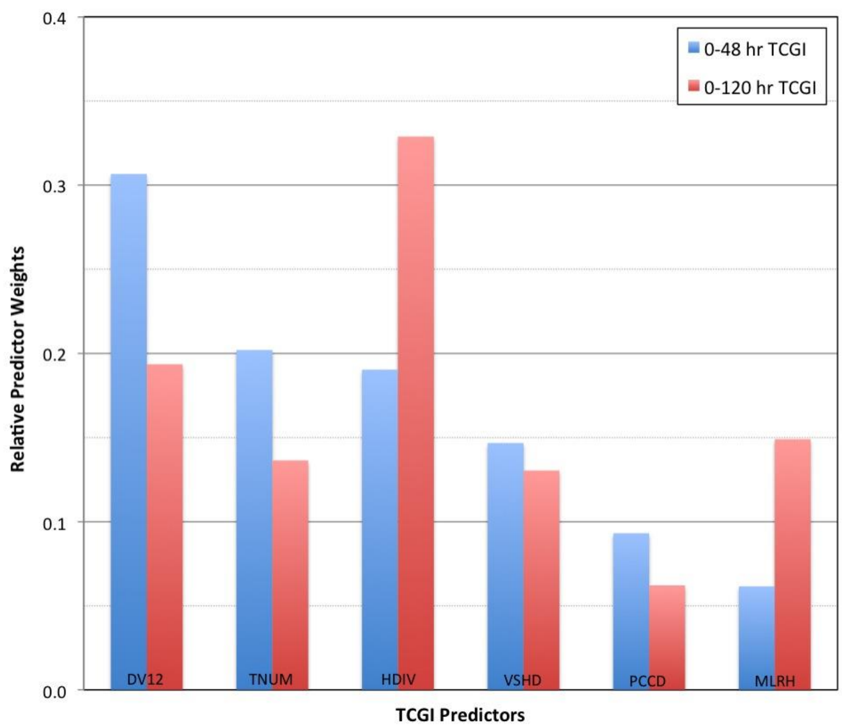

Figure 1: Predictors that were selected for inclusion in the TCGI scheme and their relative importance for forecasting 0-48 and 0-120 hr TC genesis. These predictors include: 12-hr vortex tendency (DV12, from the NOAA Global Forecast System (GFS) model), Dvorak T-Number satellite intensity estimates (TNUM, from the NOAA Tropical Analysis & Forecasting Branch), low-level divergence (HDIV, GFS model), 250-850 hPa vertical shear (VSHD, GFS model), GOES water vapor satellite imagery (PCCD), and middle level moisture (GFS model).

Research Performance Measure: This project is in the year-2 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 proposal team completed the development of 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).
2. The proposal team completed the identification and testing of potential storm and environmental predictors for the TCGI database.
3. PI Dunion presented year-2 project results at the 66th Interdepartmental Hurricane Conf., (March 2012): *Development of a Probabilistic Tropical Cyclone Genesis Prediction Scheme*.
4. PI Dunion submitted a mid-year report (March 2013) to NOAA JHT.
5. The proposal team has begun developing code to run the TCGI scheme in real-time during the 2013 Atlantic hurricane season.

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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:

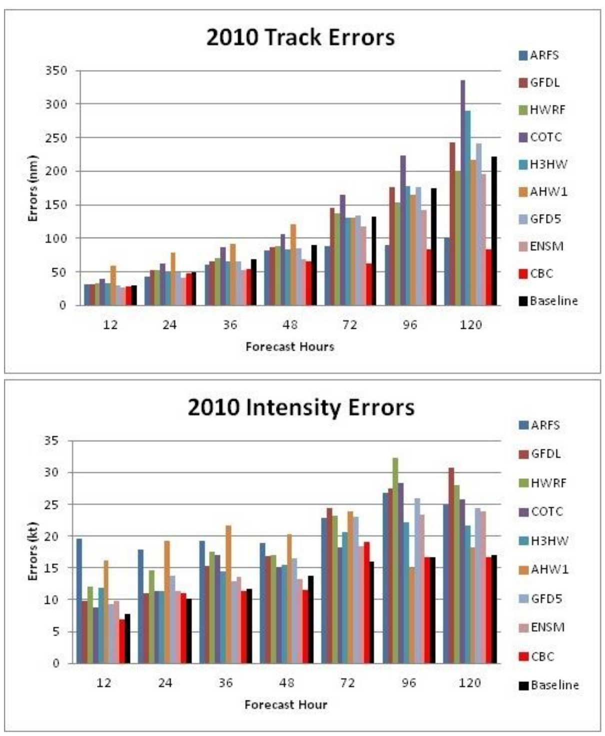
***Goal 2*:** Weather-Ready Nation - *Society is prepared for and responds to weather-related events*

NOAA Funding Unit: OAR/AOML/NWS
NOAA Technical Contacts: Alan Leonardi and Stephen J. Lord (NWS)

Research Summary:

First it should be stated that the results from the FSU multimodel superensemble are nearly always 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, 2011 and 2012 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.

It recently became possible to include the data sets for SHIPS/SPICE for the 2012 hurricane season. SHIPS was available for the hurricane seasons of 2010, 2011 and 2012. The track and intensity forecasts for the three hurricane seasons are presented in Figure 1 (a,b,c). 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. Overall the analyses confirm that the multimodel ensemble consistently provides the best results.



Cases: 74. 69. 63. 56. 48. 35. 24

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

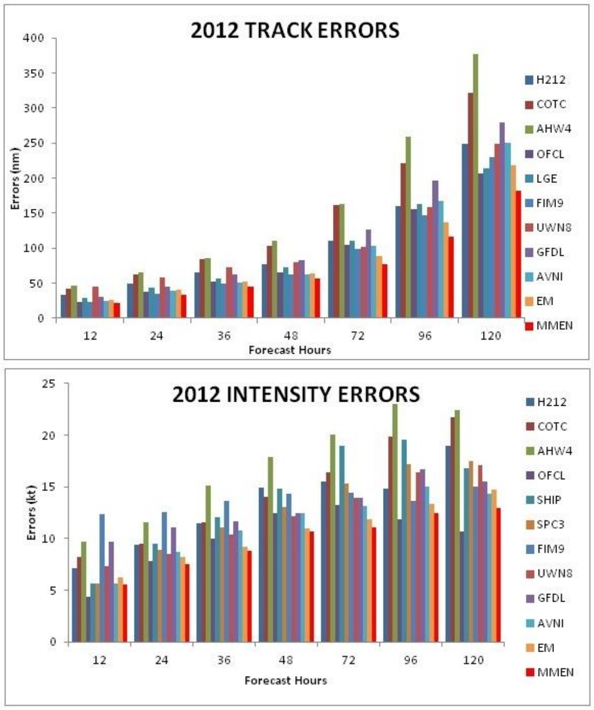


Figure 1b: Track and intensity forecast errors for all the hurricanes of 2011.

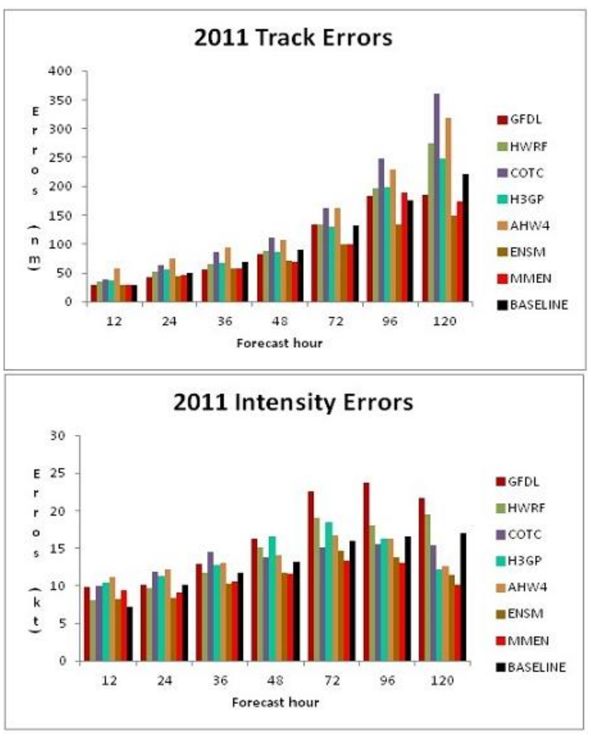


Figure 1c: Track and intensity forecast errors for all the hurricanes of 2012.

Cases: 74, 69, 63, 56, 48, 35, 24

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.

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 simulations.

In the past year, we have completed our work 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 compared the vertical distribution of vertical motion and reflectivity to similar analyses of observed storms. The nature run hurricane also reproduces a realistic eyewall replacement cycle. A full-length article on the nature run simulation and its validation was submitted and recently accepted for publication in *Journal of Advances on Modeling Earth Systems*.

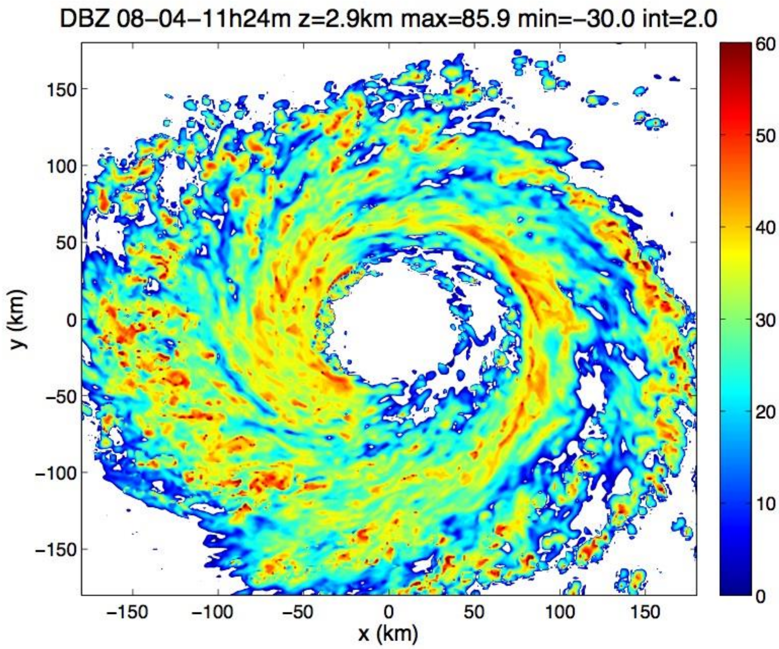


Figure 1: This figure shows the simulated reflectivity at an altitude of z = 2.9 km (approximate flight level for NOAA research aircraft) during the secondary eyewall formation simulated in the hurricane nature run. The outer eyewall forms from the long rainband that starts southwest of the center and wraps around the center to the west side of the eye. The low-reflectivity "moat" on the east side of the eyewall is a common feature for such events.

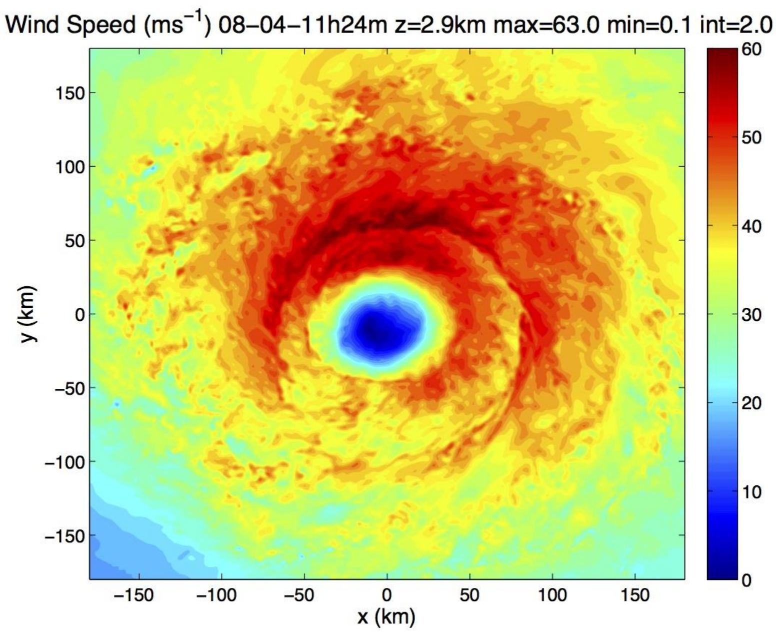


Figure 2: This figure shows the simulated wind speed at the same time and altitude as Figure 1. The secondary eyewall formation is associated with an outer wind maximum that nearly wraps around the center.

The nature run has been archived and made available to several other research groups for its intended use in OSSEs and other research purposes.

Research Performance Measure: Most of the goals for the project have been met. A second nature run is under development and we expect it to be completed in the next few months.

Real-Time Hurricane Wind Analysis

Project Personnel: B. Annane, S. Otero, 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/HRD
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).

Just in time for Hurricane Sandy, some minor refinements to the Integrated Kinetic Energy (IKE) formulas had been implemented, based on research from GPS sonde measurements. Despite Hurricane Sandy ranking only a category 1 storm per the Saffir-Simpson scale, Sandy carried record large values of IKE (> 300 TJ, with Surge/Wave Destructive Potential ratings > 5.5 in a scale of 0 to 6), due to an extensive field of winds in excess of 34 kt. Several media articles wrote about the ability of IKE-based metrics to more accurately rate the multi-faceted destructive power of a storm, versus just using the peak wind to describe intensity:

http://www.outsideonline.com/blog/outdoor-adventure/science/hurricane-researcher-brian-mcnoldy-on-the-science-behind-sandy.html

http://www.ouramazingplanet.com/3730-hurricane-sandy-second-most-powerful.html

http://www.empiricalzeal.com/2012/11/01/what-is-the-true-measure-of-a-storm/

http://usatoday30.usatoday.com/weather/storms/hurricanes/story/2011/08/New-hurricane-scale-puts-more-focus-on-storm-surge/49958782/1

For the upcoming hurricane season, the H*Wind ATCF-formatted products will be appended with IKE results per storm quadrant.

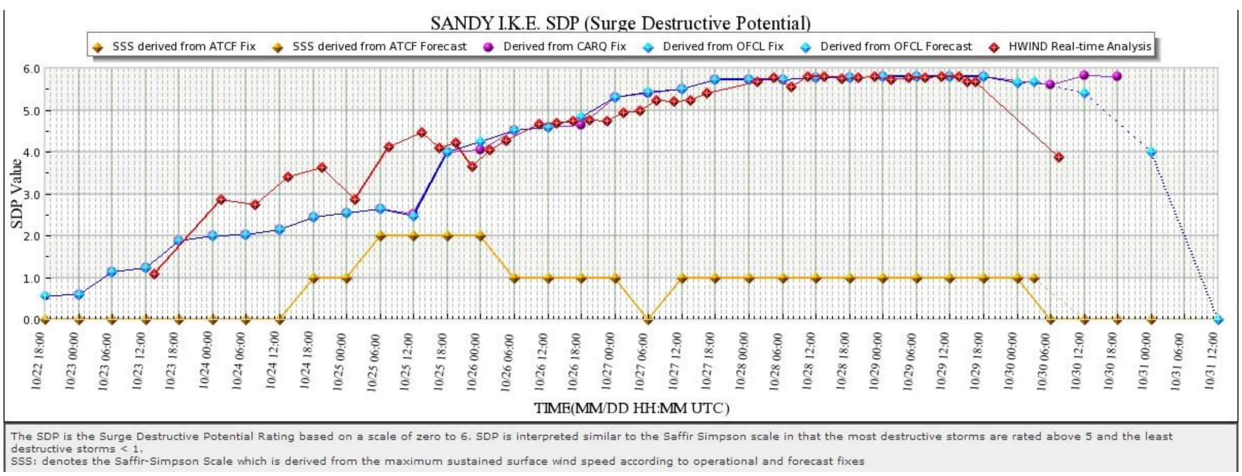


Figure 1: Time series of IKE Surge Destructive Potential of Hurricane Sandy, October 2012.

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

A Seventeen-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*

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

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 thermodynamics, and in studies of targeted observations and predictability, as well as in climate research and numerical model evaluation. For example, research with this data set has been instrumental in estimating the drag coefficients employed in numerical forecast models to simulate the effects of surface friction. As a result the representation of the hurricane boundary layer in the HWRF model has been greatly improved. Dropwindsonde data provide the only near surface observations of pressure, temperature humidity and wind direction in the hurricane inner core and are therefore crucial to this type of research. Hundreds of these profiles are obtained annually in the Atlantic and northern Pacific Oceans, and might soon become available in the Indian Ocean. Dropwindsonde data in the Atlantic obtained using unmanned aircraft should also be available beginning in 2013.

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. Additional information which might aid researchers, such as dropsonde scientist logs and notes, is provided when possible. Both numerical and graphic versions of the data are provided in order to meet the various needs of the research community. See Figure 1.

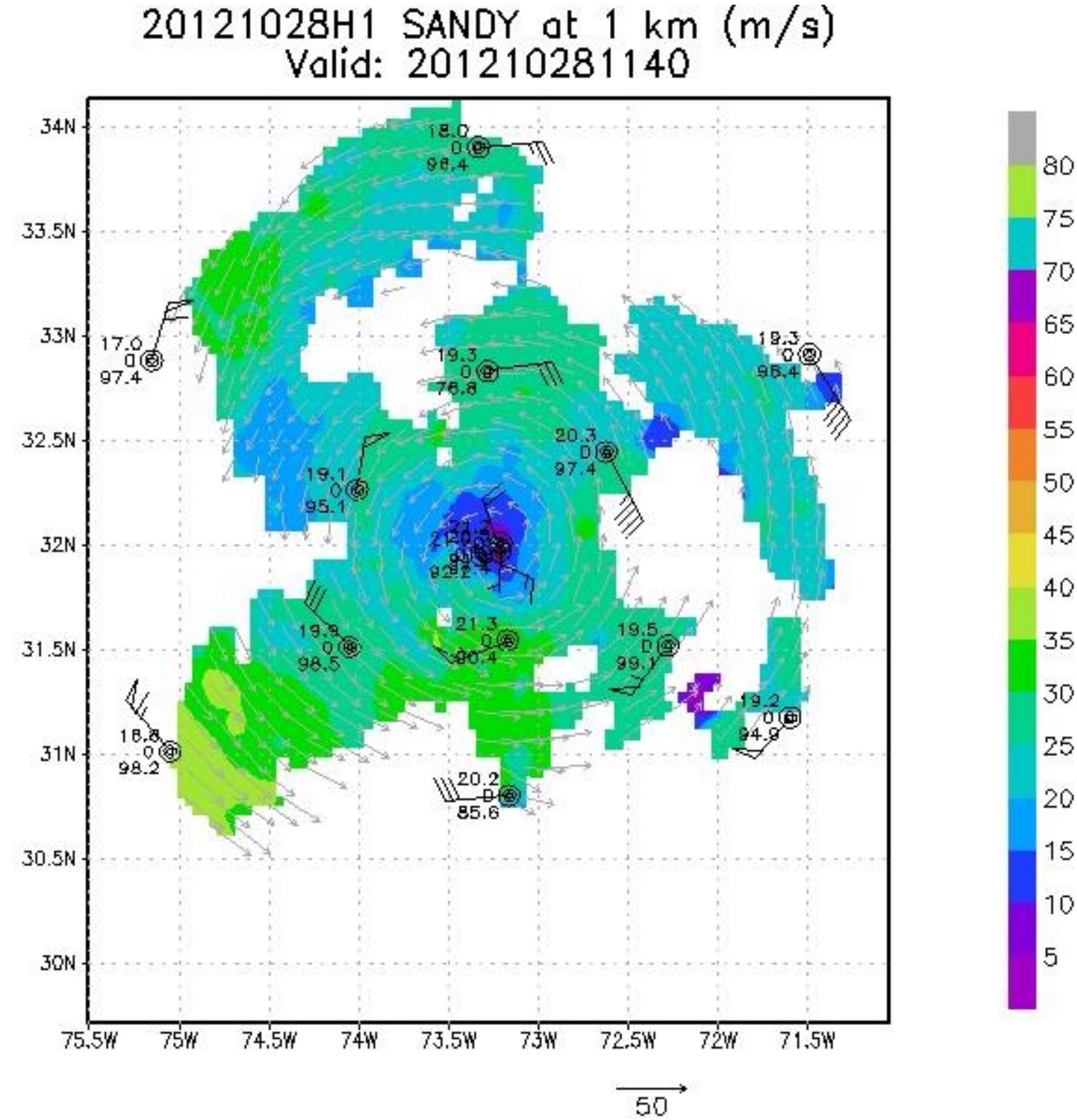


Figure 1: (a) Wind field at a height of 1 km. for hurricane Sandy, valid 12Z, October 28, 2012 produced from a composite of radar and dropwindsonde data. (b) Vertical temperature sounding taken in the eye region of Sandy during the same flight .Graphics such as these provide a quick look at the hurricane inner core structure.

Additionally we have developed computer programs which 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) since the

2010 Atlantic hurricane season. This data is also being assimilated retrospectively for the 2008 through 2012 seasons in order to evaluate the relative impact of dropwindsonde and other data types on numerical model forecasts. 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.

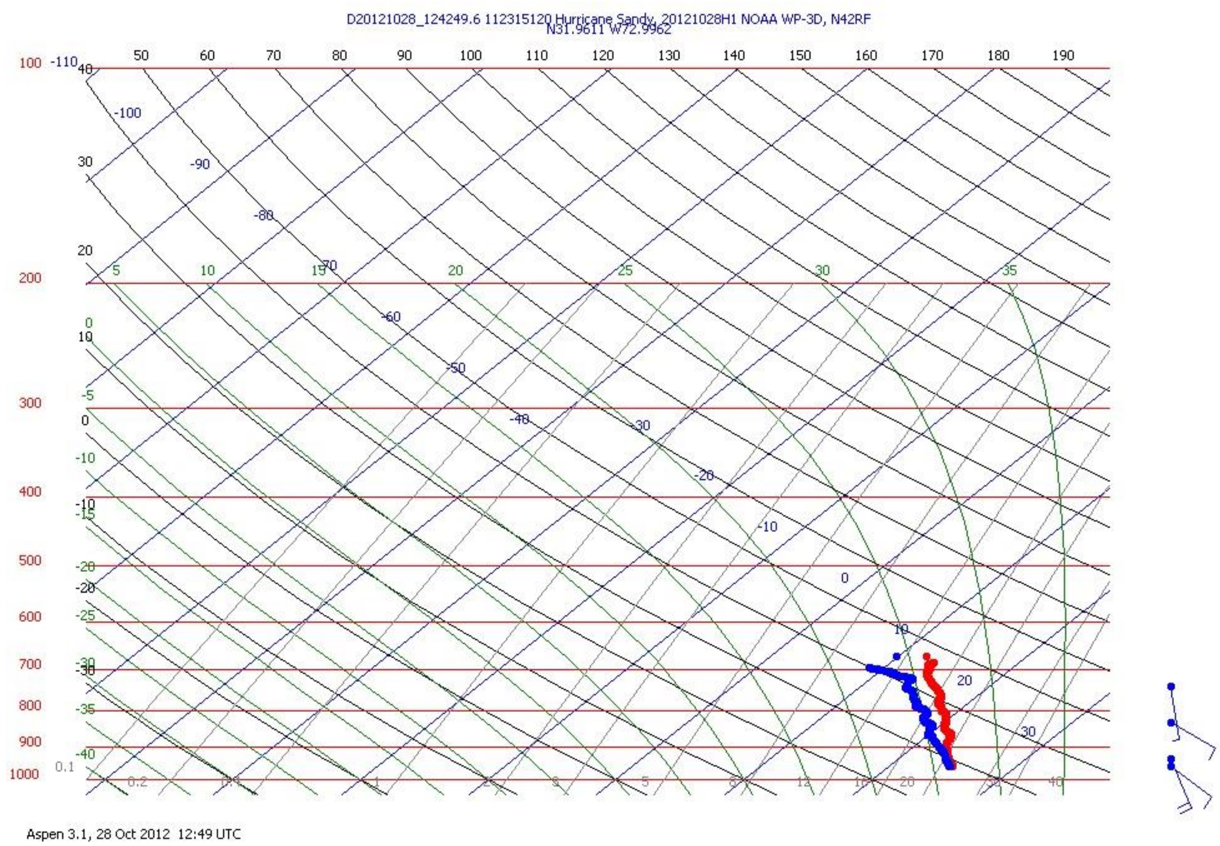


Figure 2: Initial condition for the high-resolution HWRF model produced by assimilating dropwindsonde and other data collected using NOAA and USAF aircraft during hurricane Sandy, 2012.

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

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

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

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To design, develop, and implement an HRD Web Portal that enables the researchers and scientists to connect to the database consisting of geographical and non-geographical data to integrate, mine, and analyze the raw and post-processed Tropical Cyclones data. This web portal also displays the results to the users in order to improve the public's awareness of the dangers that may be imposed by Tropical Cyclones.

***Strategy*:** To develop the web-based "HRD Web Portal" utilizing Java, Smart GWT/GWT (Google Web Toolkit), and Google Maps APIs.

CIMAS Research Theme:

***Theme 2*:** Tropical Weather *(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
NOAA Technical Contact: Alan Leonardi

Research Summary:

An HRD Web Portal was designed, developed, and implemented to render wind data from diverse sources and in different formats with geographical information in multiple visualization maps, as well as synchronized animations of various products, all geared toward comprehensive forecast and model evaluation. The database stores raw point-observational data (land, atmosphere, and ocean) and graphical products derived from observational and model data. The left-hand side of Figure 1 is the HRD Web Portal which is part of the HRD Forge framework (Figure 1) for improving the utility of NOAA's hurricane data. Figure 2 shows the visualization interface for tropical cyclone (e.g., hurricanes) forecast and model diagnostics by real natural events or idealized studies, displaying the available graphical products of model or observation in the database. The key features to enable comprehensive data inter-comparison are: 1) It is a lightweight architecture since it runs on a web-browser, and 2) It consists of a multi-map interface capable of side-by-side animations of diverse model and geo-referenced and non-geo-referenced observational data. This web portal is built by taking the advantages of the Web Services Layer as the data source and serves as an example of potential visualization applications. Using this web portal, the users can overlay different types of tropical cyclone data such as their own KML documents with proprietary data.

Research Performance Measure: All objectives were reached.

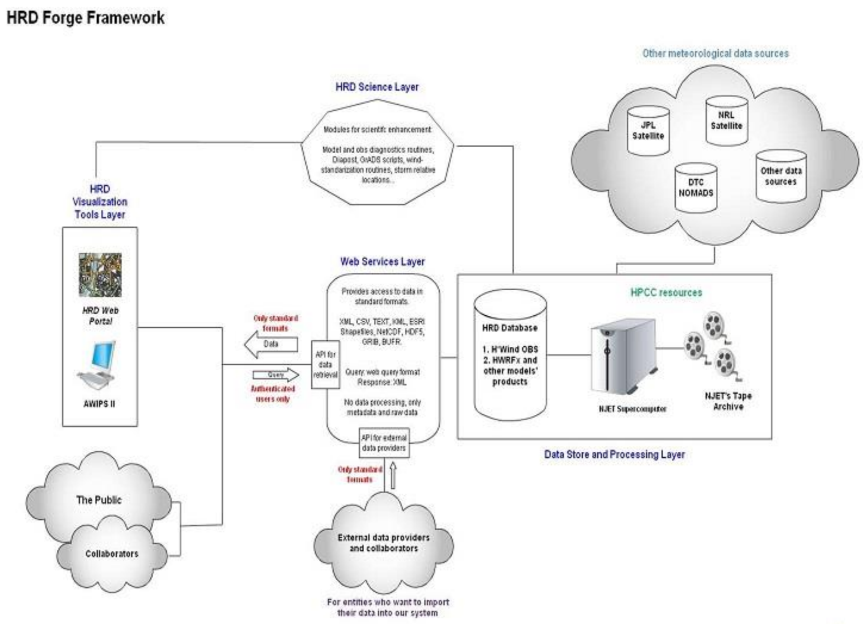


Figure 1: The HRD Forge framework for improving the utility of NOAA's hurricane data

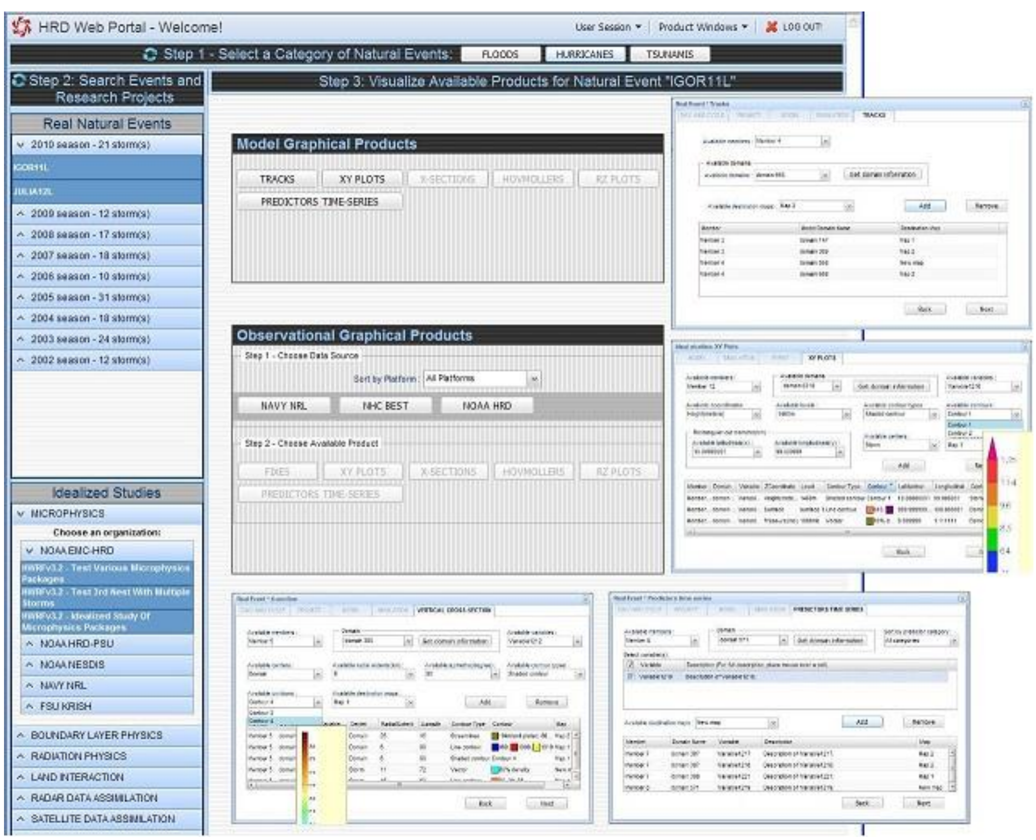


Figure 2: Snapshots of the HRD Web Portal with selection windows of graphical products (Tracks, XY plots, X-sections, and Predictors time-series)

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

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

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To develop novel data mining techniques and tools to discover useful knowledge/patterns from the rapid intensity changes in tropical cyclones (TCs), to build a database that integrates both the historical and modeling data from different sources, and to develop a web portal that displays the data geared towards scientists' needs.

***Strategy*:** To mine useful patterns/knowledge from the structure and dynamics of tropical cyclones (TCs) and to analyze specific hurricane cases using model and observational data sets. In this project, the Experimental Hurricane Weather and Research Forecast (HWRF-X) System at AOML/HRD was developed and maintained. The database stores data from the H*WIND relational database, HRD's operational flights (radar, dropsondes, AXBT, UAS), satellite, and operational and research models. The lightweight web portal for data presentation was designed and developed utilizing the industry standard developmental tools such as Smart Google Web Toolkit (SmartGWT) and Google Maps APIs.

CIMAS Research Theme:

***Theme 2*:** Topical Weather (*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 **NOAA Technical Contact:** Alan Leonardi

Research Summary:

In order to predict the tropical cyclone (TC) track, intensity, and impact, data mining techniques and tools were developed and utilized. To extract useful knowledge from TC intensity and rainfall, one must consider factors such as magnitude and direction of vertical shear of the environmental wind, upper oceanic temperature structure, and low- and mid-level environmental relative humidity. The data sets collected from the model runs on 60 hurricane cases were utilized to analyze all these parameters. The purpose is to enable the researchers with the ability to synthesize *model* and *observation* data in a centralized and comprehensive manner and to unify the modelers and observers in an efficient way to access and share data for the sake of inter-comparison, verification or other potential research tools. This is based on the fact that the advances in hurricane modeling are actually tightly correlated with the ability to quickly evaluate model output against a diverse set of observations. This activity leads to the determination of deficiencies in model forecast.

A database was designed and developed to store the hurricane data from various data sources - H*WIND relational database and satellites data. A user-friendly HRD Web Portal was implemented so that the scientists could access different real-time and historical hurricane data easily. The synchronized animation control for data products from different sources using the HRD web portal is presented in Figure 1. Figure 2 shows the implementation of creating and managing multiple animation groups on the HRD web portal.

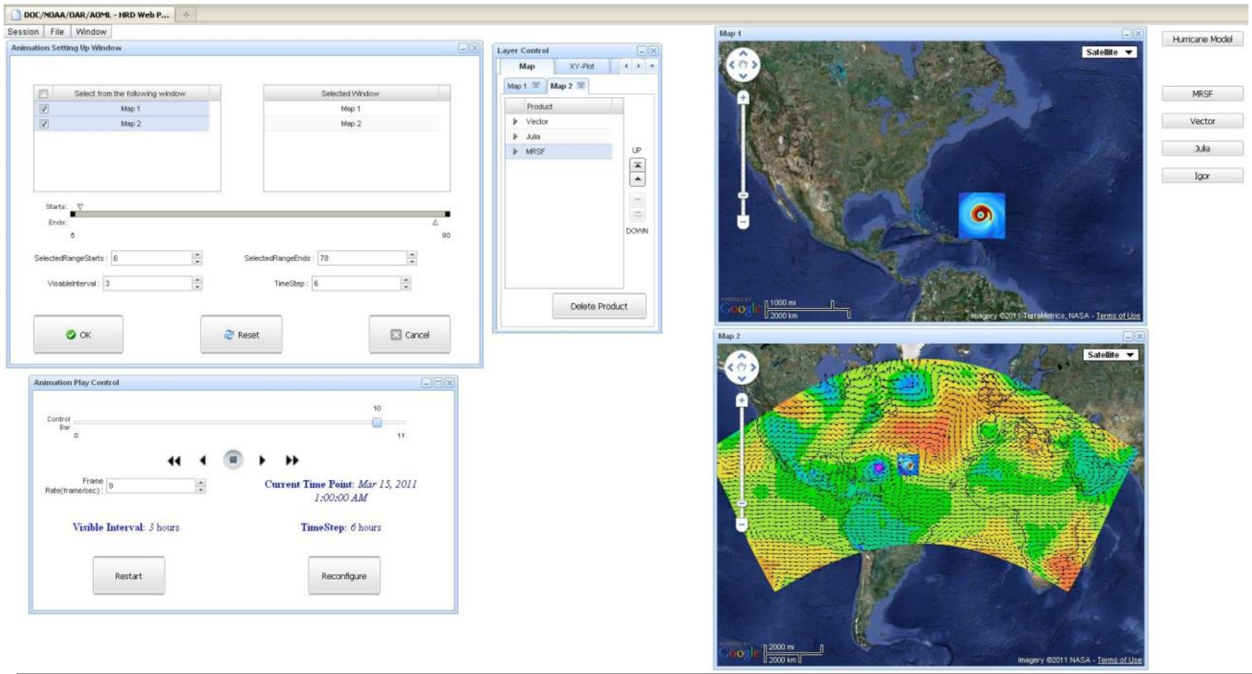


Figure 1: Synchronized animation control on the HRD web portal

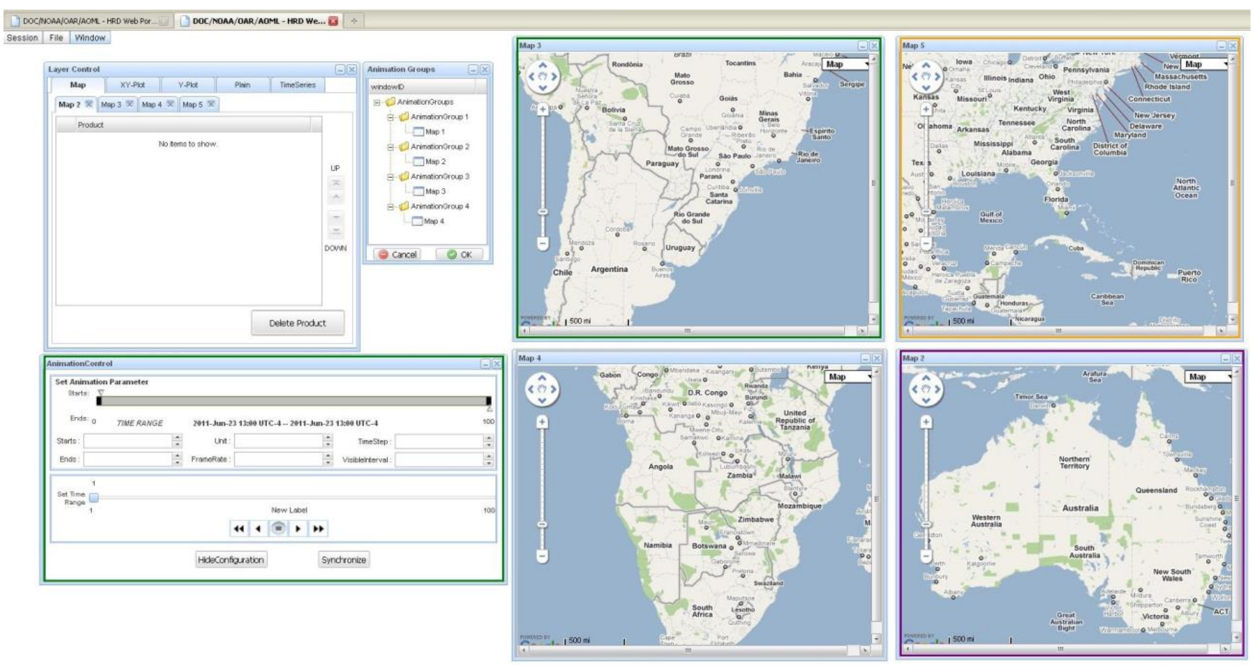


Figure 2: Animation group management on the HRD web portal

Research Performance Measure: All objectives were reached.

SFMR Wavenumber Analyses for Assessing Surface Wind Asymmetries in Hurricanes

Project Personnel: B. Klotz (UM/CIMAS)
NOAA Collaborators: E. Uhlhorn, T. Vukicevic, P. Reasor and R. Rogers (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To determine effects of wind shear and storm motion on surface wind asymmetries in hurricanes

***Strategy*:** To use SFMR data from various hurricanes to develop a low wavenumber analysis and simulate a two-dimensional surface wind field in order to develop a statistical reference for the behavior of surface wind asymmetries in the presence of vertical wind shear and in relation to storm motion

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 stepped frequency microwave radiometer (SFMR) measures surface wind speeds and rain rates along an aircraft's flight track. These winds are operationally used to assess the intensity of tropical cyclones. While the general flight track is designed to provide high-resolution wind data in radial directions, the SFMR point measurements lack substantial azimuthal coverage and alone cannot provide a two-dimensional representation of the tropical cyclone surface wind field. In fact, the SFMR tends to underestimate the operationally required 1-minute maximum sustained 10-meter wind on the order of ~10%.

Using a Fourier decomposition technique to produce wavenumber-0 and wavenumber-1 amplitude and phase (WN0, WN1, PH1), a two-dimensional representation of the surface wind speed can be produced in a storm-centric frame of reference. This type of analysis works best for well-developed tropical systems (i.e., hurricanes); therefore, 128 flights from 35 hurricanes between 1998 and 2011 were used to develop these two-dimensional analyses. Figure 1 provides a singular example from Hurricane Katrina during the 2005 season showing the resulting two-dimensional wind fields based on the Fourier decomposition for surface (left panel) and flight-level (right panel) winds. This figure simply indicates the usefulness of the analysis for hurricanes and for determining the location of the maximum surface wind. It should be noted that because these analyses only include wavenumber-0 and wavenumber-1, some of the higher harmonics that contribute to the total wind speed are not included and thus this analysis method will tend to slightly underestimate the maximum wind.

Analyses similar to the example in Figure 1 were completed for all hurricane cases in the sample. A composite analysis of the data set was produced and is shown in Figure. 2. In the left panel, it is clear that the flight-level WN0 amplitude (red line) is larger than that of the surface (black line). In fact, at the radius of maximum wind (RMW, r* = 1), the surface WN0 is about 90% of the flight-level, which corresponds with results in the known literature. Outside the RMW, this percentage reduces to about 75-80%. From the far right panel showing the storm-motion-relative PH1, it was concluded that the flight-level maximum is generally to the right of storm motion and that the surface wind maximum is also right of storm-motion and usually upwind of the flight-level value.

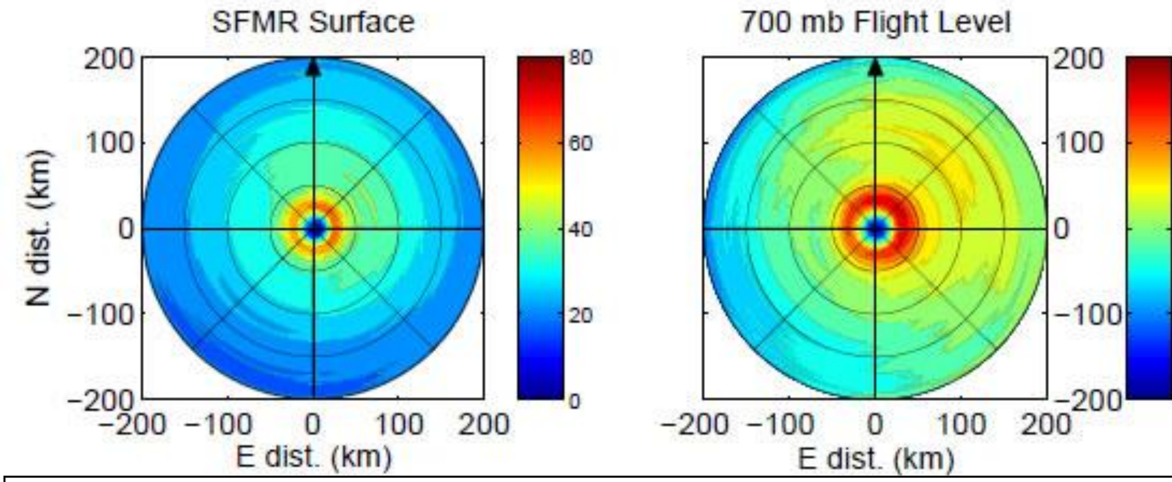


Figure 1: Surface (left) and flight-level (right) WN0+1 wind speed analysis for Hurricane Katrina on 28 August, 2005. The arrow in each panel points to the north. Wind speed units are in m s^{-1}.

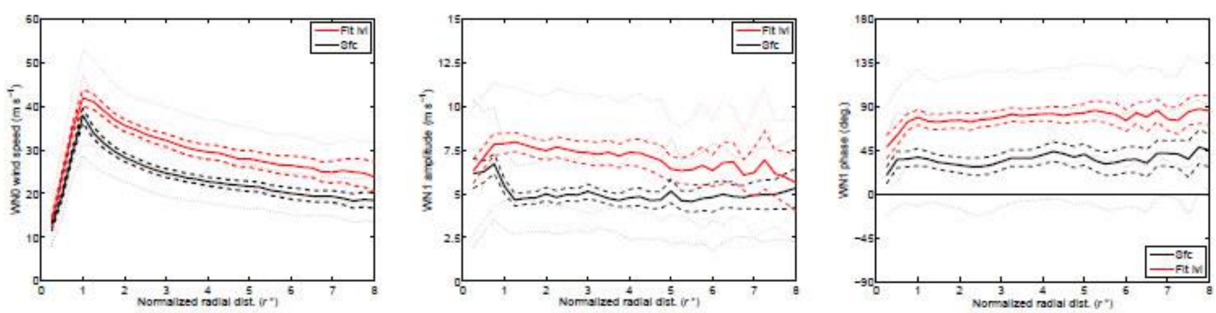


Figure 2: Composite (a) WN0 wind speed (m s^{-1}), (b) WN1 amplitude (m s^{-1}), and (c) storm motion-relative PH1 (deg.) at surface (black) and flight level (red) as functions of normalized radius (r*, r/RMW). Solid lines are averages for the n = 128 sample, thick dashed lines are 95% confidence intervals on the means, and dotted lines are 1 standard deviation.

Looking specifically at the wavenumber-1 amplitude and phase relationships to storm motion and vertical wind shear magnitude, certain trends can be seen in the data set. Figures 3 and 4 show the WN1 and PH1 relationships with storm motion and shear magnitude, respectively. From Figure 3, it seems like the trends at the surface in relation to storm motion are opposite of the trends at flight-level. There is no distinguishable signal between the storm motion and surface WN1 amplitude but there tends to be an upwind rotation of the surface PH1 with increasing storm motion speed. The opposite is true of the flight-level data where the WN1 amplitude increase noticeably with increasing storm-motion but no signal is seen with PH1. In the relationship to wind shear magnitude (shown in Fig. 4), there is not much of a trend in either surface or flight-level WN1 amplitude with increasing shear magnitude, but both flight-level and surface PH1 rotates cyclonically with increasing shear magnitude, with a statistically significant relationship at the surface.

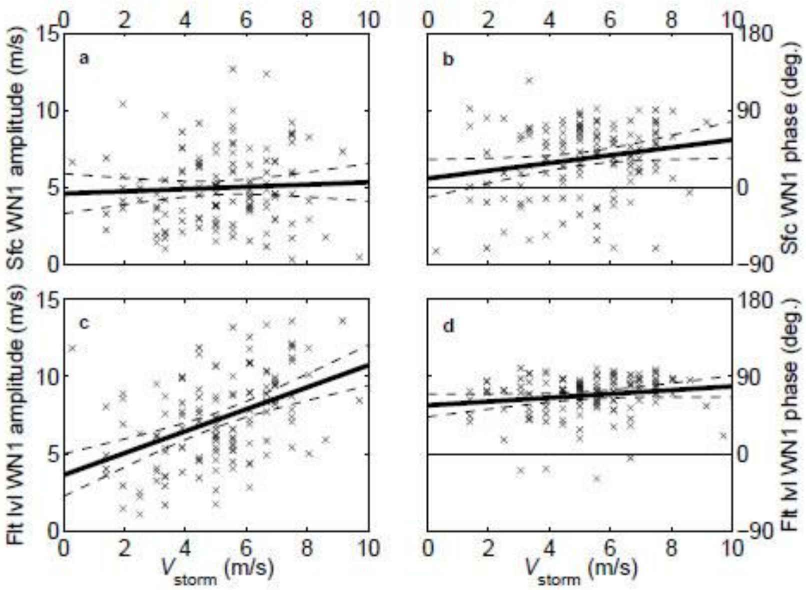


Figure 3: Surface WN1 (a) amplitude, and (b) phase; and flight-level WN1 (c) amplitude and (d) phase at the RMW for each of the 128 analyses, as a function of storm motion speed (V_{storm}, m s^{-1}). Asymmetry amplitudes are in m s^{-1}, and storm motion-direction phase angles are in degrees. Linear regressions (solid lines) and 95% confidence intervals for the fits (dashed lines) are also shown. The initials BM, RM, FM, and LM indicate locations behind, right-of, forward-of, and left-of storm motion direction, respectively.

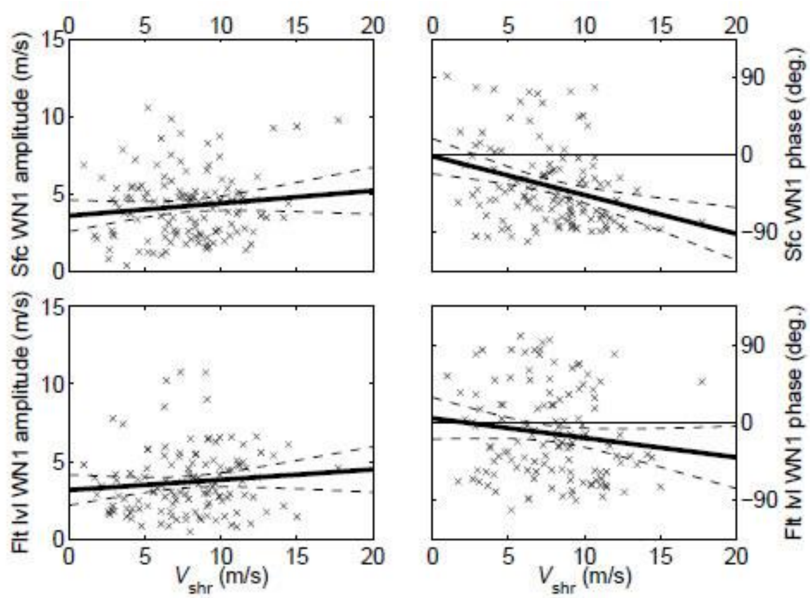


Figure 4: Same as Fig. 3, but plotted versus shear magnitude (m s^{-1}) after removing storm motion induced asymmetry. Phase angle (deg.) is clockwise azimuth relative to shear direction. The initials RS, DS, and LS indicate locations right-of, down, and left-of shear direction, respectively.

From these figures, it is clear that there are relationships between the storm motion strength and wind shear magnitude and the surface and flight-level wind maxima. This particular study exemplifies that the SFMR is useful for producing representative two-dimensional wind fields that aid in depicting wind asymmetries as well as estimates of the maximum intensity and its location within the storm.

Research Performance Measure: All major research objectives related to this project have been met. As planned, project personnel recently submitted a manuscript toa peer reviewed journal.

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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 evaluate performance of SFMR bias correction model and to formulate new wind and rain models in the SFMR algorithm that removes bias in heavy rain
***Strategy*:** To apply the bias-correction model to evaluate statistics of data from 2012 hurricane season. To develop a new wind-emissivity model function based on the bias-correction and to use rain data from independent sources to improve the rain-absorption model function.

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/USWRP/JHT
NOAA Technical Contact: Alan Leonardi

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 is degraded in conditions where weak-to-moderate winds are 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.

Based on an increased number of SFMR versus GPS dropsonde surface-adjusted wind speed pairs, a bias correction model was developed in the first year of this project. The model increasingly reduces the bias as wind speed decreases and rain rate increases. This bias correction model was applied in real-time at NOAA's National Hurricane Center during the 2012 hurricane season, and was well-received. As part of the funded JHT project, an evaluation of the model's performance is provided.

The NOAA and Air Force Reserve SFMR data from 2012 were paired with matching GPS dropsonde surface-adjusted wind speed data. There were a total of 582 usable pairs with a majority of these pairs (518, 89%) having rain rates less than 10 mm hr^{-1} and 64 pairs (11%) having rain rates greater than 10 mm hr^{-1}. At all wind speeds and rain rates, the application of the bias correction successfully reduced the wind speed difference between the SFMR and dropsondes, and at wind speeds less than 33 m s^{-1} and rain rates greater than 10 mm hr^{-1}, average wind speed differences were reduced on the order of 80%. This indicates that application of the bias correction model in heavy rain and weaker winds is successful at reducing the high bias in the SFMR winds. To showcase this concept, Figures 1 and 2 show frequency histograms of the wind speed differences with and without application of the bias correction for the 2012 SFMR data. These figures portray the entire sample of pairs as well as the pairs in moderate-to-heavy rain.

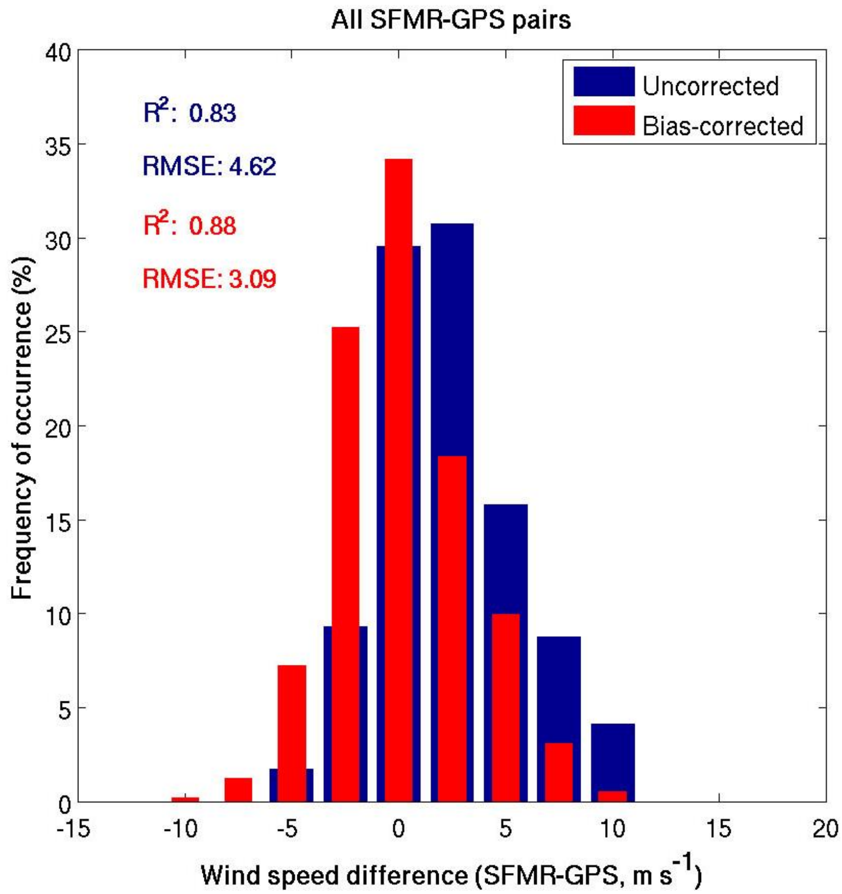

Figure 1: Histogram of SFMR-GPS wind speeds from the 2012 hurricane season for all uncorrected (blue) and bias-corrected (red) pairs. Data are plotted as frequency percentages.

In Figure 1, a clear shift toward zero occurs when comparing the bias corrected (BC) data against the uncorrected (UC) data. The overall mean for the uncorrected data is 2.30 m s^{-1} and the overall mean for the bias corrected data is 0.08 m s^{-1}. Also, the difference in these populations is statistically significant at 95% confidence based on a student's t-test. Figure 2 provides insight into data that were collected in the presence of rain. The overall mean of the UC data is 3.48 m s^{-1} while the overall mean of the BC data is 0.68 m s^{-1}, and similarly to the entire dataset, these populations differ significantly at 95% confidence according to a student's t-test. These results indicate that for all conditions and specifically for rain-coincident data, the SFMR relationship to the GPS dropsonde wind speeds is improved by using the bias correction model.

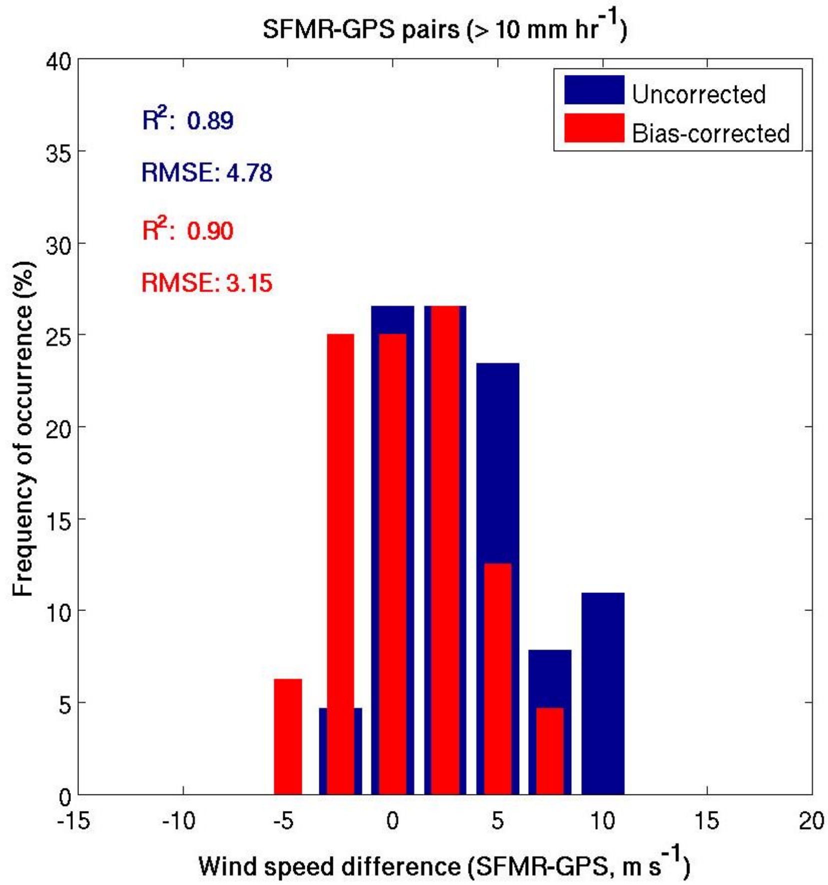

Figure 2: Same as Fig. 1 but for pairs with SFMR rain rates greater than 10 mm hr^{-1}.

With confirmation that the bias correction reduces the impact of heavy rain on the estimate of the surface wind, a new wind versus emissivity model function was developed using dropsonde wind speeds in combination with the brightness temperatures from the SFMR. Additionally, independent rain data from the NOAA Tail Doppler radar (TA) and from the Precipitation Imaging Probe (PIP) were used to compare with the SFMR rain rate. Figure 3 provides an example from Hurricane Katrina of the comparison of the three rain measurements. Based on about 10 flights from the 2005 and 2010 hurricane seasons, a new rain versus reflectivity relationship was developed from these independent sources and was used to produce a new rain versus absorption SFMR model function. Using the two new SFMR model functions, all available SFMR data were reprocessed and compared to data that were processed with the current model functions. The linear best-fits for each data-set (SFMR vs. GPS dropsonde) are provided in Figure 4. The new model functions clearly act to remove the bias since the best-fit line for the new functions is nearly the same as the line indicating the unity relationship. Statistical tests still need to be performed on the new data, but preliminary results indicate positive changes for the SFMR algorithm.

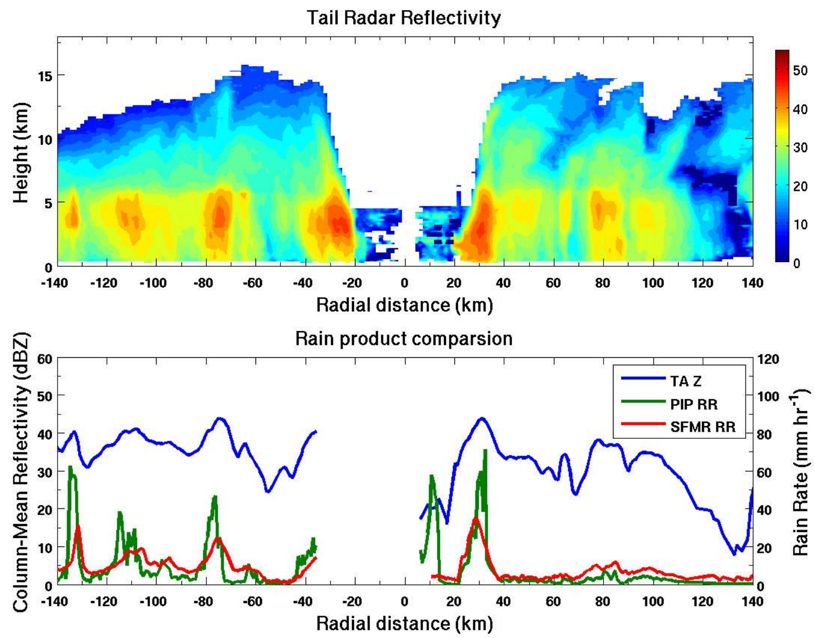

Figure 3: A single NOAA WP-3D penetration of Hurricane Katrina from 28 August, 2005 is shown. In the top panel, Tail Doppler radar reflectivity (dBZ) is shown as a function of radial distance from the center. In the bottom panel, the column-mean radar reflectivity (blue, dBZ), PIP rain rate (green, mm hr^{-1}) and SFMR rain rate (red, mm hr^{-1}) are shown over the same radial distances as the top panel.

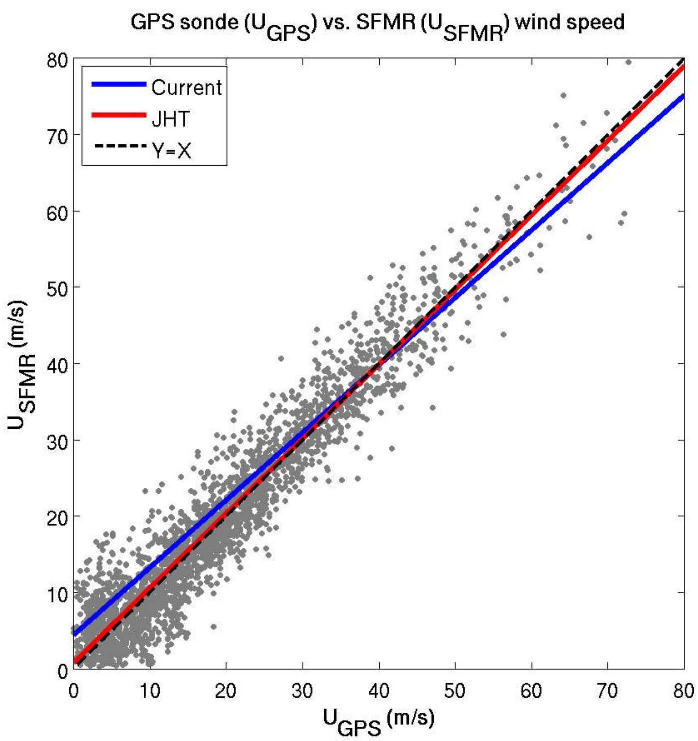

Figure 4: SFMR versus GPS dropsonde pairs are plotted for the data processed with the new model functions (gray dots). Linear best-fit lines are plotted in conjunction with the new data (red line), with the current model functions (blue line), and the unity relationship between the two wind speed measurements (black-dashed).

Research Performance Measure: All major research objectives are being met for the second year of this project. More tests need to be performed on the new model functions before these are applied in the field.

SFMR Wavenumber Analyses for developing a Multi-Scale Intensity Metric (MSI)

Project Personnel: B. Klotz (UM/CIMAS)
NOAA Collaborators: T. Vukicevic , E. Uhlhorn and P. Reasor (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To determine a multiscale intensity metric for use in regional model intensity evaluation

***Strategy*:** To use SFMR data to produce wavenumber-0 and wavenumber-1 analyses and to use these analyses to compare with operationally determined tropical cyclone intensity estimates. To produce similar analyses in a model framework and compare to those of the SFMR observations for verification purposes.

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:

Operational tropical forecasting centers produce estimates of intensity for tropical cyclones based on a maximum 10-meter, 1-minute sustained wind speed within the tropical cyclone wind field. However, due to the fact that these wind fields are highly turbulent and rapidly evolving, the operational intensity estimates are generally irresolvable in dynamical numerical weather models. Intensity forecasts within models are currently verified using the operational estimates in the Hurricane Best-Track (BT), but representative errors from both methods are difficult to quantify. In order to truly understand the intensity errors produced by the model, a technique that utilizes methods that are resolvable in both the model and in observations must be used.

In order to produce such a comparison, stepped frequency microwave radiometer (SFMR) surface winds are used to produce wavenumber-0 and wavenumber-1 analyses. These analyses (described in a previous report entry entitled *SFMR Wavenumber Analyses for Assessing Surface Wind Asymmetries in Hurricanes*) provide a Fourier decomposition of the low wavenumber amplitudes and phase that are also easily resolvable in the model. By producing equivalent analyses in the Hurricane Weather Research and Forecast (HWRF) model, a two-dimensional surface wind field is produced. In this work, 157 SFMR cases between 1998 and 2011 are used, ranging in storm strength from tropical storm and to Category-5 force surface winds. Additionally, 83 HWRF cases from 2008-2011 are used to produce the model-derived low wavenumber analyses. The observational cases coincide with the HWRF model estimates in 245 instances. Because the intensity of the tropical cyclone is the main interest, the wind speed at the radius of maximum wind (RMW) is estimated by adding the wavenumber-0 and wavenumber-1 (WN0+1) amplitudes along with a residual term to account for the remaining higher harmonics. These higher harmonic terms are the reason for the inability for the model to accurately represent intensity errors. The method described above is being portrayed as a Multiscale Intensity Metric (MSI).

This described intensity metric allows for the verification of numerical intensity forecasts at resolvable scales in terms of standard error measures, such as mean and mean absolute error, and at the un-resolvable scales (i.e. the higher harmonics) in terms of properties of probability density functions (PDFs) of a stochastic or non-deterministic residual term. In Figure 1, the relationship between the WN0+1 maximum and the BT intensity estimate is shown for the cases used in this work (for model (red) and observations (black) separately). Additionally, the PDFs of the observation and model determined residual term is provided (i.e. the difference between the maximum wind and WN0+1). From this figure, it is clearly seen that the BT maximum wind will usually be higher than the WN0+1 estimate from both the model and the observations, but the estimates are well correlated (0.91 for both datasets). The PDFs in the right panel indicate that the higher harmonics are indeed represented by a non-deterministic process and that the mean and standard deviation for the model and observations are relatively low. In fact, these representative statistical parameters are well within the known BT error of 5 m s^{-1} and indicate that the low wavenumber estimate provides an accurate representation of the intensity compared to the BT.

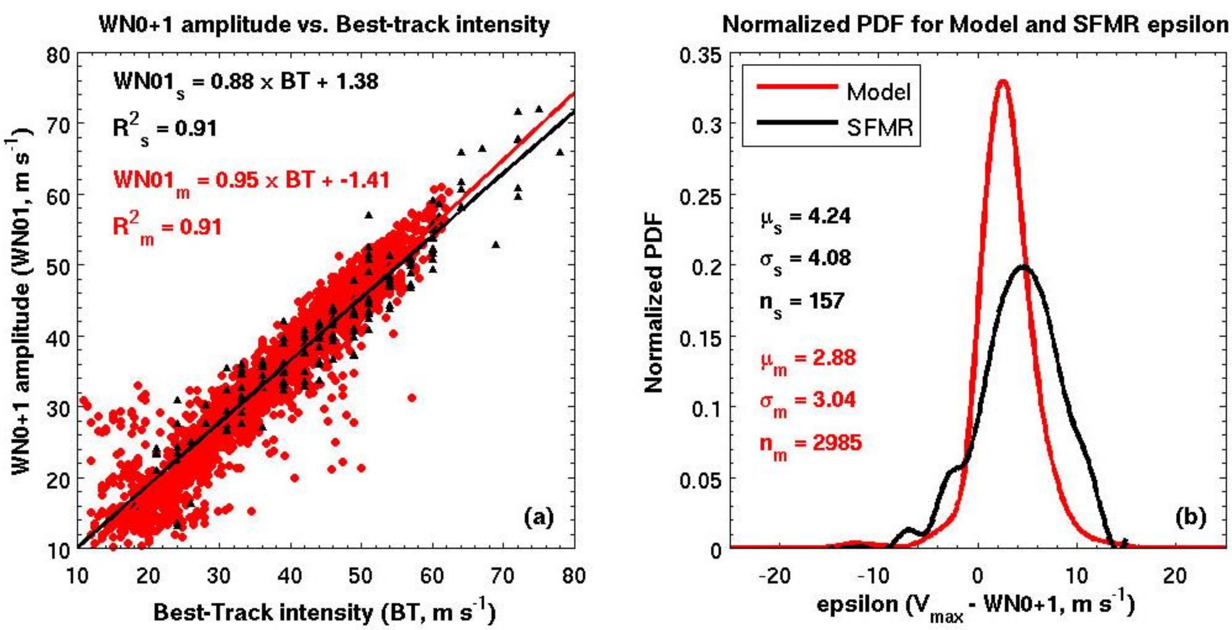

Figure 1: (a) Maximum intensity versus low wavenumber intensity, where black is for Best-Track vs. SFMR-based values for 157 observed cases in years 1998-2011 and red is for Best-Track versus forecast for 2889 instances of forecast data in years 2008-2011. In (b), the PDF of residual intensity using the same data as for (a) is shown.

In Figure 2, the mean error and mean absolute error for the low wavenumber and residual intensity as function of HWRF forecast lead time for the sample data are displayed together with the corresponding errors using the BT metric. Clearly it can be seen that the mean errors as function of forecast time for the forecast maximum (with respect to the BT values) and the wavenumber-0 (with respect to the SFMR analysis) are highly correlated. This result is consistent with the high correlation between the maximum and WN0+1 intensity evolution in the forecast and confirms that the errors with respect to the BT values are dominated by the errors in the WN0+1 component of the forecast wind. In addition, the mean errors for wavenumber-1 (red curve) and higher harmonics (green curve) are negative for all forecast times. The negative mean error for the residual intensity is consistent with the differences between the observation- and forecast-based statistical distributions in Figure 1. The effect of error compensation is also evident in the mean absolute error measure (Figure 2b) where the errors using the standard metric are of similar amplitude to the wavenumber-0 errors for the forecast times for which the mean error compensation occurs. It should be noted that the absolute errors for the wavenumber-1 and residual intensity are significant.

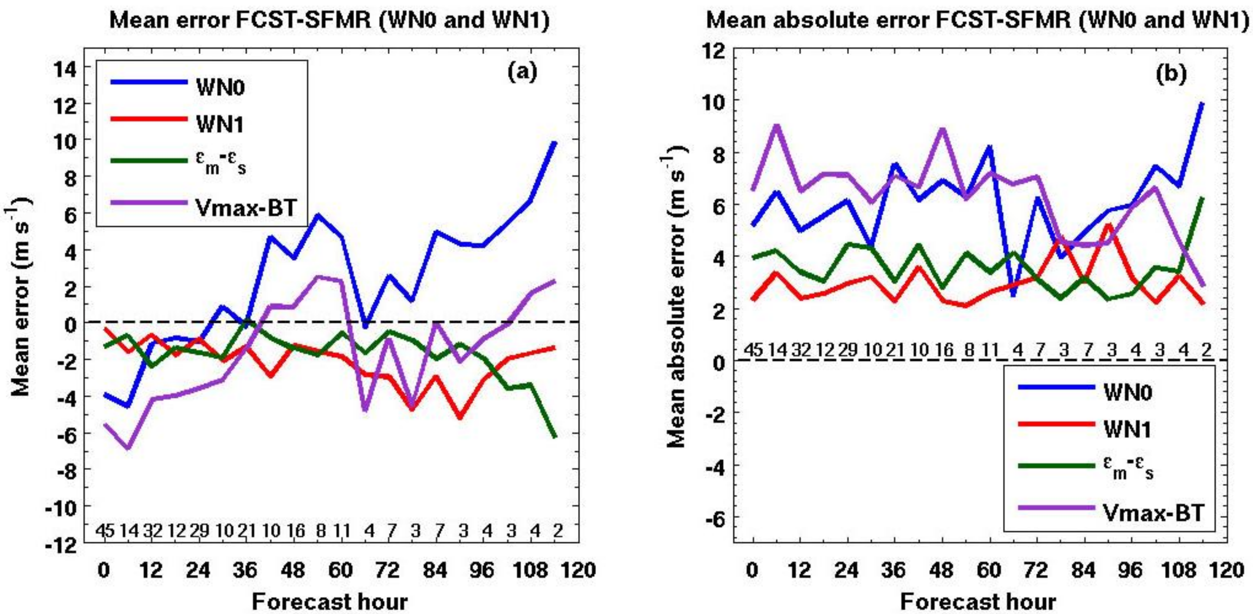

Figure 2: Mean (a) and mean absolute (b) forecast errors as function of forecast lead time using the Best-Track and MSI metrics. Wavenumber-0 and wavenumber-1 errors are shown in the blue and red curves, respectively. The green curve provides the residual intensity errors and the purple line indicates the error between the maximum estimates.

In summary, this work demonstrated that the MSI metric would provide more informative error analysis for the verification of TC intensity forecasts than the maximum intensity metric. Because the MSI metric makes use of resolvable and observable quantities, quantification of forecast errors can be made more robust leading in turn to significant improvements in operational modeling systems.

Research Performance Measure: All major research objectives for the initial performance period related to this project have been met. Project personnel recently submitted a manuscript for peer review.

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

Project Personnel: H.E. Willoughby and S. Delgado (FIU)
NOAA Collaborators: C.W. Landsea (NOAA/NHC); F.D. Marks (NOAA/AOML/HRD)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To reanalyze the years 1955–1964, inclusive, of the HURDAT hurricane climatology in order to improve understanding and statistical descriptions of historical hurricanes.
***Strategy*:** To revise and update HURDAT based upon the gamut of historical sources, additional observations, better meteorological insight, and synoptic reanalyses now available.

CIMAS Research Theme:
***Theme 2*:** Tropical Weather (*Primary*)
***Theme 1*:** Climate Research and Impact (*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/AOML **NOAA Technical Contact:** Alan Leonardi

Research Summary:
The Hurricane Database (HURDAT) is the historical archive that describes all tropical cyclones from 1851 to the present in the North Atlantic Basin, which includes the Caribbean Sea and Gulf of Mexico. NOAA's National Hurricane Center (NHC) maintains HURDAT and updates it annually. HURDAT represents six-hourly positions, intensities and central pressures for all Atlantic tropical systems. From 2004 onward, HURDAT also includes radii of 34, 50, and 64 kt (1 kt = 0.515 m s^{-1}) winds. Since HURDAT is essential to the work of research scientists, operational forecasters, insurance companies, emergency managers, and others, it has taken on the status of a legal document.

Accuracy of the HURDAT database is essential, but it originally contained both systematic biases and random errors. NHC's Atlantic Hurricane Reanalysis Project (AHRP) is a continuing effort to correct these errors based upon all available data and to provide the most accurate database possible. The present project entails reanalysis of the period 1955-1964. We are reassessing track, intensity, genesis and dissipation for each existing tropical cyclone in HURDAT. Additionally, we have detected and analyzed previously unrecognized tropical cyclones. The resulting changes will be recommended to the National Hurricane Center Best Track Change Committee (NHCBTCC) for inclusion in the next release of HURDAT. Changes to HURDAT become official only with NHCBTCC's approval.

For example, during the historic 1955 season, 3 hurricanes made landfall in the Mid-Atlantic states and affected the US coast northward to New England. Category 5 hurricane Janet struck Mexico's Yucatan Peninsula. In total, the original HURDAT documented 12 tropical cyclones. The reanalysis retains all of them, and adds 2 newly discovered tropical cyclones over the eastern Atlantic, for a total to 14 tropical storms and hurricanes combined. Because reconnaissance-aircraft aerologists systematically overestimated maximum surface winds, the number of reanalyzed hurricanes decreased from 9 to 7, and the number of major hurricanes (categories 3, 4 or 5) from 6 to 4. The intensities of some landfalling hurricanes also changed. The maximum sustained surface winds of Hurricane Connie increased from the original 65 to 85 kt, and the maximum sustained surface winds of Hurricane Diane was increased to 75 kt from the original 65 kt. The maximum sustained surface winds of Hurricane Ione were retained at 90 kt, but the Saffir-Simpson category at landfall decreased from 3 to 2. The extratropical lifetimes of several cyclones were extended because additional data supported tracking them farther eastward into the North Atlantic.

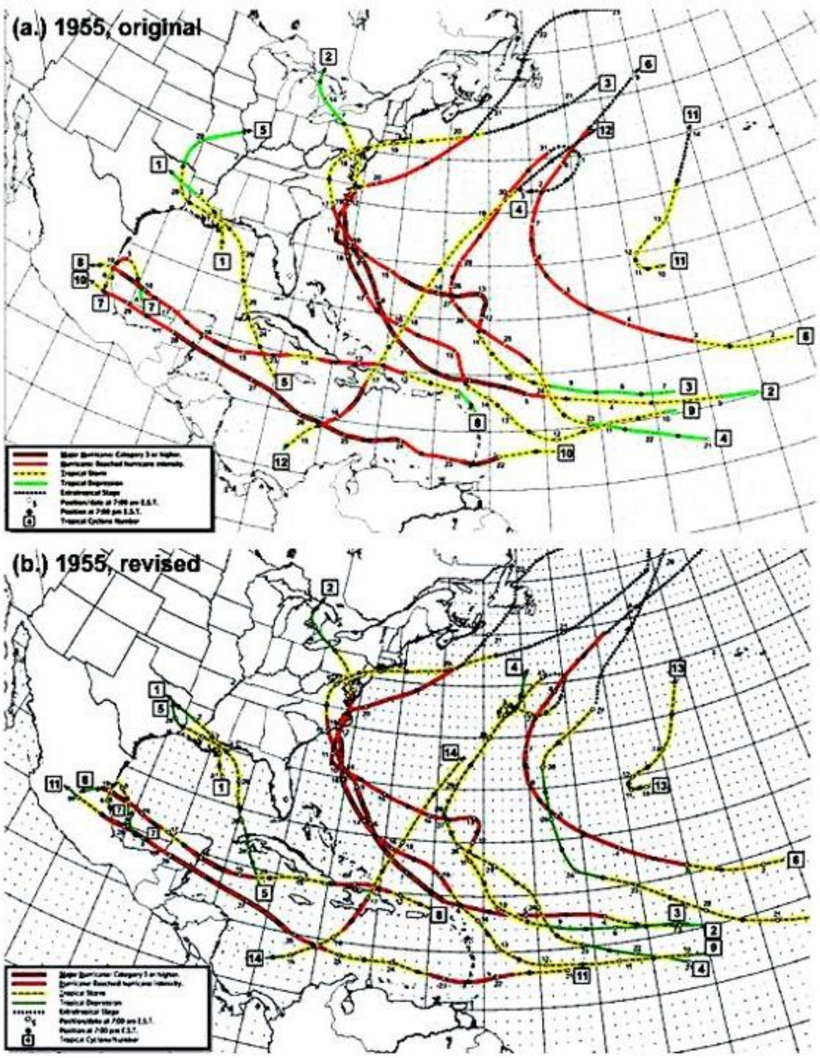

Figure 1: The tracks and intensities of hurricanes during the 1955 Atlantic season: (a) As originally depicted in HURDAT, and (b) After reanalysis.

Research Performance Measure: The 1955-1964 reanalysis should be complete when this proposal ends in August 2014. So far, the analysis is complete through 1957**.** Since the completed portion includes the active and destructive mid-50s, we are on schedule for timely completion.

Advanced Model Diagnostics of Tropical Cyclone Inner-core Structure Using Aircraft Observations

Project Personnel: J.A. Zhang (UM/CIMAS); D.S. Nolan (UM/RSMAS)
NOAA Collaborators: R.F. Rogers and P.D. Reasor (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To increase usefulness of observations in high resolution hurricane modeling systems and to develop advanced model diagnostic techniques in support of model improvements.

***Strategy*:** To generate composites of multiple types of aircraft observations from Hurricane Research Division's extensive observation database and to create metrics to quantitatively evaluate deficiencies in the inner-core structure in HWRF simulations.

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:
Much previous work has focused on evaluating the performance of numerical models using "traditional" metrics, e.g., position and intensity errors. These are useful metrics for monitoring long-term trends of forecast ability, but they provide little insight into the reasons for errors or how the models might be improved. As the horizontal resolution of operational hurricane forecast models approaches 3 km (and eventually reaches 1 km), the ability of these models to resolve tropical cyclone (TC) inner-core structures increases. Robust evaluations of TC inner-core structure are therefore crucial to assess the realism of high-resolution numerical model forecasts and identify deficiencies in the modeling system.

Funded by NOAA's Hurricane Forecast Improvement Project (HFIP), this project provides advanced model diagnostic techniques of tropical cyclone inner-core structure. These techniques include compositing model output in terms of axisymmetric and asymmetric structures. These model forecasts are evaluated by comparing them with a suite of observational analyses collected from NOAA aircraft. This project emphasizes the use of the radar, dropsonde and flight-level data to generate products such as vortex scale, convective scale, and boundary layer structure to evaluate the model output. The discrepancies in the model are identified and feedbacks are given to the model developers.

Observations of axisymmetric structures of the vortex-scale, convective-scale and boundary layer were summarized in our recently published papers (Zhang et al. 2011a; Rogers et al. 2012). Rogers et al. (2013) documented differences based on observations in the inner-core structure of tropical cyclones that are intensifying compared with those that are remaining steady-state. Reasor et al. (2013) documented asymmetric vortex-scale structures relative to the environmental vertical wind shear. The asymmetric boundary-layer structure in relation to the environmental vertical wind shear is summarized by Zhang et al. (2013a)

Our model diagnostic work was summarized in a context of model developmental framework for improving model physics (Zhang et al. 2013b). This physics improvement framework includes four steps: model diagnostics, physics development, physics implementation and further evaluation. Model deficiencies are first identified through model diagnostics by comparing the simulated axisymmetric multi-scale structures to observational composites (Fig. 1). New physical parameterizations are developed in parallel based on in-situ observational data from specially designed hurricane field programs (Fig. 2). The new physics package is then implemented in the model (Fig. 3), which is followed by further evaluation. This developmental framework has been successful in improving the surface layer and boundary layer parameterization schemes in the operational Hurricane Weather Research and Forecast (HWRF) model, resulting in improved track and intensity forecasts along with other HWRF upgrades (Fig. 4).

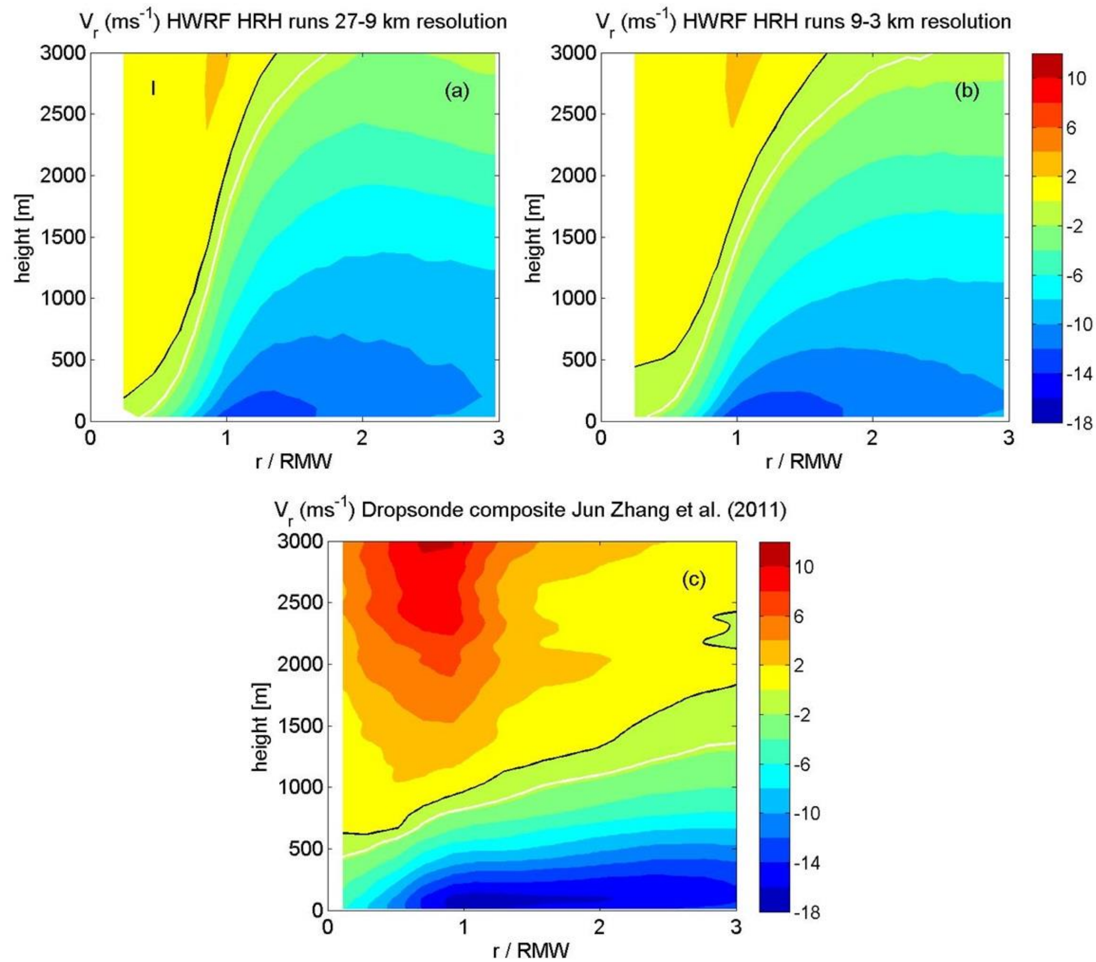

Figure 1: Composite mean radius-height plot of axisymmetric radial wind from the HRH 69 runs using the 2010-versional HWRF model for (a) 27-9 km resolution; (b) 9-3 km resolution; and (c) from dropsonde composite (Zhang et al. 2011a). Radial dimension plotted as normalized radius r*, where r* is the ratio of the actual radius and radius of maximum axisymmetric wind at 2 km. The black line represents the zero contours and the white line represents the inflow layer depth defined as the height for 10% of the peak inflow.

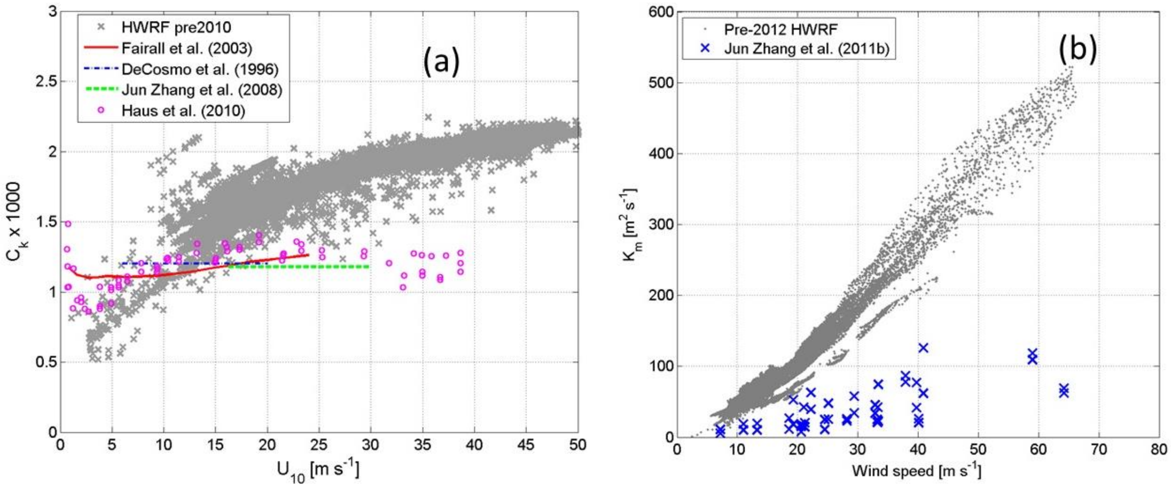

Figure 2: Plot of (a) exchange coefficients for enthalpy transfer as a function of surface wind speed from an idealized simulation with the HWRF model operationally used prior to 2010 seasons and (b) vertical eddy diffusivity for momentum flux as a function of wind speed, from an idealized simulation with the HWRF model operationally used prior to 2012 seasons.

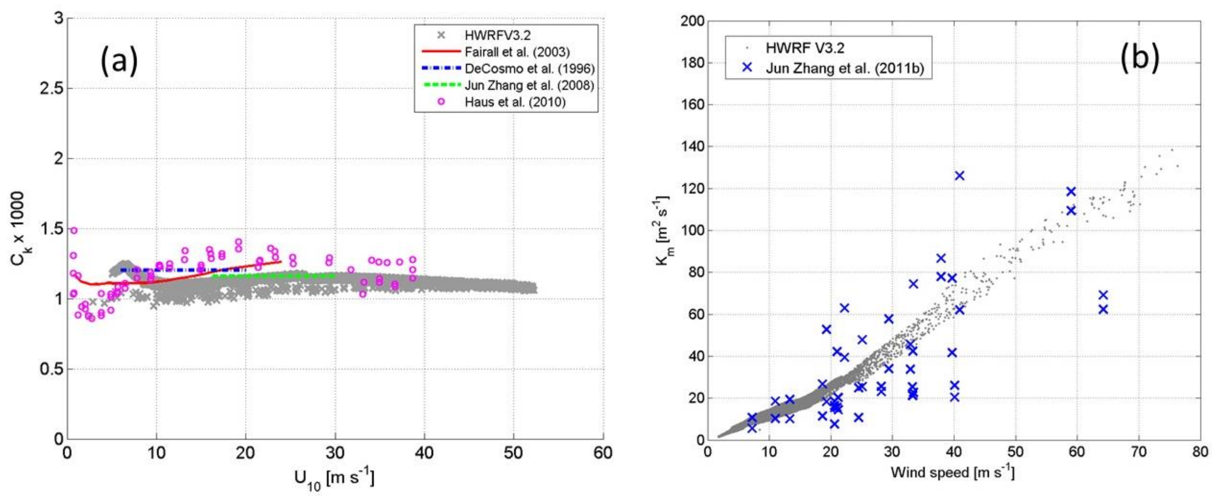

Figure 3: Plot of (a) exchange coefficients for enthalpy transfer as a function of surface wind speed and (b) vertical eddy diffusivity for momentum flux as a function of wind speed, from an idealized simulation with the 2012 version HWRF model used and from the observational studies.

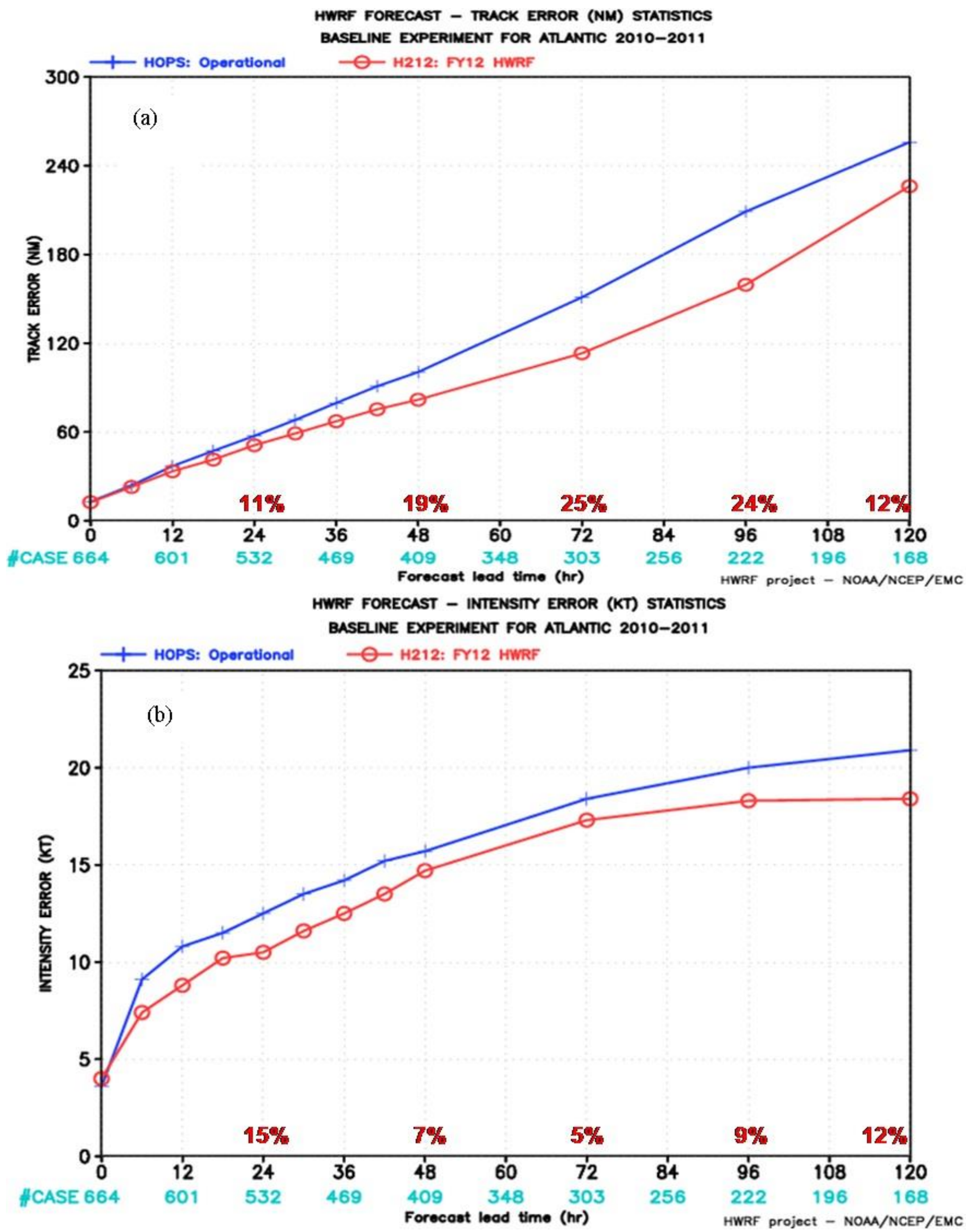

Figure 4: Comparison of average (a) track and (b) intensity errors between the 2011 (blue) and 2012 (red) version operational HWRF system for the 2010-2011 Atlantic Season tropical cyclone simulations.

Research Performance Measure: The program is on schedule. Three peer-reviewed articles have been published in *Monthly Weather Review* and *Tropical Cyclone Research and Review*. Three papers have been accepted for publication or in press in *Monthly Weather Review.*

Development of Multiple Moving Nests Within a Basin-Wide HWRF Modeling System

Project Personnel: X. Zhang and J. Delgado (UM/CIMAS)
NOAA Collaborators: S.G. Gopalakrishnan, T.S. Quirino and F.D. Marks, Jr. (NOAA/AOML); V. Tallapragada, Q. Liu, Z. Zhang and S. Trahan (NOAA/NCEP/EMC)
Other Collaborators: D.-L. Zhang (U. Maryland)

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: NWS/JHT
NOAA Technical Contact: Daniel Melendez

Research Summary

This study is part of the integrated research program "Advanced Modeling and Prediction of Tropical Cyclones" in AOML/HRD. In this study, we attempt to develop a forecast system. The system can follow multiple storms with each storm having multiple nest levels to meet both requirements of high-resolution and domain coverage to resolve the evolution of large-scale circulations, the hurricane related mesoscale convective features, and multi-scale interactions.

In collaboration with NCEP/EMC scientists, the basin scale model system configuration had been set up to fulfill the research and operational interests. The model covers both the Atlantic and east Pacific basins (Fig. 1). The vertical coordinate is 61 hybrid interface levels with model top at 2 hPa. The hybrid transitional level is at 420 hPa. Current basin-scale model system has no ocean coupling yet. The detailed configurations and physical schemes are shown in Table 1.

In order to perform the real-time forecast, we created an automatic real-time forecast system by collaborating with AOML/HRD scientist: Dr. Thiago Quirino. The multiple movable nest code was incorporated in HWRF atmospheric model component. The experimental modeling system had run with all HWRF 2012 operational implementations on HFIP's supercomputer JET system in 2012 hurricane season. The modeling system used GFS analyses and forecasts as initial and lateral boundary conditions respectively. With this system, we completed 2012 hurricane season retrospective forecasts and performed real-time forecasts of Hurricane Sandy. The real-time and retrospective products were available on the website: https://storm.aoml.noaa.gov/basin. The 6-hourly retrospective forecasts started at 00Z 19 May 2012 and ended at 00Z 04 November 2012 and performed real-time forecasts of hurricane Sandy (24 cycles, 06Z 24 October-00Z 30 October) on the JET system.

Table 1: Configuration Summary of the Basin-scale System

	27-9 km resolution	27-9-3 km resolution
Number of moving nest	2 (one storms)	Up to 8 (four storms)
Microphysics	Ferrier	Ferrier
Surface scheme	GFDL	GFDL
PBL scheme	GFS	GFS
Cumulus Parameterization	SAS	SAS
Explicit Lateral Diffusion	COAC=0.75 (27 km) COAC=3.0 (9km)	COAC=0.75 (27 km) COAC=3.0 (9km) COAC=4.0 (3km)
Initial and Lateral Boundary Conditions	GFS	GFS
Vortex initialization	No	No
Coupling	No	No

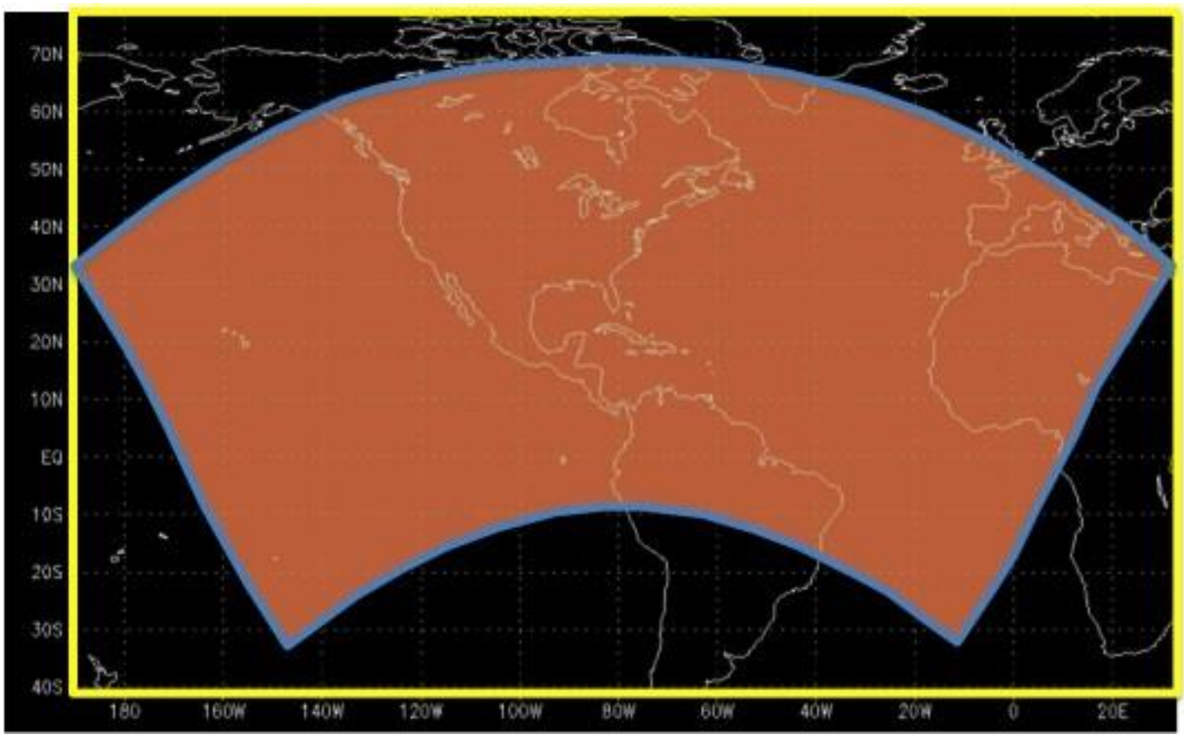

Figure 1: Basin scale model system domain.

Figure 2 shows the verification of track forecast errors in 2012 hurricane season. The results indicate that basin-scale HWRF significantly reduce the track forecast errors in the Atlantic basin and is very close to 5-year goal track errors in both the Atlantic and the East Pacific basins up to 72 hours. The 96-hour and 120-hour forecasts are better than operational HWRF although the errors are still above 5-year goal errors in the Atlantic basin. Figure 3 gives the verification of track forecast errors of all Hurricane Sandy forecasts. The performance of the basin-scale HWRF system is similar to the operational GFS track forecasts. GFS is commonly regarded as one of the best forecasts in all numerical predication models. The regional models generally perform inferior track forecasts comparing to global model forecasts. However, the statistics improvement of the track forecast accuracy in this research suggests that the basin-scale HWRF system be a potential operational approach, which could provide similar track forecast accuracy that global models have while attain superior intensity forecast accuracy/guidance by regional models through enhancing the resolution in the storm regions.

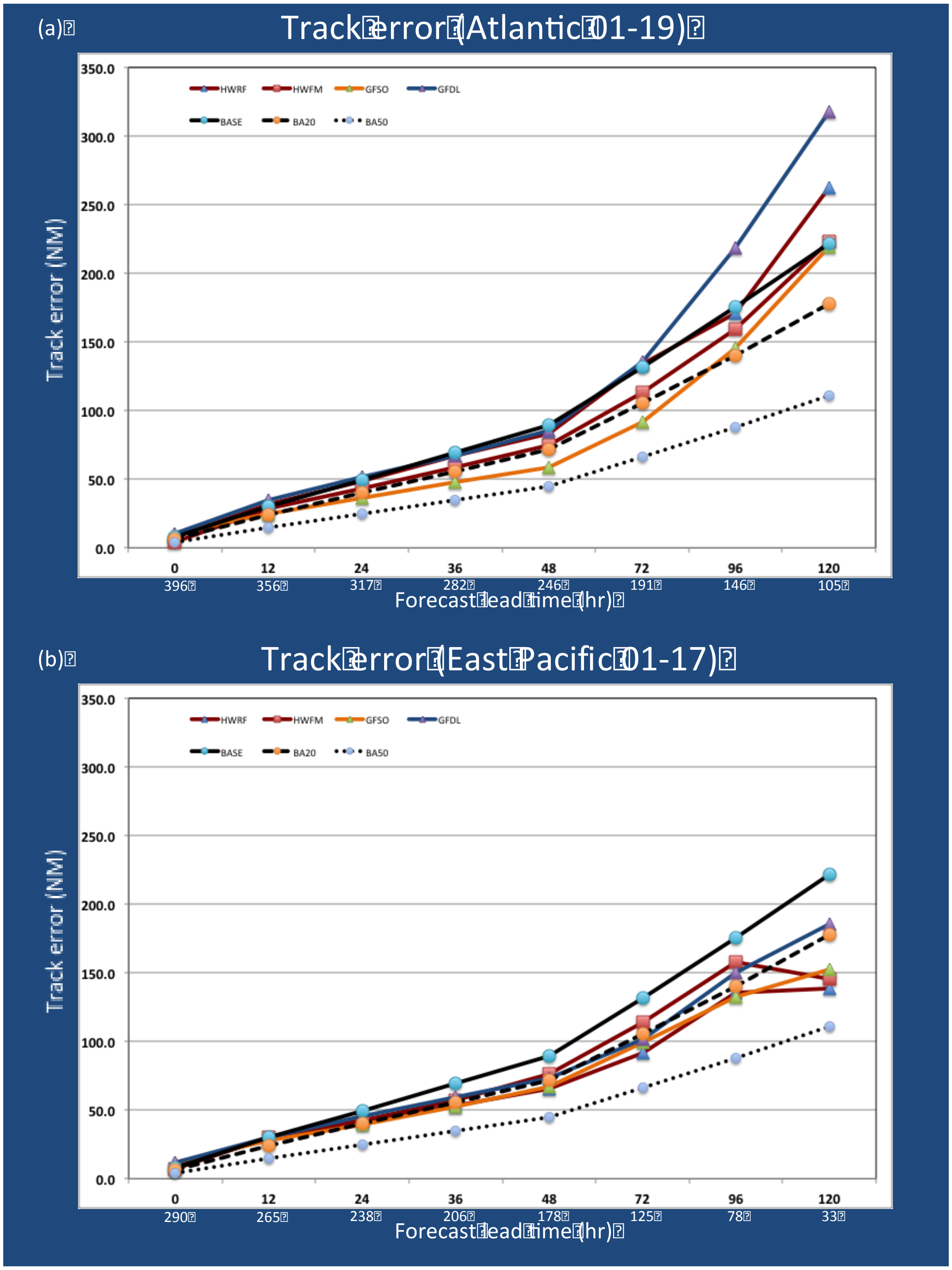

Figure 2: Basin-scale HWRF system track error verification in (a) the Atlantic Basin, and (b) the East Pacific Basin. HWRF, HWFM, GFSO, GFDL denote operational HWRF, Basin-scale HWRF, operational GFS, and operational GFDL forecast systems, respectively. BASE denotes HFIP baseline track error authored by James Franklin (detailed methodology were summarized in Gall et al., 2010), BA20 and BA50 denote HFIP 5-year (20% improvement) and 10-year (50% improvement) goal track errors, respectively.

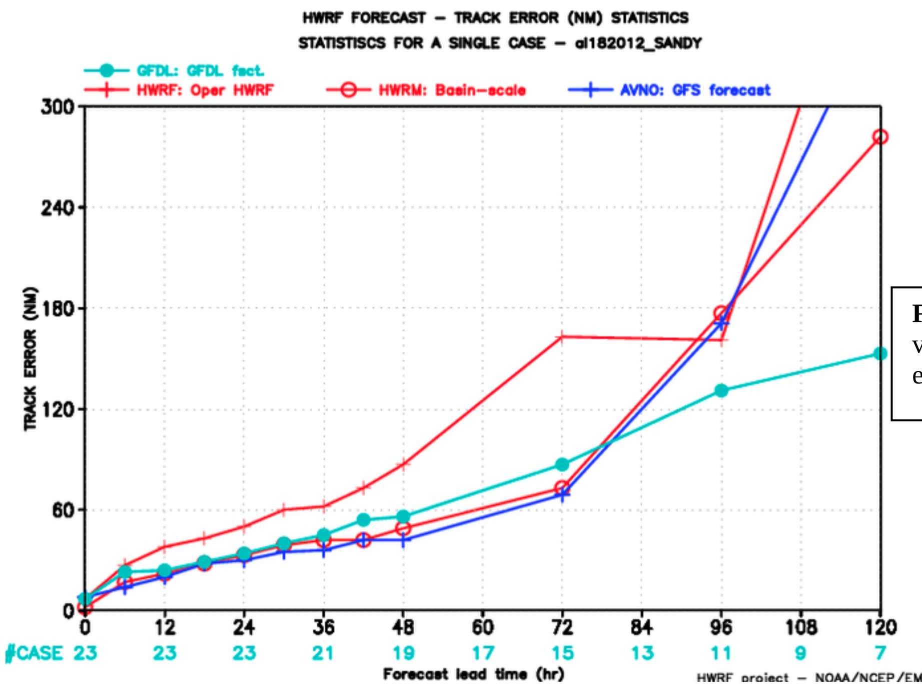

Figure 3: Hurricane Sandy verification of track forecast errors.

We constantly upgrade basin-scale baseline HWRF system following EMC's operational HWRF development through DTC repository. We are currently working on vortex initialization for nests of multiple storms in the basin wide system. The vortex initialization procedure will be implemented in 2013 basin-scale HWRF modeling system. We collaborated closely with AOML/HRD and NCEP/EMC scientists (full list in Project Personnel section) in this project. Figure 4 shows the vortex initialization procedure.

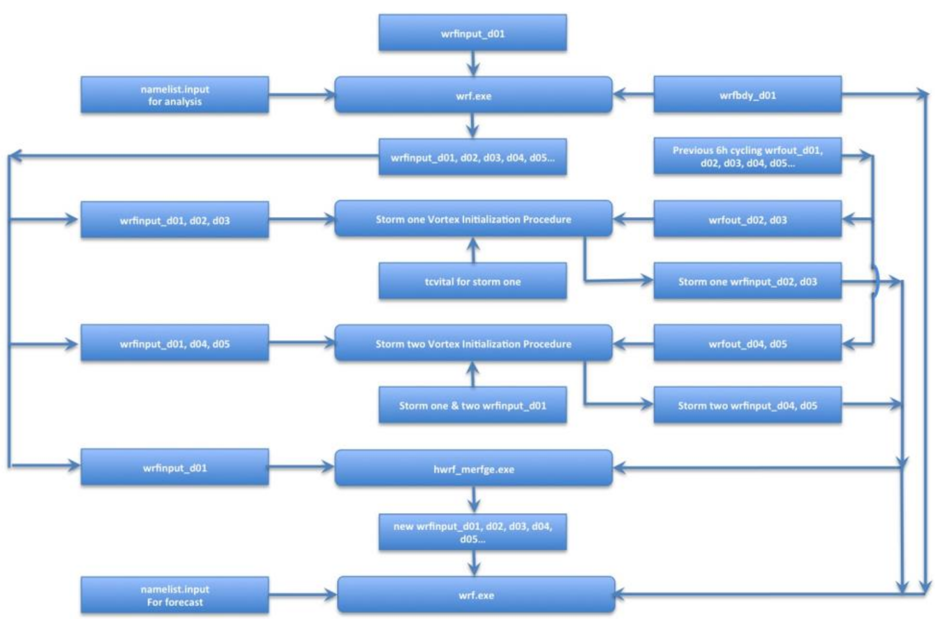

Figure 4: Implementation flowchart of vortex initialization for nests of multiple storms in basin-wide HWRF modeling system.

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

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:

The HFIP proposal submitted for this work was not funded by HFIP. It has been restructured and implemented at a reduced scale as an AOML/HRD internal effort.

During the period the reduced NASA GRIP ice water contents (hurricane EARL) were revised upwards by NCAR. The combined Cloud Imaging Probe (CIP, 50-1000 microns) and Precipitation Imaging Probe (PIP, larger than 1000 microns) size distributions have been updated. These updates include improved artifact rejection, improved particle sizing, and a correction for saturation errors on the CIP. The CIP saturation errors were significant and occurred primarily in heavy clouds containing at least 0.3 g/m3 of ice water content. The corrected particle concentrations for the CIP and the derived ice water content may be up to several times higher than previously reported in the heaviest cloud conditions. Note that there are now quite a few observations of ice water content > 3 g/m3 (Fig.1).

The most significant progress during the period was that an analysis of a tropical Atlantic deep convective cloud system was completed with results that potentially have application to the ice microphysics parameterizations used in hurricane numerical models. The microphysics of this deep convective cloud system is virtually identical to the microphysics observed in hurricane deep convection. The results of this study are immediately applicable to the parameterization of microphysics in hurricane numerical models.

A key component of this cloud analysis is the accurate measurement of the vertical winds. These updraft measurements provide the framework for the analysis defining the stage of development information for the microphysical measurements

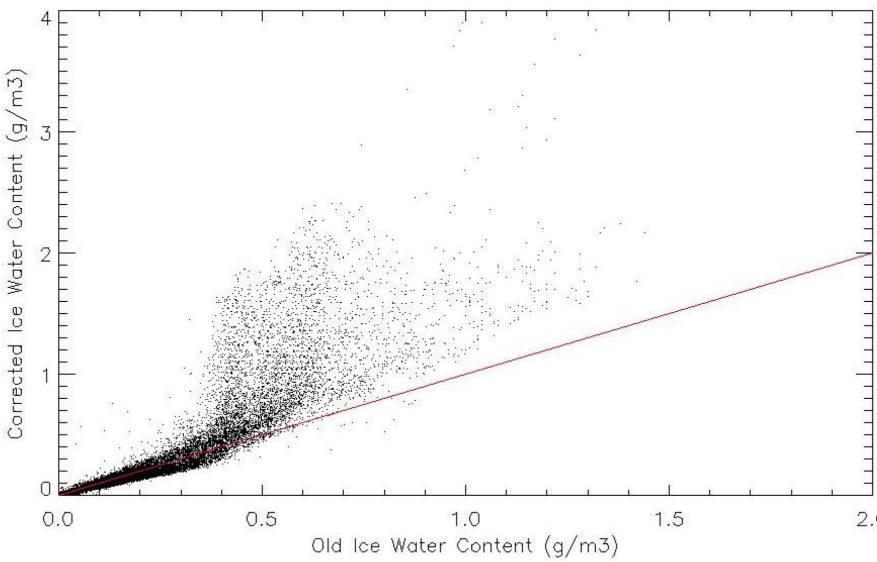

Figure 1: Updated GRIP (EARL) ice water contents.

In convective clouds, particularly over warm oceans, the observed ice particle concentrations at fairly warm temperatures (-10C) often exceed the measured or expected ice nuclei concentrations by an order of magnitude. The results of this study provide a plausible scenario to explain this discrepancy.

The deep layer of warm rain in tropical oceanic deep convection has an immense influence on the ice development in these clouds. In the deep layer of warm rain a very large fraction of the aerosol becomes immersed in the rain arriving at the -2C level. The initial primary ice development in the new freshest updrafts arriving on the upshear side of the cloud is frozen drops, some of which shatter on freezing. Since the measured updraft velocities in these updrafts pretty much bracket the drop terminal velocities in these rain drop size distributions these drops have long residence time at any given temperature level. Though they are approximately stationary in space they collect supercooled droplets at a sweepout rate proportional to their terminal velocity. These frozen drops become instant rimers participating in a prolific secondary ice production in the Hallett-Mossop zone -3 to -8C.

Since the initial terminal velocities of the frozen drops are very close to those of the parent raindrops, where +w = Vt these freezing/frozen drops have very long residence times at any given temperature level in the cloud, as well as the critical -3 C to -8 C layer. These frozen drops rime at rate determined solely by Vt, regardless of the w value. So, these frozen drops become instantaneous rimers in a Hallet-Mossop ice multiplication scenario. So that Hallett-Mossop secondary ice production is a major factor in the glaciation of these important tropical convective clouds. Immersion freezing is a likely candidate for the initial freezing of the supercooled rain drops, as the total aerosol probably becomes immersed in the -2C arrival raindrops. This conceptual model of ice development through the near-suspension of drops which are formed in the warm rain zone is a major factor in the development of ice in this important category of cloud system.

In Figure 2, I have applied the actual measured vertical winds to a range of rain drop size terminal velocities that we know exist in this tropical warm rain. Note that only in active typical tropical cloud convective up drafts are raindrops going up in the cloud. Where the updraft velocity approximately equals the raindrop terminal velocities the raindrops are nearly stationary at a temperature level.

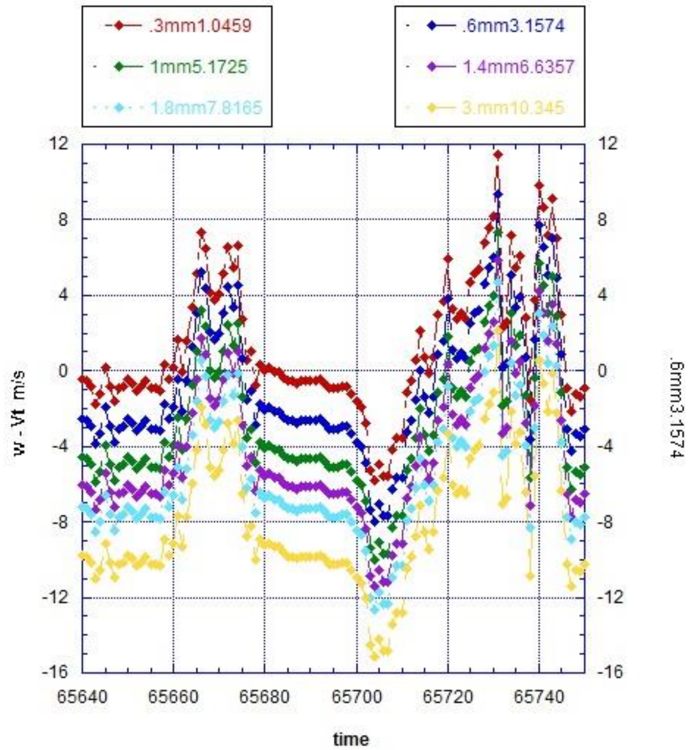

Figure 2: Measured vertical wind at -2C applied to a realistic range of raindrop terminal velocities. Only in active updrafts are raindrops ascending.

The next important task is to incorporate these results from tropical clouds into an existing microphysical parameterization scheme, i.e. Ferrier or Thompson. The idea would be to base the parameterizations of tropical cloud systems on data from tropical clouds, not based on mid-latitude data and data fits.

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

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Evaluating global and regional Observing System Simulation Experiments for hurricanes

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

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To evaluate quantitatively the potential for improving forecasts of hurricane track, structure and intensity, due to the assimilation of configurations of new and future observations.

***Strategy*:** To advance the development and conduct evaluations of Observing System Simulation Experiments (OSSEs), in global and regional models of hurricanes.

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:

For the Global model OSSE, the T511 (approximately 25 km) L91 resolution Nature Run provided by the European Centre for Medium-Range Weather Forecasts (ECMWF) has been used in collaborative OSSEs with other NOAA labs (Prive et al. 2013). This global Nature Run has also been used to provide boundary conditions for the regional Nature Run. Collaborative work with the NOAA Earth Systems Research Laboratory (ESRL) is ongoing to complete evaluations of the impact of assimilating dropwindsonde data from the Global Hawk Unmanned Aircraft System in this framework.

An initial regional Nature Run has been completed, validated and published (Nolan et al. 2013). This Nature Run has been distributed to several collaborators, at NOAA/AOML Hurricane Research Division, the NASA CYGNSS Science Team, and collaborators at the Jet Propulsion Laboratory, University of Wisconsin and at Simpson Weather Associates. Work is under way at NOAA/AOML to prepare the assimilation experiments that will be evaluated and diagnosed under funding from this research.

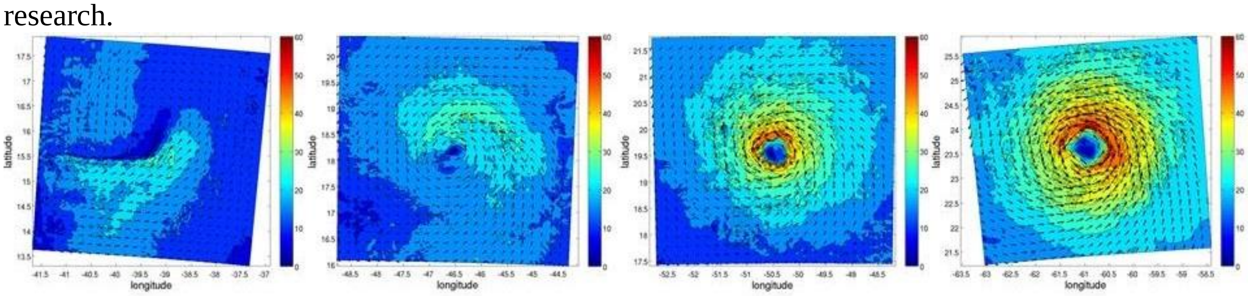
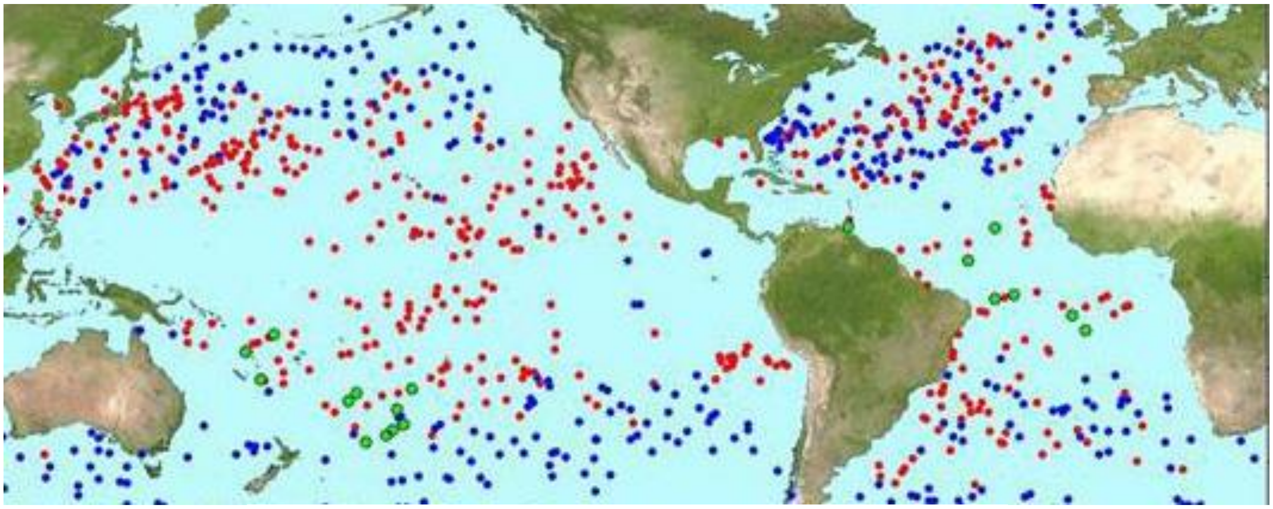


Figure 1: First Nature Run (1 km grid) in 4 stages of hurricane life cycle (Nolan et al. 2013).

Research Performance Measure: The research is still in its early stages, with little spent from the grant so far. Over the next year, the proposed objectives to evaluate the quantitative impact of assimilating synthetic satellite and aircraft data will be pursued.



RESEARCH REPORTS

THEME 3: Sustained Ocean and Coastal Observations

Developing the Operational Calibration/Validation Components for VIIRS SST Retrievals

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

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

CIMAS Research Theme:
***Theme 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 SNPP satellite in Fall, 2011 and the infrared bands were activated in February, 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. A full year of VIIRS matchups have been collected and analyzed to establish actual VIIRS SST retrieval performance. Based on these analyses, calibration adjustments have been

implemented and various forms of candidate SST retrieval equations have been investigated. To date the smallest standard deviation and bias is produced by our LATBAND approach where the globe is divided into six 20 degree wide zonal bands and retrieval equation coefficients are estimated monthly. The VIIRS SST retrievals are compared to the daily Reynolds OI Level 4 SST analysis, WINDSAT microwave SST, Figure 1, and *in situ* drifting buoy and ship based radiometer observations which provide NIST traceable validation for the satellite SST comparisons.

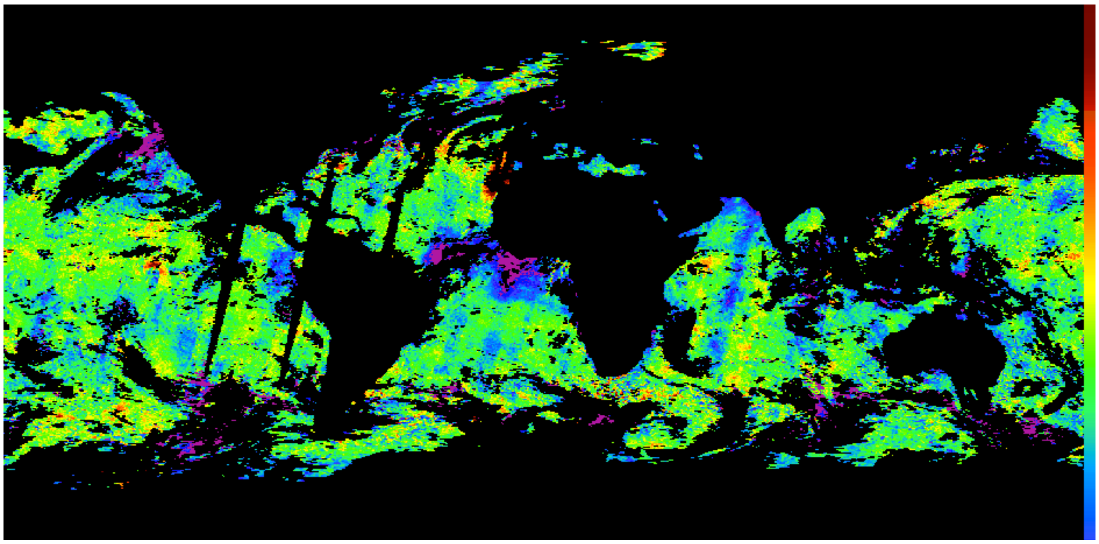


Figure 1: Global residual SST field for 2012, day 047 for VIIRS – WINDSAT 5 day composite. Purple regions reflect the present of dust aerosol which is not corrected in the current algorithm. Unlike previous IR sensors, VIIRS has wide swath coverage and thus does not show gaps between adjacent satellite swaths.

Following activation of the infrared bands on the VIIRS sensor onboard the SNPP satellite the sensor has now observed the earth's infrared signature for a year. Initial performance of the VIIRS sensor has been excellent exhibiting lower noise and higher spatial resolution observations than those available from the heritage AVHRR and MODIS sensors. Co-located and contemporaneous satellite-*in situ* observations (drifting buoy and ship based IR radiometers) have been used to validate VIIRS SST retrievals and to document approaches needed to improve the retrieval accuracy. Several suggestions resulting from processing the matchups together with patterns seen in the global SST fields have resulting in improvements in sensor calibration and updates to sensor operating parameters. In addition, a seasonal pattern was seen in the retrieval bias. A trend to cold retrievals at the edges of the VIIRS observational swath led to investigation of candidate improvements to the VIIRS SST retrieval equation. These results have been delivered to the VIIRS SST Team, and combined with efforts of the VIIRS Team has led the SST product being classified as 'Provisional' and thus is now available to the user community.

A complementary research objective is to obtain *in situ* radiometric observations of SST traceable to NIST standards to provide a basis for validating the VIIRS SST retrievals as meeting the requirements of becoming a Climate Data Record. An infrared spectro-radiometer, the Marine Atmosphere Emitted Radiance Interferometer (M-AERI) was developed and used over the last decade to provide radiometrically based SST for validation of AVHRR and MODIS SST observations. A follow-on instrument, the M-AERI Mk2, has been developed for VIIRS and deployed on a recently completed cruise from WHOI to Cape Town, South Africa where the M-AERI Mk1 and Mk2, Figure 2, instruments observed the SST and provided a cross-validation of the two M-AERI instruments, Figure 3. Two simpler, but well-calibrated infrared SST autonomous radiometers (ISAR) have been installed on commercial vessels doing long transects of the Pacific Ocean have also provided radiometric SST measurements for VIIRS SST validation.

Figure 2: The left panel shows the original Mk1 and new Mk2 M-AERI interferometers operating on board the R/V KNORR.

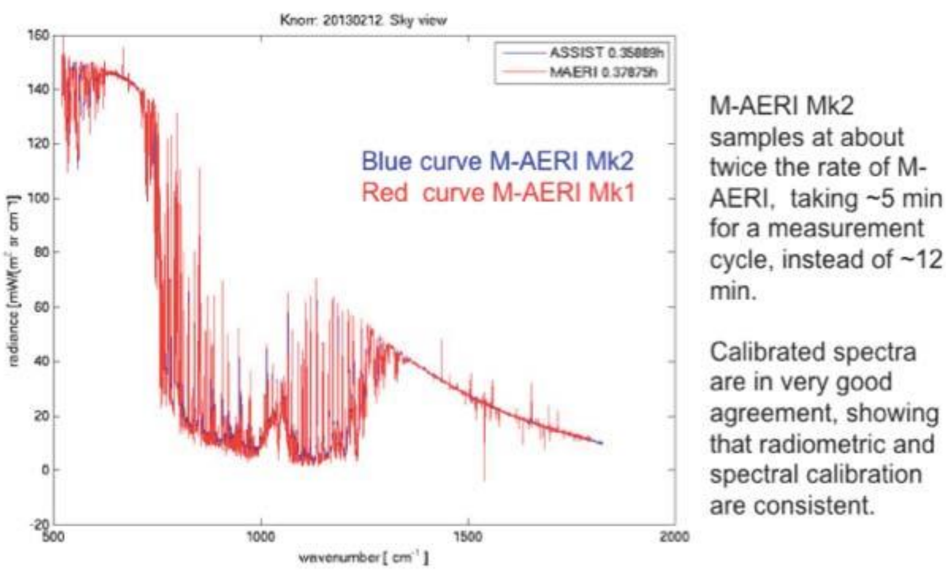


Figure 3: M-AERI Mk1 and Mk2 sky emission spectra obtained on R/V KNORR cruise. The spectra from the two instruments, blue curve is M-AERI Mk2 and red is Mk1, overlay each other showing essentially equivalent results.

Research Performance Measure: Results of VIIRS SST performance analyses, improved cloud detection and quality assignment and SST retrieval equation enhancements have been delivered to the VIIRS SST Team Leader.

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

Project Personnel: C. Atluri, R. Domingues, E. Forteza, S. L. Garzoli, M. Goes, V. Halliwell, and R. Sabina (UM/CIMAS)
NOAA Collaborator: 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*

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

The US Argo Data Assembly Center (US DAC) at AOML is responsible for deploying floats, and for acquiring and processing the data. The US DAC has developed and maintained an automatic system for decoding, 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:

- 403 floats were deployed by the USA.
- 63 of these floats were deployed jointly by AOML and CIMAS.
- 2,284 US floats actively reported data during this period.
- 76,573 profiles have been sent to Global Data Centres.
- 6,2741profiles were sent to GTS by the US DAC.

The following Software changes have been made since last year:

1) Decoders for Argos Floats

Three new APEX float formats have been added to the Argo processing system that can now handle 18 float types using the Argos system. The logic of the decoders has been improved to facilitate the adaptation to new float formats and to improve the estimation of the time an APEX float starts its transmission as it surfaces. This is important for knowing at what time a profile was taken, and for using the drift of the floats to study ocean currents. The algorithm extracting the best data from the transmissions by a float has been improved as well. This was necessary, because time spent at the surface was reduced in the effort to reduce fouling of the sensors, which increased the probability of not always getting good receptions of each message transmitted by a float.

2) Decoders for Iridium Floats

Two new Iridium decoders have been implemented, and a new table driven decoder has been developed that can handle all currently existing combinations of oxygen sensors for Iridium floats. This new decoder can be used for new formats due to its reliance on tables that contain instructions on how to decode the incoming data with no or only minor tweaks to the code. Changes have been made to the existing decoders in light of new functional requirements or missed functional requirements. Common functionality has been abstracted from the existing decoders to help effective code maintenance at times of changes of requirements. Ability to decode floats that measure new parameters e.g.: nitrate, pH, ocean color has been incorporated. For floats that spend extended periods under ice a method has been implemented to derive approximate positions for the profiles by interpolation of the latitudes and longitudes from the nearest cycles (in time).

3) Salinity adjustment determination

The program that uses the most recent profile of a given float that went through the scientific quality control to derive salinity adjustment for that float was using too much computational resources. The efficiency of the program has been improved by 90%, and will be put in operations once the testing has been completed.

4) NetCDF file production for the GDAC

Adjustments were made to the program that creates the NetCDF profile, trajectory and technical files. These were necessary to accommodate longer data lines in the input quality control text files, to correct problems in the HISTORY_QCTEST fields in the trajectory file, and to add the ability to read one, two or three values for the nominal drift pressure in the meta file.

5) TESAC file production for GTS

Minor adjustments were made to the program that produces files in the TESAC-format for distribution through GTS.

6) Real-Time Quality Control software

6a) *work completed*
Currently, real-time quality control (qc) is performed by two programs, one to analyze pressure and temperature, and another to analyze salinity. Both of these programs were converted from Fortran 77 to Fortran 90, to take advantage of the enhanced power and flexibility. The subroutine performing QC Test 14, the density inversion check was updated to implement a new method approved in the

current QC Manual. This subroutine was also converted to f90, as well as the subroutine that creates the output qc text file. These versions of of the quality control software are currently in operations.

6b) *work in progress*
A rewrite of the quality control and reformatting software was started in Fortran 90. The main reasons for doing this are the introduction of the NetCDF format version 3.0 for all Argo profile, meta and trajectory data and to facilitate adaptations to new sensors as the Argo program evolves. An additional benefit will be that the number of times the data have to be read and written will be greatly reduced. What is currently done by six programs will be done by a single program that will perform pressure and salinity adjustments, all quality control functions, as well as the creation of not just the ASCII qc files, but also the TESAC files for GTS and the NetCDF files for the GDAC. During this development, old subroutines will be revised as needed to take full advantage of the powers of Fortran 90 and to reduce the number of subroutines that essentially do the same thing for different parameters. In the current method, one program performs the pressure adjustment, another performs the salinity adjustment. The third performs the quality control got date, speed, pressure and temperature. The fourth program reads the output files of the previous program and applies quality control tests to the salinity data and creates the ASCII "qc file". The fifth program reads that qc text file and writes the TESAC-format file for for GTS, and finally the sixth program reads that same qc text file to write the NetCDF files for the GDAC.

The new program will not only be more efficient, but will be easier to maintain and modify in the future. During the development of this program, the new quality control tests for dissolved oxygen will be added, and the analysis will apply the appropriate tests to any secondary or tertiary profiles that are measured by floats (example: one float type measures three oxygen profiles at the same time).

7) Other software changes

The processing system was migrated to a new server with a faster processor and more storage capacity which enables the US DAC to double the daily data acquisition and processing.

The US DAC is maintaining a website that provides documentation and information about the operations at the US Argo DAC http://www.aoml.noaa.gov/phod/argo/index.php.

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 (SAARC), the development of the Post-DMQC analysis was completed, and has been 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 1) show overall statistics from all floats, highlighting floats that may have larger deviations from the comparison data sets with or without a time dependence. The latter could be caused, for example, by inadequate correction of sensor drift. This system will facilitate the detection of floats with potentially erroneous corrections performed during the DMQC.

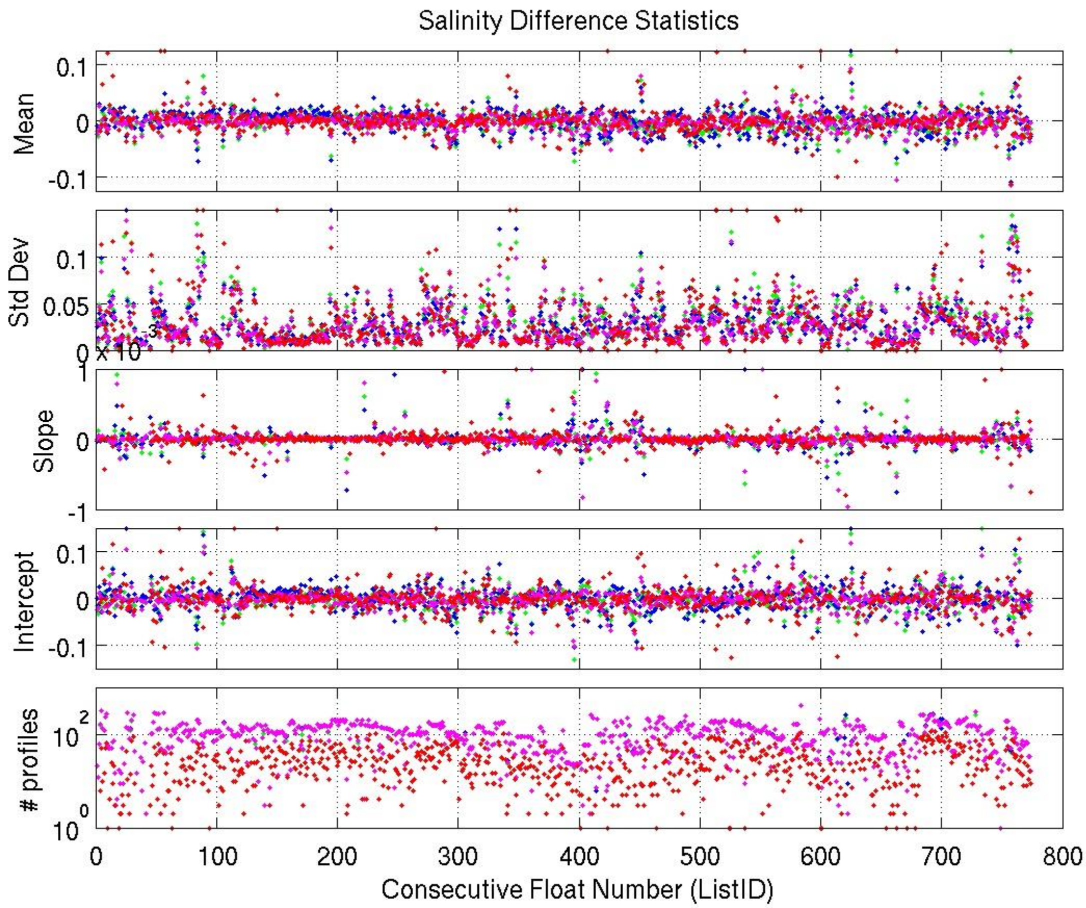


Figure 1: Summary plots of the statistical analysis performed on the salinity of the delayed-mode profiles of Argo floats in the region covered by the South Atlantic Argo Regional Center.

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.

Other ARGO Activities

1) Filling up data gaps in the South Atlantic: The Lady Amber Experience.

Argo is an international program that calls for the deployment of 3,000 free drifting profiling floats, distributed over the global oceans, which will measure the temperature and salinity in the upper 2,000 m of the ocean providing 100,000 T/S profiles and reference velocity measurements per year. The objective of the program was to achieve a data density of at least one float every 3 x 3 ° in the world ocean.

Figure 2a: The Lady Amber.

Due to the fact that most of the float deployments are made from ship of opportunity (including research vessels with a fix cruise track) some areas of the world ocean are under observed. When funds are available, dedicated cruises can be conducted to fill up these data gaps. In the South Atlantic there were regions where the data density was zero or close to zero due to the lack of navigation on the area. The NOAA Office of Global Programs provided support to charter the Lady Amber with the objective to deploy Argo floats in regions where no observations were previously collected. See Figures 2a-d.

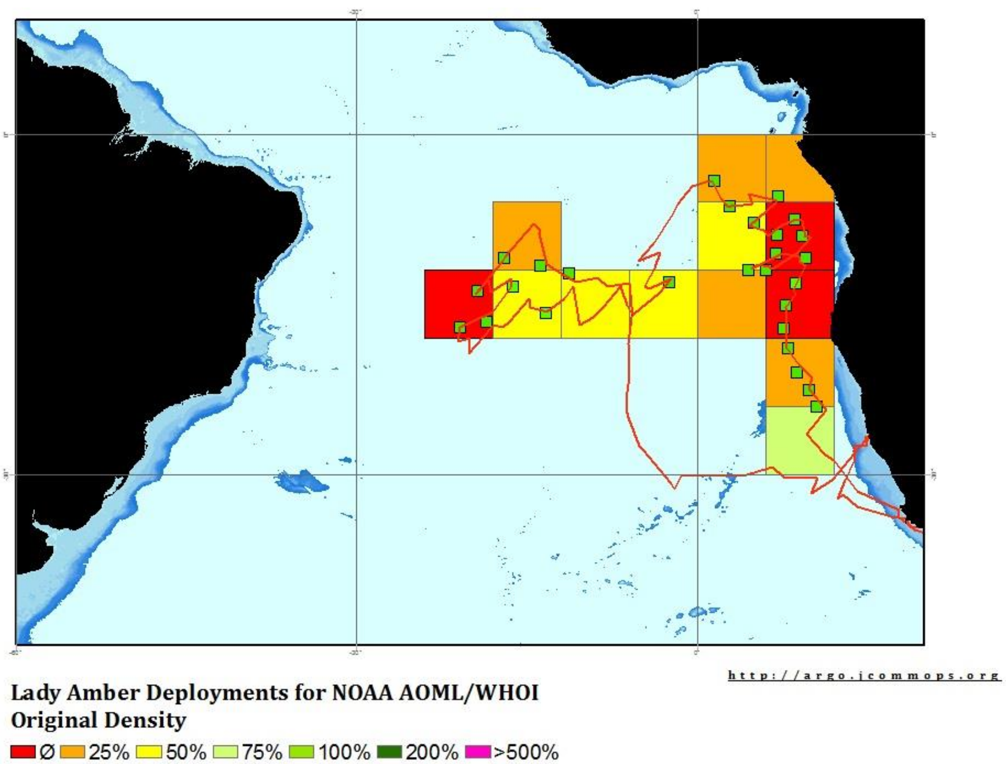


Figure 2b: Lady Amber float deployments superimposed to the data density before the cruise.

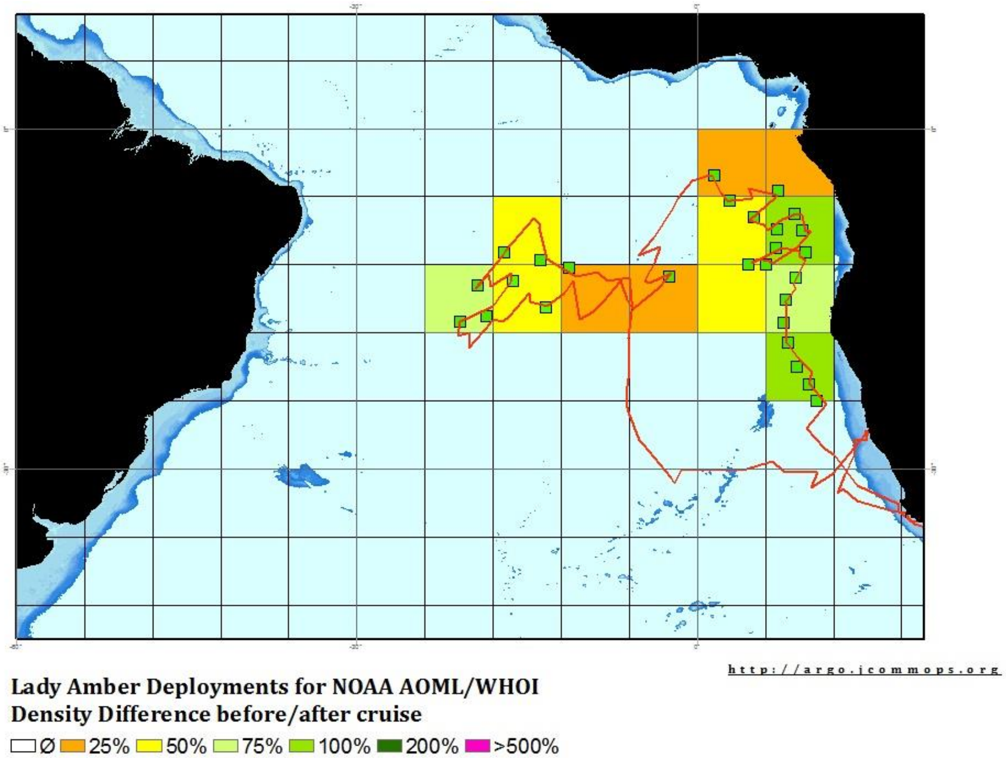


Figure 2c: Difference on density before and after the cruise.

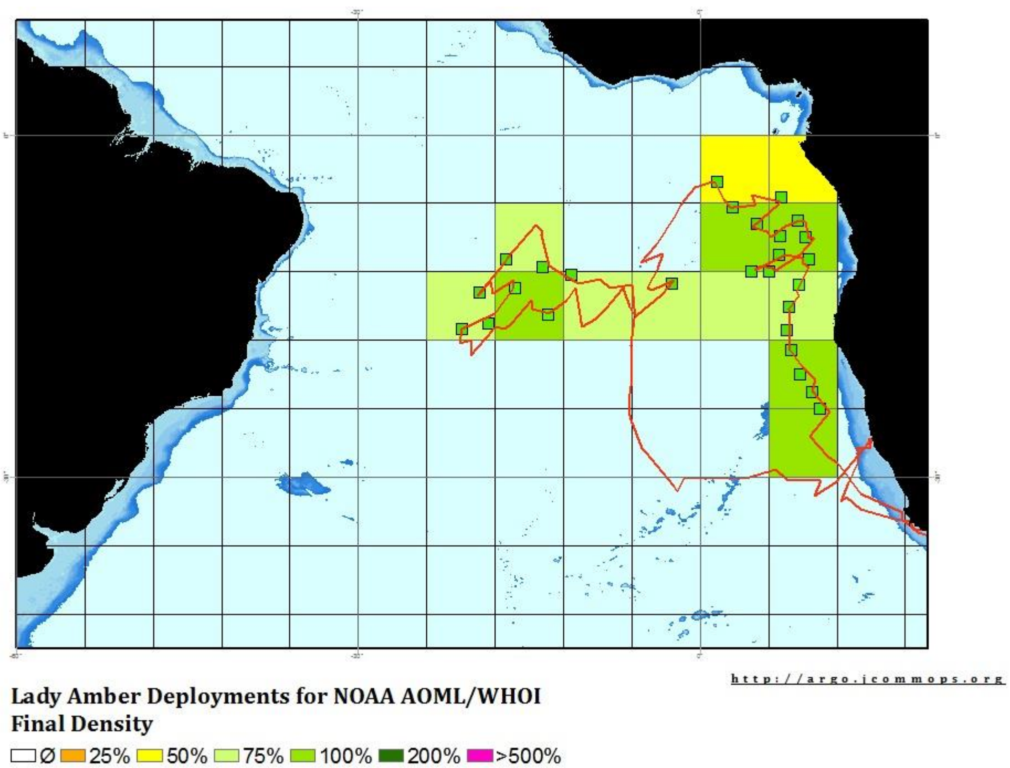


Figure 2d: Data density after deployments. (Figures courtesy of Mathieu Belbeoch, Argo Information Center).

2) Relationship between the off-equatorial current system and the tropical Atlantic variability

The equatorial Atlantic upper ocean circulation is a system of multiple eastward jets with high spatial and temporal variability. They are responsible for a large part eastward transport of the heat and nutrients, and therefore a critical component of the climate and weather variability in the adjacent continental areas. In order to understand the variability of these currents, a multiplatform observational system needs to be constructed to have both a high temporal and spatial resolution. In Goes et al., (2013), we have used a blend of data from satellite altimetry, temperature from a high density expendable bathythermograph XBT, and mean dynamic height from ARGO to construct a synthetic method. In the synthetic method, sea level height anomalies are regressed onto the absolute dynamic height and water density, in order to calculate absolute velocities and transport within water masses layers. Absolute dynamic height is calculated by applying a reference level dynamic height at 800 m depth from the IPRC (iprc.soest.hawaii.edu/) Argo mean dynamic height climatology. A strong relationship between the absolute dynamic height anomalies and sea level anomalies has been reached (Figure 3), which is necessary for the efficiency of this method. This methodology successfully reconstructed the seasonal and interannual variability of the North Equatorial Countercurrent and North Equatorial Undercurrent, and less efficiently the South Equatorial Undercurrent. We linked the dynamics of these currents to anomalies of SST and wind-stress in the tropical Atlantic, which are regulators of regional climate and weather variability.

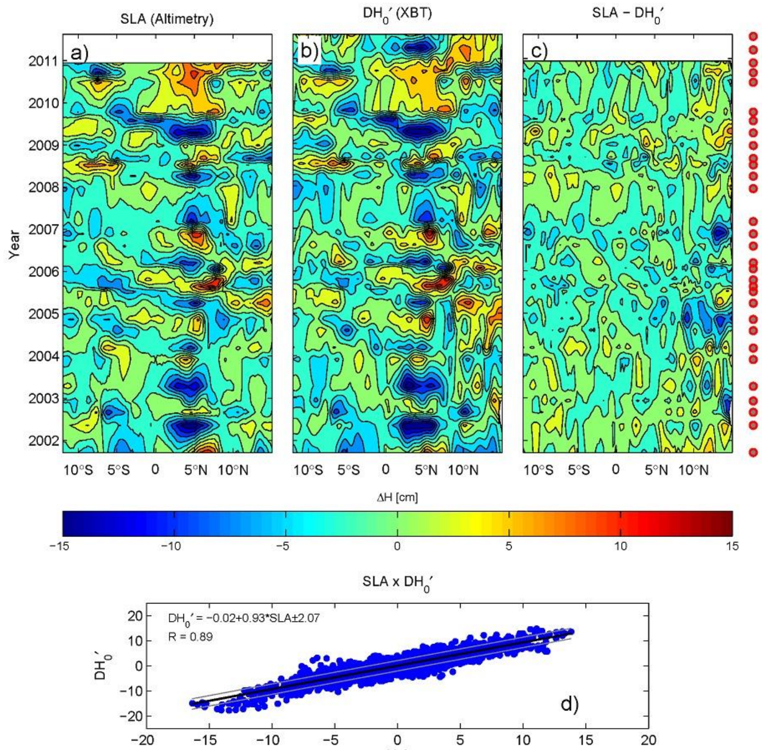


Figure 3: Comparison between SLA and surface dynamic height anomalies (DH_0'): Longitude-time diagrams of (a) SLA, (b) DH_0', and (c) SLA - DH_0'; dots on the right-hand side of (c) mark the realizations of the AX08 XBT transect. (d) Linear fit between DH_0' and SLA (thick black line) and its RMSE (gray lines).

In a scientific paper led by Ricardo Domingues (CIMAS/UM), the role of local wind stress changes in forcing variations in the structure of the Antarctic Circumpolar Current (ACC) is investigated using satellite observations and in situ hydrography. The main finding of this work is that changes in the structure and intensity of the westerlies force an immediate and integrated response in the upper layer of the ACC, and in the transports by the Subantarctic Front and by the Antarctic Polar Front (APF). This response occurs as follows: during positive phases of the Southern Annular Mode, easterly anomalies develop between 35oS-45oS, forcing the poleward advection of warmer waters through anomalous Ekman transport, and changes in the dynamic height structure, which ultimately causes the deacrease (increase) of the SAF (APF) geostrophic transport. The dynamical link between the wind stress changes and the dynamic height adjustments occurs as a combination of (i) thermosteric sea level rise due to warm anomalies in the Ekman layer, and of (ii) Ekman pumping driven sea level rise (Figure 4a). Therefore, the long term variability of the sea height anomaly (Figure 4b) is largely due to the sea surface temperature variability (Figure 4c), and to the Ekman pumping (not shown). This mechanism may have implications for the Atlantic-Indian heat and mass exchanges. The manuscript entitled "Atmospherically forced variability of the Antarctic Circumpolar Current south of Africa between 1993-2010" is currently under review at the Journal of Geophysical Research – Oceans.

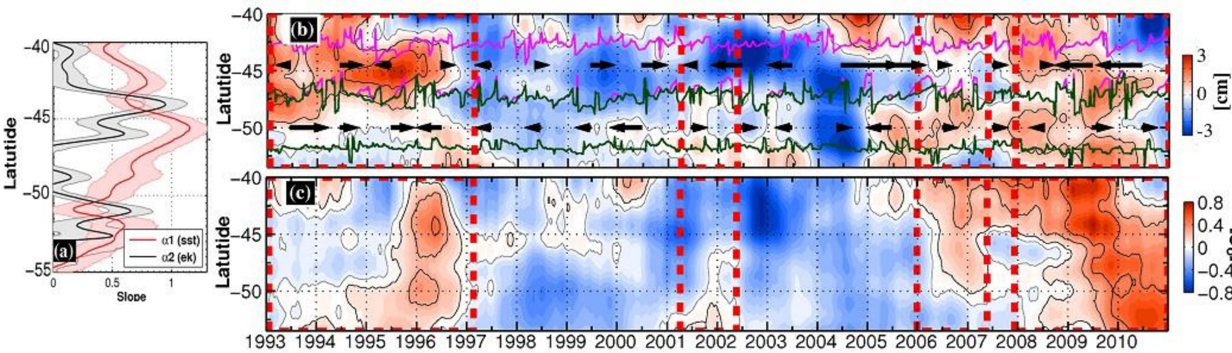


Figure 4: (a) Contribution of the thermosteric component (red line) and of the Ekman pumping component (black line) for the sea height anomaly variability as a function of latitude. (b) Observed sea height anomaly variability for time scales longer than the annual. Highlighted are the SAF (magenta lines) and APF (dark green) frontal domains, and the annual mean geostrophic velocity signal (arrows). (c) Sea surface temperature residuals (annual cycle removed) for time scales longer than the annual.

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

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Florida Area Coastal Environment (FACE) Program

Project Personnel: N. Amornthammarong, C. Brown, M. Gidley and L. Visser

NOAA Collaborators: J. Stamates, J. Bishop, T. Carsey, C. Featherstone, C. Sinigalliano (NOAA/AOML); R. Kotkowski and M. Kosenko (NOAA Corps.)

Long Term Research Objectives and Strategy to Achieve Them:

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

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

CIMAS Research Theme:
***Theme 3*: ** Sustained Ocean and Coastal Observations (*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/CRCP **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 project examining the water quality off of Broward County was completed and a NOAA Technical Report written. The project included twelve monthly cruise in the operations area, tracer studies, and an ocean current measurement component. Some results from the dye tracer study are shown in Figure 1, which shows the dramatic reduction in concentration of rhodamine dye with distance during a tracer study from the Broward-North outfall on 28-Novembe-2012. The final report from this project is under final review and will be promulgated as a NOAA Technical Report.

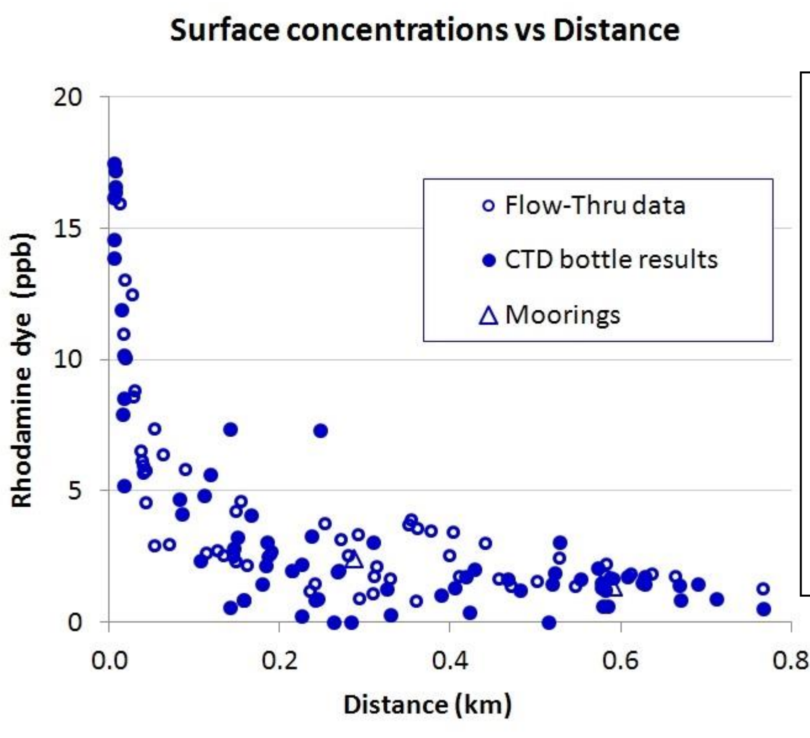

Figure 1: Concentration of rhodamine-WT dye versus distance from the Broward North treated-wastewater outfall pipe terminus. The concentrations were obtained from three sources: a flow-through seawater system on the R/V Hildebrand, from bottle samples lowered down into the water column ("CTD"), and from moored instruments located north of the outfall pipe. The dilution could be characterized by two stages; a nearfield dilution up to about 0.1 km and a farfield dilution at greater distances.

Another project underway during this time period was the NOAA/CRCP funded study of the nutrient flux from the Boca Raton and Hillsboro Inlets. The field work consists of a series of intensives at those inlets where a small boat crosses the inlet gathering flow data via a downward-looking acoustic Doppler current profiling instrument, while water samples are collected for analysis of nutrients, salinity, and other factors. These data will be interpreted together with grab samples obtained by fortnightly at each inlet during outgoing tides, which provides a measure of the change in concentration at the inlet throughout the year. An example of the results of a sampling intensive is shown Figure 2. The flow through the Boca Raton inlet is given by the black dotted line; the concentrations of various species during the ebb tidal flow also shown. These data would be used to generate a flux of these species flowing out through the inlet into the coastal ocean.

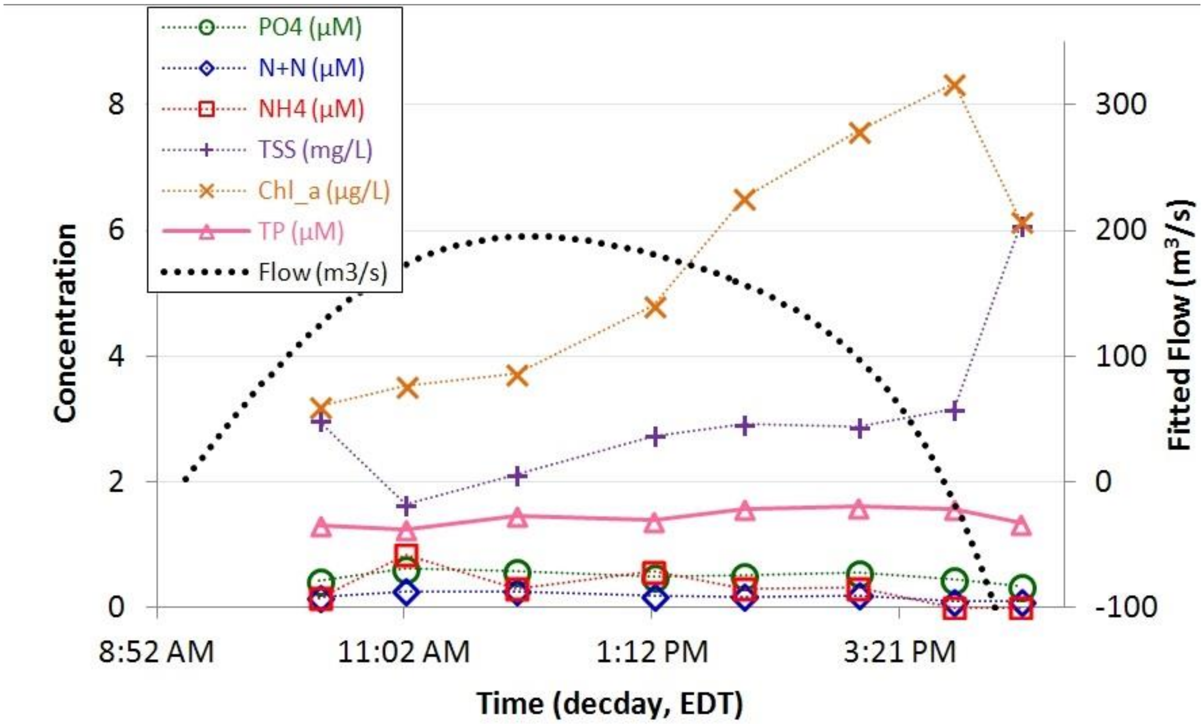

Figure 2: Results from a sampling intensive at the Boca Raton Inlet on 15-Oct-2012. The black dotted line is the flow through the inlet (ebb flow is positive); the concentrations of various species as noted in the legend is shown at various times during the tidal cycle. The concentration of chlorophyll-a and total suspended solids (TSS) increased throughout the ebb tide. The last water sample (4:25 pm) was obtained during flood tide.

Research Performance Measure: A program to investigate the water quality off of Broward County, in the vicinity of the Broward and Hollywood outfalls as well as the Pt. Everglades and Hillsboro Inlet has been completed. The report is under final review and will become a NOAA Technical Report available at the FACE website.
http://www.aoml.noaa.gov/themes/CoastalRegional/projects/FACE/faceweb.htm.

Global Drifter Program

Project Personnel: S. Dolk, V. Hormann, R. Perez 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 Units: OAR/CPO
NOAA Technical Contact: Alan Leonardi

Research Summary:
The Global Drifter Program (GDP) is a principal component of the Global Surface Drifting Buoy Array, a branch of NOAA's Global Ocean Observing System (GOOS) and a scientific project of the Data Buoy Cooperation Panel (DBCP). There are two major activities in this program.

- *Drifter Operations Center (DOC)* whose task is to maintain a global 5x5 degree array of 1250 satellite-tracked surface drifting buoys to meet the need for an accurate and globally dense set of in-situ observations of mixed layer currents, sea surface temperature (SST), atmospheric pressure, winds and salinity.
- *Drifter Data Assembly Center (DAC)* whose tasks are: to arrange data dissemination to the Global Telecommunications System (GTS); to provide uniform quality-controlled data from the historical data sets of SST and surface velocity, web access, archival and distribution. These data support short-term (seasonal to interannual) climate predictions as well as climate research and monitoring.

The design of the Global Drifter Program drifter has continued to evolve - as demonstrated by the recent large-scale deployment of salinity-measuring drifters - 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. 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 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.

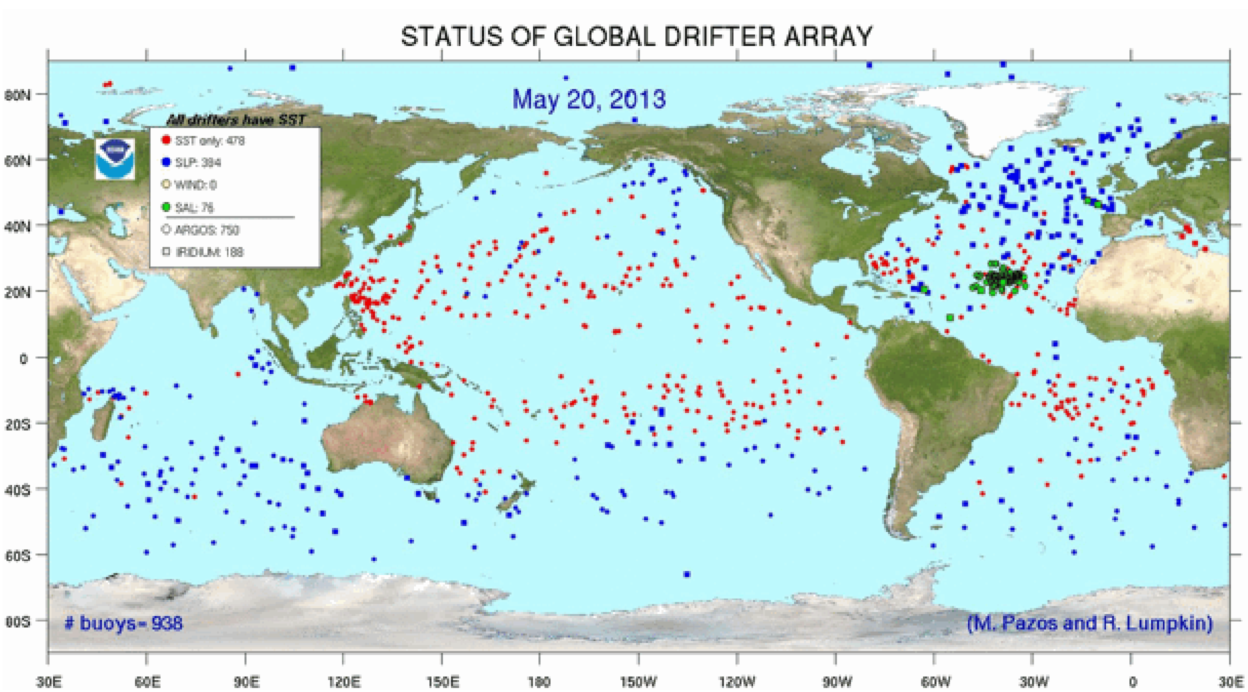

Figure 1: Status of the Global Drifter Array (updated weekly).

Research Performance Measure: As a result of shortened drifter lifetimes, maintaining a global array of 1250 drifters has been challenging. Therefore, while regional deployments were conducted to provide adequate spacial coverage, additional drifters must be deployed to achieve a global array of 1250 drifters. The goal of making timely quality-controlled data available to the research and operational communities was met.

Aquarius Reef Base

Project Personnel: J.W. Fourqurean, T.A. Potts and M.R. Heithaus (FIU)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To continue supporting maintenance and monitoring of the Aquarius undersea laboratory and provide stewardship of NOAA-owned Aquarius related equipment while developing a new business model that will support marine ecosystem research, coral reef and ocean observations, advanced undersea technology testing, diver training, education and outreach missions.

***Strategy*:** To transition personnel, assets and operating protocols from UNCW and reinvest in a new shore base of operation to allow successful completion of the 2013 American Bureau of Shipping annual survey and to limit corrosion and similar damage in line with historical trends of the NOAA-owned facility. Concurrently, to develop a stable business model that relies on users to pay the expenses associated with research, teaching and training activities at Aquarius Reef Base.

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* (*Primary*)

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

NOAA Funding Unit: OAR/OER
NOAA Technical Contact: Karen Kohanowich

Research Summary:

For the first three months of FY2013, FIU actively maintained the Aquarius habitat and related systems in accordance with Planned Maintenance System Requirements in order to meet standards for annual American Bureau of Shipping certification. Continued monitoring protocols are in place for the duration of the reporting period.

Milestones accomplished to date to meet the stewardship mandate include transitioning personnel, assets and protocols from the program’s prior host institution, the University of North Carolina Wilmington. FIU invested in a new shore facility that provides a staging location for offshore operations and includes deep-water dockage for five university vessels, workshops for dive equipment maintenance, staff offices, training conference room, telemetered command center for Aquarius saturation diving, and a media production studio for facilitating live broadcasts.

FIU also established a recharge facility to better serve in the development of a new business model built upon user-levied day rates to cover operating costs. Planning efforts with customers from academia, government, industry and the private sector with projects consistent with the CIMAS research themes are currently ongoing.

Figure 1: NOAA/FIU Aquarius undersea laboratory.

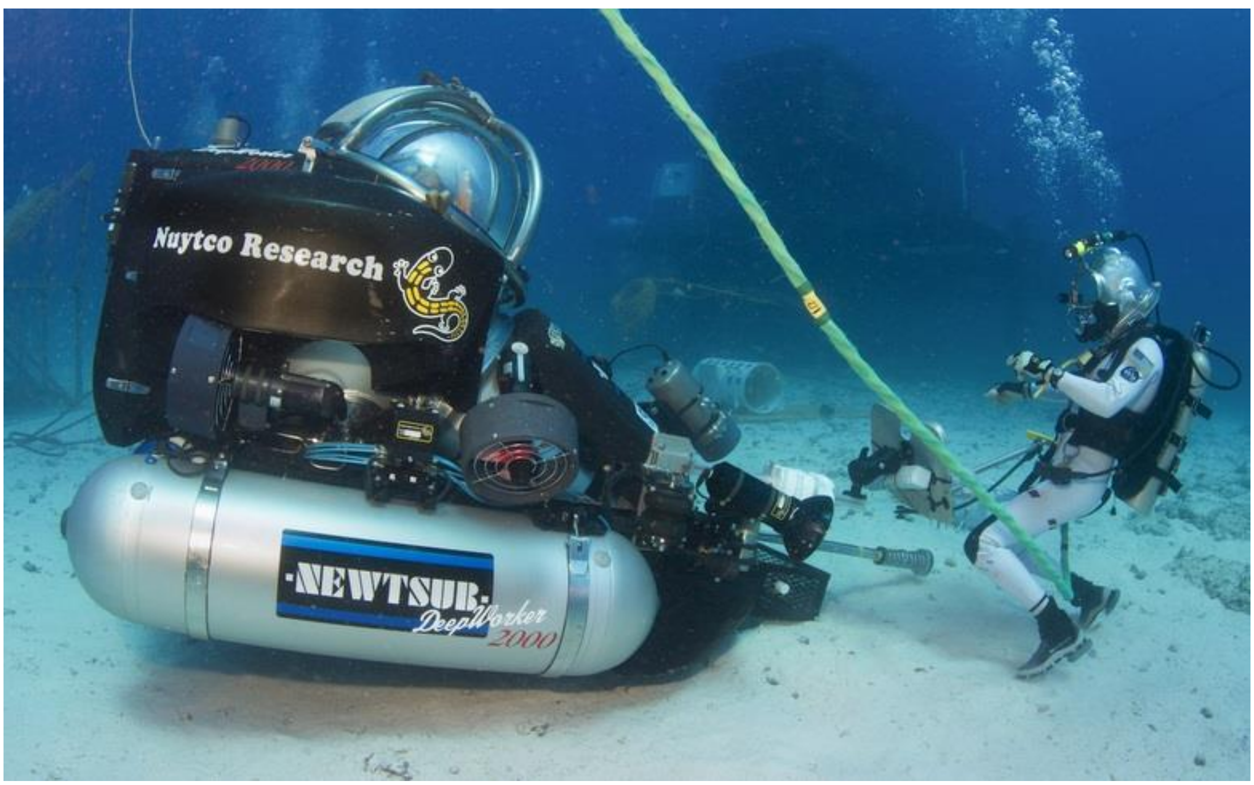

Figure 2: NASA astronauts use a Deep Worker submersible as part of the NOAA/FIU NASA Extreme Environment Operations Mission.

Figure 3: NASA astronauts simulating extraterrestrial sample collection as part of the NOAA/FIU NASA Extreme Environment Operations Mission.

Figure 4: NASA astronauts simulating near-Earth asteroid (NEA) translation as part of the NOAA/FIU NASA Extreme Environment Operations Mission.

Research Performance Measure: The project is on schedule to meet the original objectives for safety, compliance and use of Federal assets.

Ship of Opportunity Program

Project Personnel; C. Gonzalez, S. Dong, Z. Barton, R. Domingues, M. Goes, G. Rawson, Q. Yao, J. Soto, R. Roddy, K. Seaton, R. Sabina and S. Garzoli (UM/CIMAS)

NOAA Collaborators: G. Goni, M. Baringer, F. Bringas, J. Harris, U. Rivero, P. Pena, A. Stefanick, J. Farrington and Y-H. Daneshzadeh

Other Collaborators: J. Trinanes (University of Santiago de Compostela, USC), P. Chinn (Consultant)

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 network) 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/CPO **NOAA Technical Contact:** Alan Leonardi

Research Summary:

The global atmospheric and oceanic data from Ships Of Opportunity Program (SOOP) serve as a key component for understanding long-term changes in marine climate. 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) with the objective of a) monitoring meridional heat transport, b) assessing variability of boundary currents, and c) contributing with approximately 15% of the global upper ocean heat content data. NOAA/AOML is involved in one or more components of the 8000 XBTs that are deployed annually in Frequently Repeated and High Density modes (Figure 2). In addition, approximately 14000 XBT observations, from NOAA and non-NOAA operations, are quality controlled in real-time at AOML every year. 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 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, AX97. This program also collaborates 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.

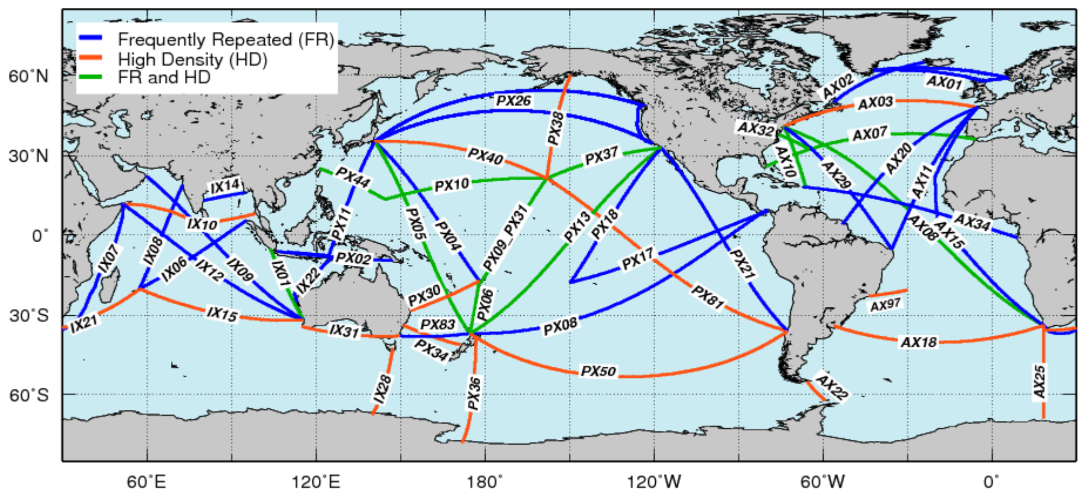

Figure 1: OceanObs09 XBT transects recommended by the scientific community to be occupied in frequently repeated mode (FR, in blue), high density mode (HD, in orange) or both (in green).

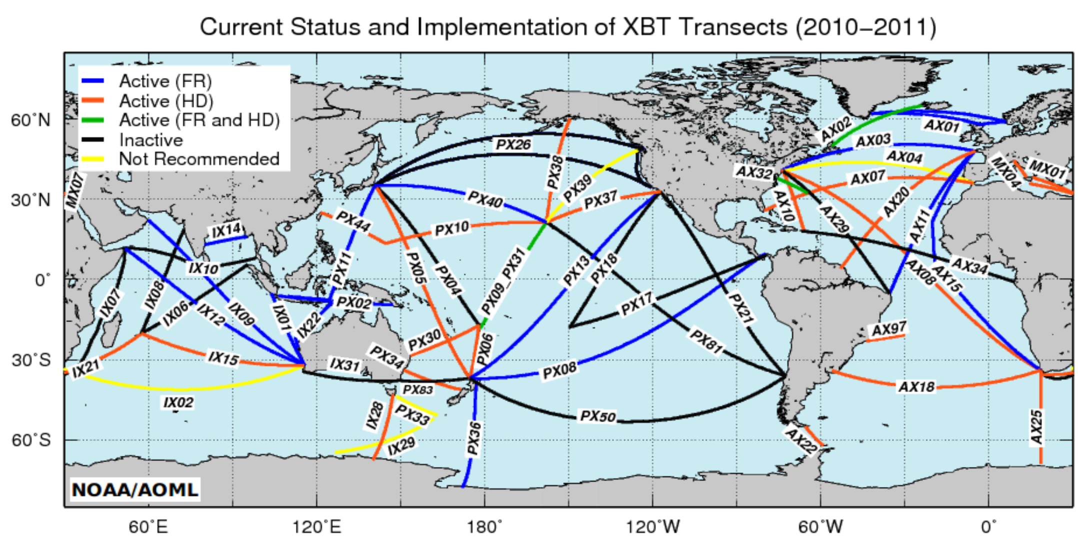

Figure 2: Current status and implementation of XBT transects recommended by the international community. Transects in black were not sampled during 2010-2011. Other colors indicate transects sampled in frequently repeated mode (FR, in blue), high density mode (HD, in orange) or both (in green). XBTs were also deployed along several transects that are not part of the scientific community recommendations (in yellow).

High Density XBT transects provide real time high resolution temperature profiles spaced approximately 20-50 km apart. These 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 200 days at sea and approximately 8000 XBTs deployed. Data obtained from these transects are provided to the scientific community to investigate the variability and upper ocean thermal structure of boundary current, subtropical gyres, equatorial current system to study and understand the role that the ocean plays in climate fluctuations, and to improve the ability to predict important climatic signals, such as the North Atlantic Oscillation. For more details about the XBT network, please see *www.aoml.noaa.gov/phod/hdenxbt/*. In addition, observations from other in situ and remote observing platforms are used to complement the observations provided by the XBT transects.

One of the most important contributions of the XBT network is the monitoring and study of The Meridional Overturning Circulation (MOC). The 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. The XBT data obtained within this program is also used to study the variability of boundary, surface, and undersurface current.

Research and Operations Highlights

Software developments. The development and update of AMVERSEAS (the software used to acquire and transmit oceanographic and marine meteorological observations) continued. The most remarkable new features introduced were: The new file name convention having distinctive names for files containing different data types in the same ftp directory. Ftp is an efficient way of data transmission to decrease the transmission costs. The Remote Command System to send commands from a remote platform to AMVERSEAS computer via email using the Iridium SMS service. Adding this system to AMVERSEAS reduces downtime, prevents acquisition data loss as a result of hardware or application programs stops or crashes, saves costs of dispatching a technician to remote locations. Making the software fully compliant with the WMO's requirements the meteorological component implements the WMO recommended formulas and algorithm to calculate the dew point and relative humidity. The AMVER component, which is used by the United States Coast Guard in support of Search and Rescue Efforts, upgrade was also completed. This application submits four (4) types of reports: Sailing plan, deviation report, position report, and arrival report. The official AMVERSEAS software website is online. This website includes software explanation, links to download the latest version of the program and several documents to assist in the installation, setup and operation of AMVERSEAS.

Data Management. In accordance with WMO TDCF migration plan, the shift from the Traditional Alphanumeric Codes into BUFR was completed during this last year. During this process, a new template for XBT data was developed and tested, and once the validation with third parties (NOAA/NCEP, Czech Hydrometeorological Institute and ECMWF) was completed following WMO guidelines, the new template was accepted for operations. XBT data are currently being distributed into the GTS in parallel, both in BUFR and BATHY formats.

Engineering developments. Several developments to the equipment used in SOOP operations were implemented. These included the redesigned of the Auto Launcher electronics: conversion to "C" based firmware code, improved motor connectors and updated system components. A new board manufacturing technique based on an AOML designed reflow solder oven was developed. The AOML constructed oven allows for improved Auto Launcher board yields and for further electronics miniaturization in future designs. Finally, an Auto Launcher Switch was developed. The Auto Launcher Switch will allow for several Auto Launchers to be controlled by a single computer and opens up the opportunity for the Auto Launchers to be deployed as a stand alone system, which will not require ship riders.

The Cat5 cabling for the autolauncher setup has continued to be put to use, and is now utilized for the major XBT transects, including AX07, AX08, AX10, and AX18. With the AX07 transect, it was learned that the laptops used could have an issue causing the USB ports to malfunction and have issues connecting with the MK21 used to interface with the XBTs. This was remedied by the inclusion of a cooling base for these computers. Recently, a representative from the Hapag-Lloyd Company, which has partnered with AOML by providing access to their ships in the AX07 transect, visited AOML to gain a more in-depth view of the XBT operations.

South Atlantic MOC Studies. Data from XBT transects have been used extensively in ocean analysis. More recently measurements from trans-basin XBT lines have been used to estimate the strength of the meridional overturning circulation (MOC) and the meridional heat transport (MHT). In particular in the South Atlantic where data coverage is sparse, studies using XBTs deployed along a zonal transect at nominally 35°S since 2002 (AX18) have significantly improved our understanding of the South Atlantic MOC and MHT. Recent study has shown that the geostrophic component of the circulation dominates the net MHT and that, at the seasonal time scale, the geostrophic and Ekman components of the circulation are out of phase. Further analysis of these data has shown that the variability of the MOC is similarly very weak on seasonal time scales. The MOC/MHT estimates from AX18 have also been used to evaluate numerical model performance in simulating the South Atlantic MOC for future model development.

Analysis of XBT and Argo data shows that the South Atlantic is responsible for a northward MHT with a mean value of 0.54 ± 0.14 PW, no significant trend is observed from 2002 to 2011. The MOC varies from 14.4 to 22.7 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. Statistical analysis suggests that an increase of 1 Sv in the MOC leads to an increase of the MHT of 0.04 ± 0.02 PW. Estimates of the salt advection from data collected from three different kinds of observations, contrary to those obtained from models, feature a positive salt advection feedback suggesting that freshwater perturbations will be amplified and that the MOC is bistable. In other words, the MOC might collapse with a large enough freshwater perturbation. Observations indicate that the mean value of the Brazil Current is -8.6 ± 4.1 Sv at 24°S and -19.4 ± 4.3 Sv at 35°S, increasing towards the south. East of 3°E, the northward flowing Benguela Current and Agulhas rings have a net northward transport of 22.5 ± 4.7 Sv. No significant correlation is observed between the MOC and the Brazil Current transport, and most of the compensation derives from the eastern boundary and interior transports (Garzoli et al., 2012). Since the publication of this manuscript, three more cruises were conducted. The mean of the four values obtained after the publication is 0.64 ± 0.12, which is indicative of a slight increase of the values.

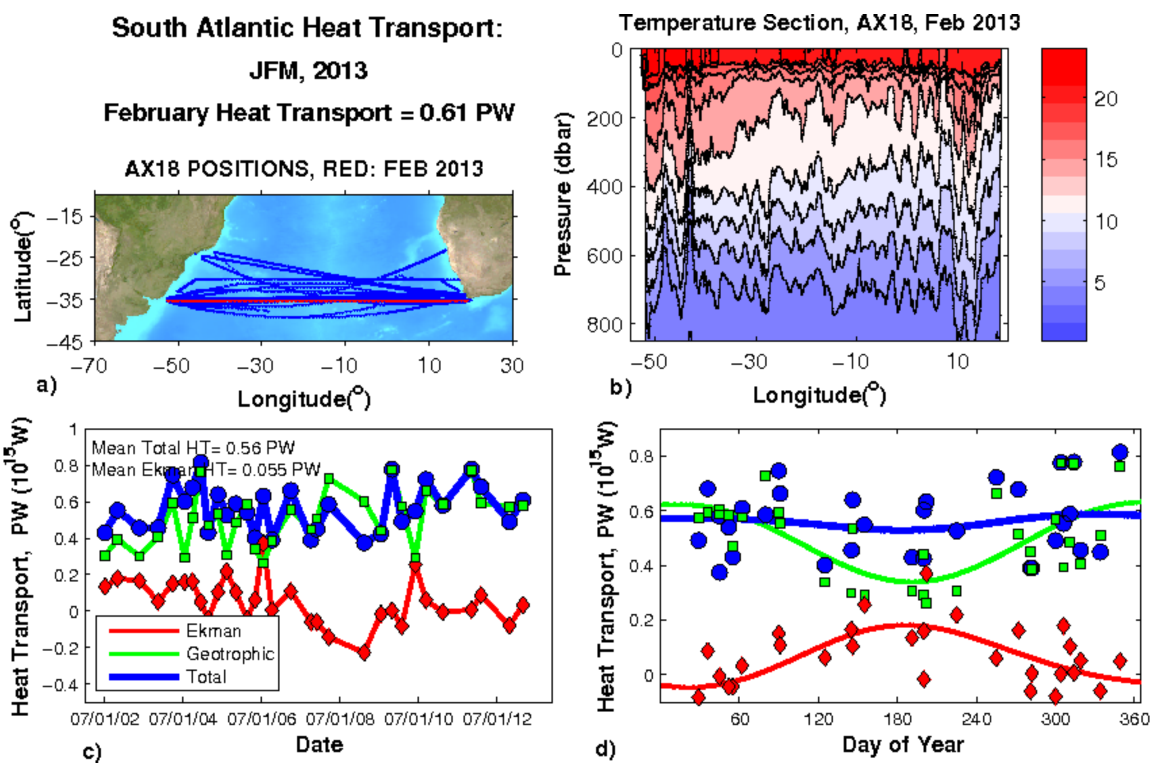

Figure 3: Meridional Heat transport at nominally 35°S computed from XBT data collected starting 2002. (Top left) Location of the repetitions of this transect; (Top right) Vertical temperature section from the last cruise (February 2013); (Bottom left) Time series of the different components of the meridional heat transport (Red: Ekman, Green: Geostrophic, and Blue: total); (Bottom right) Annual cycle of the different components.

North Atlantic MOC Studies. 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/*) 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.

Fall Rate Equation Studies. Since the XBT probe does not contain pressure sensors, its depth estimate relies on a semi-empirical quadratic relationship between time of descent and depth, known as the fall rate equation (FRE), which converts the time elapsed t (in seconds) since the probe hits the water to a depth Z (in meters). To improve the quality of XBT measurements, a prototype of a new Climate Quality (CQ) XBT probe is under development, which will include pressure switches to reduce depth biases, and improved thermistor calibration to reduce temperature errors. Goes et al., (2013) used simulated profiles to show that given the typical XBT depth biases, using just two pressure switches is a reliable strategy for reducing depth errors, and should be applied in the lower thermocline and deeper in the profile. At sea comparisons are underway and preliminary results show that XBT thermistor screening has potential to improve the temperature accuracy to an order of 10^{-2} ^{o}C.

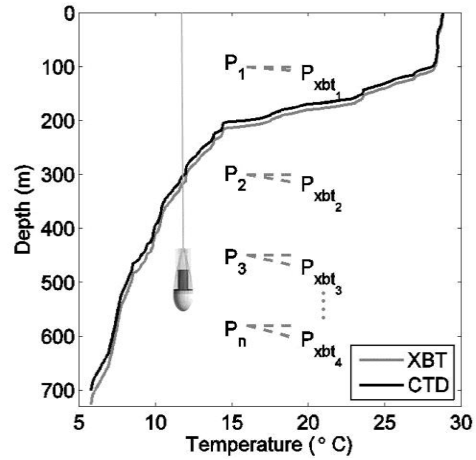

Figure 4: Schematic of the XBT depth correction with pressure switches. During the descent of the probe (probe not to scale), a temperature profile is produced. Pressure switches installed in the probe are triggered at various depths, and the recorded measurements P1, P2, Pn correct the profile to the CTD depth.

XBT Fall Rate Experiments. An experiment was conducted in July 2012 in our continued efforts to improve the fall rate equation of XBTs. This was stage 4 of the tests and was conducted at the Stennis Space Center in Mississippi. The experiment took place in an 11m deep tank inside of a 40m tall building. The tank was outfitted with cameras at 4 different depths to film the descent through the water column of XBTs dropped from different heights. The drop heights were 0m, 2.5m, 4m, 9m, 14m, 20m, and 25m, which cover the range of deployments for XBTs from small boats to the bridge wings of SOOP container ships. A ruled lined was also hung in the tank to provide reference distances for the cameras for the processing of the data. In all 250 drops were made for analysis back at AOML. Analyzing the drops involved many steps carried out by CIMAS employees. First, all the footage was digitized, separated, and cataloged based on the drop height. Next, the films were analyzed to see how many and which drops were present in most cameras. Once the individual drops were identified they were processed to determine the velocity and acceleration of the XBT by time, using special software to track the XBT in each video frame by frame. This raw data was then processed and the results used to make recommendations for future deployments and meta-data recording.

Thermosalinograph Operations. The Ship Of Opportunity Program currently maintains 4 thermosalinographs (TSGs) installed on merchant vessels. During the SOOP operational meeting of 2012, the following question has been posted: How much bias is introduced in the TSG data due to calibration? The concept is that changes in the calibration coefficients may introduce biases between measurements made before and after the calibration. Quantifying such quantity is of great relevance for the decision making process involved in the SOOP management. An investigation has addressed this question using data collected by the SBE45 Micro TSG for the period of 02/10/2011-04/21/2011 aboard the M/V Reykjafoss. The approach consisted of (1) determining the synthetic instrument output using a convergence numerical method on the geophysical functions of the instrument, (2) applying two consecutive set of calibration coefficients on the synthetic instrument output, and (3) evaluating the residuals introduced by the use of two sets of calibration coefficients. The residuals obtained were of the order of 10^{-3} ^{o}C (10^{-3} PSU) for temperature (salinity), which is a value smaller than the nominal accuracy of the instrument. Similar results have also been obtained for data collected by the instrument SBE21 Seacat aboard the M/V Oleander. As a conclusion, the current calibration practices adopted by the SOOP management are suited for maintaining the quality of the data collected.

Tropical Atlantic Dynamics. The upper-ocean zonal current system in the tropical Atlantic is of great importance for both interhemispheric and west-to-east exchange of heat, salt and nutrients. Monitoring these currents in a synoptic scale is challenging because they have relatively small spatial scales and high spatiotemporal variability. Goes et al., (2013) developed a synthetic method that is able to monitor the off-equatorial current system from daily to interannual timescales, by combining high-density XBT temperature data along the AX08 transect with altimetric sea level anomalies. The synthetic estimates show that an increased North Equatorial Countercurrent (NECC) transport is linked to a strengthening of the southeasterly trades (at a 2-week lag) and a positive meridional SST gradient pattern (i.e., warmer tropical North Atlantic and colder tropical South Atlantic) at zero lag. The North Equatorial Undercurrent (NEUC) transport is statistically related with SSTs and meridional winds in the Gulf of Guinea and zonal equatorial wind stress, similar to the negative index of the Atlantic meridional mode in interannual timescales. This study highlights the value of multiplatform observations for understanding how the ocean dynamics is liked to anomalies of SST and wind-stress in the tropical Atlantic, which are regulators of regional climate and weather variability.

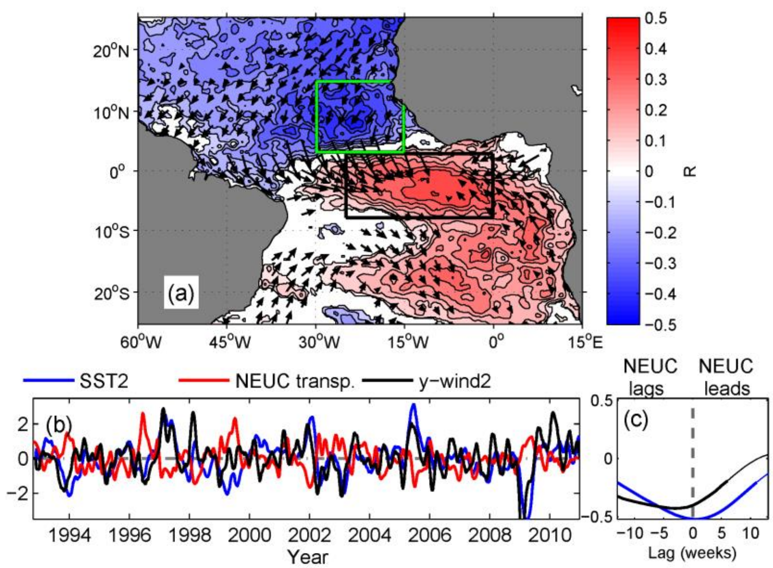

Figure 5: (a) Correlation between the NEUC transport and the SST and pseudo-wind stress in the Tropical Atlantic. The boxes are regions of high magnitude of correlation, where a SST index (SST2) and a meridional wind index (y-wind2) are taken (b). (c) Lagged correlation between the indices timeseries and the NEUC transport index.

Antarctic Circumpolar Current. The focus of this investigation is to study the role of local wind stress changes in forcing variations in the structure of the Antarctic Circumpolar Current (ACC). The main finding of this work is that changes in the structure and intensity of the Westerlies force an immediate and integrated response in the upper layer of the ACC, and in the transports by the Subantarctic Front and by the Antarctic Polar Front (APF). This response occurs as follows: during positive phases of the Southern Annular Mode, easterly anomalies develop between 35^{o}S-45^{o}S, forcing the poleward advection of warmer waters through anomalous Ekman transport, and changes in the dynamic height structure, which ultimately causes the decrease (increase) of the SAF (APF) geostrophic transport. The dynamical link between the wind stress changes and the dynamic height adjustments occurs as a combination of (i) thermosteric sea level rise due to warm anomalies in the Ekman layer, and of (ii) Ekman pumping driven sea level rise (Figure 1a). Therefore, the long-term variability of the sea height anomaly (Figure 1b) is largely due to the sea surface temperature variability (Figure 1c), and to the Ekman pumping (not shown). This mechanism may have implications for the Atlantic-Indian heat and mass exchanges. The manuscript entitled “Atmospherically forced variability of the Antarctic Circumpolar Current south of Africa between 1993-2010” is currently under review in the *Journal of Geophysical Research – Oceans*.

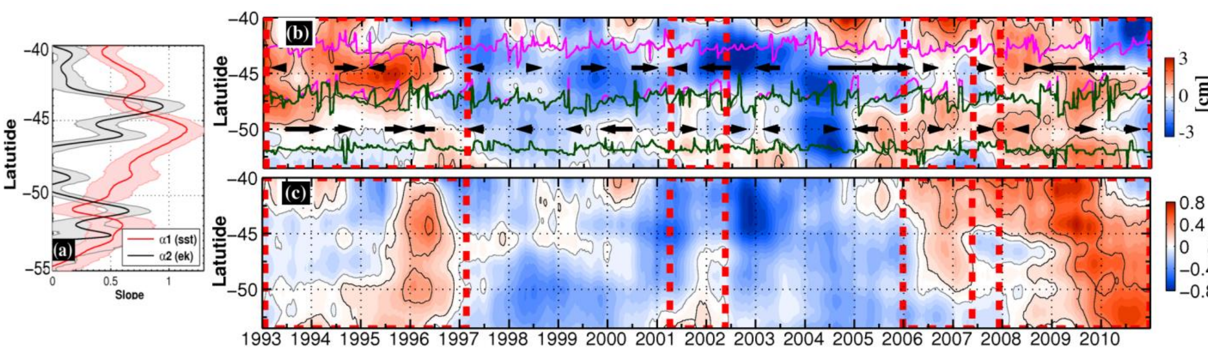

Figure 6: (a) Contribution of the thermosteric component (red line) and of the Ekman pumping component (black line) for the sea height anomaly variability as a function of latitude. (b) Observed sea height anomaly variability for time scales longer than the annual. Highlighted are the SAF (magenta lines) and APF (dark green) frontal domains, and the annual mean geostrophic velocity signal (arrows). (c) Sea surface temperature residuals (annual cycle removed) for time scales longer than the annual.

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.

Biogeochemical Measurements – Atlantic Ocean Acidification Test Bed: Cheeca Rocks

Project Personnel: C. Langdon (UM/RSMAS)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To: 1) Determine baselines rates of coral reef net community production and calcification and seawater carbonate chemistry against which future changes due to ocean acidification can be judged.

***Strategy*:** Visit a typical Florida Reef Tract inshore patch reef four times a year and make measurements of the rates of community primary production and calcification using an Eulerian and a boundary layer method.

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: CRCP **NOAA Technical Contact:** Alan Leonardi

Research Summary:

Analysis of the samples from 2012 has been completed. The data reveal that the rate of net community calcification (NCC) during the day ranges from 8.6±8.2 (n=9) mmol/m^2/h in Jan to 13.0±11.4 (n=7) in May and to 5.1±2.5 (n=17) in Sep. The aragonite saturation state of the overlying reef water is 3.48±0.03 (n=20) in January, rises to 4.00±0.03 (n=40) in May and declines to 3.43±0.03 (n=84) in September (confidence intervals for calcification and saturation state are standard errors). It is notable that the seasonal increase and decrease in calcification track the changes in carbonate chemistry of the seawater (Figure 1). The seasonal trends in saturation state are thought to be driven by changes in the balance between community primary production and respiration. During summer a positive net community production (NCP) draws dissolved inorganic carbon concentrations down relative to offshore water and in the winter and fall the opposite happens with net respiration adding CO_2 to the waters and elevating dissolved inorganic carbon of inshore waters relative to the ocean source water. This interaction between community primary production and reef calcification has been noted in several other systems. It will be interesting to see if the strong correlation between saturation state and patch reef calcification rate is observed again in succeeding years. We recognize that we are drastically under sampling the temporal variability of the processes and we are working hard at refining our methodology so that the measurements can be automated so that round the clock measurements will become possible.

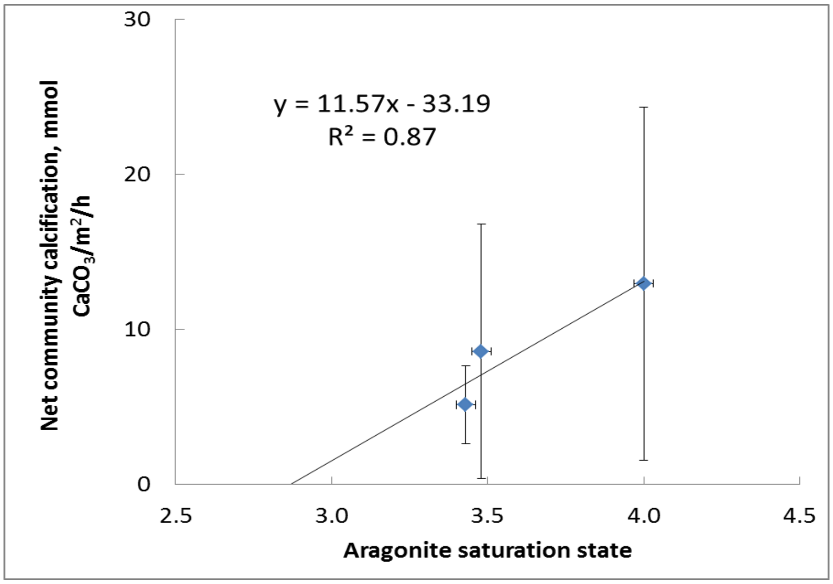

Figure 1: Correlation between winter, spring and fall rates if net community calcification rate at Cheeca Rocks and the aragonite saturation state of reef waters.

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

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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: E. Johns, C. Kelble, R. Smith, J.-Z. Zhang, L. Moore and C. Fischer (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives**:** To determine the circulation and water property patterns within Biscayne Bay, Florida Bay, and surrounding south Florida coastal waters on event to interannual time scales, and to quantify the variability in these parameters so as to provide a historical basis for distinguishing future changes that may occur as a result of the Comprehensive Everglades Restoration Plan (CERP).

Strategy**:** 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: OAR and NMAO
NOAA Technical Contact: Alan Leonardi

Research Summary:
The Comprehensive Everglades Restoration Plan (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 is 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 (FKNMS) 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 FKNMS. 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 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.

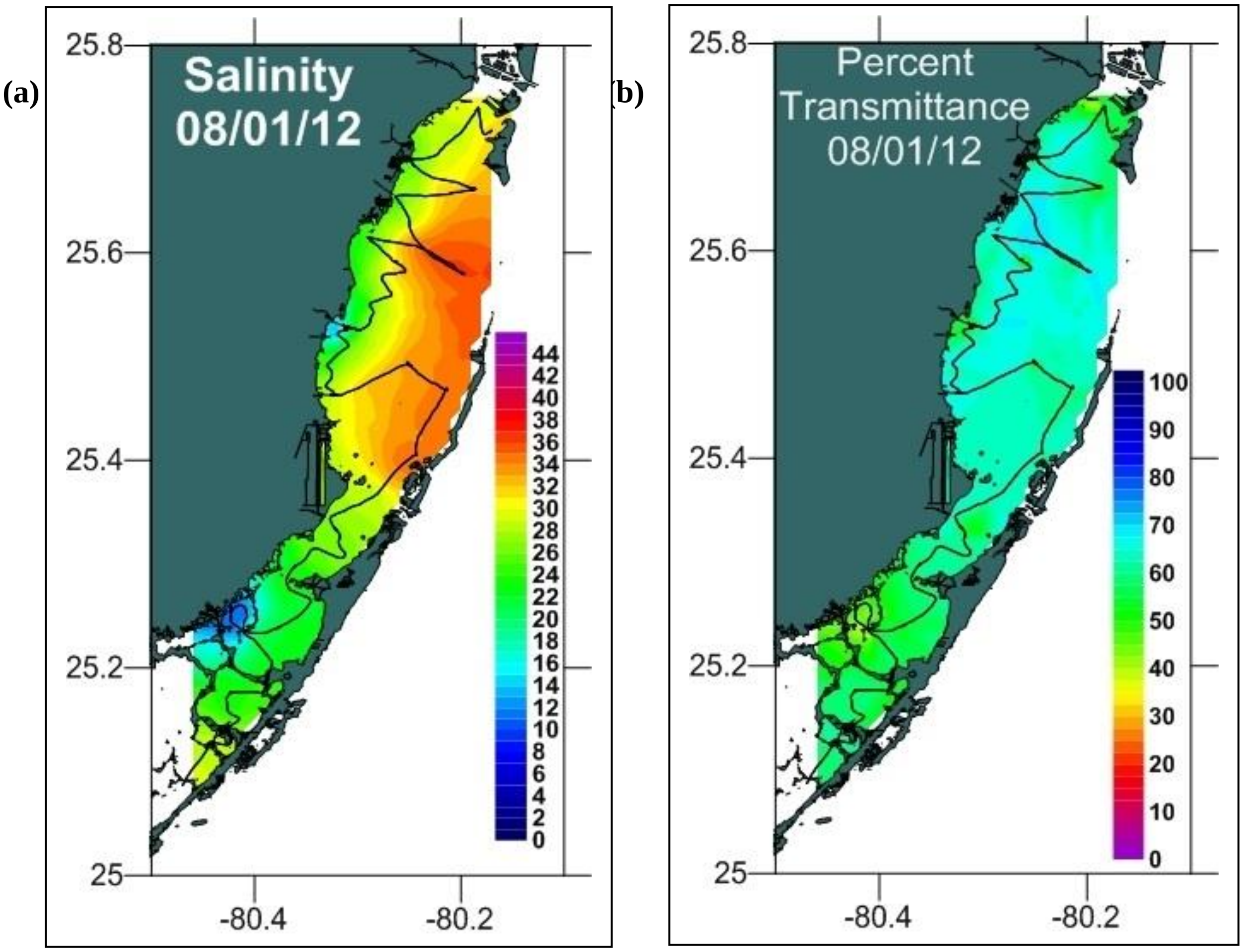

Figure 1: (a) Surface salinity and (b) % light transmission maps from data collected in Biscayne Bay on August 1, 2012 as part of the SFP. Note that the areas having the lowest surface salinity, located in the central western bay and in the southern estuaries in areas receiving direct fresh water inputs, are also areas of relatively lower light transmission. These maps and others (e.g. for Florida Bay and the surrounding coastal waters, and numerous other measured parameters) are posted on the SFP web site at www.aoml.noaa.gov/sfp.

Research Performance Measure: All major research objectives are being met on schedule. The emphasis during this report period (1 July 2012 – 30 June 2013) has been on data analysis, as the regular bimonthly SFP cruises were temporarily discontinued after the August 2012 surveys due to funding cuts. However, two new, intensive two-week studies of the optical characteristics of the middle Florida Keys coral reefs and seagrass beds were successfully completed during fall 2012 and spring 2013. 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.

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 (NOAA/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^{o}C), 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 Geo-Polar with observations from various in-situ platforms. This North Atlantic OHC product suite has been transitioned to NOAA NESDIS for 24/7 operations. The North Pacific OHC product suite is just being finalized for transitioning this fall.

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:** 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 2.1 and WOA 2001 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 included 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 improved the predictive ocean models by reducing the biases by about 50% and RMS errors by ~30% compared to the same model that assimilated altimetry only (Shay et al., 2011). Altimeter-derived sea 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 *et al.*, 2013). Results from SPORTS are also quite encouraging that includes detailed comparisons to the TOGA TAO mooring array in the equatorial Pacific Ocean.

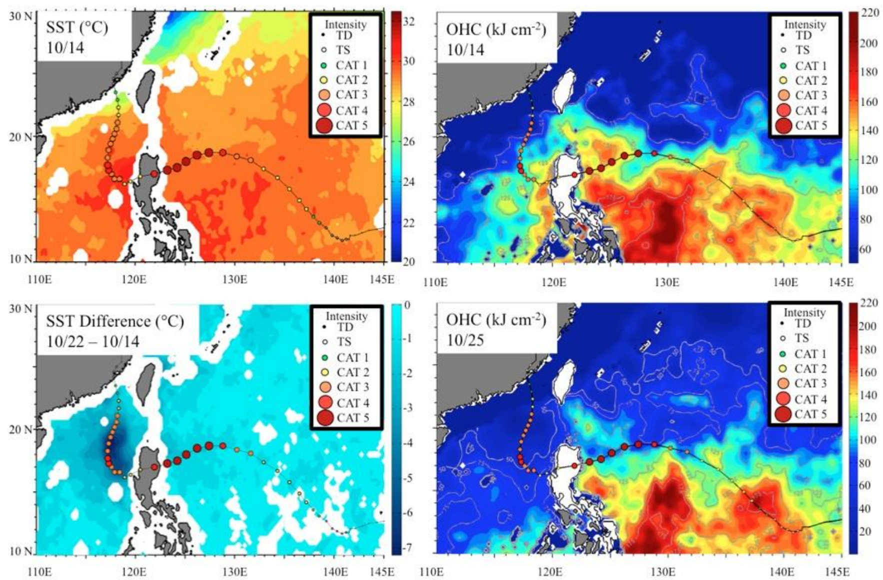

Figure 1: Upper variability during Super Typhoon Megi in October of 2010 in the western Pacific Ocean. The upper left image shows the pre-storm sea surface temperatures (SST) from 14 Oct, when Megi became classified as a tropical storm at about 140^{o}E. The lower left image show the SST cooling after Megi by subtracting the pre-storm SSTs from the post-storm SSTs, on 22 Oct, the day Megi made landfall in China. This image shows 1 to 2°C cooling in the Philippine Sea and 6 to 7°C cooling in the South China Sea. The upper right image shows the pre-storm ocean heat content (OHC) on 14 Oct, calculated from the SPORTS climatology. The lower right image shows the post-storm OHC from 25 Oct, also calculated for the SPORTS climatology.

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 is operational at NESDIS. We have utilized a similar approach in the North Pacific Basin by developing SPORTS except that over 267,000 thermal profiles were entrained into the analysis to assess the satellite-based products. When the US/Taiwan ITOP experimental data becomes available, we will to examine the details of the oceanic response in the western Pacific to a few typhoons including Super Typhoon Megi in 2010 (see Figure).

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

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

Long Term Research Objectives and Strategy to Achieve Them:

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

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

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

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

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

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

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

To assess the impact of aircraft measurements on the HYCOM analyses, two reanalyses were performed in hindcast mode. The first reanalysis (P3_GoM_HYCOM) assimilated all observations including the aircraft surveys. The second (GoM_HYCOM) is identical except for denying the P-3 observations. The reduction in bias and RMS error on each of the flight days resulting from assimilation of the aircraft observations is illustrated by comparing temperature between 30 and 360 m for experiments P3-GoM-HYCOM and GoM-HYCOM. The reduction in temperature bias is about 50% on average while the reduction of RMS error is 25 to 30% on average, demonstrating a significant and positive impact of aircraft data assimilation. Note that error reduction is not uniform across the detaching Eddy Franklin. The reduction in temperature error reaches 50% in the central region of the eddy and also along Franklin's eastern boundary. This correction reduces errors in the subsurface density distribution along with errors in the upper-ocean currents associated with this density distribution. Similarly, assimilation of the data improved the representation of depth of the 20^{o}C isotherm in P3-GoM-HYCOM between 28% and 34%, compared to GoM-HYCOM. S*ynoptic measurements from the multiple aircraft flights (of 9-hour duration) improved the fidelity of the model in simulating more realistic ocean fields and are being used in Ocean Observing Simulation Experiments with high degree of success.*

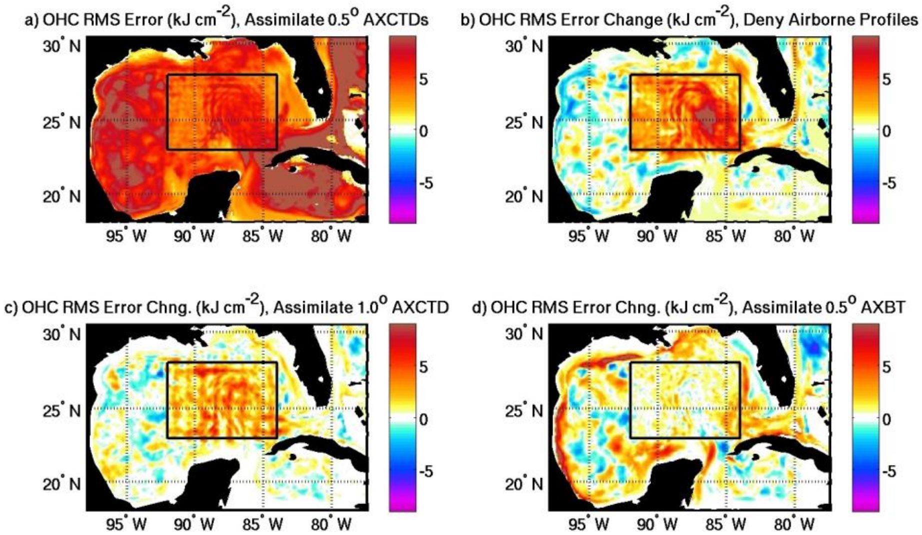

Figure 1: Images of RMS error in OHC over the time interval May through October 2010 between four OSSE experiments and the nature run. Panel (a) is from the control OSSE experiment where all synthetic observations sampled from the nature run including high-resolution, 1000 m AXCTD surveys were assimilated into a different ocean model (a different configuration of HYCOM from that used to generate the nature run). Panel (b) shows the change in RMS error that occurs when the AXCTD observations are denied, revealing substantial error increase in the box covered by the airborne surveys. Panel (c) shows the change if the AXCTDs are sampled at one-half the resolution, also revealing substantial error increase in the survey domain. Panel (d) shows the change resulting from assimilating high-resolution 400 m AXBTs instead of deeper AXCTDs, revealing little error change in the survey domain because temperature is assimilated over the depth range used to calculate OHC.

Research Performance Measure: A further consequence of this project is the direct collaboration with the CIMAS OSSE project entitled "OSSE Evaluation of Targeted Airborne Ocean Observing Strategies in the Gulf of Mexico". The airborne surveys performed for the DWH oil spill were used to evaluate the performance of a new ocean OSSE (Observing System Simulation Experiment) system, determining that the system was capable of providing realistic observing system impact assessments (See Figure). Collaboration with the OSSE project is ongoing to evaluate the impact of alternate airborne observing strategies on improving the ocean analysis products used to initialize forecast models.

PIRATA Northeast Extension (PNE)

Project Personnel: R.C. Perez, V. Hormann, G. Rawson, Z. Barton (UM/CIMAS)
NOAA Collaborators: R. Lumpkin, G.R. Foltz, C.S. Meinen, and C. Schmid (NOAA/AOML); S. Kunze (NOAA/PMEL)
Other Collaborators: D. Amaya (Texas A&M University); W. Higley (UW/JISAO)

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 that collect oceanic and atmospheric data and transmit it, 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/AOMLs contribution to PIRATA is to organize and conduct annual cruises to service moorings of the PIRATA Northeast Extension (PNE; Figure 1), and collect a suite of oceanographic and meteorological observations in the region. PNE is a joint AOML/PMEL 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.

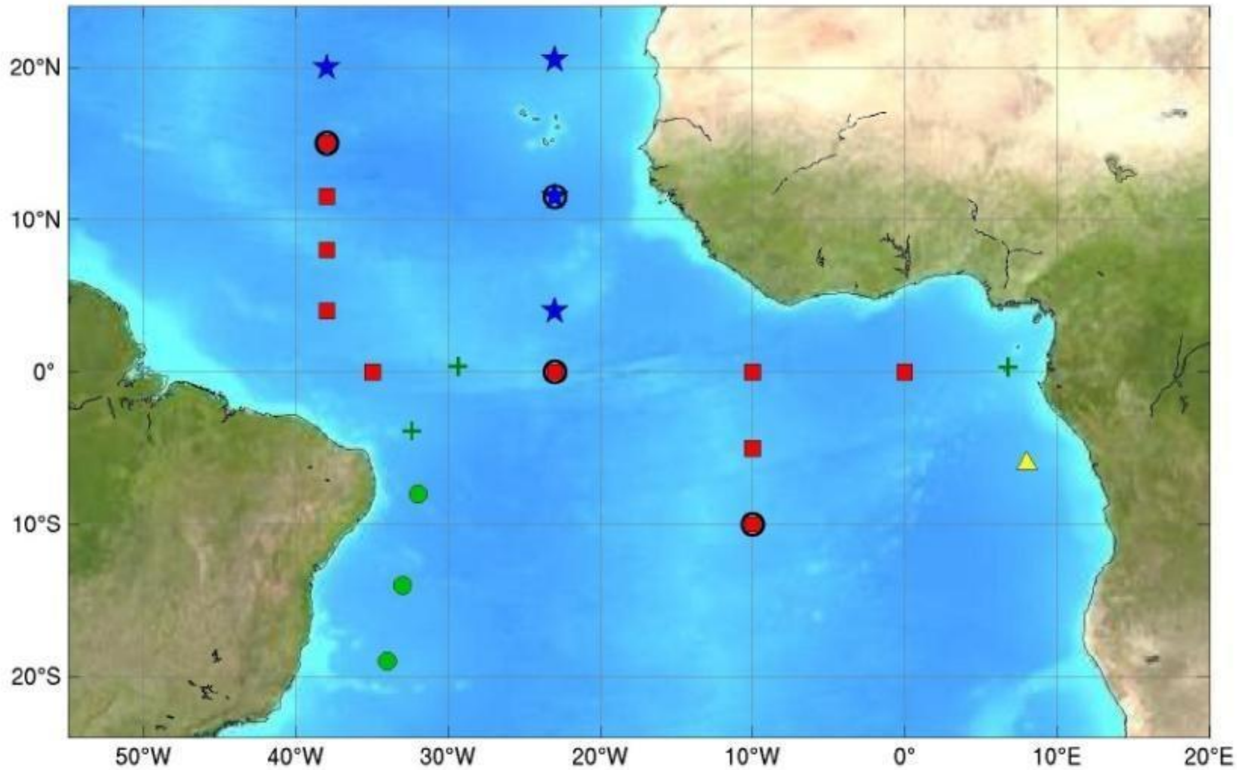

Figure 1: The PIRATA array, showing the backbone of buoys (red squares), the Northeast Extension (blue stars) led by the United States (NOAA), the Southwest Extension (green circles) led by Brazil, the Southeast Extension pilot site (yellow triangle), and island-based observation sites (green crosses).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

The PNE 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.

In January-February 2013, the PNE servicing cruise was conducted aboard the NOAA ship Ronald H. Brown on a cruise from Charleston, SC to San Juan, Puerto Rico (Figure 2). The chief scientist was Claudia Schmid (NOAA/AOML), the co-chief scientist was Gregory Foltz (NOAA/AOML) and Grant Rawson and Zach Barton were the CIMAS personnel in attendance. The cruise served to recover and redeploy all four of the PNE moorings and recover two and deploy three hydrophone 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 four floats, and (2) the collection of eXpendable BathyThermograph (XBT) and underway CTD measurements along the track line for cross-validation purposes.

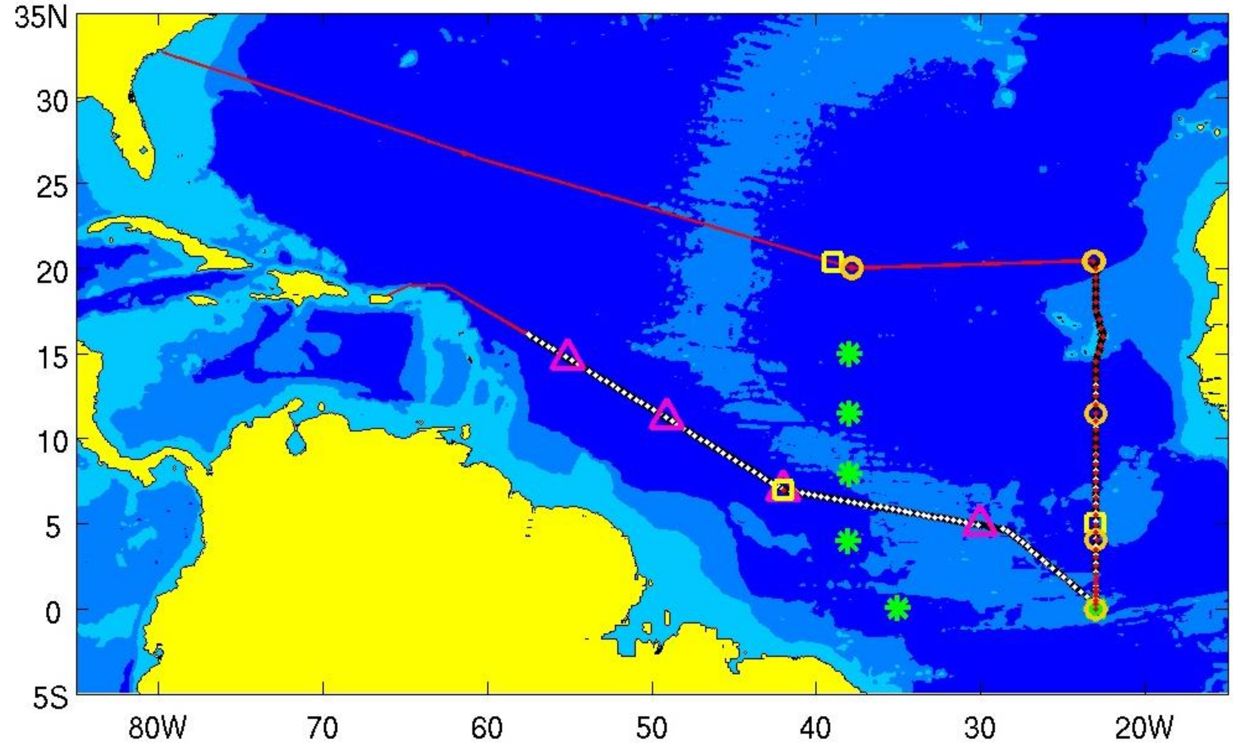

Figure 2: Map showing the cruise track of the PNE cruise in January-February 2013 aboard the NOAA ship Ronald H. Brown (red line), with PNE recovery and deployment sites (circles), CTD stations (red dots), XBT profiles (black dots), UCTD profiles (white dots), hydrophone mooring sites (squares), Argo deployment locations (triangles), and PIRATA Southwest Extension sites (stars).

Research Performance Measure: All major objectives are being met. Four PNE-related papers have been published or are in press this year in the Journal of Geophysical Research, Journal of Climate, and Journal of Atmospheric and Oceanic Technology.

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Remote Sensing in Support of Climate Research

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

Long Term Research Objectives & 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, ASCAT, etc).

The HRPT/MetOp system consists of two main units: (a) one ingest workstation connected to (b) two satellite ingest units. The first (second) unit receives and digitizes the HRPT telemetry from the NOAA (MetOp) satellites. The real-time downlink signal includes data from a variety of sensors, providing multispectral atmospheric soundings, total atmospheric ozone levels, precipitable water, surface temperatures, etc. The HRPT data stream also contains data from the Argos Data Collection System (DCS), which is operated by CNES and NOAA through a cooperative agreement, and gathers environmental data from more than 21,000 fixed and moving platforms. All Argos data are sent to the Argos Data Processing and Distribution Centers in the U.S. and France.

During last year, the satellite receiving station at NOAA/AOML was upgraded to receive telemetry from the SARAL (Satellite with Argos and AltiKa) satellite, which was launched in February 2013. This upgrade (Figure 1) allows the station to improve the reception of data from *in situ* data collection platforms, such as drifters and marine mammals equipped with Argos transmitters. The main objective of this upgrade is to provide data operationally from the Argos DCS-3 sensor aboard SARAL, which collects multipurpose data from a large number of fixed and mobile platforms, such as meteorological and upper ocean measurements from drifters, observations from remote weather stations and vertical temperature/salinity sections from Argo profilers. Argos DCS-3 improves the performance of the Argos satellite system by providing 2-way communications and allowing platform remote control and programming.

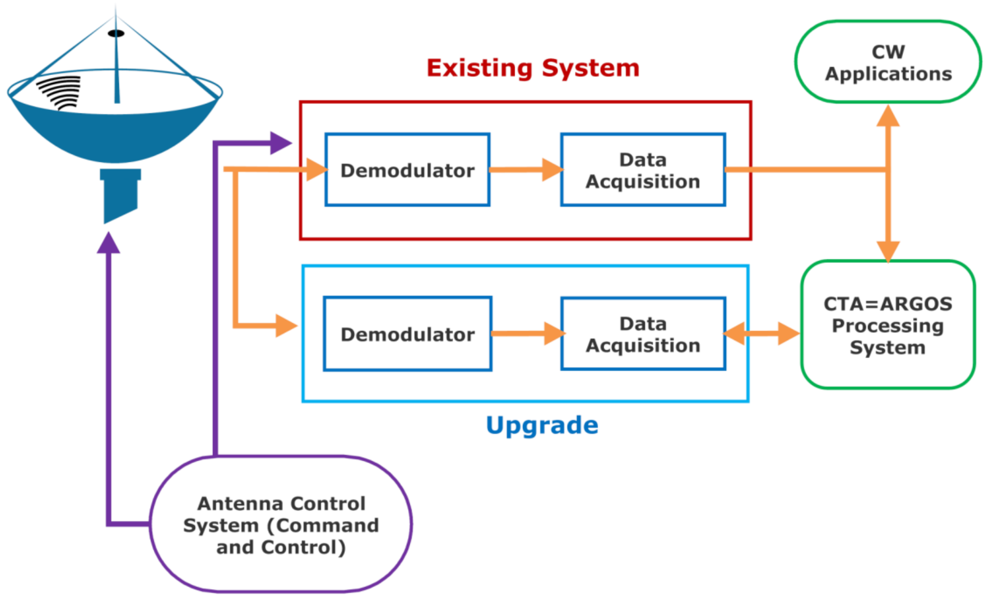


Figure 1: Scheme showing the various components of the upgraded L-band receiving station for SARAL acquisition and processing.

This upgrade is a testbed to evaluate the implementation and compatibility of the new hardware with current infrastructure. Results will determine the future upgrade of other NOAA stations in Monterey and Hawaii.

During this period we have submitted a proposal to upgrade the satellite ground station at NOAA/AOML. Through the successful achievement of the proposal, the station will be able to receive and process X-band satellite telemetry for internal and external rapid distribution from a number of sensors, including CrIS (Cross-track Infrared Sounder), ATMS (Advanced Technology Microwave Sounder) and VIIRS (Visible Infrared Imager Radiometer Suite), onboard NPP (NPOESS Preparatory Project) and the upcoming first JPSS (Joint Polar Satellite System) satellite. The proposal provides a general view of the upgrading procedures and system maintenance, as well as an itemized budget, which illustrates the minimal financial commitments to successfully materialize the upgrade.

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 (e.g. http://cwcgom.aoml.noaa.gov/thredds/catalog.html, http://cwcgom.aoml.noaa.gov/erddap/info/index.html). 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. During the past year, several advances have been made towards incorporating dynamic visualization capabilities for the suite of products currently being generated (Figure 2). Versions for Android (actually in beta stage) and IOS are being created to allow accessing all these datasets from mobile devices (Figure 3).

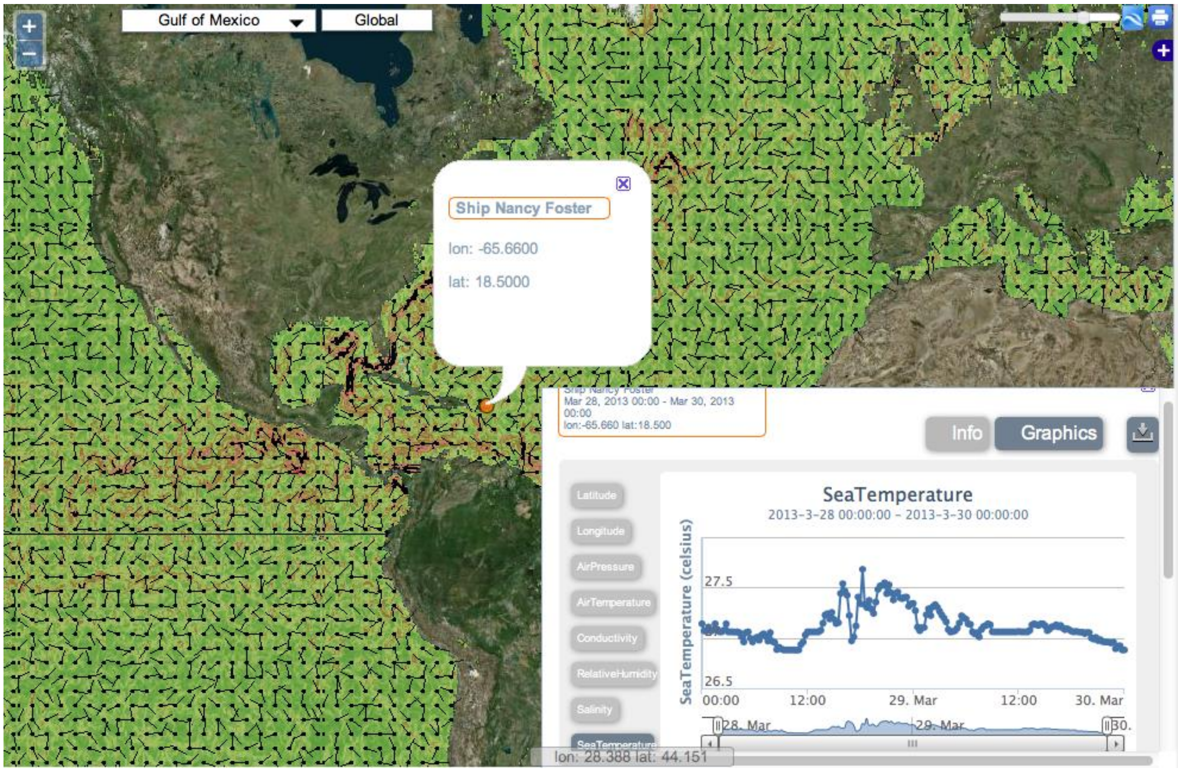


Figure 2: Dynamic interface based on OpenLayers to visualize remote sensing and *in situ* products being distributed through Web Services.

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

During this year, the implementation of frontal SST products has been finally completed. The Vibrio risk product is being tested in collaboration with ECDC and will probably be operationally implemented in the near future.

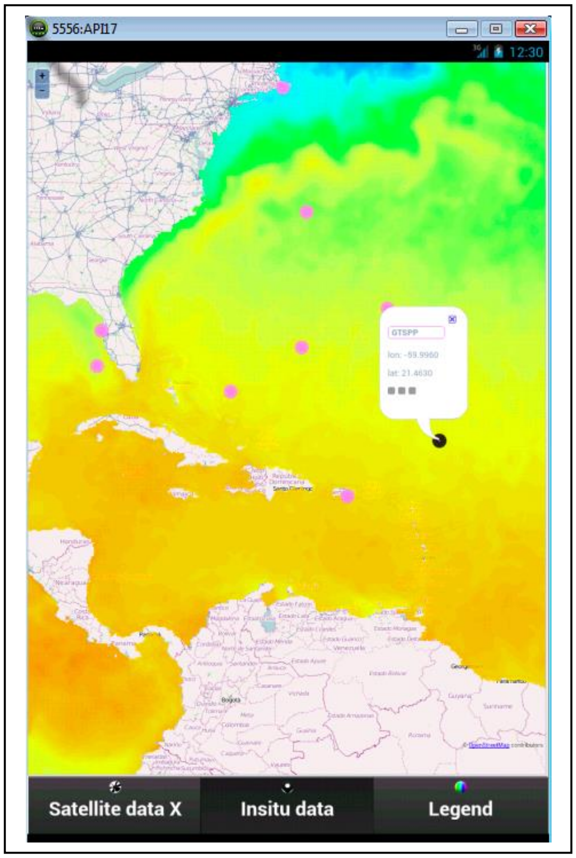


Figure 3: Example of map displayed in Android application. These developments will allow better access to our products from mobile devices.

During this last year, the following datasets in CF compliant NetCDF format have been provided for the Deepwater Horizon Natural Resource Damage Assessment:

1. Altimetry
   a) Daily sea height anomaly
   b) dynamic height
   c) zonal and meridional geostrophic velocities
   d) geostrophic current gradients which were obtained using the Sobel operator.

Resolution: 1/10th of degree.

2. Sea Surface temperature
   a) Daily Optimum Interpolated SST fields. Resolution: 1/4th of degree
   b) SST fields from Metop-A, N-15, N-17, N- 18 and N-19 individual passes obtained from the satellite receiving station at NOAA/AOML. Resolution: 1.4 km.

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. New tools have been developed for visualization and data access. These solutions have been integrated within a SOA framework.

Surface Water pCO_2 Measurements from Ships

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

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/CPO/COD
NOAA Technical Contact: Joel Levy

Research Summary:
The ship-based surface pCO_2 program is designed to provide sustained measurements of regional oceanic carbon sources and sinks on seasonal timescale by measuring surface water and marine boundary pCO_2 on ships of opportunity. It is a collaboration of investigators at the NOAA laboratories AOML and PMEL; and the following academic institutions: Columbia University, the University of Miami, and the Bermuda Institute of Ocean Sciences. 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-13 the NOAA funded participants maintained instrumentation and reduced the data from seven ships and posted the data. Figure 1 shows the tracks of those seven ships for the current period. 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.
(http://cwcgom.aoml.noaa.gov/erddap/griddap/aomlcarbonfluxes.graph)

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 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 2 containing over 10 million pCO_2 data points, has been released in June 2013 during the ICDC-9 meeting in China. Our NOAA funded effort is the single largest contributor of data to SOCAT (Figure 2).

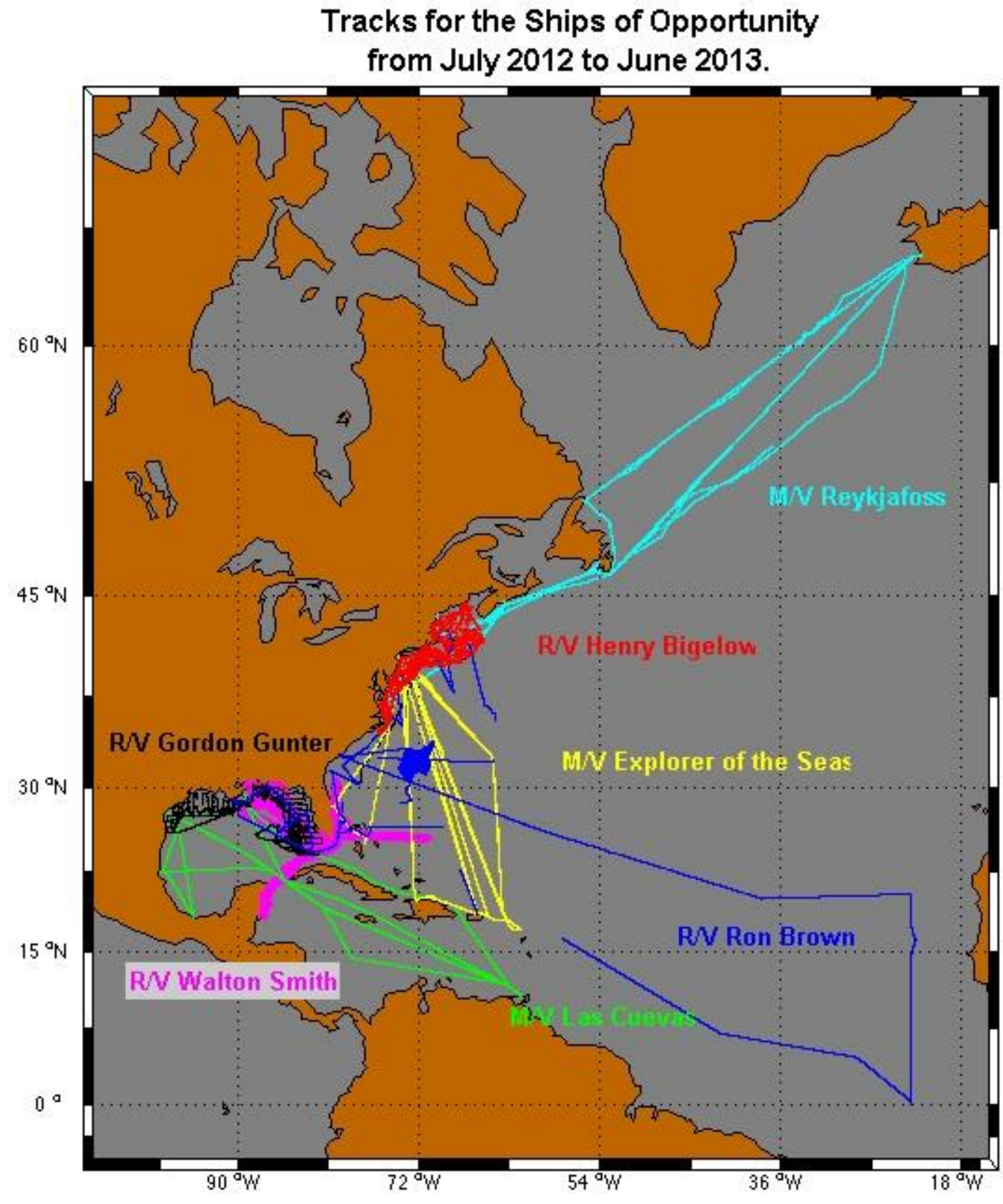


Figure 1: Tracks of the ships equipped with a pCO_2 system for the current period.

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 ships BARCELONA EXPRESS and REYKJAFOSS are transmitting TSG data. All of the seven ships send complete daily files of pCO_2 to shore via internet. We recently augmented our suite of sensors to include Oxygen on the NOAA ships BIGELOW and BROWN and container ship REYKJAFOSS. The BIGELOW has a SUNA Nitrate sensor as well.

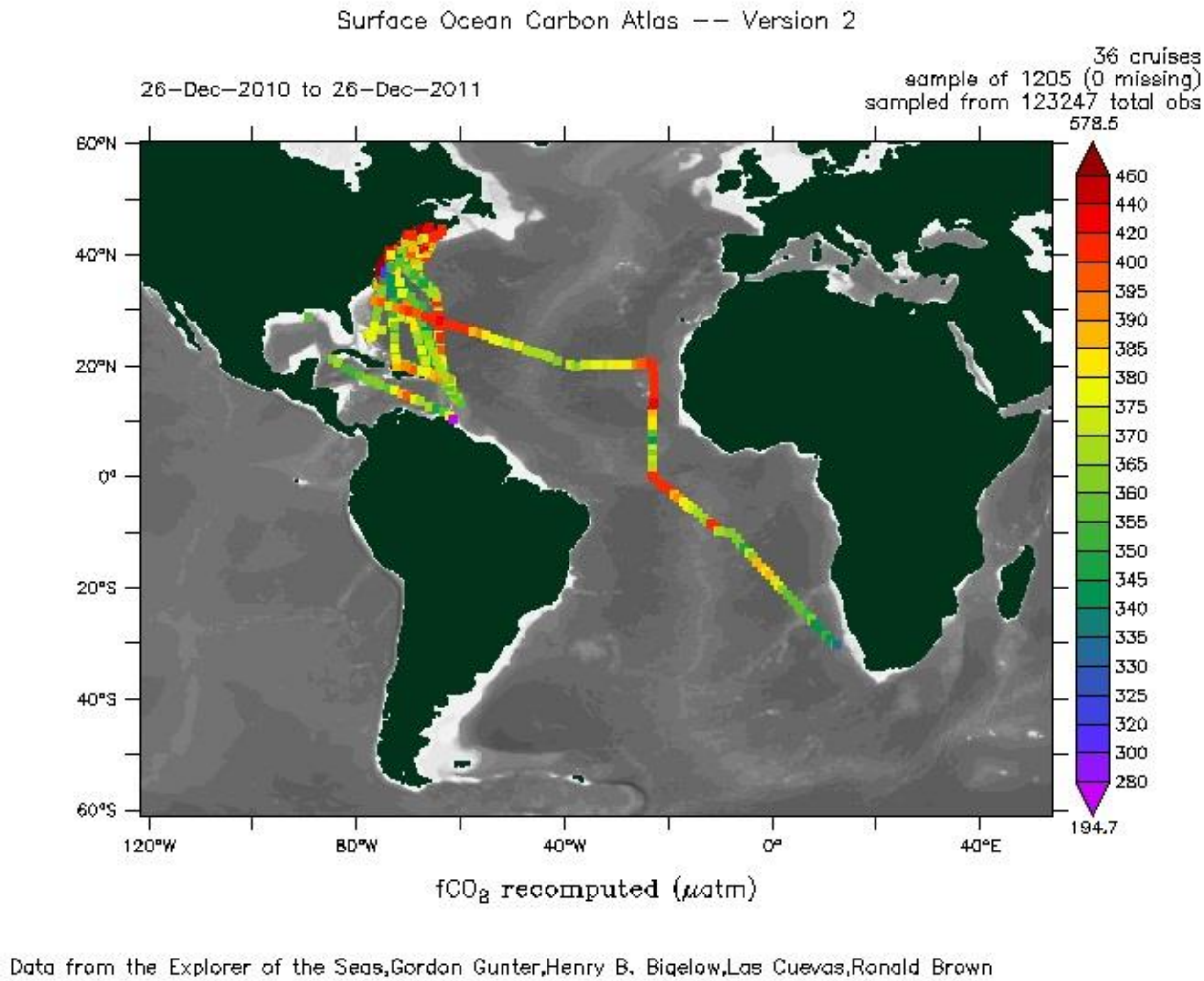


Figure 2: Data coverage provided to the science community in 2011 by 5 of the ships outfitted with a pCO_2 system.

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

The GO-SHIP CO_2 Repeat Hydrography Program

Project Personnel: K. Sullivan, L. Barbero, G. Berberian, J. Hooper, 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 physics and biogeochemistry in the ocean interior and to constrain ocean CO_2 inventories to 2 Pg C/ decade.
***Strategy*:** To reoccupy transects on a decadal timescale to observe changes in the ocean and 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: CPO/COD **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 in 2012 the first repeat of the Atlantic, Pacific and Indian Ocean transects was completed.

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-2013 we completed meridional sections off the East Coast of the USA Called A20 and A22 with full physical and chemical characterization of over 160 water column profiles. We completed data reduction and quality control of the zonal line in the Southern Atlantic (A10). CIMAS project personnel and NOAA collaborators were responsible for cruise leadership, CTD, ADCP, O_2, nutrient, and inorganic carbon measurements.

A cross section of inorganic carbon (DIC) from the A10 cruise (Oct 2011) is cruise is provided in figure1a while figure 1b shows the results obtained in November 2003. The bottom panel shows the difference over the 8 years. The invasion of anthropogenic CO_2 in the top 500 m is apparent. The deep penetration at the zero meridian and 35 ˚W correspond to large eddie features. The strong decrease at depth in the Eastern basin appears to be caused by changes in positions of fronts over time separating Northern waters with low DIC from Southern waters with high DIC.

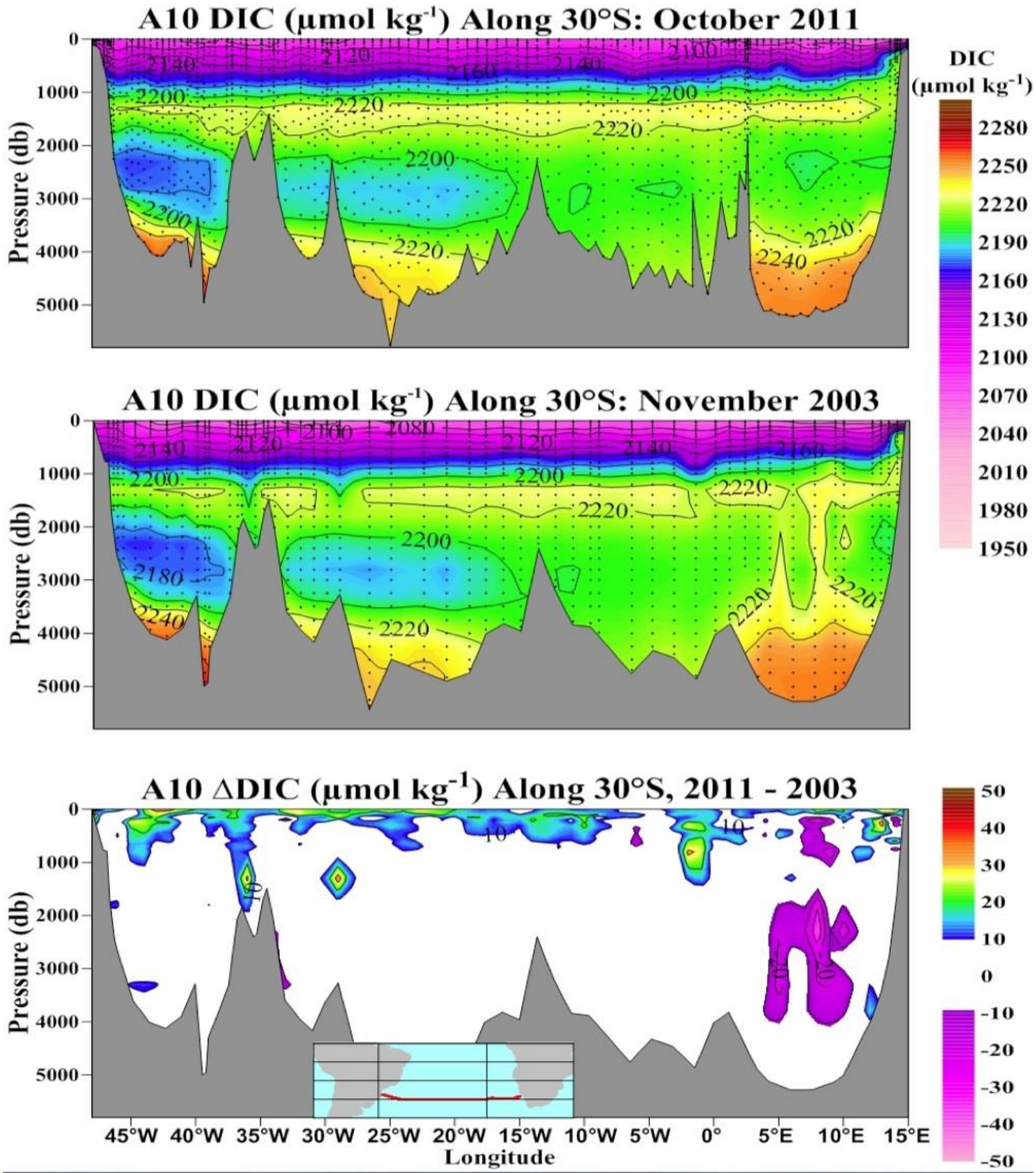


Figure 1: Cross section of dissolved inorganic carbon (DIC) for the A10 cruise in 2011 (top), the occupation in 2003 (middle), and the difference bottom. Graphics produced by D. Greeley of PMEL.

Research Performance Measure: The Repeat Hydrography Sections are progressing according to timeline of the CLIVAR CO2 Repeat Hydrography Committee (http://ushydro.ucsd.edu/cruises). The performance measure for FY 13 of completing the re-occupation of the A16N cruise is on track. The performance measure has been augmented in that we are actively interacting with modelers at Princeton, GFDL and WHOI, in part under auspices of the Regional Carbon analysis project (RECCAP), to compare our observed decadal changes with model trends.

Marine Optical Buoy (MOBY) Operations and Technology Refresh

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 processed data is 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 the 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.

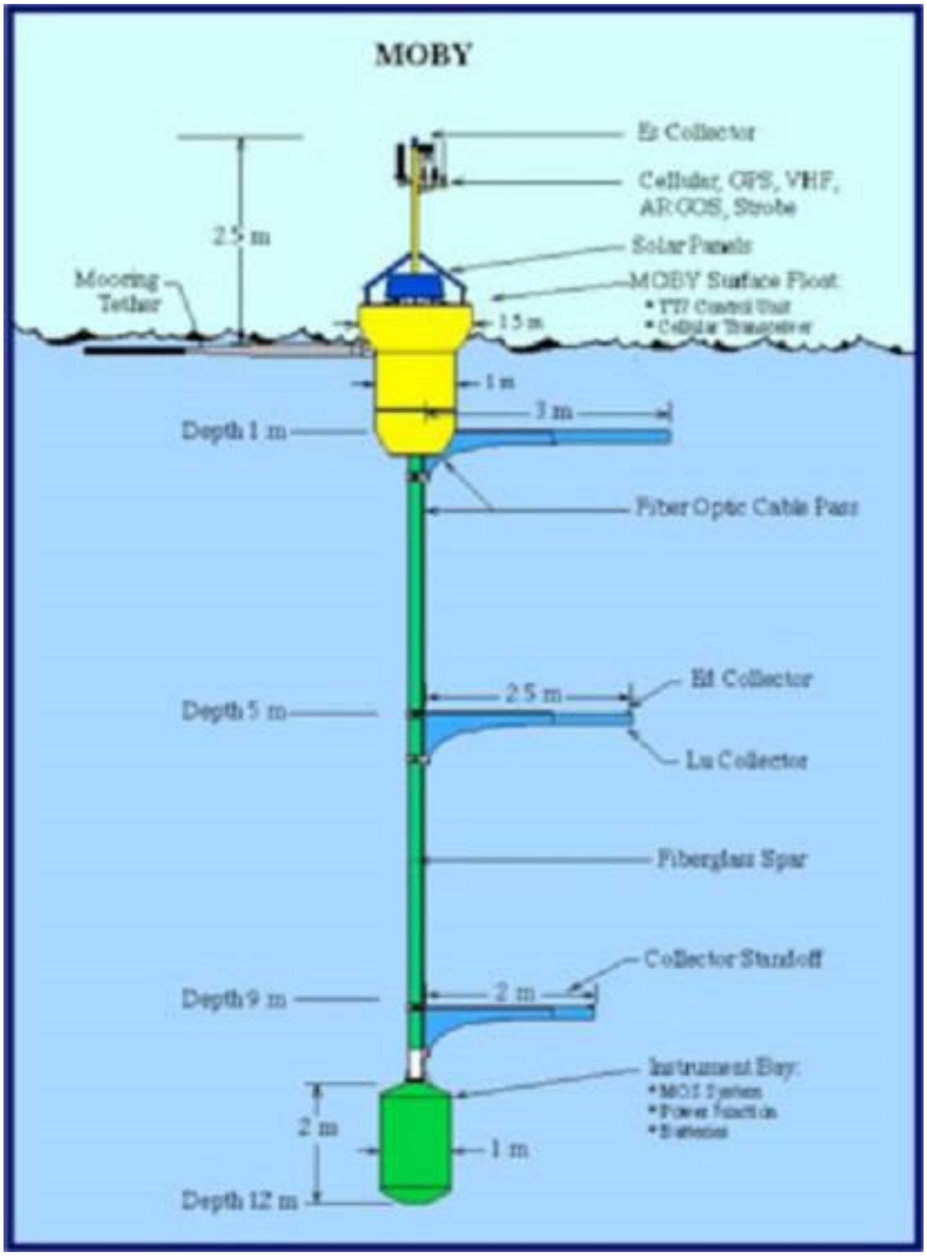


Figure 1: Schematic of the MOBY buoy currently operated off of Lanai, Hawaii, and the central focus of our work. The buoy collects hyperspectral (1 nm resolution) upwelling radiance at 3 different depths, and downwelling irradiance above the water and at 3 different depths below the surface. This data 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.

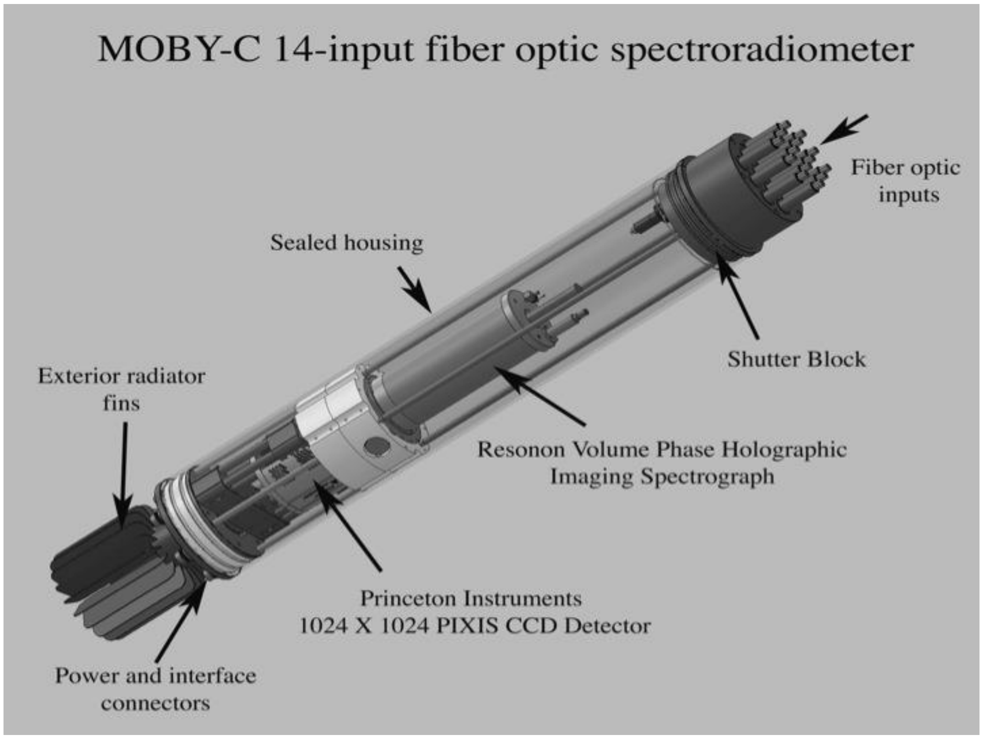


Figure 2: This is the current design of the spectrometer that will be used in the new MOBY system. The central feature is the Resonon Volume Phase Holographic Imaging spectrometer, which allows multiple channels (depths/sensors) to be spectrally measured simultaneously. This will allow all of the irradiance 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 MOBY time series of upwelling radiance (Lu) at the ocean color sensor SeaWiFS band at 490 nm from the most recent deployment is shown, along with the time series since 1997. This deployment, M252, began in March 2013 (data shown as dots on the figure). The time series is shown as the black line with +- 1 standard deviation shown in Gray. I am showing the SeaWiFS band rather than a VIIRS band, as we have a longer calculated time series for SeaWiFS than for the recently launched VIIRS. The overall annual variation is due to the seasonal variation of surface solar irradiance. 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 4 shows the MOBY data being used in action (courtesy of Menghua Wang, NOAA/NESDIS) for vicarious calibration of the VIIRS ocean color satellite. This example shows both VIIRS derived nLw's and Chlorophyll-a, and nLw's and Chlorophyll-a derived from the MOBY data. The data before February 6, 2012 were processed at NOAA using a bad pre-launch calibration file. The data after the second vertical line has had vicarious calibration gain factors obtained using MOBY applied to the data set. The improved accuracy with these gain factors (in agreement with the MOBY data set) is obvious in this figure.

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.

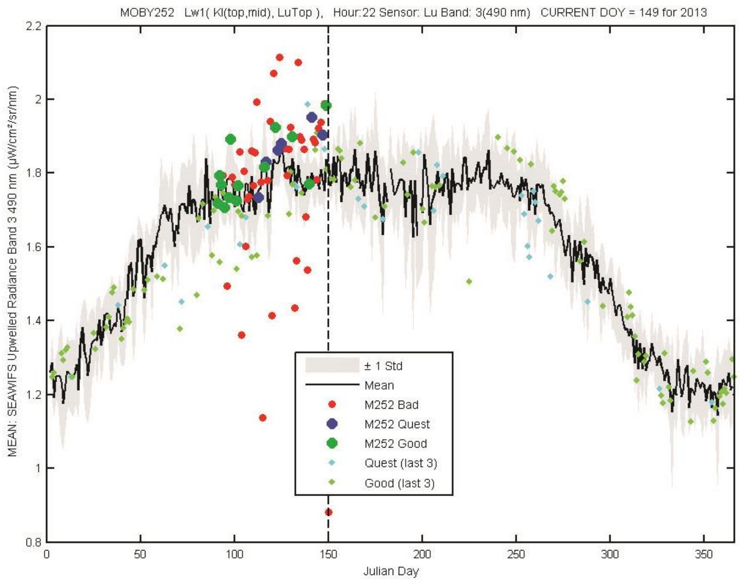


Figure 3: The MOBY time series of upwelling radiance (Lu) at the ocean color sensor SeaWiFS band at 490 nm from the most recent deployment, along with the time series since 1997. The data points are explained in the text, but this deployment, M252, began in March 2013 (data shown as dots on the figure). The time series is shown as the black line with +- 1 standard deviation shown in gray. I am showing a band calculated for SeaWiFS rather than VIIRS as we have a longer calculated time series for SeaWiFS than for the recently launched VIIRS.

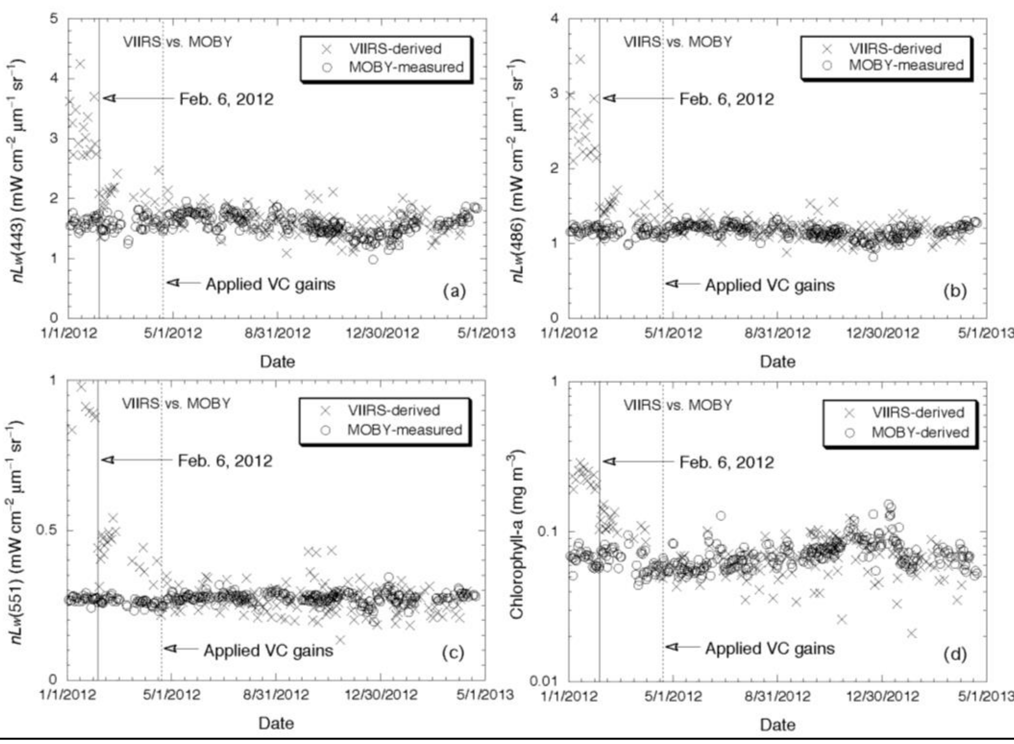


Figure 4: An illustration of the MOBY data being used for vicarious calibration of the VIIRS ocean color satellite. This example shows both VIIRS derived nLw's and Chlorophyll-a, and those derived from the MOBY data. The data before February 6, 2012 was processed at NOAA using a bad calibration file. The data after the second vertical line has had vicarious calibration gain factors obtained using MOBY applied to the data set. The improved accuracy with these gain factors (in agreement with the MOBY data set) is obvious in this figure. This figure is courtesy of Dr. Menghua Wang, NOAA/NESDIS.

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

Project Personnel: K. Sullivan, D. Pierrot and L. Barbero (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 ocean acidification-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 (*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: OAP/OAR **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 Federal Ocean Acidification Research and Monitoring (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.

During the performance period we performed a major oceanographic research cruise studying OA in the Gulf of Mexico, GOMECC2. This is the second comprehensive cruise studying OA with the first occurring in 2007. The comprehensive determination of inorganic carbon system parameters provides input to determine the aragonite saturation state in the realm that is a key indicator of ocean acidification (Figure 1).

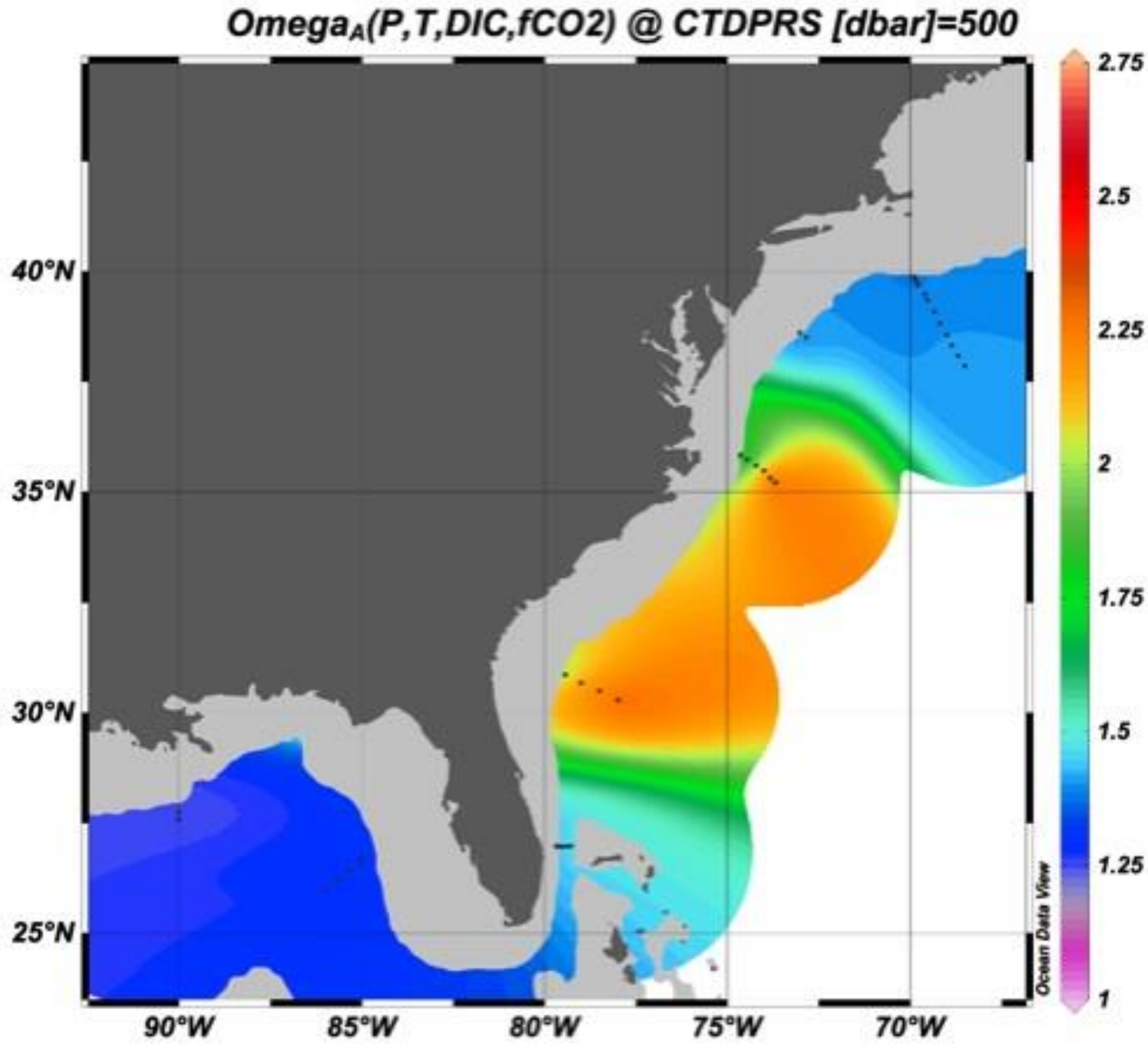


Figure 1: Aragonite saturation state at 500-m extrapolated with a simple contouring program in Ocean Data View determined from the GOMECC-2 cruise. The values and sharp gradations removed from the station locations (solid dots) should be interpreted with caution. Note, the very low saturation state at depth in the Gulf of Mexico.

As part of the OA effort we are establishing a monthly climatology of surface water ocean acidification parameters in coordination with other participants of the North American Carbon Program and the Ocean Carbon and Biogeochemistry Program. This is possible by the large increase of observational data that has been obtained from the ship of opportunity programs run by our group (Figure 2).

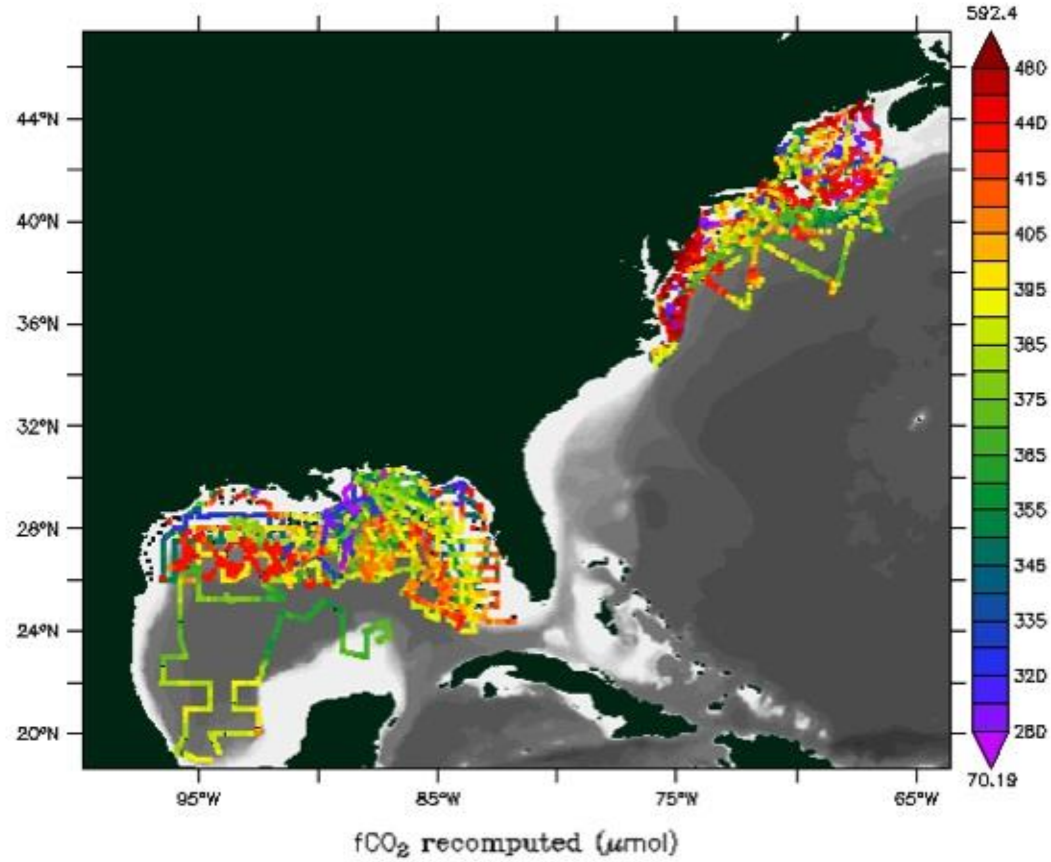
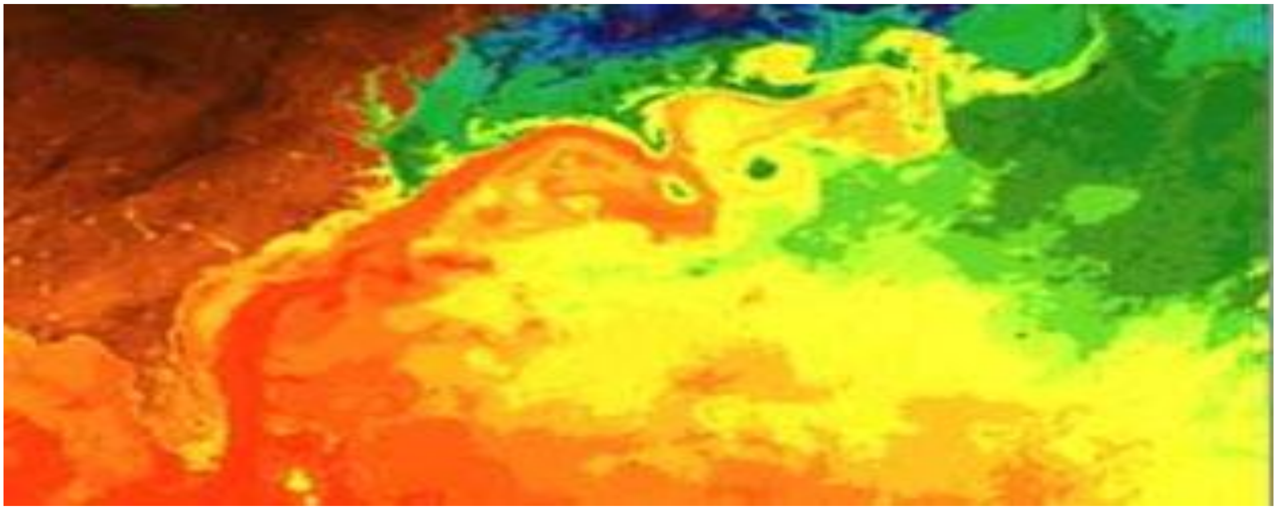


Figure 2: Cruise tracks of the NOAA fisheries ships Gordon Gunter and Henry Bigelow used as observation platforms for OA color-coded with surface water pCO_2 levels.

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 being delivered by the Gulf of Mexico Climatology.



RESEARCH REPORTS

THEME 4: Ocean Modeling

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

Project Personnel: V. Kourafalou (UM/RSMAS); M. Le Hénaff (UM/CIMAS)
NOAA Collaborator: G. Halliwell (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To develop a high resolution numerical model for the Gulf of Mexico and perform simulations over the Deepwater Horizon oil spill accident period (April-September 2010), in support of oil spill modeling.

***Strategy*:** To perform free-running simulations to study important aspects of the Gulf of Mexico circulation (with a focus on the Loop Current variability) and data assimilative simulations that can provide improved hindcasts of the year 2010, with a focus on the Deepwater Horizon oil spill event; and to use the experience gained toward an advanced predictive tool for the future monitoring of the Gulf of Mexico.

CIMAS Research Theme:

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

Link to NOAA Strategic Goals:

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

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

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

Research Summary:
This project builds on the emergency collaborative effort established shortly after the Deep Water Horizon (DWH) oil spill occurred, between modelers based at University of Miami (RSMAS), the Cooperative Institute for Marine and Atmospheric Studies (CIMAS), and NOAA/AOML/PhOD. The overarching objective has been to develop improved regional ocean nowcast and forecast products to monitor and predict circulation in the Gulf of Mexico (GoM), in support of oil spill prediction in the case of similar emergencies. The community based Hybrid Coordinate Ocean Model (HYCOM; hycom.org) code has been employed.

The existing global HYCOM and regional GoM-HYCOM models (run in real-time at the Naval Research Lab at Stennis and with horizontal resolution of $1/12^0$ and $1/25^0$, respectively) have been used to evaluate gaps in the ability to predict circulation details that are crucial for oil spill modeling. The GoM-HYCOM $1/25^0$ has been used for demonstrating the impact of mesoscale dynamics on oil transport and fate (Fig. 1, trajectory simulations as in [Mariano, Kourafalou, Srinivasan, Kang, Halliwell, Ryan and Roffer, *Dynamics of Atmospheres and Oceans*, 2011]). The same model has been used to perform scenarios of oil trajectories from several locations in the GoM, with an emphasis on the areas that have already been considered for oil exploration by Cuba. These simulations have elucidated the crucial role of the GoM mesoscale dynamics in altering the transport and fate of hydrocarbons. In particular, the phase of Loop Current evolution (which is largely controlled by the surrounding cyclonic Loop Current Frontal Eddies and the detachments and eventual separation of the anticyclonic Loop Current rings) and the meandering of the Florida Current (which is also related to eddy evolution within the Florida Straits) were found to be critical manifestations of the mesoscale GoM circulation with respect to oil transport and fate (Fig. 2).

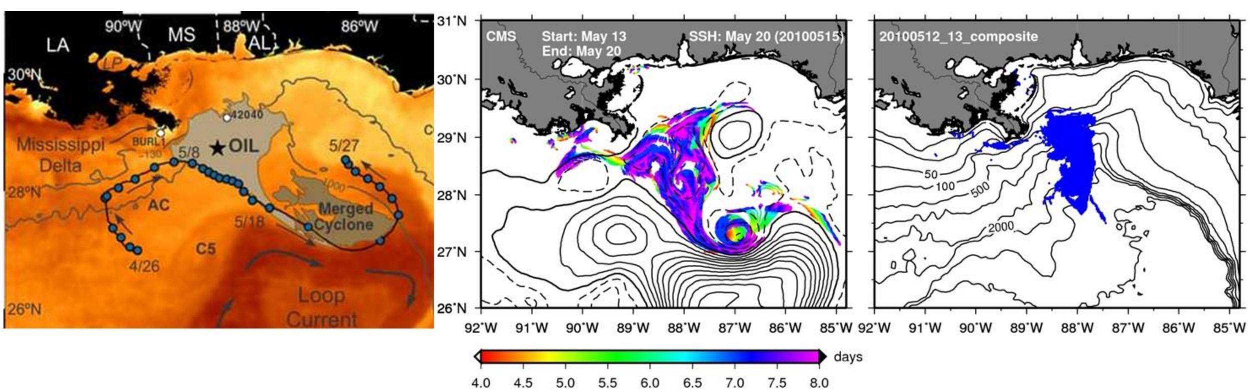
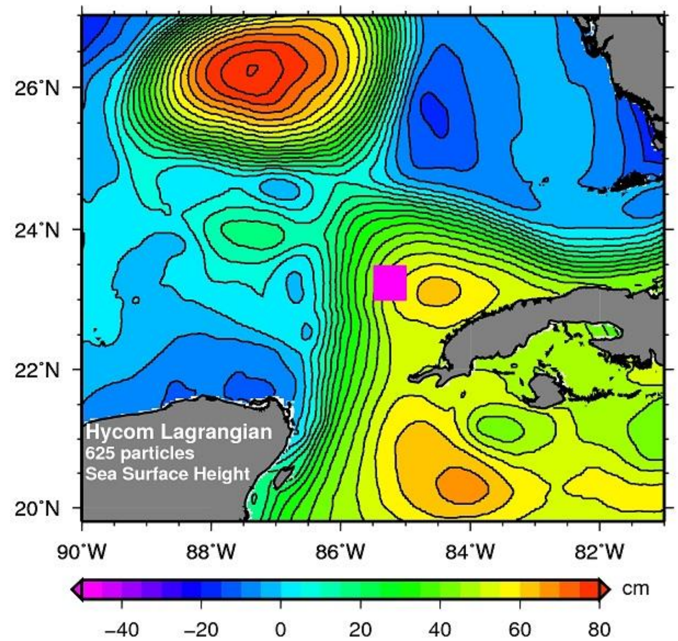


Figure 1: Evolution of the DeepWater Horizon surface oil patch under the influence of the Loop Current and associated eddy field. (Left, plot provided by Nan Walker, LSU): entrainment of oil by a cyclonic Loop Current Frontal Eddy on May 20, 2010 based on observations, both remote (oil patch in grey and brown over background of Sea Surface Temperature) and in-situ (drifters, positions marked as circles). (Middle): Model predicted positions of oil particles after 1 to 8 days (time provided in color code), starting on May 13 and ending on May 20 (2010), over background contours of model predicted Sea Surface Height showing the position of the Loop Current and the cyclonic Loop Current Frontal Eddy that entrained the oil. (Right): Initial position of oil (digitized from satellite observations) on May 13, used to initialize the model prediction through May 20, 2010.

The new regional GoM-HYCOM model has several improved attributes. First, horizontal resolution is ~1.8 km (and thus called the GoM-HYCOM $1/50^0$ model), which is between 1.6 and 4 times finer than the resolutions of existing operational products. It can, therefore, resolve smaller scales along with the narrow convergence zones of ocean fronts associated with the Loop Current and eddies where oil and other debris tends to accumulate. Second, it contains an improved representation of river plume dynamics [Schiller and Kourafalou, *Ocean Modeling*, 2010], which is critically important to oil spill dispersion in the Northern Gulf due to the Mississippi River plume. In contrast, all existing global and regional ocean models relax salinity to climatology, thus degrading the river impact. Finally, it is fully nested in the global HYCOM model, through the development of an appropriate procedure to treat boundary conditions. Thus, realistic inflows from the Caribbean and outflows toward the Atlantic Ocean are resolved. A comprehensive study of mesoscale variability in the GoM based on the NOAA-AOML multi-year drifter data set has been completed, which forms a basis for model evaluation.



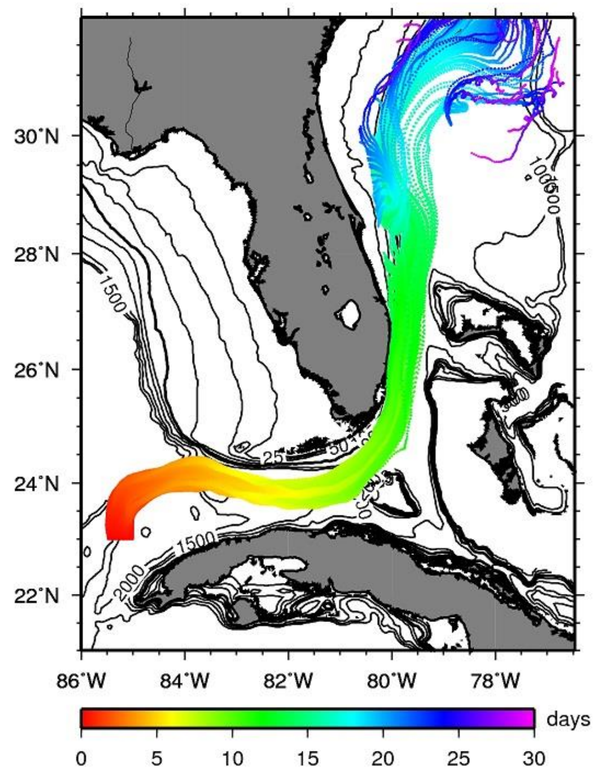


Figure 2: Model computed oil spill scenario for particles released within the core of the Loop Current when it is in a retracted position (following the detachment of a ring). (Left): Sea Surface Height (SSH) contours for November 13, 2011, depicting high SSH for the Loop Current and the anticyclonic ring and low SSH for the cyclonic Loop Current Frontal Eddies; the initial location of 625 oil particles is within the pink box. (Right): Model predicted positions of oil particles (over background contours of topography), after 1 to 30 days (time provided in color code, starting on November 13, 2011), showing that this particular scenario would have oil particles reaching the southeast Florida coastline within 2 weeks.

Research Performance Measure: All major objectives have been met.

Estimating Uncertainty in Ocean Models

Project Personnel: W.C. Thacker (UM/CIMAS); M. Iskandarani and A. Srinivasan (UM/RSMAS)
Other Collaborators: 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 2**:** Weather-Ready Nation - *Society is prepared for and responds to weather-related events* (*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:
An ocean model provides 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 that reflect the uncertainties of their inputs and on the reduction of uncertainties of both inputs and outputs by exploiting information provided by observational data. Our earlier efforts, which examined the uncertainties of the circulation within the Gulf of Mexico that might be attributed to the inflow through the Yucatan Straits and those that might be attributed to parameters influencing mixing, demonstrated that our approach was practical for ocean models.

This year our focus has been on two important issues. The first is demonstrating whether our approach provides a practical way to obtain improved estimates for model parameters by exploiting information provided by observational data. Based on our earlier result that mixing in the upper ocean is more sensitive to the wind drag than to other parameters, we thought we might be able to use the AXBT data that had been collected during Typhoon Fanapi to improve estimates for parameters controlling the drag's dependence on wind speed. A high-resolution atmospheric model provided the wind forcing for the oceanic model that simulated the AXBT data. The Bayesian framework for inferring the three parameters controlling the drag's dependence on wind speed allowed a posterior probability density for the parameters to be estimated by sampling from the prior density using a Markov Chain Monte Carlo technique, which would be computationally unaffordable if the ocean model had to be run repeatedly for the thousands of parameter combinations that would be needed. However, by fitting polynomials to the results of a manageable number of simulations, a surrogate for the model was constructed, which allowed for inexpensively approximating the simulated AXBT data for all the required parameter combinations. The resulting posterior density provided optimal estimates for the parameters through its mean or maximum as well as information about their reliability through measures of its spread.

The second issue we addressed was that of further improving the efficiency of such computations. The needed simulations for constructing the polynomial surrogates that allow the method to work dominate the computational effort. The number of simulations, which depends on the degree of the polynomials needed to describe the response as the parameters are varied, can increase geometrically with increasing numbers of parameters. So we explored the use of sparse quadrature techniques, which can reduce the number of model simulations that are required. This allowed us to use more accurate polynomials of higher degree and to address problems involving more parameters.

While its impact is less than that of the sparse quadrature, avoiding the need for the Monte Carlo sampling can also improve efficiency. Our approach here is to sacrifice the goal of constructing the full posterior density and settling on an estimate of its center and spread as given by a Gaussian. The center is found by maximizing likelihood in a manner similar to what is routinely done for data assimilation but which does not require an adjoint for the model as the polynomial surrogates can be easily differentiated to get the gradient needed for finding the center. Similarly, the Hessian matrix of second derivatives is easily evaluated to give the inverse of the covariance matrix that measures the uncertainty of the parameters.

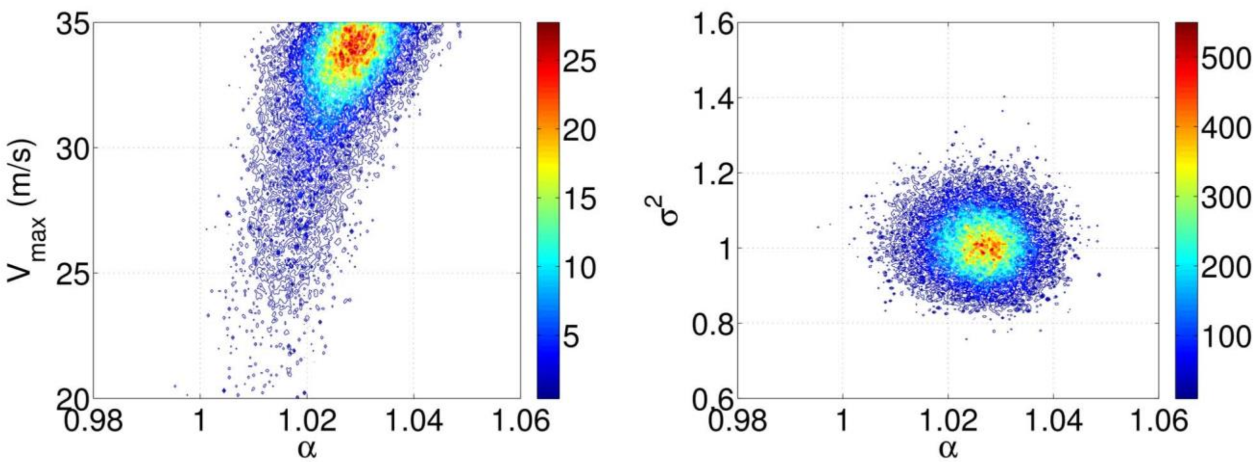


Figure 1: Posterior probability density inferred from AXBT data. Left panel shows the density for V_{max}, the parmeter controlling the wind speed for which drag is maximum, and α, the parameter controlling the magnitude of the drag while preserving the shape of its dependence on wind speed. Right panel shows the density for σ^2, which scales the difference between AXBT measurements and their simulated counterparts, and α.

Research Performance Measure: A paper describing results has been submitted for publication.

OSSE Evaluation of Targeted Airborne Ocean Observing Strategies in the Gulf of Mexico

Project Personnel: M. Le Henaff and H. Yang (UM/CIMAS); V. Kourafalou (UM/RSMAS)
NOAA Collaborators: George Halliwell and Robert Atlas (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 existing and new ocean observing systems for a broad range of oceanographic problems.

***Strategy*:** Develop the code base required to perform Observing System Simulation Experiments (OSSEs) and Observing System Experiments (OSEs) at NOAA/AOML and UM/RSMAS, including the ocean data assimilation system and the toolbox to sample synthetic observations from the nature run. The OSSE system is designed to be relocatable so that regional observing system evaluations can be conducted upon request.

CIMAS Research Theme:

***Theme 4*:** Ocean Modeling (*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* (*Primary*)

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

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

Research Summary:

This project is performed by the joint AOML/CIMAS/RSMAS Ocean Modeling and OSSE Center (OMOC; http://www.ci-mas.org/omoc.html). An ocean OSSE system has been developed following strict design criteria and rigorous evaluation procedures that enable a-priori determination of the expected realism of observing system impact assessments obtained from the system. This is the first ocean OSSE system to employ all of the techniques developed and long used to provide realistic assessments of atmospheric observing systems. Evaluation of the ocean system in the open Gulf of Mexico demonstrated that it is capable of providing unbiased estimates of observing system impacts without the need to calibrate the final assessments. The effort over the past year also focused on development of the ocean data assimilation procedure used in the OSSE system, specifically the Tendral Statistical Interpolation System (T-SIS). The design and evaluation of the OSSE system, along with an evaluation of the T-SIS data assimilation system, are presented in Halliwell *et al*., (2013a, Development and rigorous evaluation of a fraternal twin ocean OSSE system for the Gulf of Mexico. Under review).

After completing initial system evaluation, the work conducted in recent weeks has focused on performing actual OSSEs to evaluate targeted airborne ocean observing strategies in the Gulf of Mexico. The starting point of this work is the nine airborne surveys conducted in the interior eastern Gulf of Mexico in response to the Deepwater Horizon oil spill between 8 May and 9 July 2010.

These surveys raised the question of whether they were optimally designed in terms of temporal resolution along with spatial resolution and coverage to improve the initialization of ocean forecast models used to forecast oil spill transport and dispersion. The underway OSSEs are addressing several specific questions. The impact of temporal separation of airborne surveys on the accuracy of ocean analysis products is being assessed by assimilating synthetic airborne profiles from surveys conducted at 16, 8, 4, 2, and 1 day intervals over a several month time interval. The impact of airborne probe type is being assessed by assimilating synthetic profiles obtained by AXBTs (temperature profiles only down to 400 m) and AXCTDs (temperature and salinity profiles down to 1000 m) at the same survey grid points. The impact of horizontal resolution of survey profile locations is being assessed by comparing the accuracy of ocean analyses produced by assimilating profiles at 0.5º versus 1.0º resolution. A paper describing this initial application of the ocean OSSE system is in preparation (Halliwell *et al*., 2013b, OSSE evaluation of rapid airborne ocean observing strategies in the Gulf of Mexico for improving ocean forecasts).

An example of these OSSE results are presented in Figure 2, with the airborne sampling array presented in Figure 1. The control OSSE experiment, assimilates all synthetic observations including temperature and salinity profiles from synthetic AXCTDs sampled daily on the 0.5º array in Figure 1. In the impact assessments presented in Figure 2, Tropical Cyclone Heat Potential (TCHP; http://www.aoml.noaa.gov/phod/cyclone/data/at.html) is used. The RMS error map between the control OSSE experiment and the nature run is shown in Figure 2a. Figure 2b shows substantial RMS error increase over the region covered by the airborne array when all airborne profiles are denied, demonstrating the importance of airborne observations in constraining TCHP in ocean analyses. A smaller but still substantial error increase is realized when airborne profiles are sampled at coarser horizontal resolution (Figure 1), demonstrating the importance of resolving smaller-scale horizontal structure in the TCHP field. Finally, if 400 m T profiles sampled by synthetic AXBTs are assimilated instead of T and S profiles sampled by 1000 m AXCTDs, errors in the airborne sampling domain are unchanged because the AXBTs sample T over the depth range where TCHP is calculated. However, for model dynamical variables such as sea surface height and currents, the deep AXCTDs do have a positive impact (not shown).

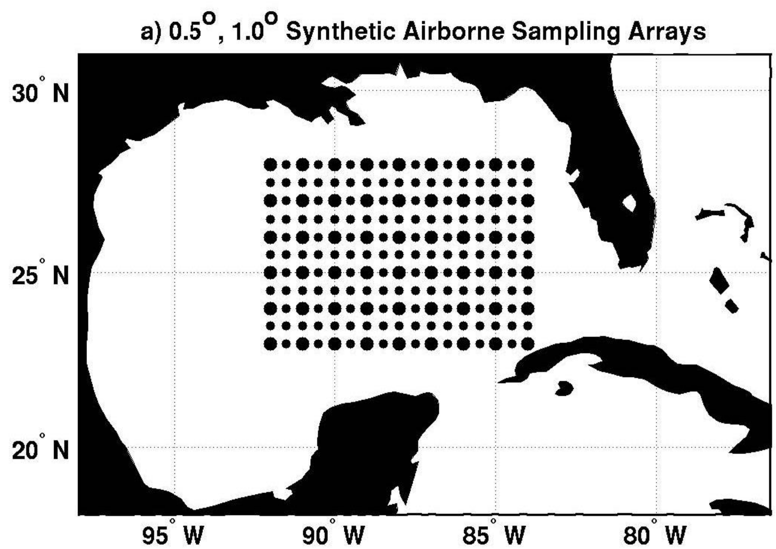


Figure 1: Map of the synthetic airborne survey arrays. Low-resolution profile surveys were taken at 1-degree resolution marked by the large points while high-resolution profile surveys were taken at 0.5-degree resolution marked by all points.

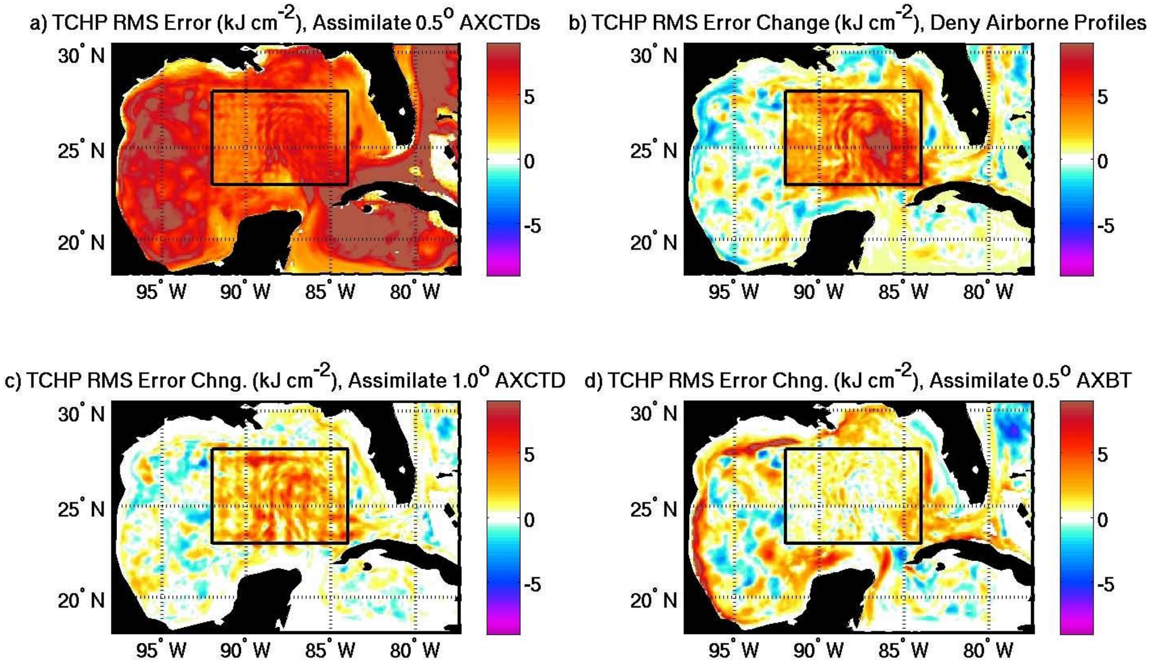


Figure 2: Maps of RMS error in TCHP (OHC) over the time interval May through October 2010 between four OSSE experiments and the nature run. Panel (a) is from the control OSSE experiment where all synthetic observations sampled from the nature run including high-resolution, 1000 m AXCTD surveys were assimilated into a different ocean model (a different configuration of HYCOM from that used to generate the nature run). Panel (b) shows the change in RMS error that occurs when the AXCTD observations are denied, revealing substantial error increase in the box covered by the airborne surveys. Panel (c) shows the change if the AXCTDs are sampled at one-half the resolution, also revealing substantial error increase in the survey domain. Panel (d) shows the change resulting from assimilating high-resolution 400 m AXBTs instead of deeper AXCTDs, revealing little error change in the survey domain because temperature is assimilated over the depth range used to calculate TCHP.

Research Performance Measure: We have achieved our first important research measure by successfully designing and validating the new OMOC OSSE system. The next step will be to complete the set of OSSEs now underway in the Gulf of Mexico. Concerning future performance measures, with support from the Sandy Supplemental, the system will be initially expanded to cover a large tropical/subtropical Atlantic Ocean domain to demonstrate the capabilities of the relocatable OSSE system. It contains the entire North Atlantic hurricane region including the Caribbean Sea and Gulf of Mexico and will be used to study the impact of different ocean observing strategies for performing research on the ocean response to hurricanes. The OSSE system will also evaluate observing strategies for other purposes such as monitoring subsurface heat content associated with the Atlantic Warm Pool and monitoring the Amazon River freshwater plume.

Simulation of the Argo Observing System

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

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To examine how well the Argo observing system determines the state of the global upper ocean, and to understand factors that control accuracy of the reconstruction of the oceanic state.
***Strategy*:** To employ a suite of observation system simulation experiments (OSSE) in ocean general circulation models, to sub-sample oceanic fields in these experiments in ways similar to how the Argo float array samples the ocean, to quantify errors in reconstructions of the oceanic state, and to study factors that control these errors.

CIMAS Research Theme:
***Theme 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: CPO **NOAA Technical Contact:** Joel M. Levy

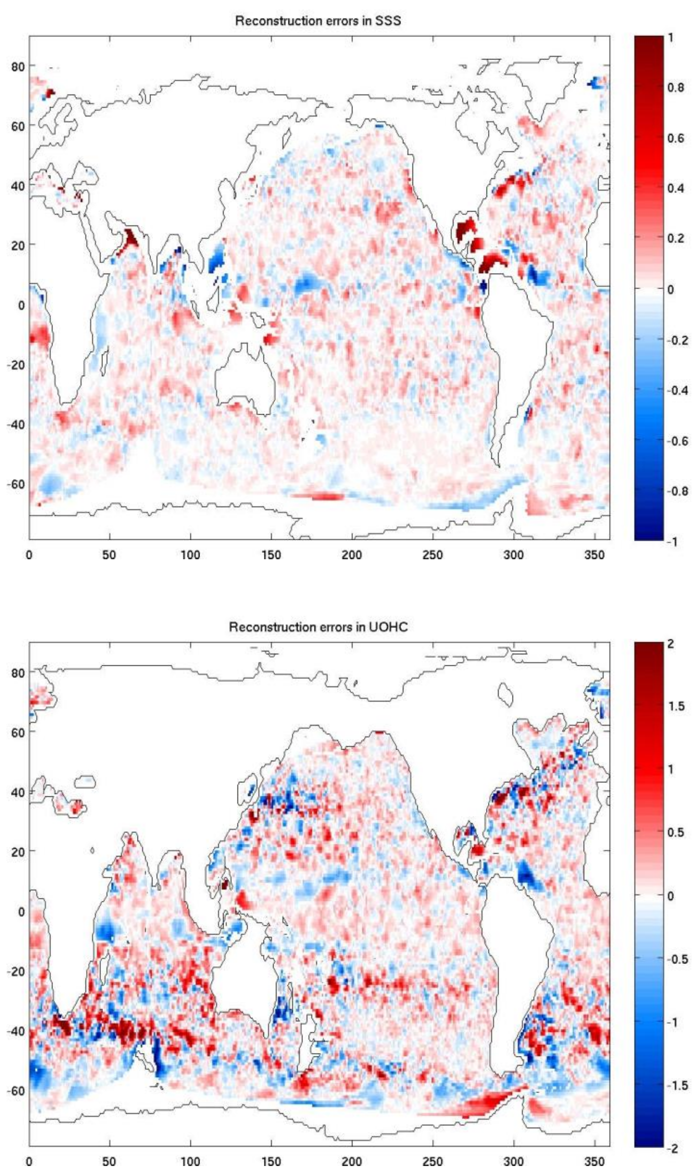
Research Summary:
The main goal of this study is to examine how well the Argo observing system determines the state of the global upper ocean. For this purpose, this study employs observation system simulation experiments (OSSE) in ocean general circulation models. Oceanic fields in these experiments are sub-sampled in ways similar to how the real Argo float array samples the real 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 Argo data.

We carried out simulation of the Argo observing system in one of the most comprehensive numerical models of the World Ocean: a high-resolution ($1/12^{o}$) global Hybrid-Coordinate Ocean Model (HYCOM). HYCOM model has been used extensively at National Research Laboratory (NRL). A list of publications, and on-line presentations, are available at http://www.hycom.org. The model stratification closely resembles observations and the flow field is sufficiently realistic. The simulated Argo floats move with model velocities and the deployment sites and times closely match those for the actual Argo.

Oceanic circulation, in this model and in the real ocean, is characterized by powerful mesoscale eddies – currents with the size of 50-200km. The Argo float trajectories exhibit strong signature of this mesoscale eddies. In the most of the domain, the eddies help to achieve more uniform spatial coverage, acting to reduce gaps in the spatial coverage. In contrast, the floats are removed by ocean currents from some regions. It is important to identify these regions, because they will require continuing redeployment of the floats.

We next analyze the **reconstruction errors** – the differences between the reconstructed and actual model-simulated fields. These errors can be used as a convenient metric for the evaluation and development of the various analysis techniques, as well as for the optimization of the observing system design. In many parts of the domain, improved coverage in the presence of eddies corresponds to reduced reconstruction errors. Gaps in the sampling coverage do not, however, always correspond to elevated reconstruction errors.

The reconstruction errors in several key variables, such as the upper-ocean heat content, sea surface salinity and upper-ocean stratification are small in most of the World Ocean (Figures 1 and 2). The errors, however, tend to be significant in several regions characterized by strong oceanic currents and insufficient spatial data coverage. In particular, the reconstruction errors are large in the northern part of the Southern Ocean, due to sharp fronts in temperature and salinity and fast movement of the floats. The depth of the deep mixed layers in this region is also significantly underestimated in the reconstructed fields (Figure 2). The reconstruction errors are also particularly large in the vicinity of the Gulf Stream.



(a)

Figure 1: Reconstruction errors in: (a) sea-surface salinity (in PSU); and (b) the upper-ocean heat content (UOHC), shown as the depth-averaged (over the upper 1000m) temperature (in K). The values are for October 2006.

(b)

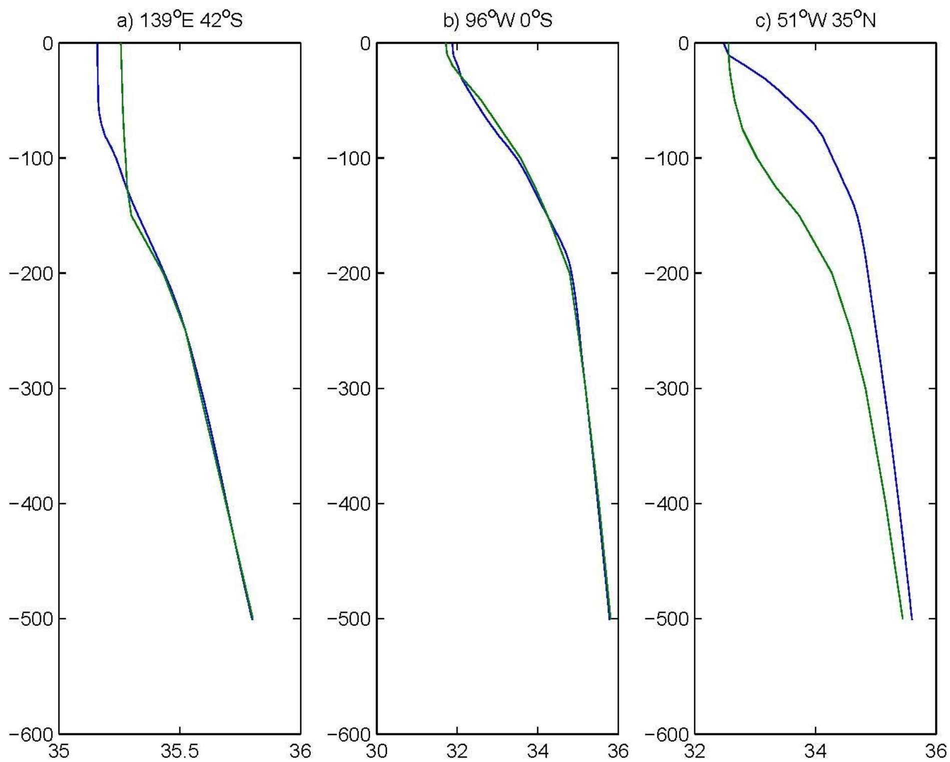


Figure 2: Reconstructed (blue) and actual model-simulated (green) density at three locations: a) south of Australia; b) equatorial eastern Pacific; c) North Atlantic (vicinity of the Gulf Stream).

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

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

Project Personnel: D. Willey (UM/CIMAS)
NOAA Collaborator: G. Halliwell (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 to design observing system enhancements (both operational and rapid-response) that will improve ocean model initialization for coupled forecast models. Evaluate and improve ocean model performance in the HWRF coupled forecast model. Collaborating with NOAA/NCWCP/EMC to evaluate ocean model performance in the pre-operational testing of the HYCOM-HWRF coupled forecast model.

CIMAS Research Theme:
Theme 4**:** Ocean Modeling *(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: USWRP/HFIP
NOAA Technical Contact: Alan Leonardi

Research Summary:
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) evaluate ocean model performance in coupled hurricane forecast models and devise strategies to improve the ocean model response to hurricane forcing.

The new ocean OSSE system developed by the joint AOML/CIMAS/RSMAS Ocean Modeling and OSSE Center (OMOC; http://www.ci-mas.org/omoc.html) is now being applied to test ocean observing strategies that can improve the accuracy of initial ocean fields provided to coupled forecast models. This work is evaluating not only the impacts of improving the existing operational ocean observing system, but also the impacts of rapid-response ocean observing programs for individual storms. The initial OSSE work is highlighted in another CIMAS report entitled "Evaluation of Targeted Airborne Ocean Observing Strategies in the Gulf of Mexico" by G. Halliwell, V. Kourafalou, and R. Atlas, and is not repeated here.

There are two components to the ocean model evaluation effort. The first component involves a collaborate with NOAA/AOML/HRD modelers to perform idealized studies of the impact of the ocean on intensity forecasts as a function of ocean and storm parameters on the intensity evolution in coupled forecasts. This study uses a version of the WRF atmospheric model coupled to a one-dimensional ocean model. A large set of experiments were designed that minimize the impact of atmospheric processes on intensity and thus allow the impact of the ocean to be unambiguously identified. Figure 1 presents an example of how the impact of the ocean model on intensity is affected by ocean and storm parameters, specifically Tropical Cyclone Heat Potential (TCHP; http://www.aoml.noaa.gov/phod/cyclone/data/at.html) which is an index of thermal energy available to a storm, and also storm translation speed and storm size. The upper panels of this figure display contours of intensity represented by minimum central pressure as functions of TCHP and translation speed for large and small storms. The lower panels are the same except for presenting contours of maximum wind speed to represent intensity. Overall, the intensity of small storms is less affected by the ocean than for large storms. TCHP has a larger impact on intensity that translation speed except for slow storms traveling at < 4 m s^{-1}. These idealized experiments are being further analyzed to identify physical processes controlling the complex interactions between the oceanic and atmospheric surface boundary layers that controls SST cooling and enthalpy flux.

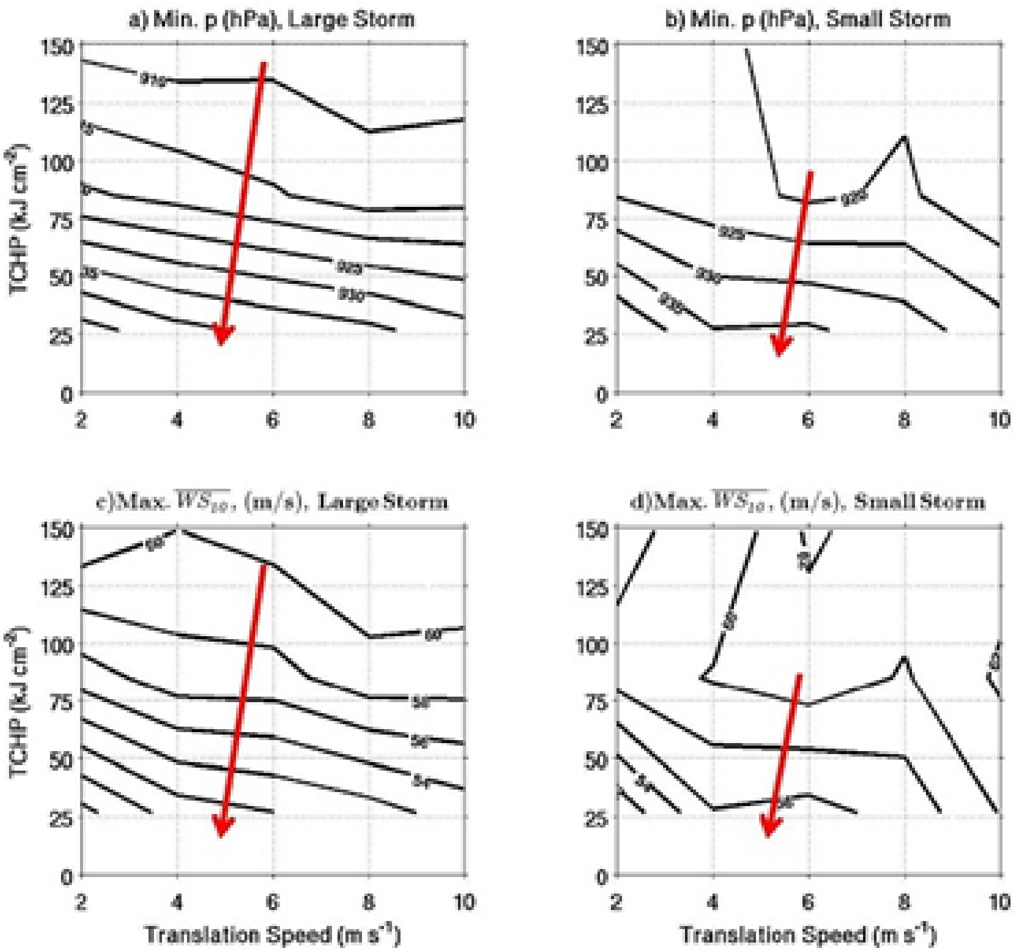


Figure 1: Minimum central pressure from an ensemble of idealized experiments for (a) large and (b) small storms, and maximum 10 m wind speed for (c) large and (d) small storms, all contoured as functions of storm translation speed and ocean TCHP. The two measures of storm intensity were averaged over forecast hours 72 to 96 to reduce the impact of high-frequency intensity fluctuations. The red arrows indicate the directions of intensity increase, demonstrating that at translation speeds above 4 m s^{-1}, ocean TCHP has more impact on intensity than speed. The impact of translation speed increases for slower moving storms.

The second component of the ocean model evaluation effort involves collaboration with NOAA/NCEP/EMC to evaluate ocean model performance in the HYCOM-HWRF coupled hurricane forecast model that will be undergoing pre-operational real-time testing during the 2013 and 2014 hurricane seasons. G. Halliwell is now working with EMC (Dr. Hyun-Sook Kim) to optimize HYCOM configuration for the 2013 tests and will contribute to the analysis of the ocean model response as the tests are run. To evaluate the impacts of altering the ocean model configuration and the sensitivity of the ocean model response to changing model parameters, an idealized testbed was set up. It consists of a horizontally uniform f-plane ocean forced by an idealized representation of hurricane Frances. These forcing fields were calculated using analytic functions provided by Dr. Jim Price (Woods Hole Oceanographic Institution).

The most significant issue identified by this optimization effort is that the vertical coordinate structure used by the Navy global HYCOM analysis product that is used to initialize the EMC RTOFS analysis that then provides initial ocean fields to HYCOM-HWRF is not optimum for resolving the upper-ocean response to hurricanes in the tropical ocean. An example zonal cross-section taken from one of the idealized Frances experiments illustrates the poor upper-ocean resolution provided by the initial vertical coordinates below 30 m depth (Figure 2, top panel). This cross-section is displaced one degree to the right of the storm track and shows the ocean response to storm forcing. There are problems with the model response due to the large truncation errors that result from poor vertical resolution, including the collapse of model layer 10 to near zero thickness. To correct these problems, the vertical coordinate structure was re-mapped to a new hybrid isopycnic-z coordinate structure that did not add new model layers, but traded thicker deep model layers for more layers in the nearsurface level coordinate domain. The ocean model response in the latter case is more orderly (Figure 2, lower panel). The maps in Figure 3 demonstrate that the larger truncation errors present with the original vertical coordinate structure significantly affect the SST cooling pattern forced by the storm and generally lead to overcooling.

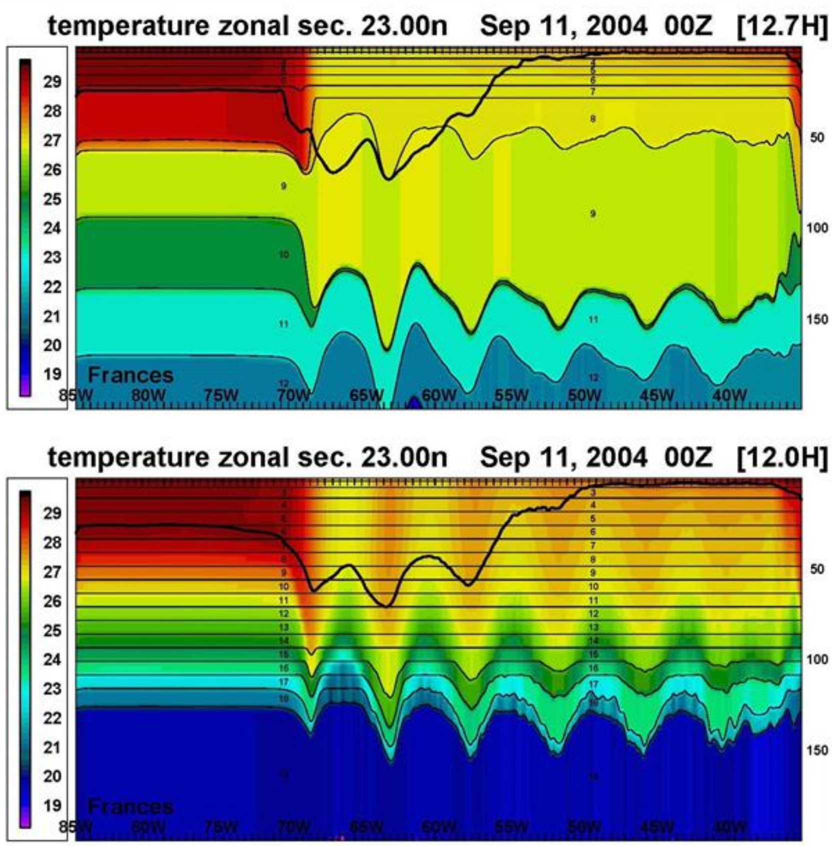


Figure 2: Zonal cross-sections of temperature from two idealized experiments illustrating the ocean response to an idealized representation of hurricane Frances. The section is along 23ºN, exactly one degree to the north of the center of the westward propagating storm. The top panel is from a model run that used the original vertical coordinate structure employed by the Navy global HYCOM analysis product used as input to RTOFS and then provided as initial fields for HYCOM-HWRF. The bottom panels show the same sections with the vertical coordinate structure re-mapped to provide improved vertical resolution and reduce model truncation errors that adversely impact vertical mixing and SST cooling in response to the storm.

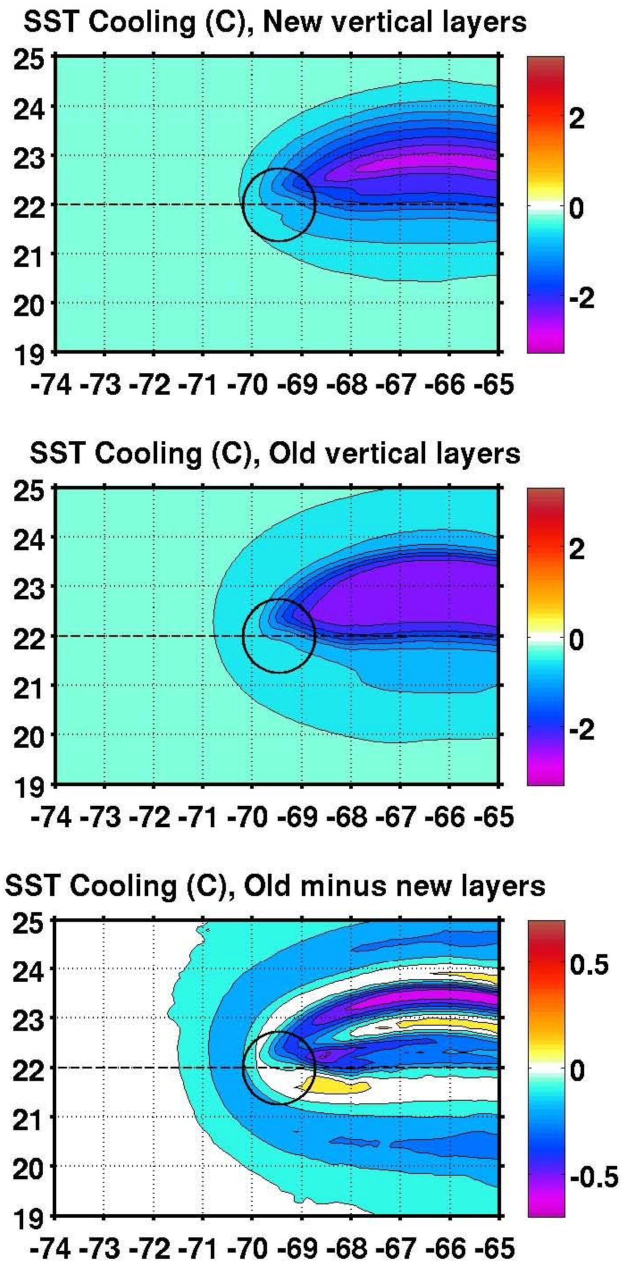
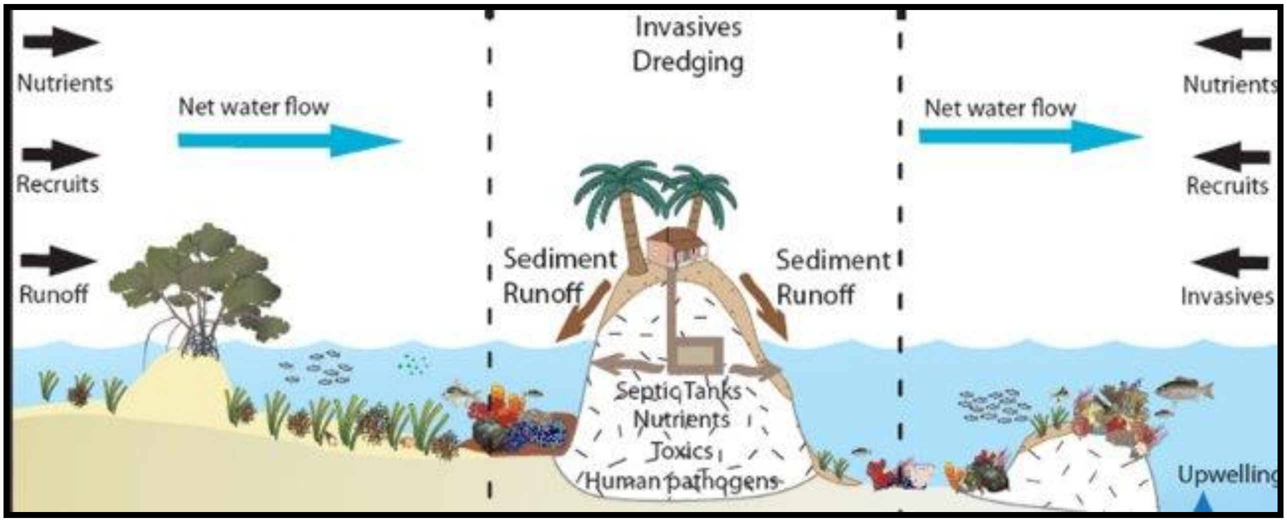


Figure 3: The SST cooling patterns forced by the idealized hurricane Ftances. The top (middle) panel shows the cooling for the original (new) vertical coordinate structures while the bottom panel shows the difference (new minus original). The circles are situated at the storm center and have a radius of twice the radius of maximum wind.

Research Performance Measure: A paper is now in preparation that presents results from the ocean sensitivity study performed in collaboration with HRD modelers. Results of the ocean model evaluation effort in collaboration with EMC should increase the chances that the HYCOM-HWRF will perform well during the upcoming real-time tests, particularly with regard to intensity forecasts.



RESEARCH REPORTS

THEME 5: Ecosystem Modeling and Forecasting

Evaluation of Management Strategies for Fishery Ecosystems (a continuation of Simulation of Management Strategies)

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

Long Term Research Objectives 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 the Atlantis whole-ecosystem modeling framework as well as individual-based modeling and to improve the use of data in fishery stock assessment.

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

A major focus of the U.M. portion of this project has been the development of an ecosystem model for the Gulf of Mexico, using the Atlantis modeling framework. Cameron Ainsworth of USF is the lead PI, and collaborators include NOAA/SEFSC and U.M. From U.M., Ph.D. student Matt Nuttall, who is fully funded under this grant, has analyzed available data on deep sea benthic organism abundance and distribution to parameterize the biological component of the model. Matt is writing his proposal on using the Atlantis model, as well as other ecosystem models such Ecopath, for management strategy evaluation. U.M. Ph.D. student Holly Perryman, who is funded by SeaGrant, has taken the lead in compiling and analyzing the catch data from the U.S., Mexico and Cuba, to parameterize the fishing fleet component of the Atlantis model. For her dissertation, she intends to use Atlantis to evaluate the use of indicators for ecosystem-based management, focusing on the indicators developed by the NOAA Gulf Of Mexico Integrated Ecosystem Assessment Program (IEA). For the spatial management/ habitat component of the project, U.M. Ph.D. student Bill Harford has developed simulation models to generate patterns of spatial heterogeneity in fishing effort and fish abundance, one describing spiny lobster dynamics in Belize and one describing black grouper dynamics in the Florida Keys. Empirical analyses of black grouper life history and exploitation characteristics, and habitat use patterns have also been completed.

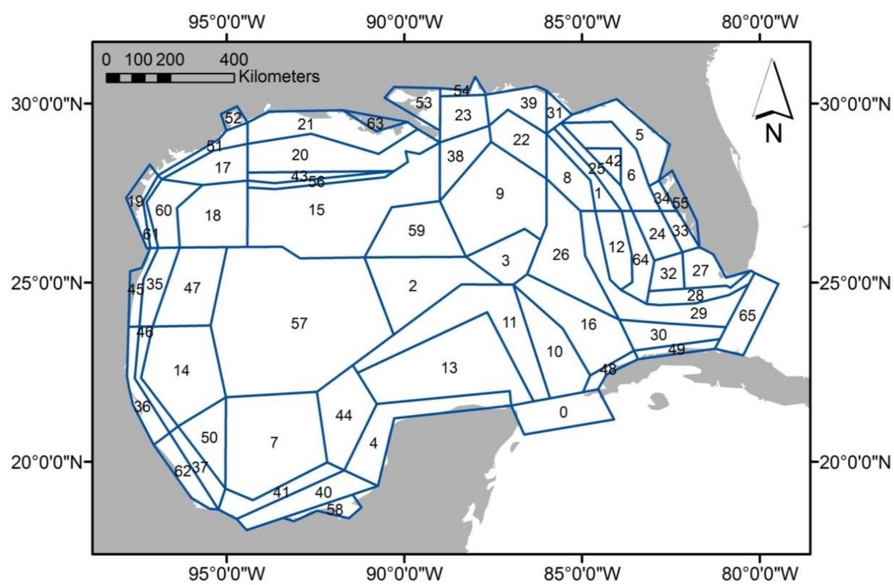


Figure 1: The Gulf of Mexico Atlantis model includes 65 spatial polygons, each of which has multiple depth strata. The model, which includes ocean circulation, food web dynamics and fishing fleets, can be used for ecosystem-based management strategy evaluation.

For VIMS component of the project, M.S. student Kristen Omori began her research involving tagging studies. VIMS developed a model for interpreting tagging data from a mixed stock assemblage. M.S. student Lisa Ailloud began studies of the ICCAT tagging database with special reference to growth of bluefin tuna. An SCRS paper was prepared for the ICAAT Bluefin Tuna meeting in Tenerife in May and was presented by John Walter from NOAA. Kristen Omori began studies of the effects of under-reporting catch and effort on production models used by ICCAT for stock assessment. Matt Smith was formerly funded by this project but he has since been funded by a NMFS/Sea Grant stock assessment fellowship. Work he began while funded by this project includes analysis of catch curve methods and an analysis of gear selectivity based on generalized linear models of tag return data. The former has been published and the latter has been submitted for publication.

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

1. *Develop methodology to characterize trade-offs in reef fish management objectives for spatial management strategies under uncertainty about the spatial dynamics of marine populations*. U.M. Ph.D. student Bill Harford is just finishing his dissertation on this project component.
2. *Develop an ecosystem model for the Gulf of Mexico using the Atlantis modeling framework* As of May 6, 2012, the biological component of the Atlantis model for the Gulf of Mexico is operational. U.M. Ph.D. student Matt Nuttall contributed data analyses for the biological model. U.M. Ph.D. student Holly Perryman is nearly done developing the catch input files.
3. *Develop quantitative methodology to estimate disease mortality of American lobster, striped bass and snow crab.* VIMS student Matthew Smith, Dr. John Hoenig and others have submitted a paper on this work. Smith also published a paper on catch curve analysis.
4. *Evaluate of electronic tag models for stock assessment.* VIMS student Lynn Waterhouse and Dr. John Hoenig have published two papers on this work. VIMS student Lisa Ailloud, Dr. Hoenig and others presented a paper on bluefin tuna growth at ICCAT.
5. *Hold workshops on fisheries quantitative methods.* In April 26, Dr. Hoenig taught a class on advanced R programming at RSMAS. The remainder of the workshops will take place later in the year.

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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 developed a three-species intraguild predation model in early 2012 which includes prey switching by the top predator (Zabalo, *Bull. Math. Biol.* 74:1957–1984, 2012). We worked on extending this ODE model to a PDE model which incorporates non-random dispersal and harvesting. The goal was to develop a general model that can provide a better understanding of how complex interactions between the species can affect the overall dynamics of an ecosystem. This can lead to a better understanding of the mechanisms responsible for maintaining coexistence among interacting populations which, in turn, can lead to the development of better models resulting in better conservation strategies.

Research Performance Method: A proposal to fund this work was submitted to NSF but was not successful in obtaining funding therefore this project was stopped at the end of 2012 and the CIMAS project is considered to be completed.

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Creation of a Species Distribution Model for the Bryde's Shale, Balaenopteraedeni edeni, Residing in the Gulf of Mexico and Improve the Quality of Data Collected During Atlantic Marine Assessment Program for Protected Species (AMAPPS) Vessel and Aerial Surveys

Project Personnel: R. Duncan (UM/CIMAS)
NOAA Collaborators: L. Garrison and K. Mullin (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To develop models and/or tools to transform the collected survey data into spatially-explicit density estimates which takes into consideration any habitat characteristics. To improve the data quality from aerial and vessel surveys of marine mammals that will be used to support stock assessments and habitat models.
Strategy*:* To create a species distribution model for the Bryde's whale using the oceanic variables Bathymetry, Sea surface height and sea surface temperature. Develop and implement processes for quality assurance of visual survey data collected during large vessel surveys and aerial surveys conducted along the U.S. Atlantic coast during 2011 and 2012.

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 productive ecosystems*

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

Research Summary:
Bryde's whales are the only baleen whale that resides year-round in the Gulf of Mexico. Bryde's whales are considered a resident stock, sighted mainly in the northeastern Gulf region that likely

consists of fewer than 50 individuals. To gain a better understanding of these whales' habitat, a Species Distribution Model (SDM) was created. The SDM was used to identify the environmental variables that are important to these marine mammals. The input for the model was Bryde's whale sightings coordinates during National Marine Fisheries Service (NMFS) abundance surveys and remotely sensed values of various oceanographic parameters, such as Climatological averages for Sea surface temperature, Chlorophyll a etc. for the Gulf. The SDM found that Bryde's whales prefers warm temperatures, low sea surface heights and moderately deep water along the De Soto and West Florida Slope. The distribution model also identified unsurveys areas which could be potential whale habitats within the Gulf.

In addition to the Bryde's whale study, the Southeast Fisheries Science Center conducts large vessel and aerial visual surveys of marine mammals along the U.S. east coast as part of the Atlantic Marine Assessment Program for Protected Species (AMAPPS). These data will be used to support stock assessments and develop SDM models similar to that developed for Gulf of Mexico Bryde's whales. I have implemented quality assurance procedures and prepared these data for incorporation into future habitat models.

Figure 1: Picture of a Bryde's Whale in the Gulf of Mexico; taken during the 2011 Abundance Survey.

Research Performance Measure: The major objective is being met. The Species Distribution has been created and the results have been analyzed and are being organized into a scientific paper with hopes of being published soon. Data from one vessel survey and three aerial surveys have undergone quality assurance review and edited data are being used to develop habitat models.

Development of an OSMOSE (Object-oriented Simulator of Marine biOdiverSity Exploitation) model for the West Florida Shelf ecosystem, OSMOSE-WFS

Project Personnel: A. Grüss (UM/CIMAS)
NOAA collaborator: M. Schirripa (NOAA/NMFS/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:
Objectives: To develop an ecosystem simulation model to provide stock assessments (SEDAR) with parameter estimates each year, and explore the trophic functioning of the West Florida Shelf ecosystem in the past, present and future.
Strategy: To set up collaborations with various American and French research institutes, so as to access the best available information and knowledge to construct, parameterize and calibrate the OSMOSE-WFS model.

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:
OSMOSE-WFS is being developed to serve the Gulf of Mexico Integrated Ecosystem Assessment (GOM IEA) project. The main intent of the GOM IEA project is to design a framework for regularly incorporating ecosystem considerations into the SEDAR process (i.e., into stock assessments for the Gulf of Mexico).

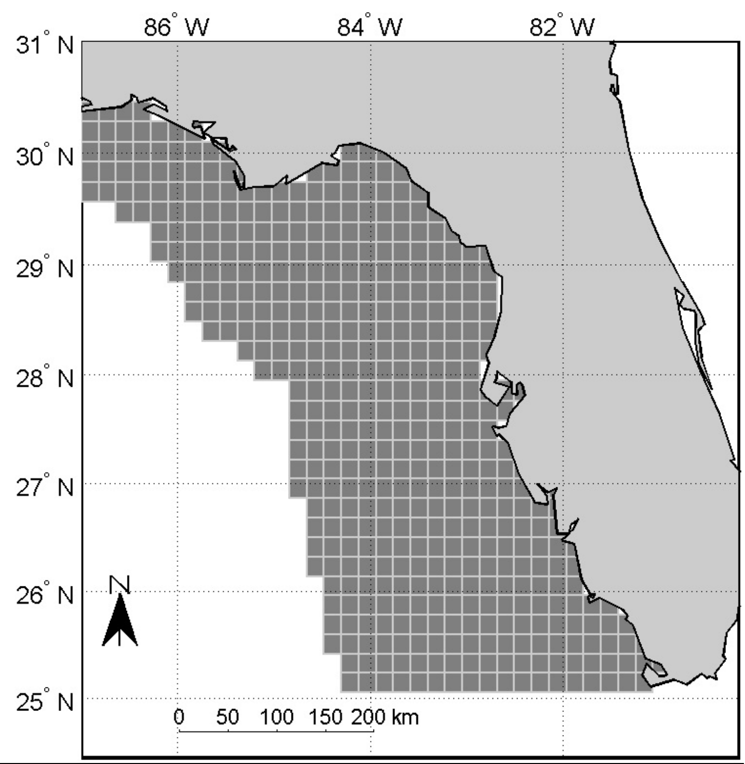

Figure 1: Map of the West Florida Shelf in the Gulf of Mexico showing the spatial cells of OSMOSE-WFS (filled in dark grey).

OSMOSE-WFS builds on an existing ecosystem model, WFS EwE (Ecopath with Ecosim model for the West Florida Shelf ecosystem), in that OSMOSE-WFS and WFS EwE share a number of characteristics (e.g., the spatial domain considered, reference biomasses; Figure 1). However, the structure and assumptions of OSMOSE and EwE models are very different. Therefore, the use of the OSMOSE-WFS and

WFS EwE models is interesting to have two different perspectives on the same questions, while being able to identify where discrepancies between the two models may stem from. Using a model ensemble approach reduces our uncertainties on emergent properties of ecosystems, or at least helps identify avenues for research to that goal.

The development of the WFS EwE and OSMOSE-WFS models offers numerous perspectives to explore the trophic functioning of the West Florida Shelf ecosystem in the past, present and future; but also to provide management with ecosystem considerations, and estimates of parameters that are highly difficult to evaluate from empirical data. Currently, the primary goal of WFS EwE and OSMOSE-WFS within the GOM IEA project is to regularly provide SEDAR with parameter estimates. In 2013, simulations will be run with the two models to deliver estimates of deviations in natural mortality rates and recruitment as well as diet composition for gag (*Mycteroperca microlepis*) to SEDAR 33 for the contemporaneous time period (the 2000s), as well as for the periods 1950-2009 (historical perspective for gag) and 2009-2029 (future perspective for gag). 2013 is seen as a pilot year, which will help define a consistent framework for the long-term.

OSMOSE-WFS is presently being calibrated to a reference state matching the mean conditions in the West Florida Shelf region over the period 2005-2009 predicted by WFS EwE. The calibration of OSMOSE models is a relatively long process which is useful to detect errors and inconsistencies in the model code or in the configuration, as well as to understand the sensitivity of the dynamics of the modeled system to inputs.

Research Performance Measure: OSMOSE-WFS is parameterized and currently being calibrated. The biomasses of almost all the high trophic level groups that are explicitly considered in model are within valid intervals. Once OSMOSE-WFS is fully calibrated, simulations will be run to evaluate first estimates of natural mortality rates and diet composition for gag in the 2000s. These estimates will be provided to SEDAR 33. Besides., the trophic functioning of the West Florida Shelf ecosystem in the 2000s will be analyzed in more details. Then, the OSMOSE-WFS model will be improved and recalibrated using time series of biomasses and landings, so as to explore the dynamics of the West Florida Shelf ecosystem in the past, present and future.

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

Project Personnel: S. Privoznik, B. Muhling, A. Ender and E. Malca (UM/CIMAS)
NOAA Collaborators: J. Lamkin and T. Gerard (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 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 examines the impact of the Florida Current, a Western boundary current, on the distribution and abundance of larval fish. The Florida Current flows northward past the Florida Keys to the eastern shore of Florida transporting water and biological particles. In collaboration with the Quarterly 27N cruises that have been measured along the 27N latitude between South Florida and the Bahamas, our objectives are (1) assess the abundance and composition of larval fish occurring in the Florida Current (2) determine the distribution of ecologically and commercially important species in South Florida waters and (3) evaluate temporal variation of the larval composition and abundance in South Florida

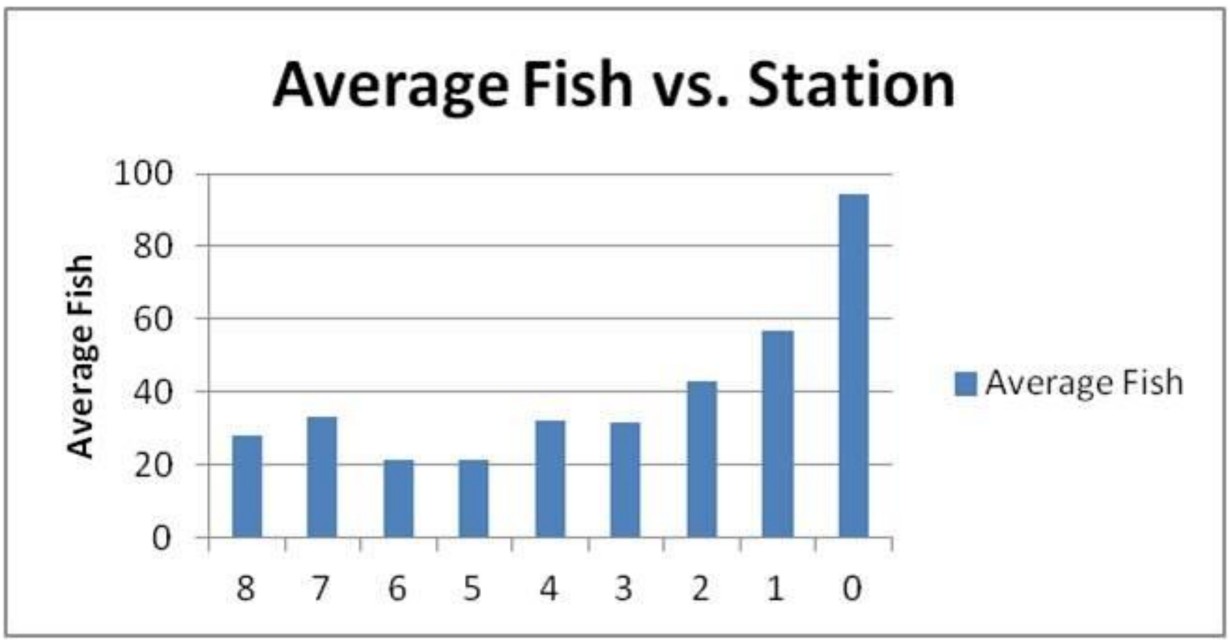

Figure 1: Bar graph summarizing average larval fish collected at each station during the research cruises.

Research Performance Measure:
The research program is on schedule. Unfortunately, due to ship time limitations, this project will no longer continue in 2013. Thirteen cruises have been carried out since September 2009 with 134 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.

Two additional cruises took place in the current cooperative agreement period and ten cruises have been processed for ichthyoplankton. The remaining three 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.

A final report will be generated to summarize the monitoring efforts from 2009-2012. Preliminary analysis of the data so far indicates that fish abundance was greater at stations closer to the Florida Peninsula (stations 0- 4). In terms of seasonal patterns, so far larger abundances were observed in the summer, least in spring and fall.

Figure 2: Undergraduate Hollings Scholar Nadia Makara processing plankton samples at the Early Life History laboratory during summer 2012.

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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)
Other Collaborators: A. Maggied (OMAO)

Long Term Research Objectives and Strategy to Achieve Them:
Objectives: To examine bluefin tuna spawning grounds in the western central Atlantic, including the Gulf of Mexico and Caribbean Sea
Strategy: To complete detailed fisheries oceanography surveys of the western Caribbean and western Atlantic 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*) were previously assumed to spawn only in the northern Gulf of Mexico during spring (April to June). However, collections of small bluefin tuna larvae east of the Yucatan Peninsula in recent years (since 2009) have led to speculation that some spawning activity may be taking place in other areas. To investigate this possibility, scientists from UM/CIMAS, NOAA/SEFSC, the University of South Florida, IEO (Instituto Español Oceanográfico) and El Colegio de la Frontera Sur - ECOSUR (Mexican Academic) have been participating in collaborative research surveys in the western Caribbean Sea, in 2011 and 2012.

During 2013, the research area was extended to include waters around and north of the Bahamas (Figure 1).

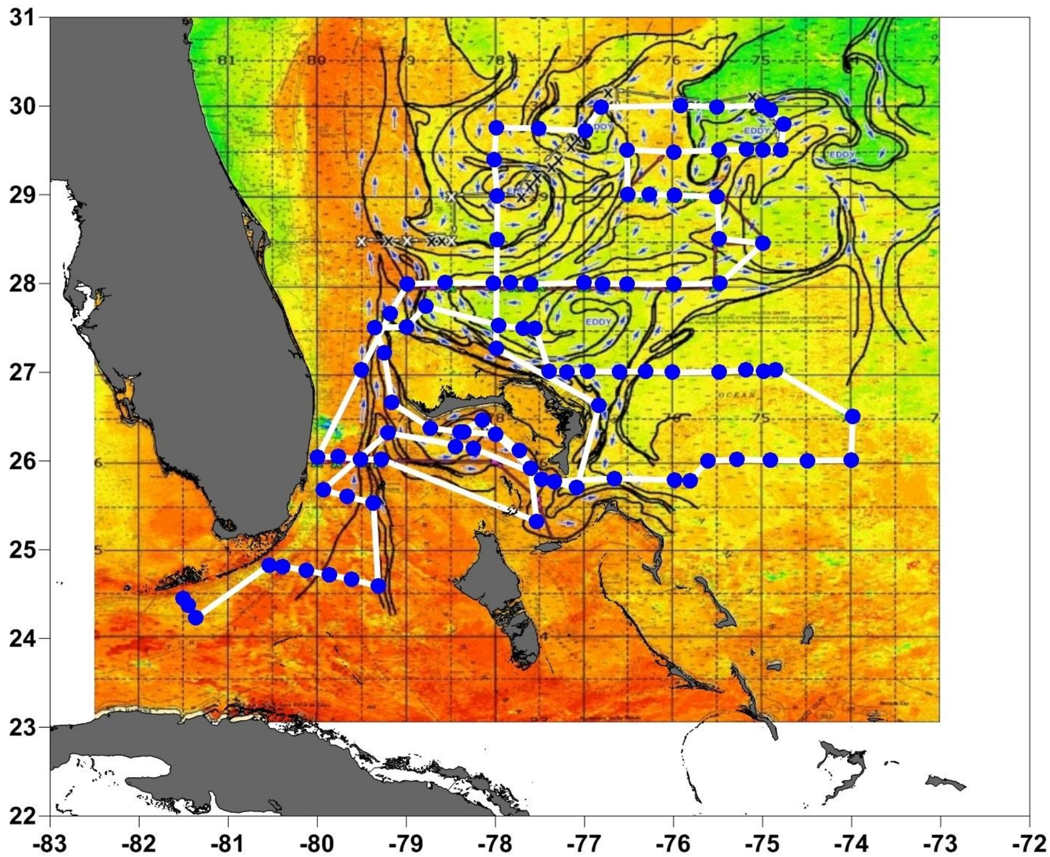

Figure 1: Stations sampled (blue) and cruise track (white) for May 2013 cruise. Satellite sea surface temperature and frontal analysis from Roffs for May 20th 2013 is shown as an underlay.

Similarly to previous years, 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. NOAA Ship Nancy Foster was used for the 23 days of continuous sampling.

Preliminary identifications of larvae collected during the survey indicate that some bluefin tuna larvae were collected near Nassau, and north of the Bahamas. However, their origin is as yet unclear. Future work on aging and oceanographic backtracking will address this question. Larvae of other tunas were also collected in samples, and were most abundant in the Gulf Stream region, between Florida and the Bahamas (Figure 2).

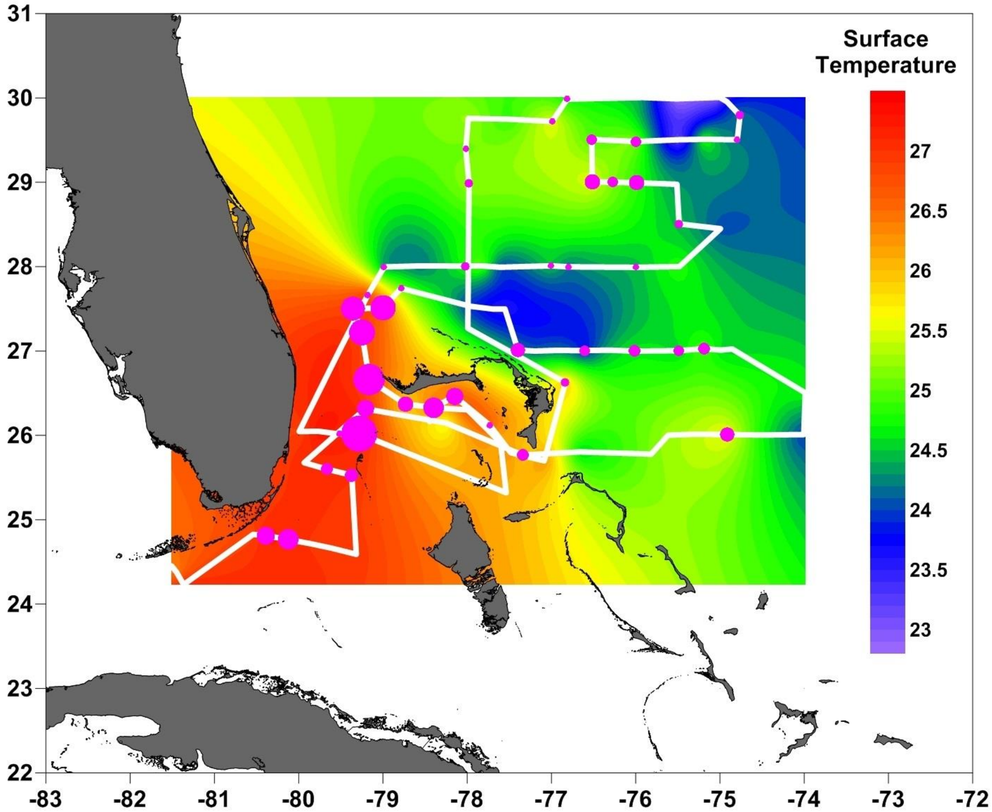

Figure 2: Cruise track (white) and catch locations of tuna larvae (pink) from May 2013 cruise. Surface temperatures from CTD are also shown, interpolated between station locations.

Results from the 2012 western Caribbean cruise showed high abundances of tropical tuna larvae, but very few bluefin tuna. This tends to confirm results of the 2011 cruise, which suggested that the western Caribbean Sea was a minor spawning ground, at least in the time period sampled (early April).

Our general research objectives are to (1) examine the oceanographic conditions in which bluefin tuna and other tuna larvae were collected, and (2) compare oceanographic conditions in the Gulf of Mexico to other nearby regions. In addition, (3) stable isotope analyses on larvae collected during 2012 and 2013 are underway, and will be used to investigate questions of trophic level dynamics. Results will be compared 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.

Research Performance Measure: The research program is on schedule. Samples from the 2012 cruise are currently being sorted. This year's cruise was successfully completed on May 24, 2013; sample processing and sorting will begin shortly.

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 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: CRCP international and SEFSC
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. Two workshops were carried out, one in 2010 and the second in 2012 in Chetumal with field components in Xcalak, Quintana Roo.

The research component of this project focuses on providing assessments and building capacity to assess the critical habitats in the interior lagoons and shallow coral reefs of the Mesoamerican Barrier Reef System. The 2nd workshop provided hands-on training for local managers and to setup an experiment to build comparable baseline information for recruitment of reef fishes along the region. Outcomes of the workshop were to develop research and field protocols and distribute them to carry out this project in a 3rd workshop to be conducted in Fall 2013. During the 2012 workshop, the invasive species (lionfish, *Pterois volitans*) was discussed at the request of the local managers; therefore a third protocol was developed to obtain baseline abundance data from extraction rallies that take place throughout the region.

Research Performance Measure: The program has been proceeding on schedule despite some difficulties. Funding limitations and reductions have delayed launching of the simultaneous experiment that was scheduled for this summer 2012. A third training workshop is scheduled for Fall 2013, if funding is secured from our various partners.

Despite some setbacks, we have developed three protocols in English and Spanish to support this project and distributed them to all participants and posted them on the project's websites that also serves to utilize social networking media to promote the project among participants and stakeholders.

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How Precise and/or Accurate do Forecasts of Environmental Factors Need to be Useful to Stock Assessments

Project Personnel: E.B. Peebles and D. L. Jones (USF); M.D. Murphy (Florida Fish and Wildlife Commission)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To provide information that will allow fisheries management to adapt to climate impacts on the productivity of living marine resources.

***Strategy*:** To analyze the response of fish to climate cycles and climate change and to determine whether and how indicators for these climate factors should be included in advanced stock-assessment models.

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 productive ecosystems*

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

Research Summary:

During the report period, USF doctoral student and FWC employee Michael Murphy has progressed on the work required under this Fisheries and the Environment (FATE) dissertation project, familiarizing himself with population simulators (NOAA's PopSim and Phil Goodyear's FSIM) and the stock assessment model, Stock Synthesis 3. This involved some collaboration with the FSIM developer, Dr. Phil Goodyear, to gain access to the source code and understand the setup - particularly the unusual parameterization of the stock recruitment model. Stock Synthesis 3 is becoming a standard single-species assessment model used by the NMFS throughout the U.S. because of its broad versatility in incorporating many types of data. The disadvantage of this versatility is its extremely complex setup. Through the developer Dr. Richard Methot and analyst Dr. Michael Schirripa, Mr. Murphy obtained the coding for this model to help understand its structure. He is currently working on running these analyses with 1) no environmental linkage to the environment, 2) a linkage throughout the time period of the modeling exercise, and 3) a linkage only through the forecast time period. Repeated application of these runs should provide information on how well incorporating forecast environmental effects into these analyses can improve the forecasts of recruitment and stock productivity. Finally, Mr. Murphy has received or has obtained access to a couple fish monitoring program databases, including all of their physical and biological data: SEAMAP and FWRI-FWC FIM. These are the most current indices of juvenile abundance for Gulf menhaden and blue crab in the Gulf of Mexico and for Atlantic menhaden in the Atlantic, and these were shared with Dr. David Jones. Dr. Jones is exploring the multivariate data for logical relationships between the abundance indices and environmental variables. Additional indices of abundance can be developed from the monitoring data.

Figure 1: Initial efforts to incorporate climate predictions into fisheries models are being directed to pelagic species in the open waters of the Atlantic Ocean (photo by Dr. Ernst Peebles).

Research Performance Measure: To date, doctoral student Michael Murphy has produced working models set up to run swordfish-like population dynamics that simulate the population and provide for the necessary outputs to parameterize Stock Synthesis 3 for inclusion of climate-cycle data.

RESEARCH REPORTS

THEME 6: Ecosystem Management

Florida Reef Track Fish Monitoring and Assessment

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

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To provide a comprehensive quantitative evaluation of status and trends of coral reef fish populations and communities 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). In addition, to transfer these methodological approaches to the U.S. Caribbean.

***Strategy*:** Conduct statistically rigorous regional multispecies reef fish assessments, map coral reef habitats and spatially-based monitoring of coral reef fish composition, occurrence, abundance, and size structure on the Florida Keys reef tract (e.g., Smith et al. 2011a,b; Ruttenberg et al. 2012; Glynn et al. 2012; Ault et al. 2013; Bryan et al. 2013). Use strategic applications of probabilistic sampling design theory and acoustic telemetry methods (e.g., Farmer and Ault 2011, 2013; Farmer et al. 2013) to obtain key spatial population size-structured abundance and movements data to assess population changes, ontogenetic habitat associations, and ecosystem responses to fishing, recreational use, pollution, MPA zoning and, eventually, Everglades restoration.

CIMAS Research Themes:

***Theme 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 [see Figure 1].

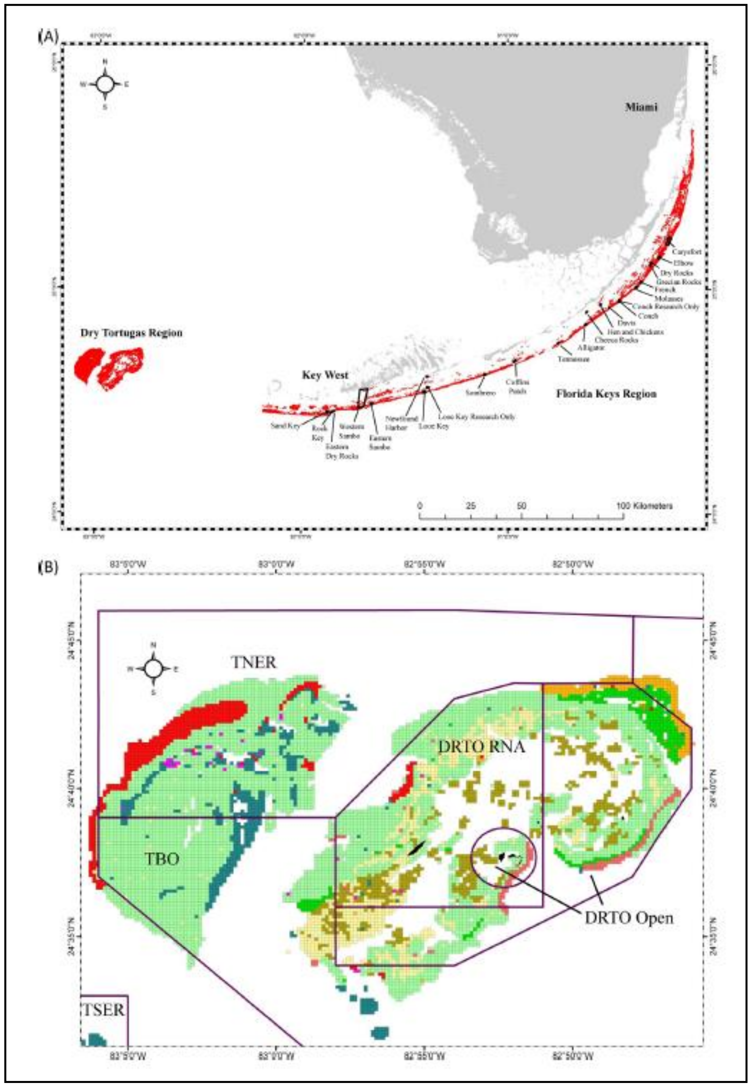

Figure 1: (A) South Florida reef fish visual survey domain (red, mapped coral reef habitats), with managed no-take marine reserve (NTMR) boundaries (black) for the Florida Keys region. (B) Survey domain for the Dry Tortugas region showing spatial management zones and primary sample unit (PSU, 200 m × 200 m) gridding of coral reef habitat types (colored grid cells comprise 326 km2). TNER is Tortugas North Ecological Reserve, a NTMR; TSER is Tortugas South Ecological Reserve, a NTMR; TBO is Tortugas Bank Open access to commercial and recreational fishing; DRTO Open is Dry Tortugas National Park open to recreational angling; and DRTO RNA is Dry Tortugas National Park Research Natural Area, a NTMR. From Smith et al. (2011a).

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, and expanded our survey domain to the SEFCRI region which runs north to Martin County. 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 reef fish visual census (RVC) is a collaborative multiagency reef fish monitoring efforts, conducted annually by a large and highly-skilled a team of 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 (Brandt et al. 2009; Smith et al. 2011a). This amazing team efforts completed successful 20-day biennial census in the Tortugas region 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. This unprecedented collaboration allowed the team to complete more than thousands of scientific dives annually, which greatly helps to further establish a baseline for the state of reef fish stocks and coral reef habitats in Florida's dynamic coral reef ecosystem.

By statistically comparing a current year's findings to previous baseline survey information collected, scientists can determine what effects no-take marine reserves are having on the productivity of exploited fisheries in the Tortugas and through the entire coral reef ecosystem. For example, if we look at mutton snapper spatial data we can see that the extent of occupancy markedly increased after implementation of the protected areas (between 1999-2000 and 2008-2010) [Figure 2]. We see that there are significantly more (and larger) fish in the two protected areas but not in the fished area where the number of large animals continued to decrease This phenomenon has been observed for a broad range of intensively exploited reef fish species.

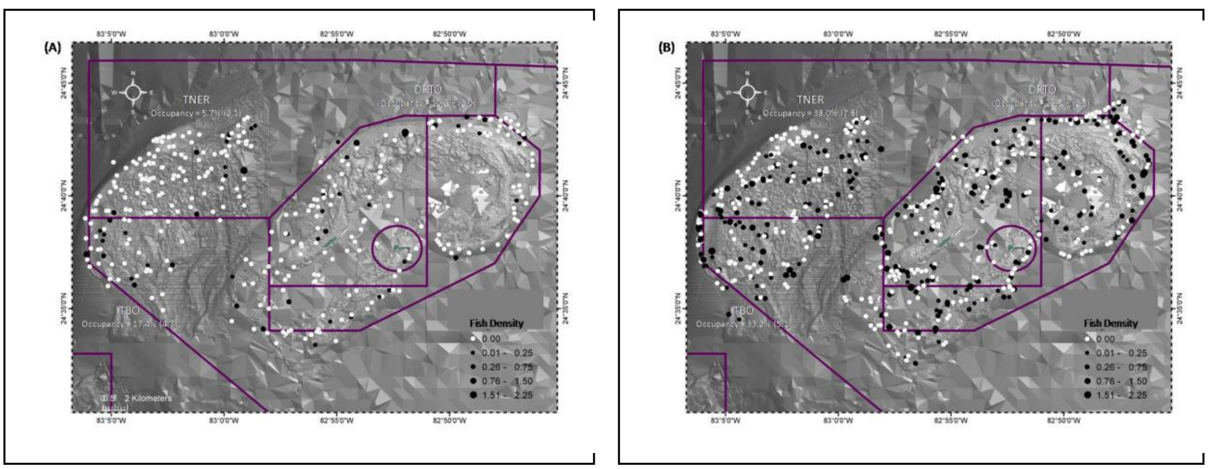

Figure 2: Spatial distribution of density for exploited life-stage mutton snapper (mean number of fish per SSU, 177 m^2) from Tortugas region visual surveys conducted in (A) 1999-2000; and, (B) 2008-2010. Each point is the average sample value within a PSU (200 by 200 m grid cell). Also shown are mean occupancy rates (SE) for three principal management zones. From Ault et al. (2013).

Overall, we have been very encouraged to see that exploited stocks have slowly begun to recuperate since the implementation of ‘no-take’ marine protected areas in the Tortugas 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.

However, a rather disturbing trend has been the apparent explosion of the exotic invasive Indo-Pacific lionfishes, *Pterois volitans* and *Pterois miles*, venomous members of the scorpionfish family (Scorpaenidae). These species have invaded and spread throughout much of the tropical and subtropical northwestern Atlantic Ocean and Caribbean Sea. These species are generalist predators of fishes and invertebrates with the potential to disrupt the ecology of the invaded range. Lionfishes have been present in low numbers along the east coast of Florida since the 1980s, but were not reported in the Florida Keys until 2009. We have documented the appearance and rapid spread of lionfishes in the Florida Keys using multiple long-term data sets that include both pre- and post-invasion sampling [Ruttenberg et al. 2013; Figure 3]. Our results are the first to quantify the invasion of lionfishes in a new area using multiple independent, ongoing monitoring data sets, two of which have explicit estimates of sampling effort. Between 2009 and 2011, lionfish frequency of occurrence, abundance, and biomass increased rapidly, increasing three- to six-fold between 2010 and 2011 alone. In addition, individuals were detected on a variety of reef and non-reef habitats throughout the Florida Keys. Because lionfish occurrence, abundance, and impacts are expected to continue to increase throughout the region, monitoring programs like those used in our studies will be essential to document ecosystem changes that may result from this invasion and how they may influence the performance of management measures like NTMRs.

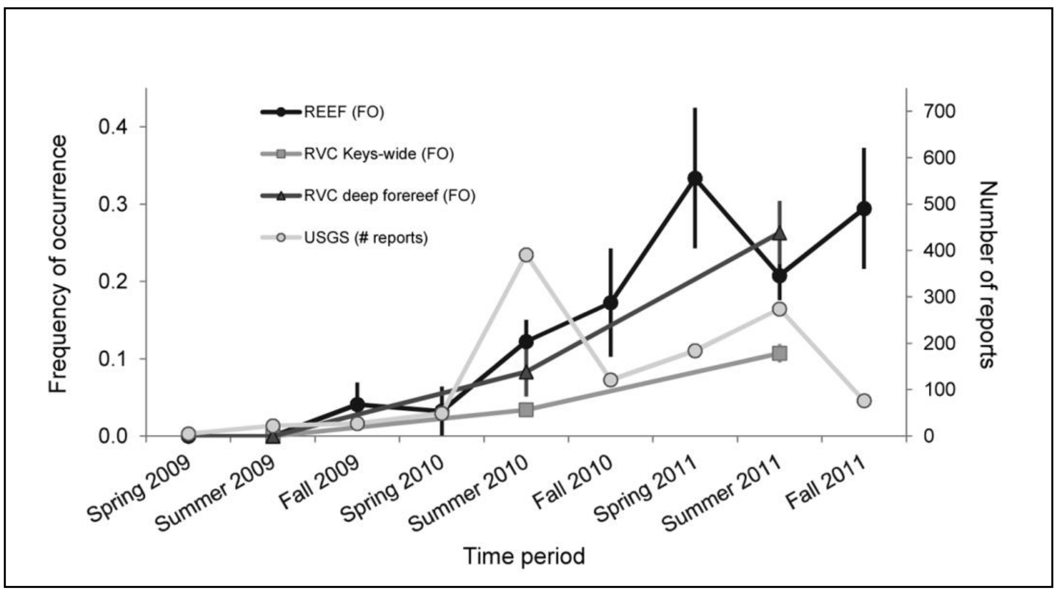

Figure 3: Frequency of occurrence (FO) and number of sightings of lionfishes in the Florida Keys from 2009 to 2011. REEF and RVC data are shown as frequency of occurrence [left axis (SE)], and USGS are number of reported lionfish sightings (reports, right axis). REEF and USGS data are show for three periods per year (spring: January–April; summer: May–August; fall: September–December). REEF sample sizes by time period are: 28, 226, 49 (2009); 31, 139, 29 (2010); 27, 159, 34 (2011). RVC data include estimates of frequency of occurrence for the entire Florida Keys (open circles), as well as the deep forereef (dark triangles), the habitat with the highest occurrence. RVC sampling occurs only during summer as indicated.

Figure 4: School of permit (*Trachinotus falcatus*) rising over a spectacular pinnacle reef in the Tortugas Ecological Reserve during an RVC monitoring survey expedition of the Dry Tortugas region (Smith et al. 2011; Ault et al. 2013).

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.

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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 Collaborators: B. Ruttenberg (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives**:** To provide continued reef fish and habitat monitoring in Florida's coral reef tract to assess population and habitat trends, fish-habitat associations, and ecosystem responses to natural events (e.g. hurricanes), 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**:** Employ a multi-agency (UM/CIMAS, NOAA/SEFSC, Florida Fish and Wildlife Commission FWC, and the National Park Service NPS), spatially-explicit, fishery-independent monitoring program 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. These efforts were extended and now include the entire reef tract up through Martin County. 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 enabling 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 is needed. Additionally, the sampling domain extended north through Martin County and additional agencies were added. 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 approximately 840 sampling sites, stretching from Miami to the Dry Tortugas. Another 226 sites were also completed between Miami/Dade and Martin Counties by a number of new partner agencies including, Broward County, CRCP, West Palm DEP, FWC Tequesta, Miami/Dade County and NSUOC. The ability to monitor the entire Florida reef tract, from Martin County to Dry Tortugas, 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.

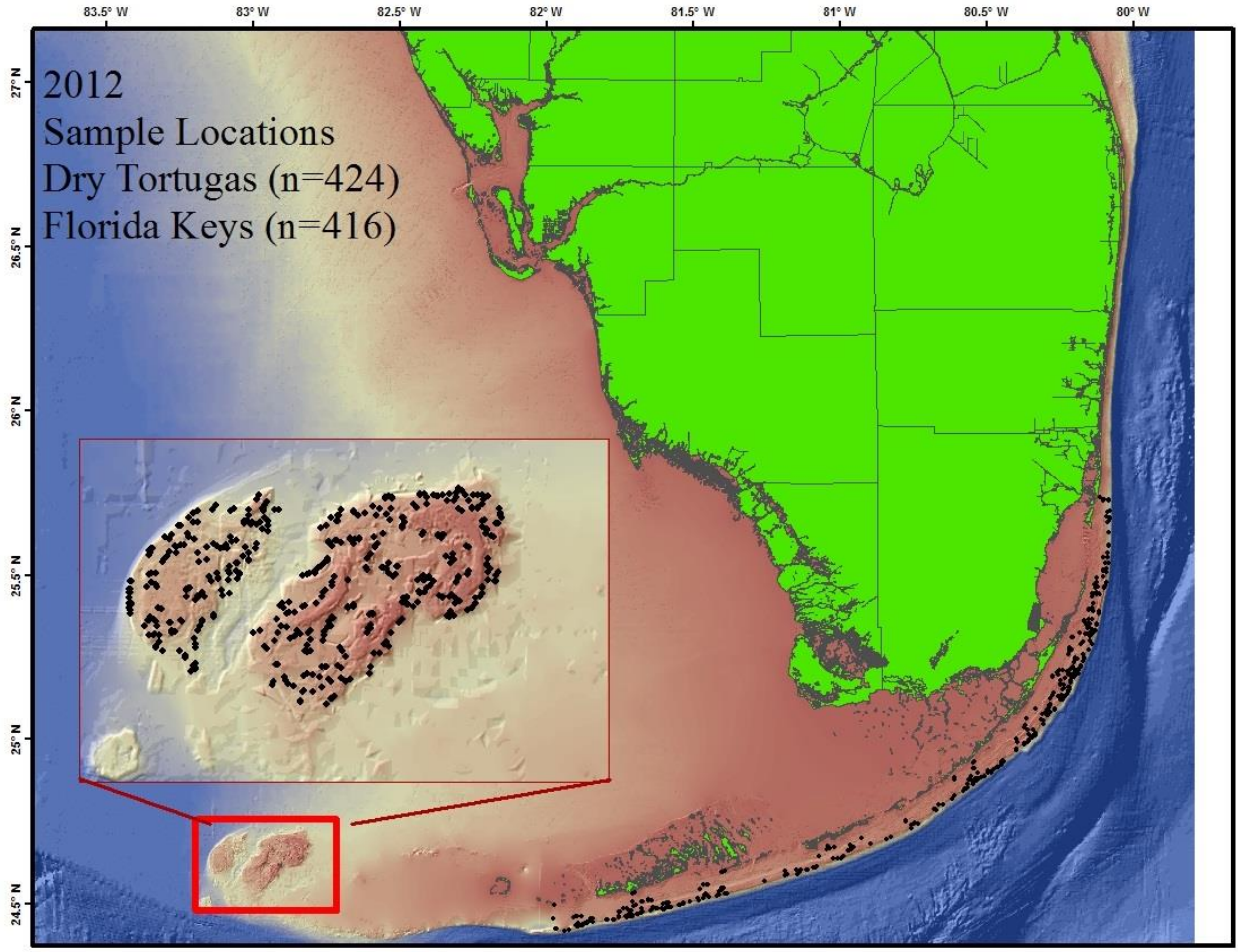

Figure 1: Sampling site locations for 2012 in the Florida Keys and Dry Tortugas

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.

Research Performance Measure: A total of 840 sampling sites (3193 individual dives) were completed in the summer and fall of 2012 along the Florida reef tract, including the Dry Tortugas. On completion of field sampling all QAQC procedures were completed and data readied for dissemination. All milestones were met and objectives completed.

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

Project Personnel: D. Burkepile and T. Adam (FIU)
NOAA Collaborators: B. Ruttenberg and M. Miller (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. Field studies will focus on behavioral and ecological patterns of grazing rates and grazing preferences in a suite of parrotfish species.

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: CRCP **NOAA Technical Contact:** Theo Brainerd

Research Summary:

Although the project technically started on June 1, 2011 the hired post-doc, Dr. Adam, began his tenure on the project on June 4, 2012. Thus, the main body of research was initiated less than 1 year ago. Dr. Adam is using a three-step approach to better understand the importance of parrotfish in maintaining coral communities and coral reefs. During year 1, Dr. Adam has begun a thorough review and synthesis of the existing literature and existing datasets that have examined the relationship between parrotfish, parrotfish grazing, and various measures of the status of coral populations and communities (e.g. 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. As part of this synthesis, the team, led by Dr. Adam, identified some of the critical gaps in our knowledge, and have begun preparing a manuscript describing these gaps. This manuscript is step one in the workplan, and will help guide scientists and funding agencies to target the information that is most critical to management that we currently lack. We expect to have a full draft of this manuscript by the end of June.

Step 2 is to begin conducting some of the field research to address the most critical of our knowledge gaps. This field research will begin during summer 2013, and will employ techniques in behavioral ecology to identify feeding preferences, grazing rates, and foraging ranges of as many of the reef-based parrotfish species as possible. These data will be used to determine the level of functional similarity that exists among different species, and to estimate the total impact of each species on the benthos. At a minimum, this work will target the larger parrotfish species (e.g. blue, midnight, rainbow, stoplight, redtail, yellowtail) and may include some of the smaller parrotfish (e.g. princess, queen, striped, redband).

Step 3 will be to complete the synthetic review of the relationship between parrotfish grazing, algae, and corals. We will include details of 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 also influence this relationship, and will be considered.

During year 2, we will produce a manuscript summarizing the results of the field study, as well as a comprehensive manuscript of the review.

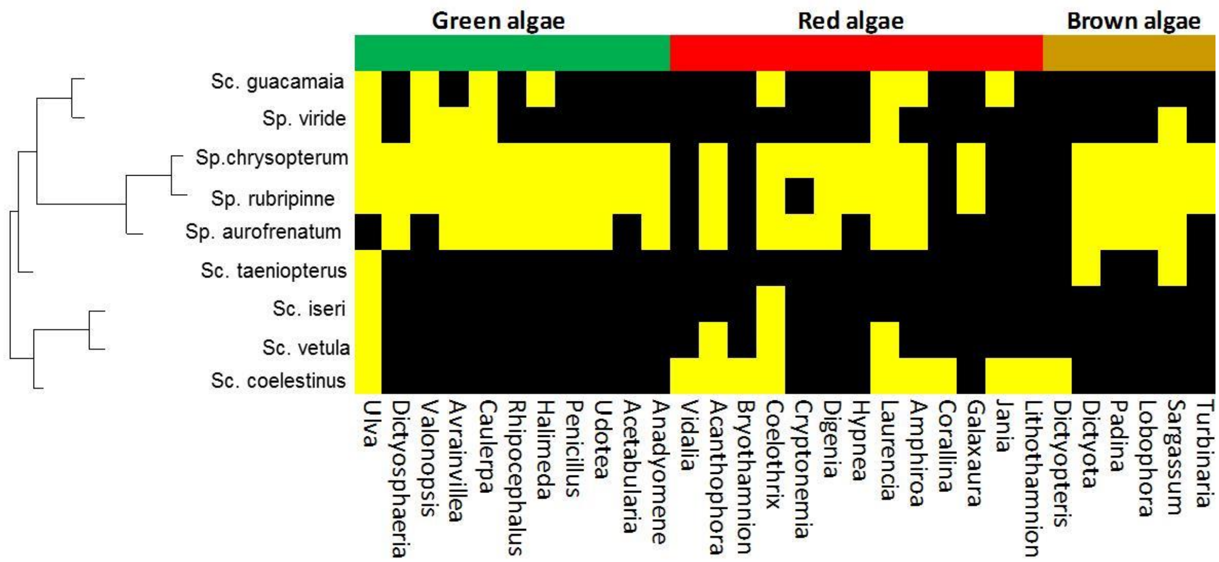

Figure 1: Diet overlap between nine species of reef-associated parrotfish. Parrotfish are clustered based on diet similarity, and yellow shading shows seaweed genera eaten by each species. Diets were determined through gut content analysis (Randall 1967) and feeding observations (Burkepile unpublished data). *Sparisoma chrysopterum*, *Sparisoma rubripinne*, and *Sparisoma aurofrenatum* feed on many species of green, red, and brown macroalgae. Their ability to remove large amounts of mature macroalgae makes them functionally important herbivores. *Sparisoma viride* and parrotfish belonging to the genus *Scarus* have more restricted diets. By scraping and excavating dead coral substrate while targeting algal turfs and endolithic algae, these parrotfish create suitable habitat for coral settlement.

Research Performance Measure: Although the project technically started on June 1, 2011, Dr. Adam began 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. The delays have pushed the end date back a full year. At the moment, the project is on track; we anticipate that the first manuscript will be ready for submission during fall 2013, and fieldwork plans are set for summer 2013. The final two manuscripts will be produced during the end of 2013 and 2014.

Gulf of Mexico Integrated Ecosystem Assessment

Project Personnel: G.S. Cook (UM/CIMAS)
NOAA Collaborators: C.R. Kelble (NOAA/AOML); M. Karnauskas, M. Schirripa (NOAA/SEFSC), P. Fletcher (NOAA/Florida Sea Grant)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives**:* To develop scientific products and analyses required to inform ecosystem-based approaches to management in the Gulf of Mexico.
***Strategy**:* To accomplish these objectives we are conducting integrated ecosystem-level risk assessments, developing methods for exploring trade-offs among multiple user-groups, and informing resource management decision-making to minimize risk to ecosystem services while bettering the sustainability and resilience of coastal communities.

CIMAS Research Theme:
***Theme 6**:* Ecosystem Management (*Primary*)
Theme 5: Ecosystem Modeling and Forecasting (*Secondary*)
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: OAR/AOML **NOAA Technical Contact:** Alan Leonardi

Research Summary:
People enjoy a broad spectrum of benefits from the marine environment, including seafood, opportunities for recreation and commerce, protection from storms, buffers to pollution, and energy sources. Because of these benefits, coastal communities are the fastest growing population centers in the nation, placing increased demands on these regions to sustain healthy and productive natural ecosystems, ultimately threatening the economic sustainability, health, and resilience of coastal populations and communities. In order to protect human communities inhabiting coastal regions it is necessary to develop ecosystem-based management approaches that protect and safeguard marine ecosystems and the services they provide.

The Gulf of Mexico (GoM) provides numerous ecosystem services by supporting recreational and commercial fishing industries, oil and gas production, tourism, and habitat for endangered species. While only five U.S. states (Texas, Louisiana, Mississippi, Alabama, and Florida) border the Gulf of Mexico, the footprint of the Gulf, through its linkages with upstream watersheds and communities, is much greater; 31 of 50 U.S. states comprise part of the Gulf of Mexico watershed. Clearly, sustaining the resilience of this marine ecosystem and the services it provides is vital to our nation and its economy.

To meet this need and understand how various pressures, both natural and anthropogenic, impact the ecosystem services provided by the Gulf we are working with multiple stakeholders to identify and develop ecosystem indicators for the GoM. Given the vast geographic scope of the region we started this process by leveraging existing partnerships within the South Florida region to begin a pilot project for developing the necessary ecosystem-based methods. As part of synergistic activities with those involved in the Marine and Estuarine Goal Setting for South Florida (MARES) process we developed a framework and methodology for quantifying how various pressures impacting the south Florida coastal environment influence critical ecosystem states such as coral reefs, seagrasses, and beach ecosystems (Figure 1). In turn we were able to determine how those ecosystem states impact ecosystem services.

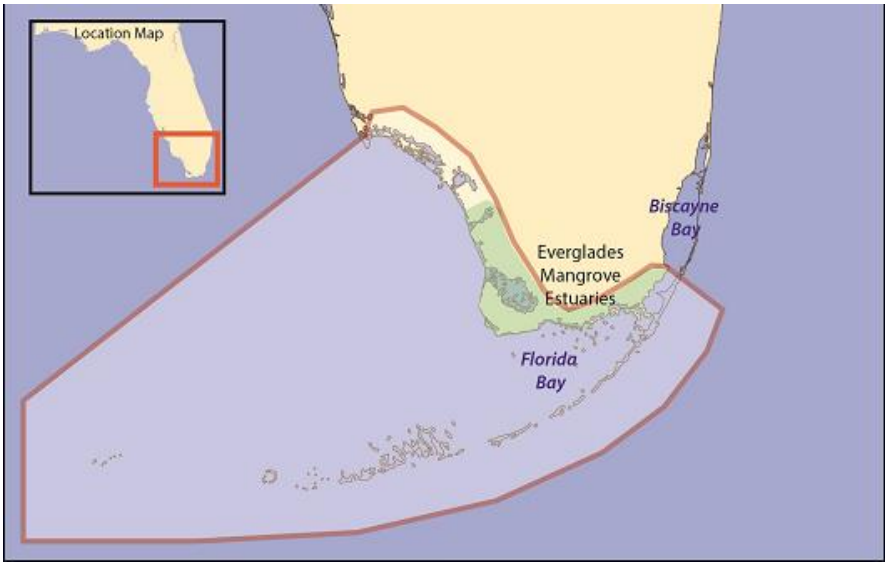

Figure 1: Map of South Florida coastal ecosystem. Outlined in red is the region taken into consideration when experts quantified interactions among *Pressures*, *States*, and *Ecosystem Services*. Inset shows location of study region relative to state of Florida, USA.

Through this pilot project we developed a framework for exploring the relative impact of various pressures to the sustainability of ecosystem services. Within the south Florida coastal marine ecosystem Freshwater Delivery has the greatest relative impact on ecosystem services; recreational fishing has the lowest relative impact on ecosystem services (Figure 2). These findings identify management trade-offs and suggest that within the south Florida coastal ecosystem management actions targeting relatively pervasive pressures, such as freshwater delivery, will have broad effects on ecosystem services, while management actions targeting smaller pressures, such as recreational fishing, will have direct and but focused effects within the coastal marine environment.

Research Performance Measure: All major research objectives are being met and are on schedule. Through our participation in the MARES process we developed a method for linking ecosystem pressures to ecosystem services and ranking relative risk to individual ecosystem states. Currently we are adapting these methods to the broader Gulf of Mexico marine ecosystem, and conducting risk assessments for the numerous ecosystem states comprising the GoM by quantifying the relative susceptibility and resilience of individual ecosystem states to perturbation.

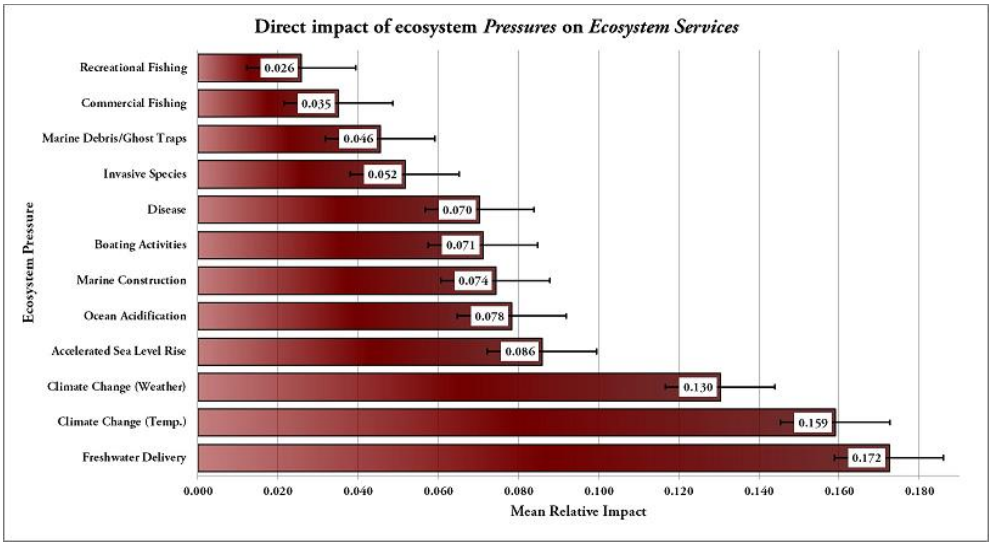

Figure 2: Relative direct impact of twelve ecosystem *Pressures* to eleven *Ecosystem Services* identified through the MARES process. Error bars represent standard error of mean impact of individual ecosystem *Pressures* across all eleven *Ecosystem Services*.

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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.

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* (*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:

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 (Fig.1) and (3) release them to study their horizontal and vertical movements for periods up to 180 days. This past year's deployments included white marlin off the coast of Aruba. 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 information that is not available through Argos transmissions. Examples of recent PSAT analyses include descriptions of Atlantic blue marlin and sailfish habitat use. Specifically, time spent at depth and temperature relative to the surface temperature. And, movement and habitat usage, with regard to dissolved oxygen levels 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 (Fig. 2).

Figure 1: Blue marlin along boat, showing attached pop-up satellite archival tag.

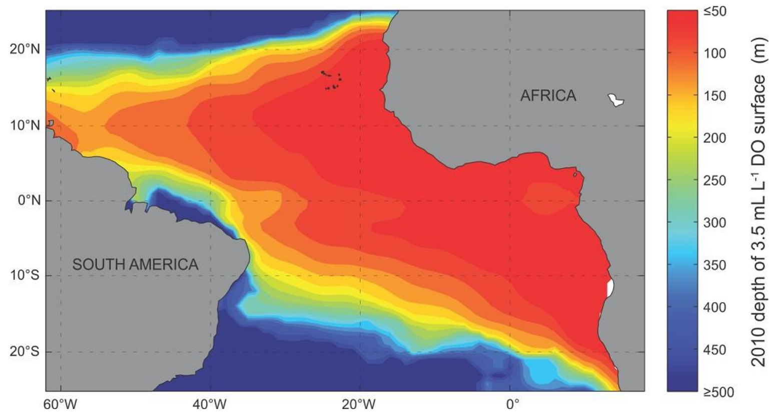

Figure 2: Oxygen minimum zone in the tropical Atlantic Ocean.

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 2012-13 are listed in the Publications section of this report. Others can be accessed at: http://www.sefsc.noaa.gov/fisheriesbiology.jsp.

Pelagic Fisheries Logbook Program

Project Personnel: A. Shideler and 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 collection and processing of pelagic longline vessel logbook data for entry in the Fisheries Logbook System (FLS) and pelagic individual fish weight data for entry in the Domestic Longline System (DLS), including efforts to improve compliance and quality control; and to provide data summaries and reports when requested by researchers, law enforcement, and vessel owners.

***Strategy*:** To identify potential sources of data error with colleagues and create programs that identify errors and inconsistencies; to communicate with commercial fishermen with regards to information required for logbook completion and permit renewal; to conduct regular audits to identify logbook compliance issues and to expand these audits to encompass a broader region.

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 has collected commercial pelagic longline fishing data from 1986 to present for fishing activities targeting various species in the Gulf of Mexico, Caribbean, and Atlantic Ocean. The fishery-dependent data collected by this program focus on Atlantic highly migratory species (HMS) including swordfish and tunas (Figure 1, Figure 2). Data collected by the program are used in annual reports to the International Commission for the Conservation of Atlantic Tunas (ICCAT) on overall landings, catch rates, and catch at size (Figure 3). Additionally, landings data are used in quota monitoring by the HMS division. Of particular interest to the program is the improvement of data flow and quality control to ensure that future assessments and analyses of the data facilitate accurate fishery management decisions. This program requires collaboration with individuals within the Sustainable Fisheries Division at NOAA Southeast Fisheries Science Center (SEFSC).

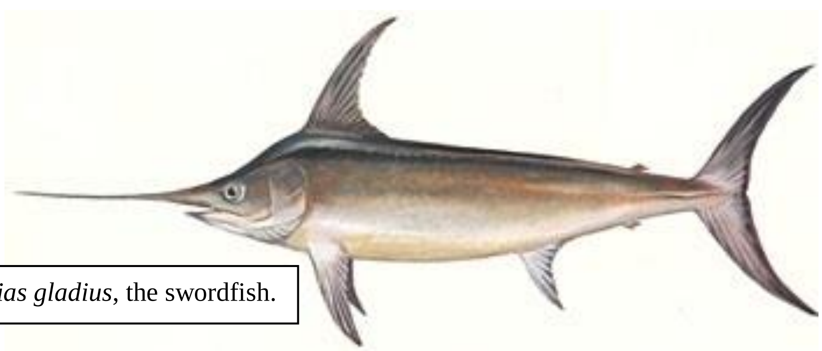

Figure 1: *Xiphias gladius*, the swordfish.

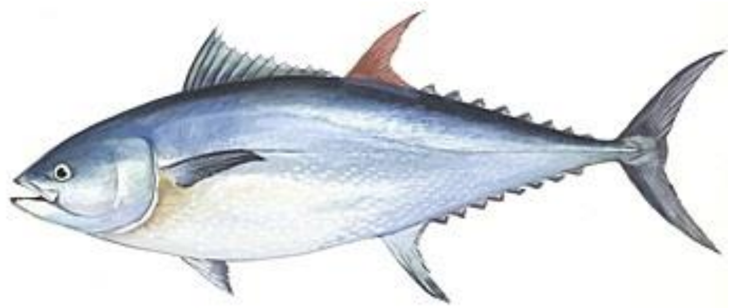

Figure 2: *Thunnus thynnus*, the Atlantic Bluefin Tuna (www.safmc.net)

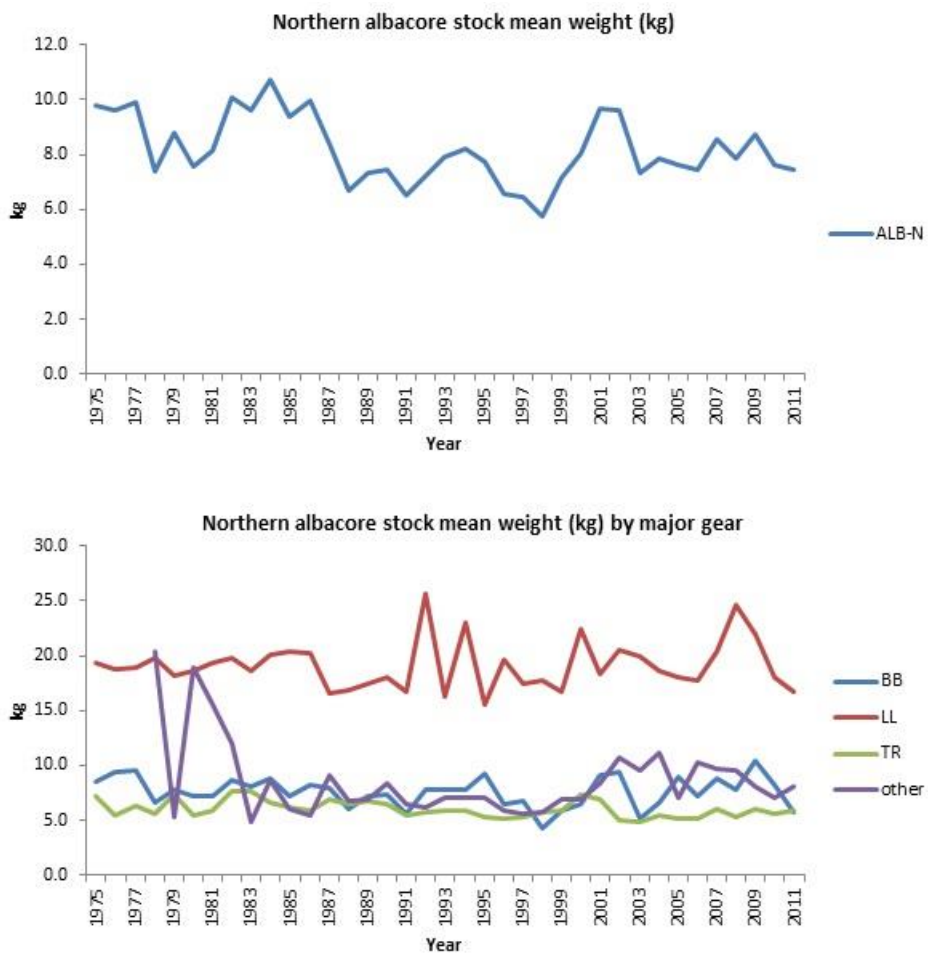

Figure 3: North Atlantic mean weights (in kg, overall and by major gear) obtained from the catch at size (CAS) (http://iccat.int/en/meetingscurrent.htm).

Research Performance Measure: All major objectives are being met.

Socioeconomic Impacts of the Gill Net and Trammel Net Ban in St. Croix (USVI)

Project Personnel: F. Tonioli (UM/CIMAS)
NOAA Collaborator: J. Agar (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To evaluate the socio-economic impacts of the gill and trammel net ban and buyback program in St. Croix (USVI).

***Strategy*:** In-person interviews were conducted with former gill and trammel net fishermen and other stakeholders that participated in the buyback and ban process. The surveys elicited information about their demographics, participation in the fishery, changes in fishing practices and their views about the biological, economic and social impacts of the ban. Likert scale responses were used to investigate whether the ban protected parrotfish populations, mitigated by-catch, and protected coral reefs. They were also used to probe whether the ban had impacted fishermen's ability to support themselves and their families, generated economic hardships to the local fishing community, and reduced user conflicts.

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: CRCP and SEFSC
NOAA Technical Contact: Theo Brainerd

Research Summary:

This project investigated the main socio-economic impacts caused by the gill and trammel net ban and buyback in St. Croix, U.S. Virgin Islands. The objective of the ban was to protect parrotfish populations and minimize by-catch and gear-habitat interactions whereas the intent of the buyback was to minimize the socio-economic hardship of the soon to be enforced net ban.

A preliminary assessment of the survey results revealed conflicting perceptions about the usefulness of the buyback since stakeholders' views were strongly influenced by the process and outcome. Predictably, net fishermen were the most disaffected user group because it took away their most profitable fishery without adequate compensation. While this sentiment was shared by several resource managers; as a group, they believed that they did their best with the available landings information and buyback funds. Many members of the environmental, diver, charter and resource manager groups believed that the process had been fair since it was the result of a lengthy, consultative process. A few members of the environmental, diver, charter community also believed that the process had been fair because fishermen had received some minimum level compensation to transition to other gears. Witnesses to the buyback process indicated that fishermen were more concerned with the ban than with the buyback itself because of the adverse impact of their livelihoods. Fishermen believed that resource managers had their mind set on the ban and did not adequately consider the use of seasonal closures or other sources of fisheries management.

The survey also found that overwhelmingly net fishermen believed that the net ban had adversely impacted the profitability of their fishing operations. They offered three main reasons for their dissatisfaction. First, nets were substantially more productive than other fishing gears; hence, when the ban became effective, parrotfish landings and the associated earnings decreased significantly. Fishermen reported that their revenues and landings decreased by 45% and 56% respectively. Second, the net prohibition forced them to make substantive investments in alternative fishing gears, especially traps. Fishermen pointed out that the buyback funds received were insufficient to transition to other gears. Moreover, many reported that they could not afford to take on additional loans to purchase materials (e.g., wire, ropes, buoys) and fishing equipment (e.g., spear guns, scuba) to stay in business since they already held loans for the house, truck and boat. Third, the new gears were not only less productive but also more expensive to operate and maintain. A number of fishermen stated that setting up and running their operation had become more costly because they had to venture further out. They stated that the duration of their fishing trips (measured in hours) had increased by 22%. Finally, fishermen reported that the lower landings and profits had made it harder to eke out a living for them and their crews. Only five of the original nine net fishermen that were bought out remained as owner operators.[1] Also, fishermen reported that the number of crew employed decreased by 50%.

Crucian Gillnet (Kojis, 2004)

Research Performance Measure: This study met the original objectives of the proposal. However, the sampling protocol had to be modified. The original plan was to sample all 44 documented gill and trammel net fishermen (35 gillnet and 9 trammel net fishermen) which were identified in the 2003 U.S. Virgin Islands census of commercial fishermen (Kojis, 2004). However, while conducting out the fieldwork, DFW (Department of Fish and Wildlife) and CFMC (Caribbean Fishery

[1] Two of them reported that they had begun fishing on full-time basis for others. A third one became a part-time fisherman who also worked in construction to eke out a living. Oddly, two of these former owner operators began fishing for a former net fisherman who participated in the buyback. The fourth fisherman no longer lived on the island.

Management Council) liaisons suggested that the size of our target population was high because many fishermen had misreported the gears they actually used or owned to pre-empt future regulations. Our liaisons suggested that about half of our identified target population were bona fide net fishermen. Therefore, we ended up interviewing 8 of the 9 net fishermen that participated in the buyback (9^{th} fisherman left the island), and 9 other bona fide former net fishermen. Key members of the resource management, environmental, diving and charter community were surveyed opportunistically based on the recommendations of our liaisons.

RESEARCH REPORTS

THEME 7: Protection and Restoration of Resources

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: 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 7**:** Protection and Restoration of Resources (*Primary*)
Theme 5**:** Ecosystem Modeling and Forecasting (*Secondary*)
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: 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 – Feb. 2013 and includes water quality data from 71 quarterly sampling events, initially at at 205 stations and at 11 stations since Nov 2012, 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.

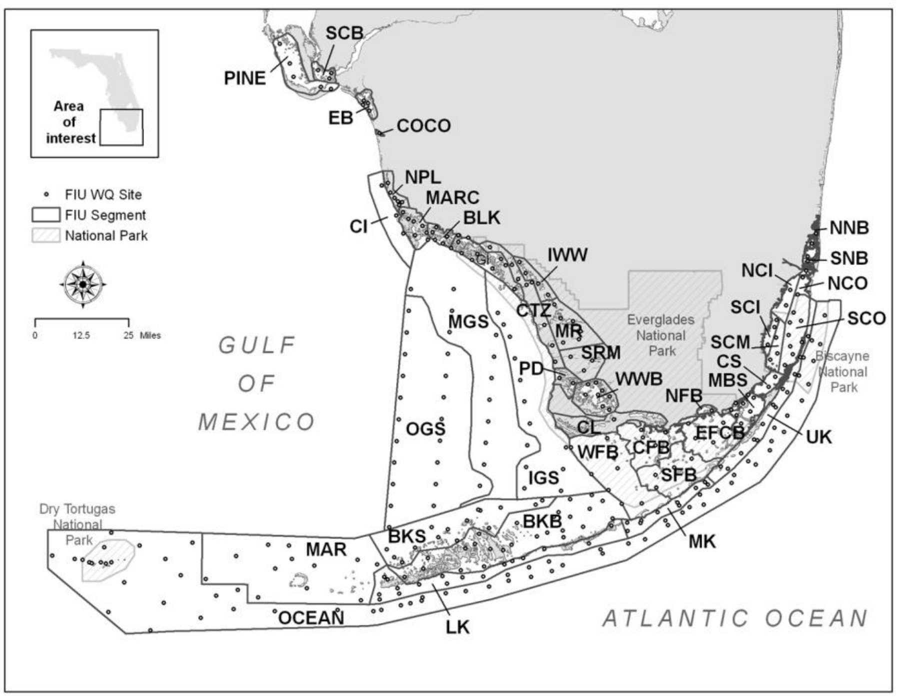

Figure 1: Sampling sites in the Florida Keys National Marine Sanctuary and the SW Florida Shelf. Segments: OCEAN=Offshore; MAR=Marquesas; LK=Lower Keys; MK=Middle Keys; UK=Upper Keys; BKS=Back Shelf; BKB=Back Bay; OGS=Outer Shelf; MGS=Middle Shelf; IGS=Inner Shelf.

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 for the previous report (2012). We have obtained the original logs from the RV Bellows and final corrections were performed.

Fluorescent Hydrocarbon Analysis Relating to the Deepwater Horizon Oil Spill - Nancy Foster Cruise

Project Personnel: P.G. Coble (USF)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To improve in situ detection and quantification of oil contaminants in seawater, especially at levels of minimum detection.

***Strategy*:** To analyze samples collected by NOAA during the R/V Nancy Foster cruise, and additional samples of interest, using excitation-emission matrix (EEM) spectroscopy to determine concentration and optimal wavelengths for in situ instrument design.

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

Research Summary:

The response to the Deepwater Horizon Oil Spill involved numerous field investigations to determine the distribution and fate of the oil and its byproducts. One of the primary technologies for spill detection throughout the water column is in situ fluorometry. Several off the shelf (OTS) in situ fluorometers were used by US Coast Guard, NOAA, EPA, and other researchers for oil detection, however, these instruments are only capable of measuring fluorescence in fixed bands of excitation and emission and the "right" wavelengths for detection of oil vary with degree and type of weathering. All of these instruments also measure naturally occurring components in seawater (colored dissolved organic matter (CDOM) and proteins), and they require proper calibration for comparison of results from different investigations. Our technique of excitation-emission matrix spectroscopy (EEMS) provides the level of detailed information required to properly evaluate the oil tracking efforts and to provide researchers and regulators

Twelve unfiltered water samples plus duplicates collected at four stations during the R/V Nancy Foster Cruise NF1013 in July 2010 to the West Florida Shelf were analyzed using a Horiba Fluoromax 2. Unfiltered water samples were acidified to pH=2.0 with 10% HCl and stored refrigerated for up to two weeks prior to analysis in the laboratory. Figure 1 shows fluorescence intensity of the oil fluorescence (at Ex/Em = 225/330nm) and background CDOM fluorescence (Ex/Em = 350/460nm). The highest value for CDOM at the surface at station 73 was associated with a low salinity value of 25.52, and thus likely contained some CDOM from coastal waters. Oil fluorescence was highest at the surface and at depths between 1000 and 1200m. Overall, concentrations of oil observed in these samples were low to moderate. Although there was no correlation between oil fluorescence and total aromatics as measured by chromatography, the sample with highest oil fluorescence also had the highest concentration of total aromatics, 265 ng/L.

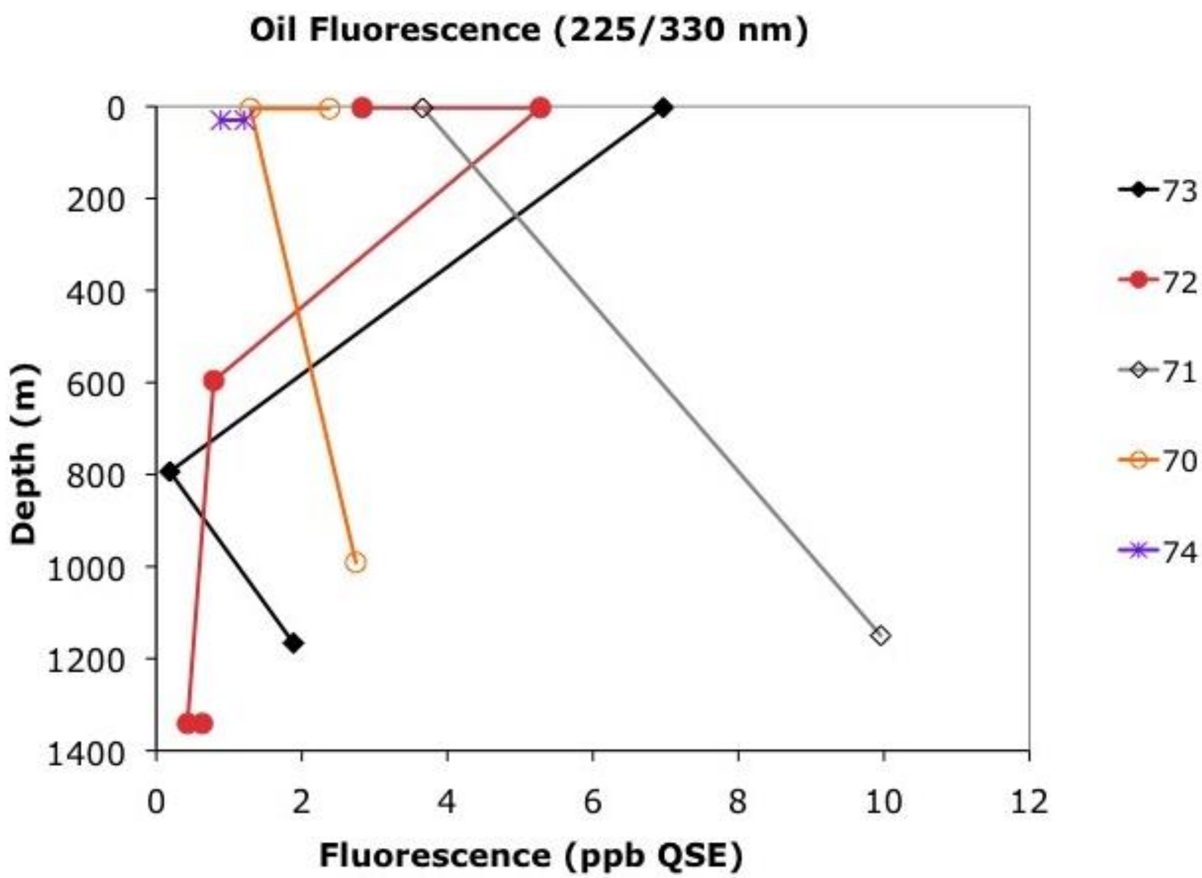

Figure 1: Fluorescence intensities for oil (at Excitation = 225 nm and emission = 330 nm) and colored dissolved organic matter (CDOM; at excitation = 350 nm and emission = 460nm) plotted as a function of depth for all samples analyzed from the R/V Nancy Foster Cruise NF1013 in July 2010. High CDOM at 0 m at station 73 is likely of coastal origin, with an observed value for salinity of 25.52.

Fluorescence contour plots are shown in Figure 2 for a sample containing only natural background levels of CDOM (top) and for a sample contaminated by oil (bottom). Although the level of oil contamination is fairly low, the wavelengths at which maximum fluorescence occurs is distinctly different and typical of the Macondo 232 crude oil.

Research Performance Measure: All work was successfully completed, however only 12 samples were sent to our lab for analysis. None of these had more than moderate concentrations of oil contamination, and results were inadequate for a research publication. Results will be incorporated with results from other field studies performed during the DWH incident into a PhD thesis that describes distribution of the spill in subsurface waters of the Gulf of Mexico and describes best measurement practices (Abercrombie, expected Spring 2013).

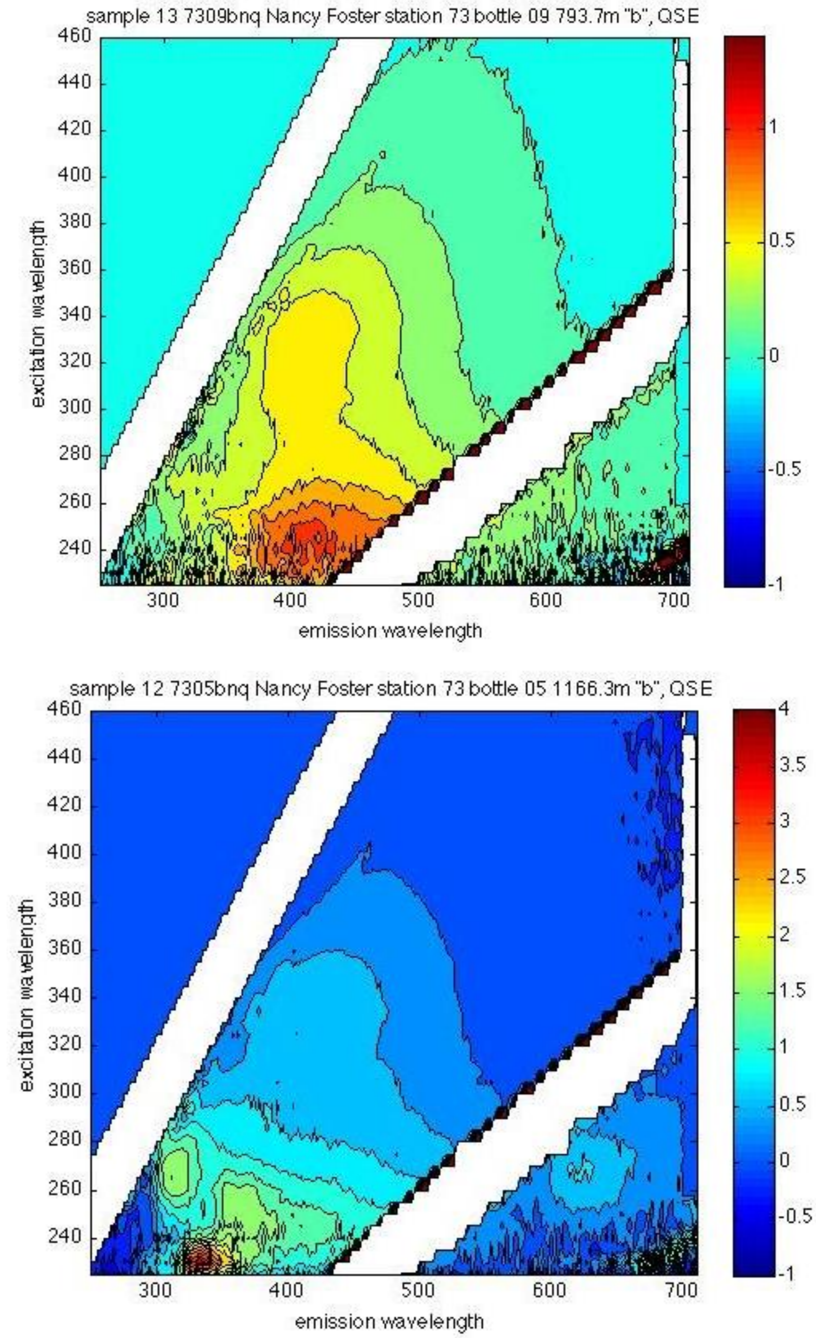

Figure 2: Excitation-emission spectra collected at Sta. 73 during the R/V Nancy Foster Cruise at 793 m showing no oil (CDOM only) and 1166m showing oil contamination. Note both spectral and concentration differences between the two samples.

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
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:

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 and temperature influences on growth and survival of pink shrimp postlarval and early juvenile stages (see CIMAS Report 2011 for description). A block 3 x 3 factorial design was used to compare performance (growth, survival, and biomass production) of these life stages under different treatments of water temperature (22, 27, 32 ^{o}C) and salinity (15, 35, 55 ppt). Subjects were taken from a cohort of shrimps obtained from a single spawning event. Analysis of data clearly demonstrated that temperature was

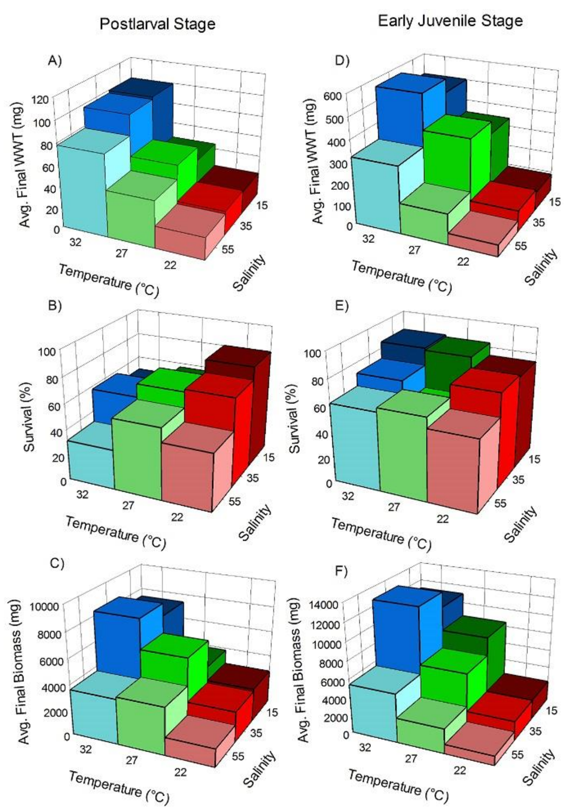

Figure 1: Histograms depicting average final wet weight (WWT) (mg), survival (%), and 824 average final biomass (mg) within each temperature and salinity treatment for Postlarval 825 (A, B, and C, respectively) and Early Juvenile (D, E, and F, respectively) experimental 826 stages.

more influential on growth and survival than salinity (Fig 1). Biomass production increased significantly with temperature during both postlarval and early juvenile stages, whereas the response to salinity became significant in the early juvenile stage when hypersalinity (55 salinity) depressed growth. Hypersalinity (55 salinity) had a detrimental effect on all performance outcomes; however performance outcomes in 15 and 35 salinities were comparable. This demonstration of deleterious outcomes for pink shrimp under hypersaline conditions is of great significance for CERP and provides further evidence that hypersaline events in western Florida Bay negatively impact pink shrimp growth, survival, and, ultimately, biomass productivity.

Research Performance Measure: The objectives already have been accomplished; results from this laboratory investigation regarding salinity influences on growth and survival were submitted to the peer reviewed "Journal of Shellfish Research". The manuscript is currently in review.

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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*:** To assist the Southeast Fisheries Science Center (SEFSC)'s Protected Resources and Biodiversity Program in management and conservation of protected species under the Marine Mammal Protection Act (MMPA). To support the Marine Mammal Health and Stranding Response Program (MMHSRP) in stranding responses in the southeast region of the United States and ensure data quality in compliance with the Data Quality Act. To support the investigation of Marine Mammal Unusual Mortality Event (UME) in data management and sample tracking under Chain of Custody procedures during Natural Resource Damage Assessment (NRDA) studies associated with the Deepwater Horizon Oil Spill in the Gulf of Mexico.

***Strategy*:** To assist in project planning, data and sample management, and support field work during NOAA research cruises and small boat operations. To validate historical stranding data (1996 to 1998) working with the SEFSC staff and stranding network members to implement effective data auditing and correction. To respond and coordinate response actions during cetacean strandings dead or alive in the Southeast Region and assist with marine mammal necropsies at the SEFSC. To support the investigation of Marine Mammal Unusual Mortality Event (UME) performing data management, auditing and photographic evidence handling. To maintain file collections of samples shipped under Chain of Custody procedures collected during 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 research activities I supported at the SEFSC's Marine Mammal Program relate to two main divisions of investigation within the program: 1- Marine Mammal Population Assessments and 2- Health and Stranding Response. Population surveys were conducted in both near shore and offshore waters of the Gulf of Mexico and U.S. Atlantic coasts. I participated in an offshore survey onboard the NOAA Ship Gordon Gunter dedicated to biopsying and satellite tagging sperm whales (*Physeter macrocephalus*) from the little known southeastern Gulf of Mexico population. During small boat assignments, I assisted in coordinating a bottlenose dolphin (*Tursiops truncatus*) photo-identification (photo-ID) project in Biscayne Bay, FL and also supported a photo-ID effort in Pamlico Sound, NC. During the course of stranding actions, I responded to marine mammal strandings in the US southeast region and assisted in necropsies and sample management at the SEFSC. In addition, I validated historical stranding data, implementing effective data auditing and correction in compliance with the Data Quality Act.

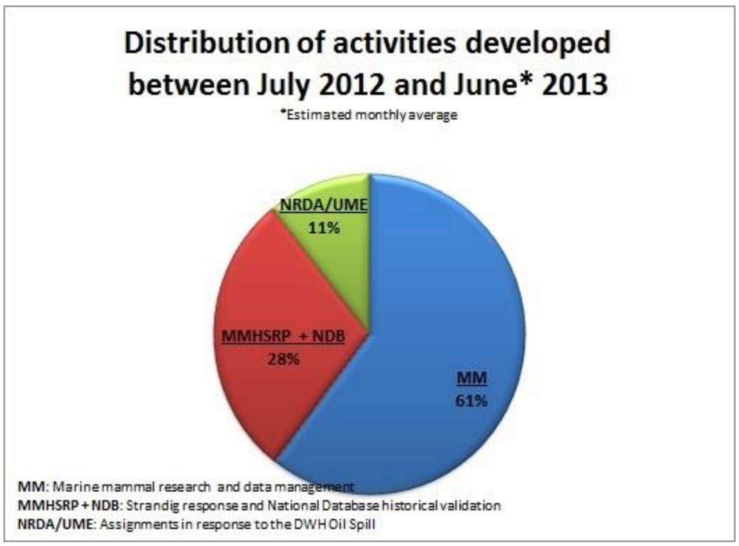


Figure 1: Distribution of activities developed between July 2012 and June 2013_31May13.

Concomitant to the SEFSC Marine Mammal Program's mission, the investigation of the Deepwater Horizon Oil Spill continues highly active. In the past year, I have managed data coming from the Gulf of Mexico in response to the oil spill such as photographic evidence and Chain of Custody files for samples collected during NRDA studies.

Research Performance Measure: all objectives were completed on time.

- Worked as a marine mammal observer, data and sample manager, and photographer during the dedicated sperm whale research cruise in the Gulf of Mexico, totaling over 60 sea-days.
- Managed data and samples collected in past NOAA cruises.
- Assisted in writing official documents such as permit renewals and internal reports.
- Assisted in project planning for the Biscayne Bay Photo-ID project also working as a photographer during field efforts.
- Worked as a photographer during a dedicated photo-ID effort of bottlenose dolphins in North Carolina.
- Audited and validated historical stranding data from 1998.
- Managed the photographic evidence for over 670 stranded cetaceans during the UME in the Gulf of Mexico.
- Maintained Chain of Custody files (electronic and hard copies) for nearly 4000 samples collected during NRDA studies in the Gulf of Mexico.
- Completed trainings required for different projects within the program (DOT/IATA hazardous material shipping training).

Coastal Fisheries Logbook Program

Project Personnel: J. Diaz (UM/CIMAS)
NOAA Collaborator: D. Gloeckner, M. Judge, N. Baertlein and J. Hall (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Theme:
***Objectives*:** To determine the fishing effort of federally-permitted commercial fishers in the South Atlantic and Gulf of Mexico.
***Strategy*:** To collect fisheries dependent catch data by providing trip report logbooks to all federal South Atlantic Snapper/Grouper, Gulf of Mexico Reef Fish, Shark, King Mackerel, Spanish Mackerel, and Dolphin/Wahoo permit holders in the U.S. Atlantic and Gulf of Mexico.

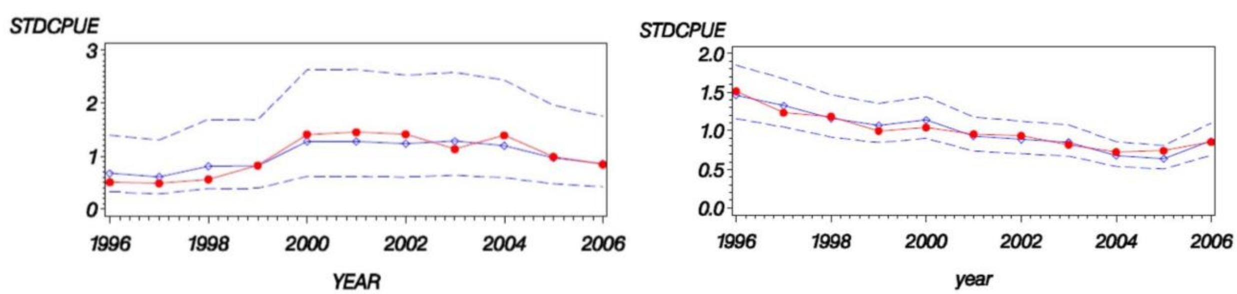
CIMAS Research Theme:
***Theme 7*:** Protection and Restoration of Resources

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

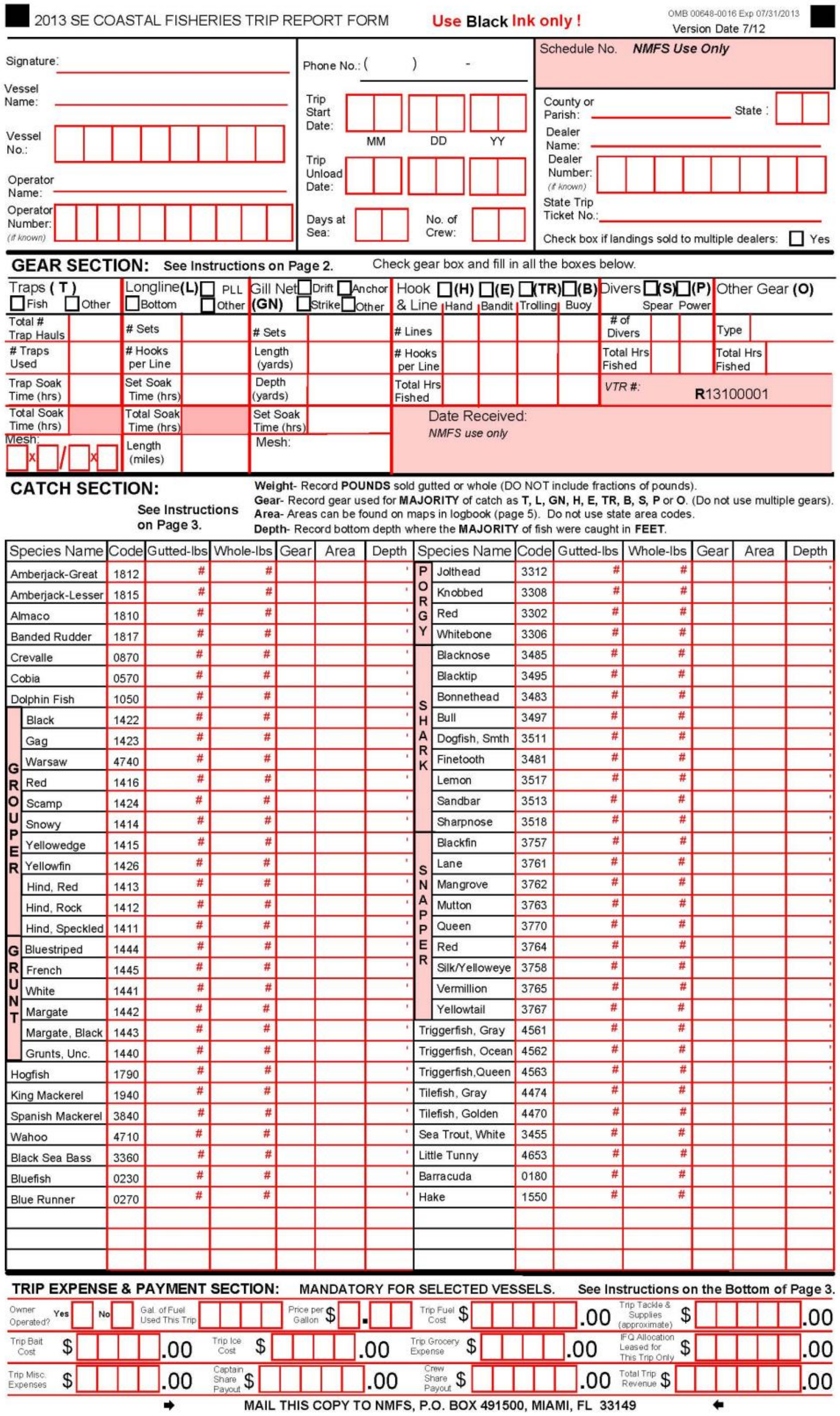
NOAA Funding Unit: NMFS/SEFSC **NOAA Technical Contact:** Theo Brainerd

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 Gulf of Mexico red grouper utilized a indices of abundance created from logbook data.

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



Figures 1 and 2: Recent SEDAR 31 (SouthEast Data, Assessment, and Review) assessments of red snapper utilized indices of abundance created using logbook data. Figures 1 (left) and 2 (right) shows figures of standardized indices for vertical line gear in the eastern and western Gulf of Mexico.



2013 SE COASTAL FISHERIES TRIP REPORT FORM **Use Black Ink only !** OMB 00648-0016 Exp 07/31/2013 Version Date 7/12

Signature: ______ Phone No.: ( ) - ______ Schedule No. *NMFS Use Only*

Vessel Name: ______ Trip Start Date: MM DD YY County or Parish: ______ State :

Vessel No.: ______ Dealer Name: ______

Operator Name: ______ Trip Unload Date: Dealer Number: (if known)

Operator Number: (if known) Days at Sea: No. of Crew: State Trip Ticket No.: ______

Check box if landings sold to multiple dealers: ☐ Yes

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

Traps (T) ☐Fish ☐Other		Longline(L) ☐PLL ☐Bottom ☐Other		Gill Net ☐Drift ☐Anchor ☐Strike ☐Other (GN)		Hook & Line ☐(H) Hand ☐(E) Bandit ☐(TR) Trolling ☐(B) Buoy	Divers ☐(S) Spear ☐(P) Power		Other Gear (O)	
Total # Trap Hauls		# Sets		# Sets		# Lines	# of Divers		Type	
# Traps Used		# Hooks per Line		Length (yards)		# Hooks per Line	Total Hrs Fished		Total Hrs Fished	
Trap Soak Time (hrs)		Set Soak Time (hrs)		Depth (yards)		Total Hrs Fished	*VTR #:*	**R**13100001		
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 3: 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.

Indicators for Water Management & Ecosystem Restoration of South Florida Estuaries

Project Personnel: D.J. Die, I. Zink (UM/RSMAS)
NOAA Collaborators: J. Browder and J. Serafy (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To provide science input to water-management-related ecosystem restoration projects in south Florida that will affect the volume, timing, and distribution of freshwater inflow to estuaries.
***Strategy*:** To create a baseline characterization of the present-day sportfish and prey-base epifauna, determine species relationships with salinity, address fundamental ecological questions about indicators, and formulate performance measures and targets for assessing the effect of water management changes on Florida's southernmost estuarine and nearshore ecosystems.

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:
Previous efforts to better understand temperature and salinity relationships with growth, survival, and biomass productivity of the pink shrimp *Farfantepenaeus duorarum* (Comprehensive Everglades Restoration Plan indicator species) have focused on controlled, laboratory studies (Zink et al. In Review, CIMAS Reports: Criales et al. 2011, Criales et al. 2013). These studies were extended to field conditions by conducting an *in-situ* mesocosm cage experiment with early juvenile pink shrimp inhabiting two Everglades National Park study sites with substantially different salinity regimes: western Florida Bay (Johnson Key Basin, JKB) and Whitewater Bay (WWB). This study investigated impacts of natural conditions at each study site on transplanted shrimp vs. resident shrimp by examining pink shrimp production, viewed as the product of survival and growth. The project explored the possible effect of pre-transfer acclimation to the salinity regime of the source system. This *in-situ* study followed a laboratory study (CIMAS Report: Criales et al. 2012) that suggested the tagging procedure did not negatively affect subsequent performance.

In May/June of 2012, a pilot *in-situ* mesocosm study was conducted to obtain preliminary results and verify practicality of study procedures. Pink shrimp exponential rate of wet weight (WWT) growth (mean ± 95% CI: 0.0100 ± .0037) was ~10% of those obtained under similar laboratory temperature and salinity conditions. This result supported our plan to provide supplemental feeding in the cages. In Sept. 2012, a full study of 4 experimental treatments, each with 4 replicates, resulted in deployment of 8 cages per study site (JKB and WWB) for a total of 16 cages within the study. Within each site, cages were randomly assigned to shrimp from that source site (Home Shrimp, n=4) or from the alternate source site (Away Shrimp, n=4). When weather conditions allowed, mesocosm cages were visited daily over the 8 day study to provide supplemental feeds (~25% tagged shrimp biomass d^{-1}), record water quality parameters, and clear cages of debris (primarily accumulation of drift algae). A YSI 600XLM data-logger deployed at each study site recorded temperature, salinity, depth, and pH at 15 min intervals. Mean ± 95% CI of temperature (WWB: 29.41 ± 0.079 °C; JKB: 29.63 ± 0.12 °C) was similar between sites ($P > 0.05$) while salinity (WWB: 5.75 ± 0.012 ppt; JKB: 36.20 ± 0.032 ppt), pH (WWB: 7.84 ± 0.005; JKB: 8.42 ± 0.009), and dissolved oxygen (mg l^{-1}) (WWB: 4.71 ± 0.52 mg l^{-1}; JKB: 7.20 ± 1.81 mg l^{-1}) significantly differed ($P < 0.05$) between sites.

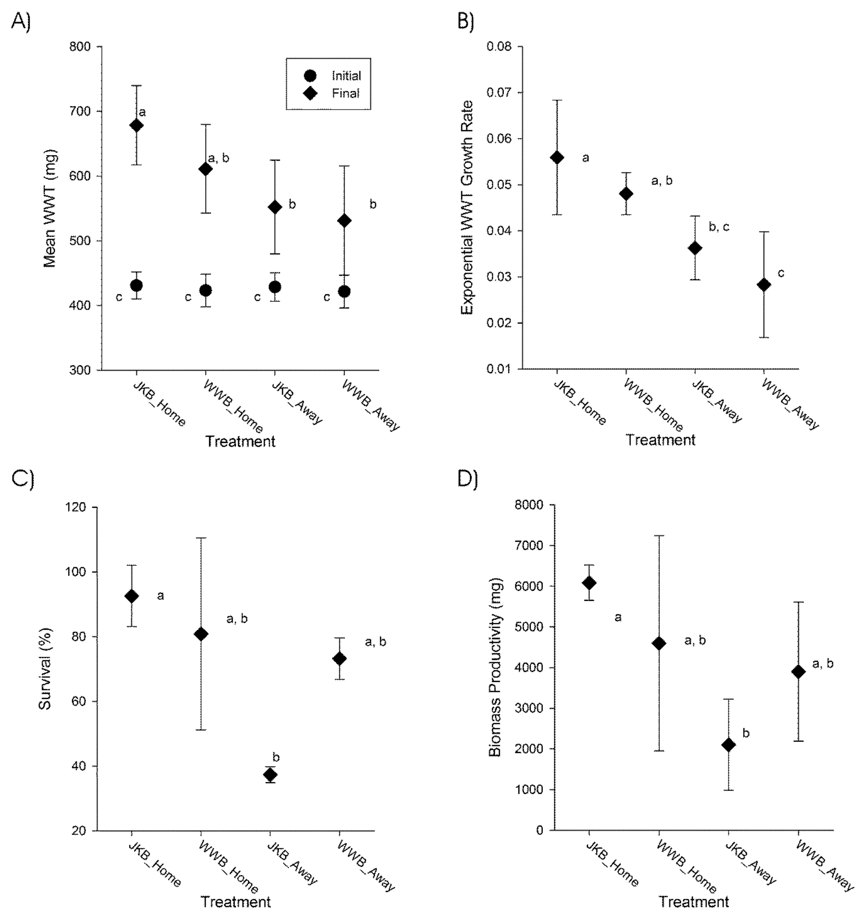


Figure 1: Plots of mean ± CI of A) mean final wet weight (mg), B) exponential wet weight growth rate, C) back-transformed survival (%), and D) biomass productivity (mg) grouped by the four treatments of the full *in-situ* mesocosm caging study: site source (Johnson Key Basin – JKB; Whitewater Bay – WWB) and Home or Away within study sites (i.e. transplant shrimps). Letters denote statistical similarity between treatments within each plot.

Treating each cage as a primary sampling unit, four performance outcome metrics were analyzed: 1) mean individual final WWT (mg), 2) exponential WWT growth rate, 3) survival (arcsine transformed proportion), and 4) biomass productivity (mg) (i.e. total biomass of surviving shrimp, thus incorporating survival and growth as one metric). Contrary to previous laboratory work with similar sized shrimps from the same sources and salinity regimes (Criales et al., CIMAS Report 2012), no significant differences between Home Shrimp of each study site were detected ($P > 0.05$; Fig. 1). However, relative to WWB, a trend for higher performance was observed for JKB Home treatment replicates (Fig. 1). Possibly the study duration was not sufficient to allow accumulation of statistically significant differences or sample size limited statistical power. Significant differences ($P < 0.05$; Fig. 1B) in exponential WWT growth rates were noted between Home and Away treatments within each source of shrimp (JKB and WWB). WWB Away Shrimp growth rates did not statistically match those of JKB Home Shrimp, suggesting that factors other than a simple transplant to conditions expected to be more optimal (JKB salinity regime) based upon previous work (Browder et al. 2002). This could be related to general lack of acclimation to receiving physiological conditions affecting the study outcomes. At the JKB site, JKB Home shrimp growth rates were significantly higher than WWB Away ($P < 0.05$); however, at the WWB site, WWB Home and JKB Away shrimp growth rates did not statistically differ ($P > 0.05$) (Fig. 1B). Comparison of survival between treatments revealed significant differences between JKB Home and Away treatments but not between WWB Home and Away treatments (Fig. 1C). These non-symmetrical survival and growth results suggest that, over the salinity ranges of this study, survival was more influenced by direction of salinity change (high to low vs. low to high) than by source (i.e., home)salinity. Similar patterns can be observed in biomass productivity (Fig. 1D), whose values seem to be dominated by survival in this study. Statistical analysis of study data is currently ongoing. Future analysis of study data will compare site submerged aquatic vegetation and epifaunal communities between sites, relationships with potential prey densities, size-specific shrimp growth, and submerged aquatic vegetation and faunal communities inside cages relative to those outside of cages. The full study will be replicated in the Fall of 2013 provided comparable salinities prevail.

Research Performance Measure: The objectives have been partially accomplished; results from field investigations regarding salinity influences on growth and survival as well as ecosystem differences between these study sites continue to be finalized. After the continuation of the study in the Fall 2013, the finalized data will be presented in a publication to be submitted to a peer reviewed journal.

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

Project Personnel: A. Gleason (UM/CIMAS)
Other Collaborators: G.T. Kellison and C. Taylor (NOAA/Beaufort, NC Laboratory); A. Acosta (FL FWCC)

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: NMFS/SEFSC **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.

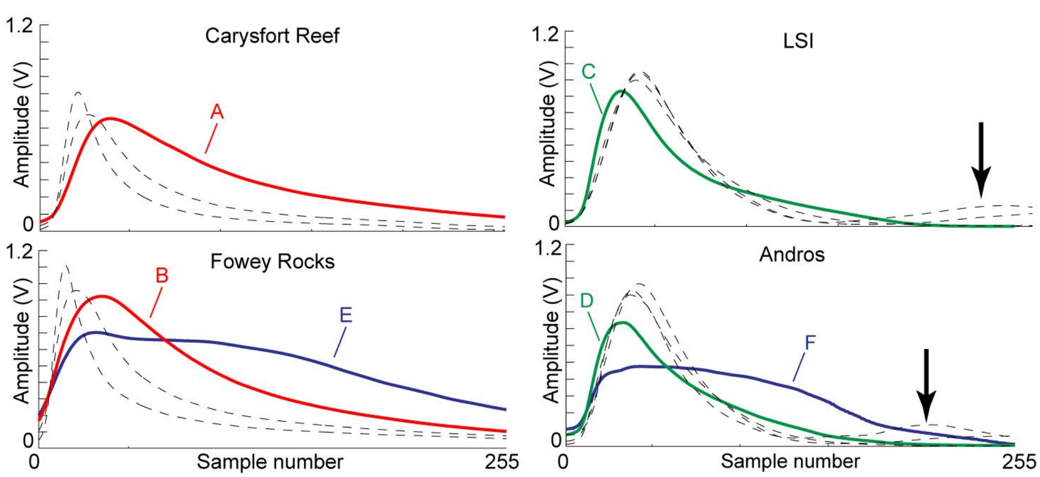

Figure 1: Mean echoes for acoustic classes grouped by survey area. Sample number is proportional to time (i.e. time increases to the right). All classes associed with sediment substrate are plotted as dashed lines. The hardbottom classes are plotted with solid lines, colored according to their general shape, and labeled with letters corresponding to pictures in Fig. 2. Black arrows point to second echoes visible for some of the LSI and Andros classes. Note that, discounting the second echoes, the hardbottom echoes have longer duration than the sediment echoes.

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.

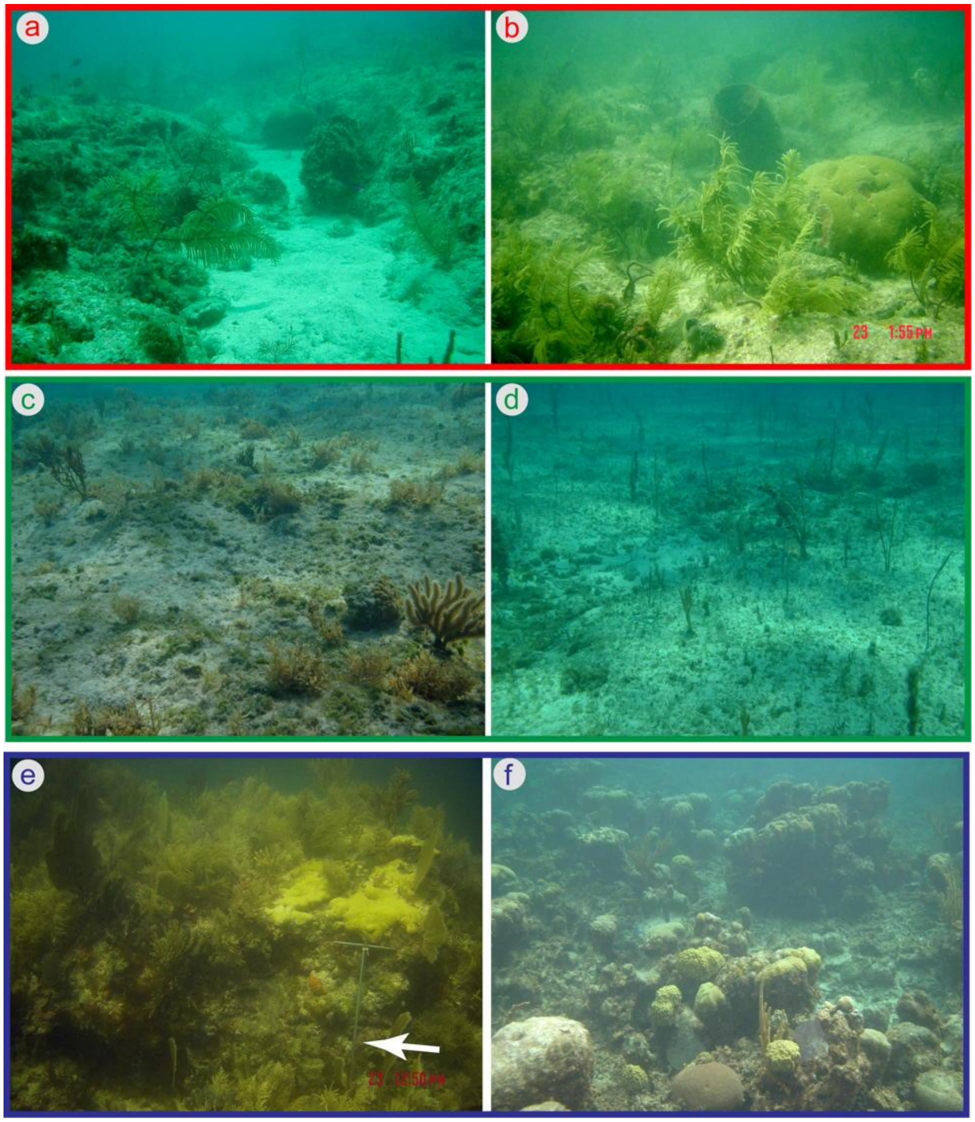

Figure 2: Oblique underwater photographs from sites corresponding to the six hardbottom classes plotted in Fig. 1. A and B are low-relief hardbottom at Carysfort Reef and Fowey Rocks, respectively. C and D are nearly flat "pavement" at Andros and LSI, respectively. E and F are areas of relatively higher relief hardbottom at Fowey Rocks and Andros respectively. White arrow points to a 1 m-long, T-shaped scale bar.

Research Performance Measure: All planned activities were accomplished. We continued efforts to identify and assess reported FSAs in the Florida Keys. Building on our prior research in the upper and lower FL Keys, we focused on multiple sites in the lower and middle Keys to accomplish two objectives: (1) assess whether reported FSA sites are characterized by similar habitat characteristics, with a focus on geomorphological features, and (2) assess fish utilization patterns of reported FSA sites.

Fishery Bycatch Analyses

Project Personnel: D.R. Johnson (UM/CIMAS)
NOAA Collaborators: D. Gloeckner and K. McCarthy (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives: To provide support to the fisheries statistics division and stock assessment program that provides advice to regulators of federally-permitted commercial fishers, especially those managed through Individual Fishing Quotas in the Gulf of Mexico

Strategy: To analyze fisheries dependent data from commercial fishing vessels that fish for Gulf of Mexico Reef Fish.

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 with healthy and productive ecosystems*

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

Research Summary:

Fishery observer data have been collected from the Gulf of Mexico reef fish fishery since July 2006. Data collection efforts have been primarily directed towards the vertical line and bottom longline fisheries. Detailed information such as catch per set, size and weight of catch, gear information, fishing location, depth, bottom type, bait, and targeted species were collected by observers aboard fishing boats.

The Coastal Logbook Program collects fisheries-dependent data through trip report forms for vessels that possess federal commercial fishing permits. Data includes total landings per trip, effort per trip, discards per species, condition of fish released, and fishing area.

Fisheries observer data were used in conjunction with fisheries logbook data (self-reported logbook data) in stock assessments to estimate discard rates from the fisheries.

The project began in January 2013. SEDAR documents have been prepared on size

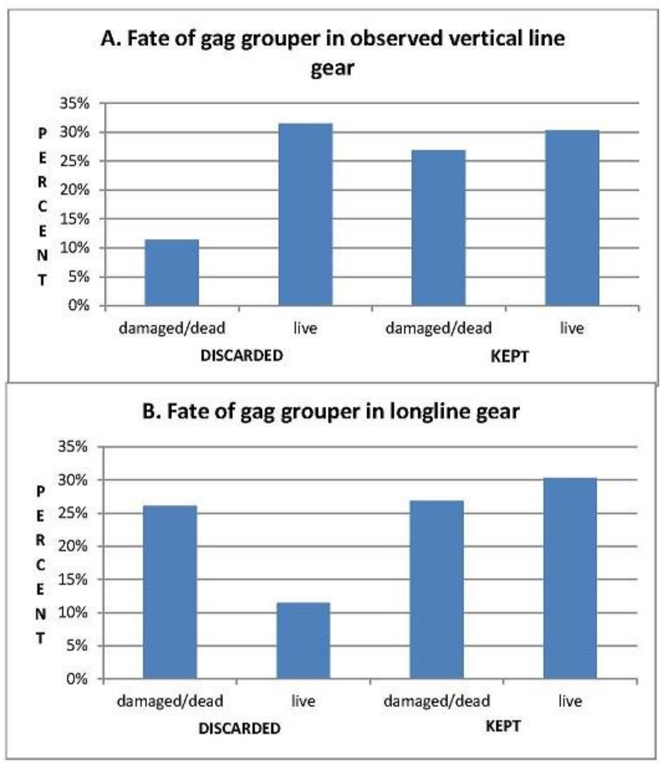

Figure 1: Fate (kept or discarded) of gag grouper in relationship to condition (damaged or dead, live) of fish in observed vertical line (A) and longline (B) gears.

composition and discard data for two ongoing stock assessments: gag grouper and greater amberjack. The following shows examples of the types of data that have been provided for the gag grouper stock assessment. Similar analyses were also conducted for greater amberjack.

Figure 1A shows the condition of gag grouper (kept or discarded) in relationship to fate for the vertical line and the longline gears. Size composition of gag grouper observed in the Gulf of Mexico bottom longline fishery (Figure 2) and vertical line fishery (Figure 3) for vessels with various amounts gag allocation are also presented.

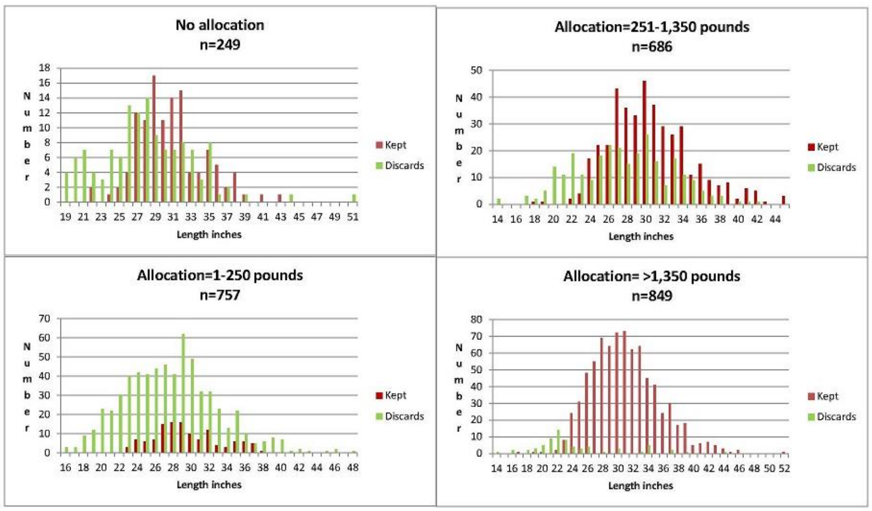

Figure 2: Commercial bottom longline Gulf of Mexico observed gag grouper size composition by gag allocation, 2010-2012.

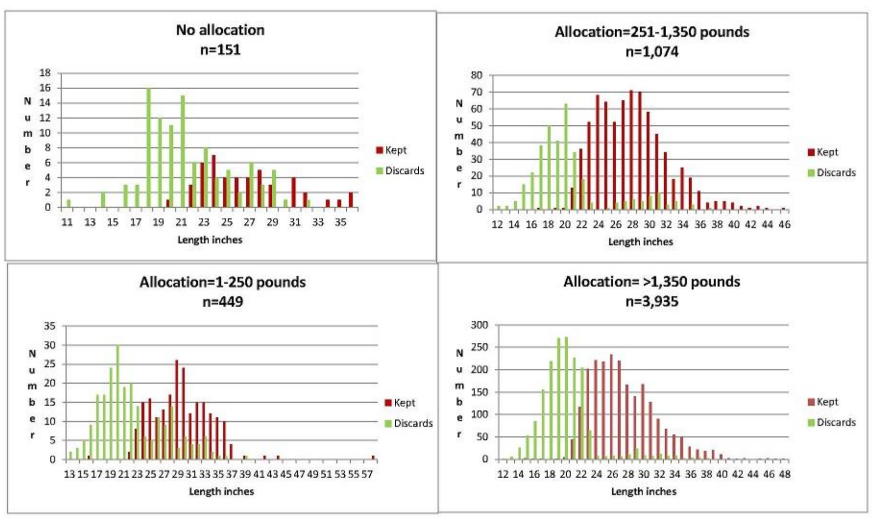

Figure 3: Commercial vertical line Gulf of Mexico observed gag grouper size composition by gag allocation, 2010-2012.

Research Performance Measure: Reports on size composition and discard characteristics were prepared for the SEDAR 33 data workshop for gag grouper and greater amberjack.

Biscayne Bay's Nearshore Submerged Aquatic Vegetation (SAV)

Project Personnel: D. Lirman (UM/RSMAS)
NOAA Collaborator: J. Serafy (NOAA/SEFSC)

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*:** To conduct seasonal SAV surveys of nearshore habitats using geo-tagged images of the bottom and collect concurrently 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 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 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.

In this study, we examined whether the proposed expansion of mesohaline conditions through the introduction of additional fresh water into Biscayne Bay would result in: 1) increases in seagrass cover; 2) expansion in the cover of *Halodule*; and 3) a reduction in the dominance of *Thalassia,* as hypothesized in the Comprehensive Everglades Restoration Plan. From 2008-2012, we have collected data on the seasonal abundance and distribution of SAV communities from > 3000 sites in central and southern Biscayne Bay. Seagrasses were present at 98% of sites where they covered 23% of the bottom. Salinity was the only physical variable with a significant relationship to the occurrence of all SAV taxa. Occurrence of *Thalassia*, *Halimeda*, and *Penicillus* increased significantly with increasing salinity, but *Halodule, Syringodium*, *Laurencia, Udotea, Batophora, Caulerpa,* and *Acetabularia* showed a significant negative relationship with salinity. The salinity range in which both *Thalassia* and *Halodule* had similar frequency of occurrence was 15-25 psu. The low abundance of *Thalassia* along the shoreline is not only due to its exclusion from low-salinity environments but also by higher nutrient availability that favors *Halodule*. Nutrient levels recorded in seagrass tissue suggest that Biscayne Bay experiences high Nitrogen inputs and is Phosphorus-limited. Thus, increased P availability may facilitate an expansion of *Halodule*. The data presented suggest that increased mesohaline conditions, a desired target of CERP activities, will increase seagrass abundance and support co-dominance by *Halodule* and *Thalassia* as hypothesized, but raise concerns that current high N availability and the potential for increases in P may prompt a shift away from seagrass-dominated to algal-dominated communities under enhanced freshwater inputs.

The documented relationships between seagrass abundance and distribution with respect to salinity and nutrients provide unique baselines that are important to the understanding, assessment, and forecasting of present and future impacts of changes in the hydrology and water quality of the Everglades watershed as the activities and projects of CERP proceed.

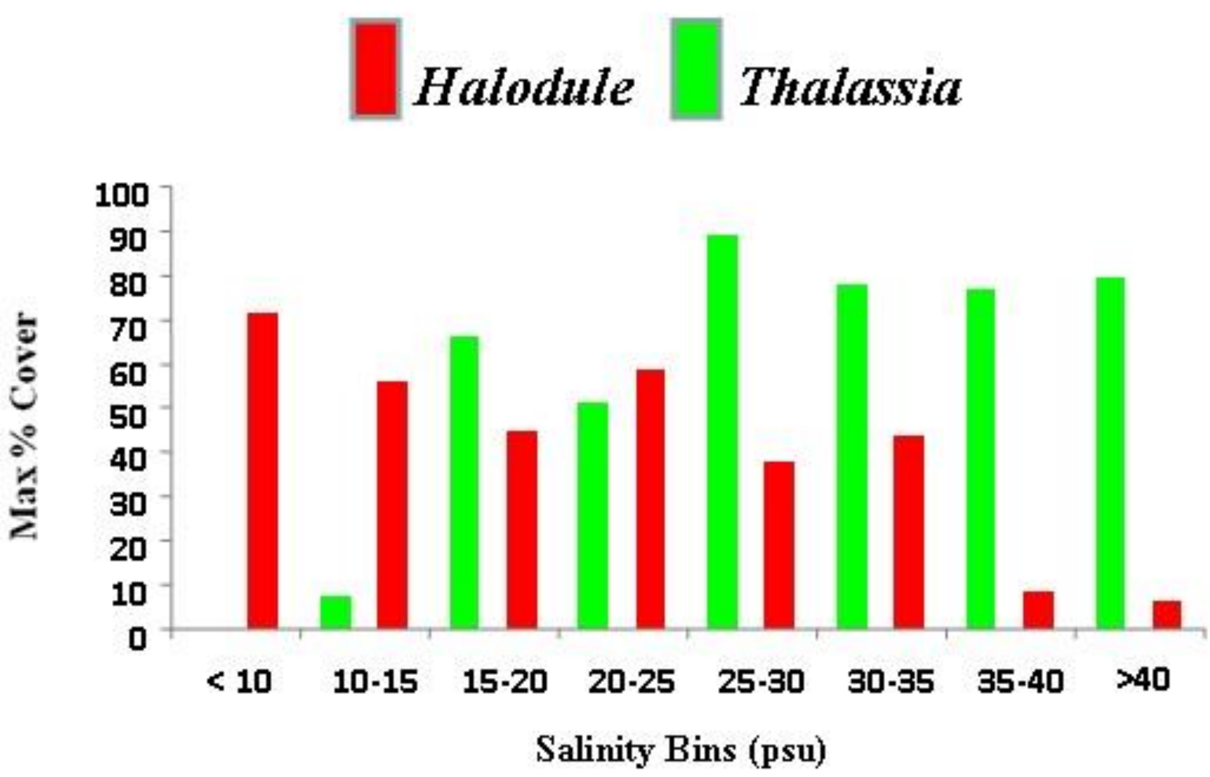

Figure 1: Maximum cover of seagrasses in western Biscayne Bay in relation to salinity bins.

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.

Neonate Loggerhead Dispersal, Behavior and Survivorship in the Western North Atlantic

Project Personnel: K.L. Mansfield (FIU)
NOAA Collaborator: S. Epperly (NOAA/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*

Funding Unit: NMFS/SEFSC

Technical Contact: Theo Brainard

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 north Atlantic. Argos-derived and satellite imagery data, allows us to characterize fine-scale habitat selection, oceanographic conditions/features, and oiled areas encountered by the turtles.

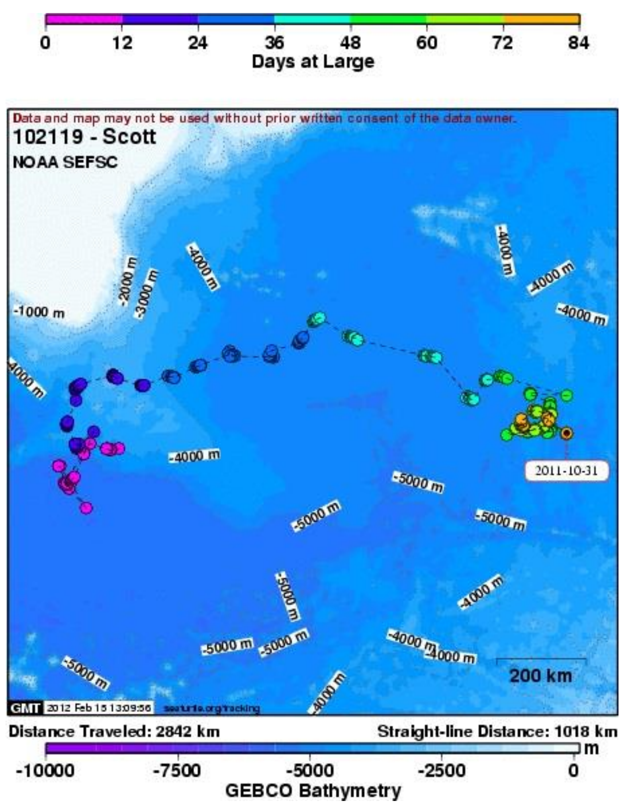

Figure 1: Satellite tracks of an oceanic juvenile loggerhead sea turtle captured in the North Atlantic Ocean, 2011. Map generated by seaturtle.org's Satellite Tracking and Analysis Tool.

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: No turtles were captured by cooperative fishermen during the fall 2012 sampling period. This is due, in part, to severe weather affecting the NED. This is an on-going project and will continue beyond the duration of this CIMAS contract; additional sampling is scheduled for July 2013. We are progressing to meet all major project objectives.

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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 Collaborators: S. Epperly and P. Richards (NOAA/SEFSC)
Other Collaborators: N.F. Putman (Oregon State University)

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. A secondary objective is to tag and release neonate loggerhead (*Caretta caretta*) sea turtles in the South Atlantic in collaboration with TAMAR, a Brazilian sea turtle conservation agency. The goal of this secondary project is to characterize the post-release movements and behavior of neonate sea turtles in the South Atlantic for comparison with data from the North Atlantic.

***Strategy*:** to accomplish our objectives in the Gulf of Mexico, 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. To accomplish our goals in the South Atlantic, satellite tagged loggerheads were to be released during three separate releases: November 2012, February and April 2013, periods representing different current regimes offshore of the turtles' natal beaches.

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.

Figure 1: Example of Kemp's ridley being satellite tagged for release in the Gulf of Mexico.

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 multi-year project with field sampling occurring late summer 2011, and spring-fall 2012, and additional sampling from 2013-2015.

Also following methods by Mansfield et al. (2012), neonate loggerhead turtles were satellite tagged in 2012-2013 from the east coast of Brazil. Argos-derived and satellite imagery data, allows us to characterize fine-scale habitat selection, oceanographic conditions/features, and oiled areas encountered by the turtles.

Research Performance Measure: For our work in the Gulf of Mexico, to date, we have satellite tagged 29 oceanic stage and wild-caught sea turtles in the northern Gulf of Mexico. This includes the first wild-caught oceanic stage hawksbill (*Eretmochelys imbricata*). We also released 10 pairs of oceanographic drifters in conjunction with the tagged turtles. 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 sea turtles 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 review.

For our work in Brazil, we successfully released 15 tagged turtles during three different releases. We released 6 drifter pairs in conjunction with the turtle releases. We are currently collecting data from the tagged animals and are on track to conclude this portion of the grant by early 2014.

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Development of a Towed Camera System for Assessing Demersal Fish Stocks: C-BASS (Camera-Based Assessment Survey System)

Project Personnel: S. Murawski, S. Grasty, C. Lembke, S. Butcher, A. Silverman (USF)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To 1) Complete hardware engineering of towed imaging system; 2) Complete sea trials of camera system operations, 3) Conduct a partial survey of reef fish abundance and distribution along the West Florida shelf. Areas surveyed will include the Madison-Swanson, the Florida Middle Grounds and the Steamboat Lumps closed areas, 4) Define requirements for software systems for rapid image classification

***Strategy*:** To engage a multidisciplinary team of biologists and engineers to collaborate on the development of an altogether new technology to determine the abundance, habitat associations and species interrelationships among reef fish populations inhabiting untrawlable habitats.

CIMAS Research Theme:

***Theme 7*:** Protection and Restoration of Resources (*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/ST **NOAA Technical Contact:** Theo Brainerd

Research Summary: During the project period we completed work on the first prototype of the towed camera system, including tow sled, power management system, internal computers, lighting, environmental instrumentation and systems management interface (dashboard). A major breakthrough was the engineering to supply the camera system with 750v power through the standard CTD cable of the research vessel and to simultaneously receive images from one of 4 (selectable) of the onboard cameras plus all relevant environmental data. This allows three important things:

(1) there is virtually unlimited "soak time" for the vehicle so long deployments (at operational speeds of 3.5-4 kn) will result in extensive ground covered, and (2) the vehicle can be deployed off of virtually any research vessel world-wide that has a CTD winch and cable, making it available to a wide variety of researchers, and (3) because real-time altitude data, imagery and other information is fed to the operational dashboard, the operators can "fly" the vehicle very near coral reefs to image fish populations there.

Research Performance Measures: Objectives 1 and 2 (as described above) were accomplished, but some work is ongoing to improve the cameras, lighting systems and navigation of the vehicle. In particular, we are upgrading to four analog cameras and two digital cameras, including the machine vision camera Prolistica 1920, which is a high resolution, high frame rate camera capable of low light operations. Also, we are upgrading the lighting system to provide better color resolution by doubling the number of lights and using diffusers and polarizers. Last, we are upgrading the analysis system ashore to provide an "end-to-end" analysis system.

Objectives 3 and 4 are in process. We will conduct a survey cruise during June 10-17 in the Florida Middle Grounds, the Madison-Swanson and Steamboat Lumps areas to assess fish abundance there. We will likely conduct a second survey of these areas in October-November, 2013.For objective 4 we have been reaching out to video engineers at SRI International who have a video processing system that holds promise for auto-classification systems for such imagery.

Figure 1: The C-BASS (Camera-Based Survey Sampling System) tow vehicle, prototype 1. In the front there are four cameras (I digital and 3 analog) and two light strobes.

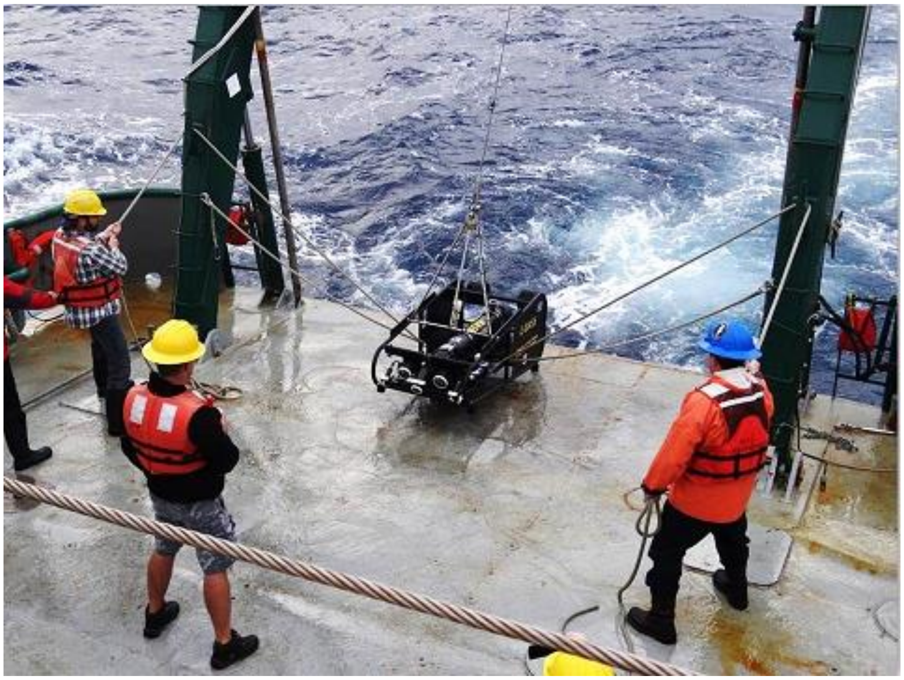

Figure 2: The C-BASS tow vehicle being launched from the stern of the research vessel. Note lateral stability and control. The vehicle can be safely launched and retrieved in up to 2 meter wave seas.

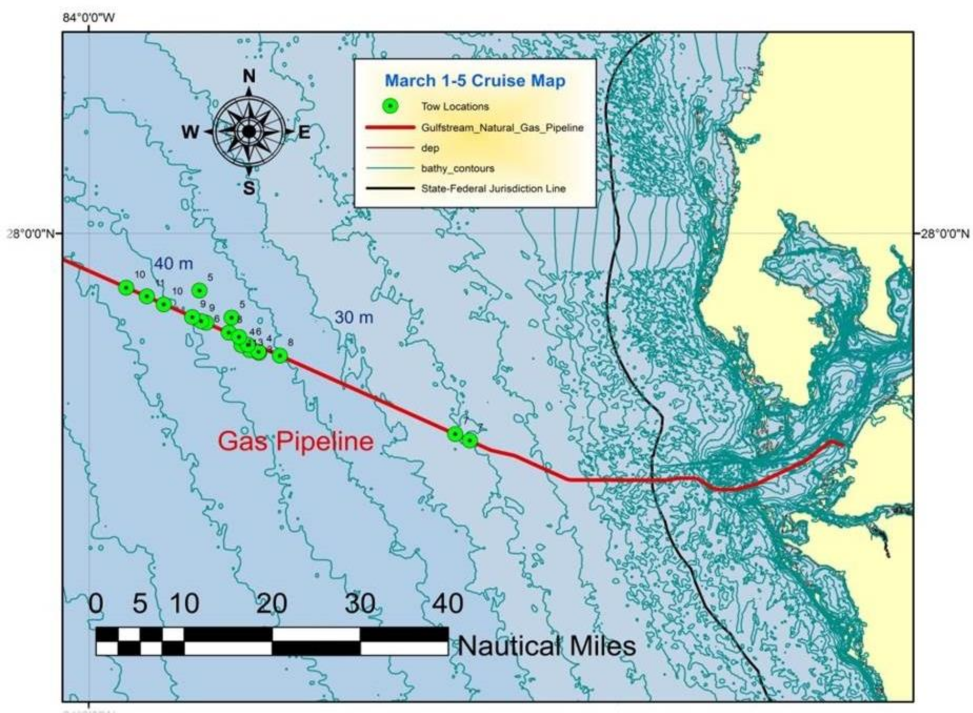

Figure 3: Locations of C-BADD camera system deployments along the Gulfstream gas pipeline, March 1-5, 2013. The green dots are coded to the beginning and ending tow locations.

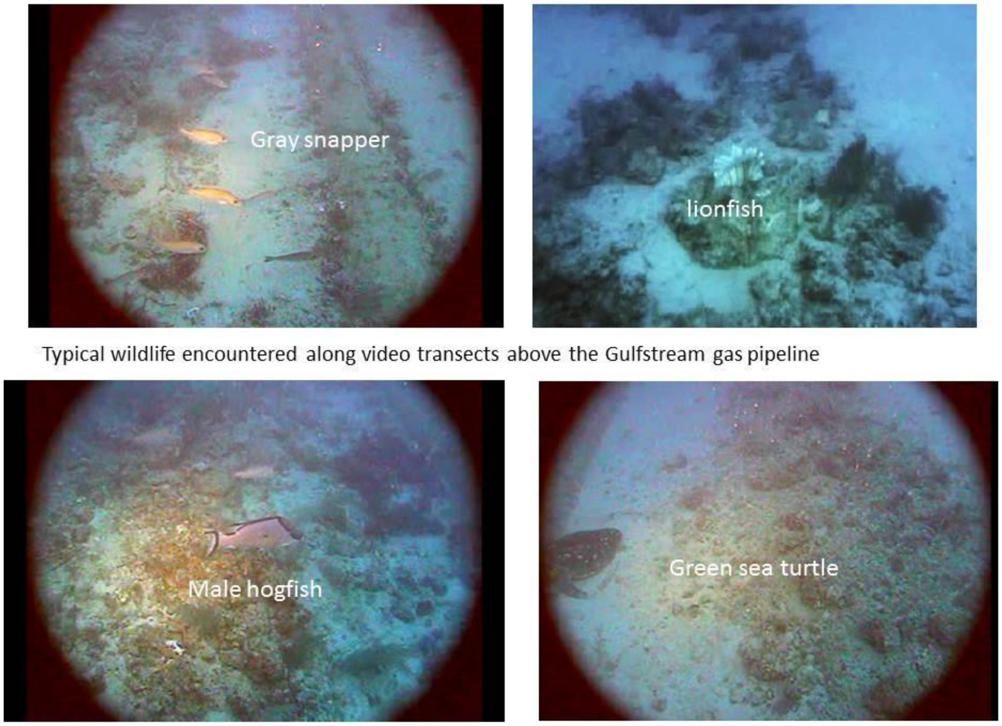

Figure 4: Images of typical wildlife encountered and imaged by the analog cameras on the C-BASS camera system in 40 meters of water depth along the Gulfstream gas pipeline. Note invasive lionfish, which were the third most abundant fish species encountered.

Figure 5: The C-BASS Technical team, a broad coalition of biologists and engineers dedicated to creating a new platform for in situ fishery independent sampling of reef fishes.

Stock Structure of Bottlenose Dolphin in the Bays, Sounds and Estuaries in the Northern Gulf of Mexico

Project Personnel: N.M. Phillips (UM/CIMAS)
NOAA Collaborators: P.E. Rosel, L. Garrison and K. D. Mullin (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To understand population structure and gene flow of bottlenose dolphins in the bays, sounds and estuaries in the northern Gulf of Mexico in order to accurately assess and quantify the impacts of anthropogenic and environmental threats on these stocks.

***Strategy*:** To assess the population structure of bottlenose dolphin via genetic analysis, using a combination of mitochondrial and microsatellite markers.

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:

Bottlenose dolphins (Figure 1) are exposed to a wide variety of both anthropogenic and natural threats in the bays, sounds and estuaries (BSE's) in the northern Gulf of Mexico (GoMx), including pollution, commercial fisheries, shipping, dredging, construction activities, oil and gas drilling, disease and algal blooms. In addition, there have been repeated Unusual Mortality Events (UME's) involving bottlenose dolphins in the northern Gulf of Mexico, some of which have unknown causes. Determining the impacts of these stressors on dolphin populations within the BSE's of the GoMx is currently difficult due to the limited information available on the seasonal movements and genetic connectivity of these stocks. Therefore, the aim of this research is to assess the population structure of bottlenose dolphins in the bays, sounds and estuaries of the Gulf of Mexico using genetic methods.

Figure 1: Bottlenose dolphin, *Tursiops truncates*.

A total of 85 tissue samples were collected in 2012 from bottlenose dolphin in the Corpus Christi Bay and Matagorda Bay areas in Texas for genetic analysis (Figure 2). Genomic DNA was extracted from these samples and we have genetically determined the gender of the sampled dolphins. Genetic data have been generated for these samples using two different molecular markers, mitochondrial DNA (control region) and microsatellite loci. We have also generated genetic data from another 137 tissue samples previously collected in Cedar Key, FL, Pensacola Bay, FL, Choctawhatchee Bay, FL, and the coastal areas of the Florida panhandle, to expand the study across a broader geographic area. Additional sampling is planned to take place in the coastal areas of Texas in June 2013. We are also in the process of developing a threat assessment priority scoring system that prioritizes the dolphin stocks in the BSE's in the GoMx based on the number and level of threats the dolphins face and the availability of data for the stocks.

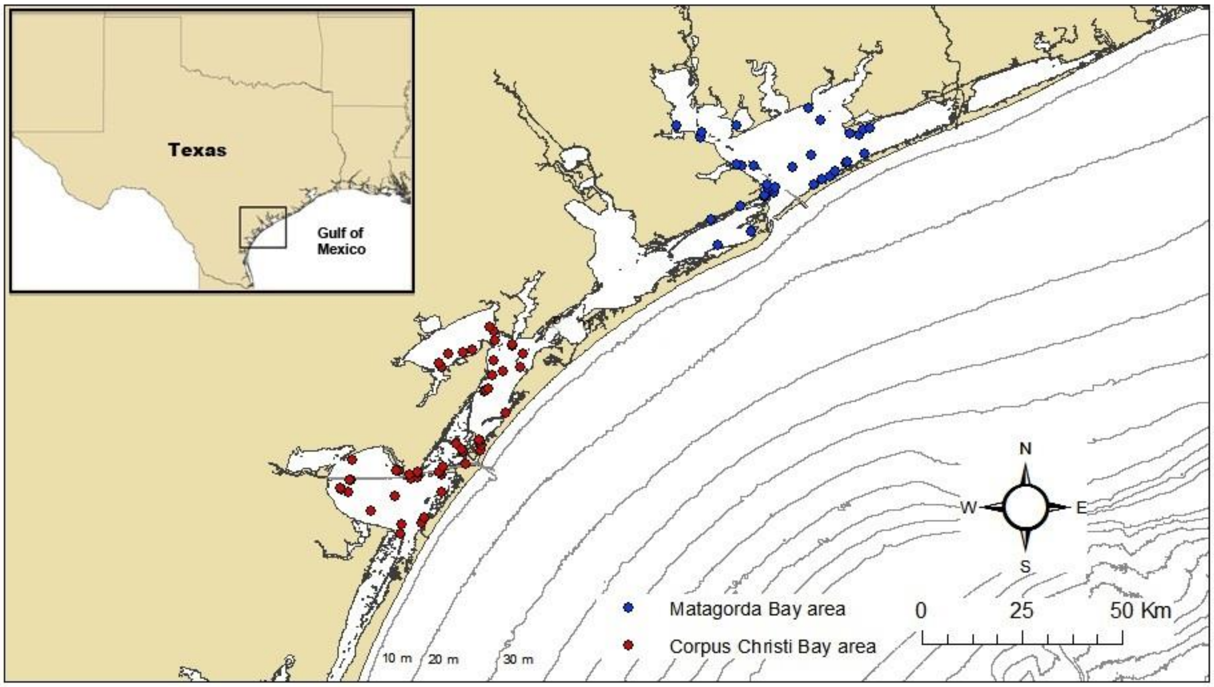

Figure 2: Sampling locations of bottlenose dolphin in Corpus Christi Bay (red) and Matagorda Bay (blue) areas, Texas

Research Performance Measure: All tissue samples collected in the first year of the study have been analyzed; DNA has been extracted, sex has been determined and all have been sequenced and genotyped as planned. All major objectives are being met.

Natural Resource Damage Assessment Plankton Processing

Project Personnel: S. Privoznik, A. Ender, P.E. Fortman, H. Krakoski, L. Rock, A. Jugovich, J. Barbaro, (UM/CIMAS)
NOAA Collaborators: J. Lamkin and T. Gerard (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To assist the NOAA Natural Resource Damage Assessment with respect to the Deep Water Horizon oil spill.

***Strategy*:** Analyze plankton samples through conducting measurements of sample displacement volume, removal of fish eggs, fish larvae, and debris.

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:

Plankton sampling in response to the DWH oil spill has generated more samples than can be processed at marine laboratories in the Gulf region and/or at the Plankton Sorting and Identification Center in Poland where NOAA/ NMFS/SEFSC normally sends SEAMAP plankton samples for analysis. The laboratory of Dr. John Lamkin at the NOAA/NMFS Southeast Fisheries Science Center, Miami is prepared to assist in the analysis of DWH plankton samples which are critical not only to ongoing DWH oil spill impact assessments but also to advance understanding of plankton dynamics in the Gulf.

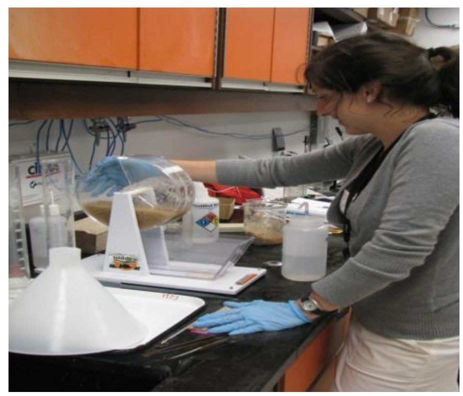

Figure 1: Technician Kathleen Griffith follows the adequate protocols to create an aliquot from a plankton sample collected in the Gulf

Figure 2: The plankton processing team at the laboratory diligently working on plankton samples from the Deep Water Horizon spill in the Gulf of Mexico.

Research Performance Measure: SEFSC Miami Lab has processed approximately 800 of the 1100 total samples received. Specifically, samples from the following prioritized Tiers have been completed: Tier 1A, B and C, McArthur II, Bunny Bordelon 6, Sarah Bordelon 3 and 4, and Meg Skansi 3 and 4. Tier 2A and B, McArthur II, Bunny Bordelon, and Sarah Bordelon. All ichthyoplankton samples from Tier 1B have been scanned on a flatbed scanner. The Miami Lab also received its ZooScan instrument which will provide a digital record of zooplankton.

Marine Mammal Research

Project Personnel: J. Wicker (UM/CIMAS)
NOAA Collaborators: 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 by supporting data collection and management within the Marine Mammal Program.
Strategy: To perform field work including large vessel surveys, aerial surveys, and small boat studies to collect data on marine mammals throughout the Gulf of Mexico and Atlantic Ocean. To lead surveys within the Southeast Atlantic Marine Mammal Assessment Program to collect samples and data on the abundance, habitat, and spatial distribution of cetaceans within U.S. waters. 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. To assist on the Biscayne Bay Bottlenose Dolphin photo-identification study

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 National Marine Fisheries Service (NMFS) is responsible for monitoring the populations of arine mammals in southeastern United States waters. This project supports data collection efforts throughout the Gulf of Mexico and Atlantic Ocean resulting in over 300 marine mammal sightings, 40 biopsy samples, and 4,000 (km) of visual survey effort. The Southeast Gulf of Mexico Sperm Whale Study assessed the abundance, habitat and spatial distribution of sperm whales by means of visual and passive acoustic monitoring, biopsying sampling and deployment of satellite tags.

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 Small boat coxswain onboard NOAA Research vessels during the marine mammal summer cruise of 2012.
- 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 Bottlenose Dolphin 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
- Assist in NOAA small boat field work through SE United States.

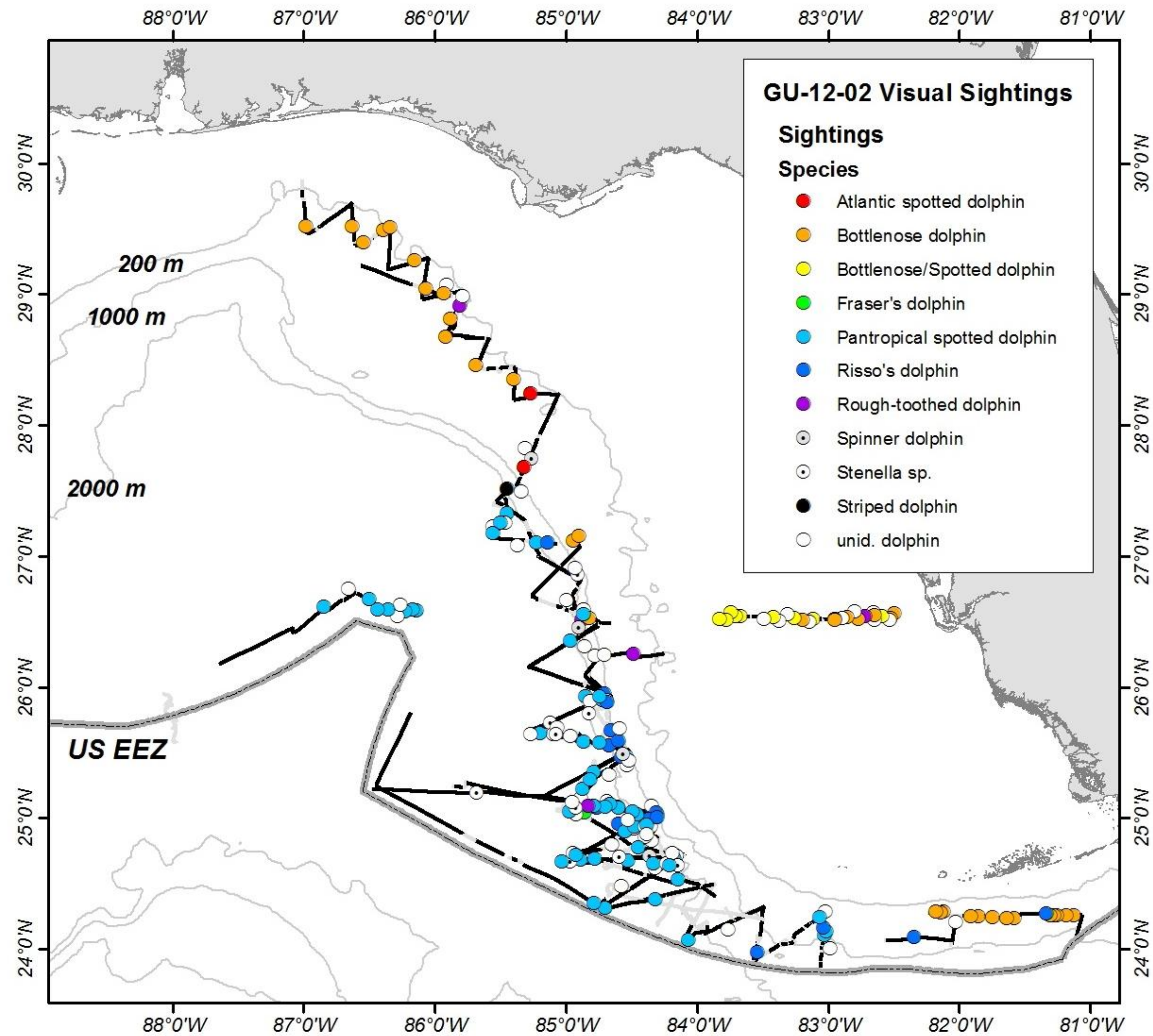

Figure 1: GU-12-02 Visual Sighting.

Coral Recovery/Restoration Research

Project Personnel: D.E. Williams, C.M. Cameron, A. Bright, B. Huntington, (UM/CIMAS); C. Kiel (UM/RSMAS)
NOAA Collaborators: M.W. Miller (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:
***Objective*:** To enhance scientific basis for implementing recovery and restoration of coral populations in the Florida Keys, especially those listed or proposed under the Endangered Species Act.
***Strategy*:** To (a) characterize wild/recovering populations of staghorn coral as restoration/recovery targets; and (b) undertake observational and experimental studies to evaluate factors affecting the success of coral populations via natural recruitment of early life stages and transplant/restocking experiments.

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 (2012/13) we completed a two-year study 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 implemented disease mitigation treatments (e.g., epoxy band applied over tissue disease line and excision of healthy-looking branches from diseased colonies) to test their effectiveness. Results showed that disease continues to have devastating impacts on both wild and restored staghorn coral patches, but no consistent differences were discernible in disease dynamics, intensity, or identity between wild and restored patches. The passage of Tropical Storm Isaac was the only consistent, discernible, environmental trigger yielding a spike in disease occurrence across all sites. Unfortunately, results of the mitigation treatments gave ambivalent results (Figure 1).

A second ongoing project component initiated in 2012 is undertaking observational and experimental studies to characterize naturally recovering staghorn populations in three regions with the primary objective of discerning potential thresholds in coral density with functions such as fish habitat provision. The very dense, recovering staghorn thickets characterized in the Dry Tortugas (DT, Pulaski Shoal region) housed significantly higher fish richness and abundance compared to moderate thickets in the DT or in the USVI. These DT thickets also showed improved coral condition (i.e., lesser predation and colony partial mortality) suggesting facilitation at this high abundance. Future experimental studies are planned to investigate potential mechanisms underlying such facilitation.

Research Performance Measure: The disease surveillance/mitigation study has been concluded as planned (one manuscript in prep). Multiple sampling field trips to the Dry Tortugas and St. Thomas, USVI and data analyses have been completed for the first phase of the staghorn recovery characterization project, with two manuscripts in review.

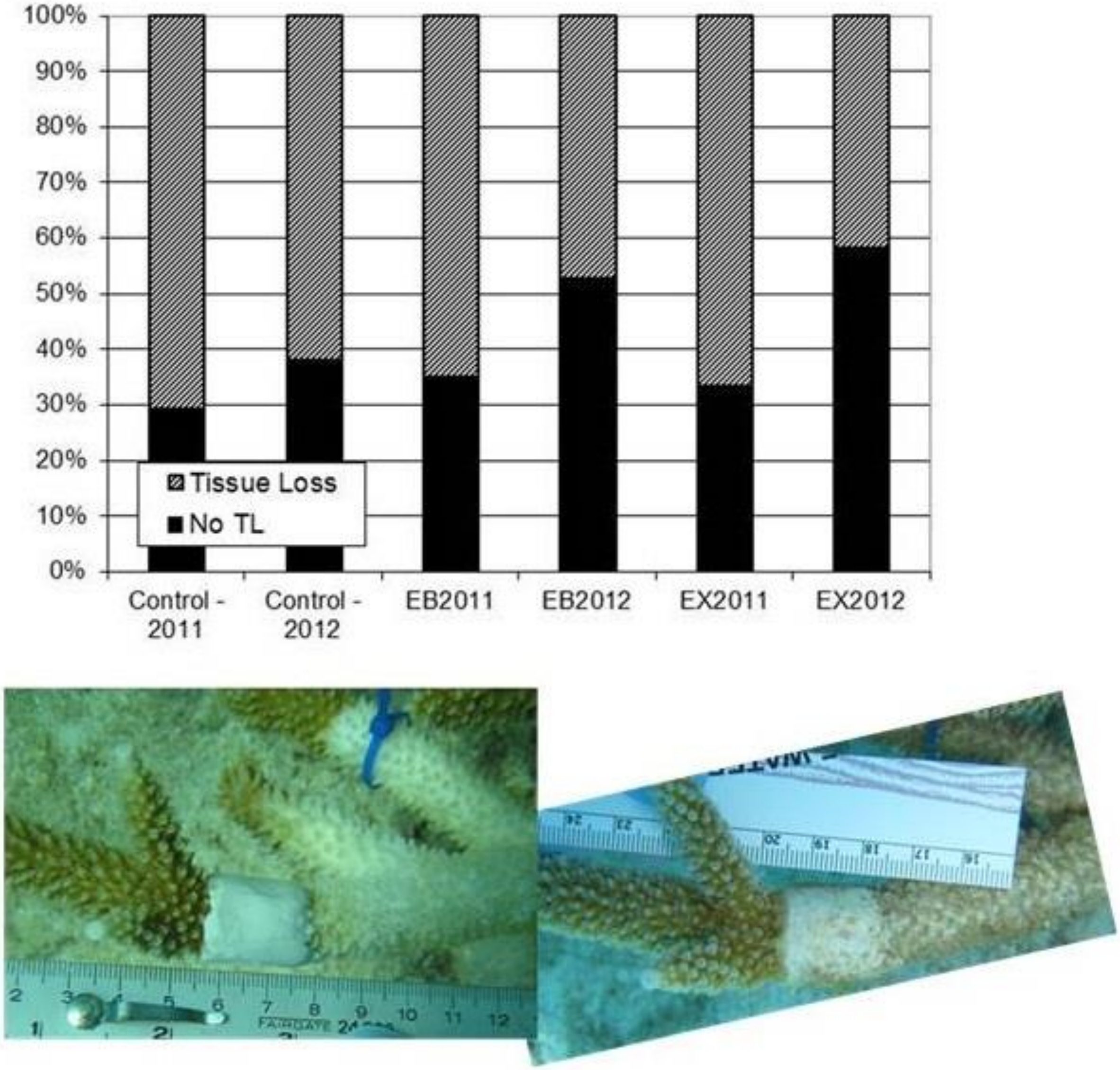

Figure 1: Results of experimental disease mitigation trials showing response in each year for Epoxy Band (EB), Excision (EX) and Control (cable tie placed around disease margin on a branch) treatments as the percent of replicates showing arrested tissue loss after one month, as illustrated in the photos below (right image at initiation of EB treatment, left image one month later showing successful arrest of tissue los and beginning growth over the EB). Chi-Squared Goodness of Fit tests indicate no significant difference in the proportions of the three treatments showing continued tissue loss when all replicates across years are pooled.

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

Research Summary:

The fluorescence spectroscopy portion of this award was completed in 2012, therefore what is reported here relates to the second goal of relating satellite remote sensing to assessment of environmental effects of the DWH incident.

PhD student, David Lindo-Atichati, from the Universidad de Las Palmas de Gran Canaria, Facultad de Ciencias del Mar, Las Palmas de Gran Canaria, Spain, conducted internships at NOAA AOML, the University of Miami and University of South Florida, College of Marine Science. The study examined variability of mesoscale circulation structures in the Gulf of Mexico (GOM) 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.

Master's student Brendan O'Connor at the University of South Florida, College of Marine Science, developed a thesis that focuses on two general problems related to remote sensing of the Deepwater

Horizon oil spill tragedy in 2010. The first was a response to a published report that concluded that the Deepwater Horizon spill led to the stimulation of a massive phytoplankton bloom to the east/southeast of the Mississippi Delta in August 2010. We have carefully reviewed the evidence and find that this bloom is consistent with regional periodic fertilization by the Mississippi River plume. The enhanced bloom of August 2010 may have been related to the oil spill simply from the point of view that additional water was discharged into the Louisiana marshes through diversions of the main Mississippi flow, in an attempt to mitigate contamination of the coastal wetlands by oil washing ashore. The resuspension and export of nutrients was likely enhanced by severer storms affecting the area. We examined time series of various satellite remote sensing data and numerical model output to support this conclusion.

A second topic was whether it is possible to identify the oil floating at the surface using hyperspectral imagery. One of the principal challenges to the recovery, cleanup and subsequent restoration of an oil spill is the ability to identify, monitor and detect the physical extent to which the oil spreads (National Research Council 1985). Being able to predict the pattern and flow of an active oil spill maximizes the efficient use of available resources in the cleanup efforts. Identifying the scope of the areas affected by an oil spill also allows agencies to judiciously focus mitigation efforts. Synoptic imaging proved to be the best way to map 'recoverable oil', and yet it has been difficult to process massive amounts of data in a way that oil is identified quickly.

The AVIRIS instrument is comprised of 224 individual detectors that collect data at specific wavelengths, producing data that extend from the visible to the shortwave infrared, specifically 400 to 2498nm. Two different AVIRIS instruments were flown during the Deepwater Horizon (DWH) disaster (Figure 1, Figure 2), one on the NASA high-altitude ER2 and on occasion another one on a De Havilland Twin Otter.

Figure 1: Location, size and distribution of AVIRIS flight scenes collected during the Deepwater Horizon event, between May 6th and October 4th 2010.

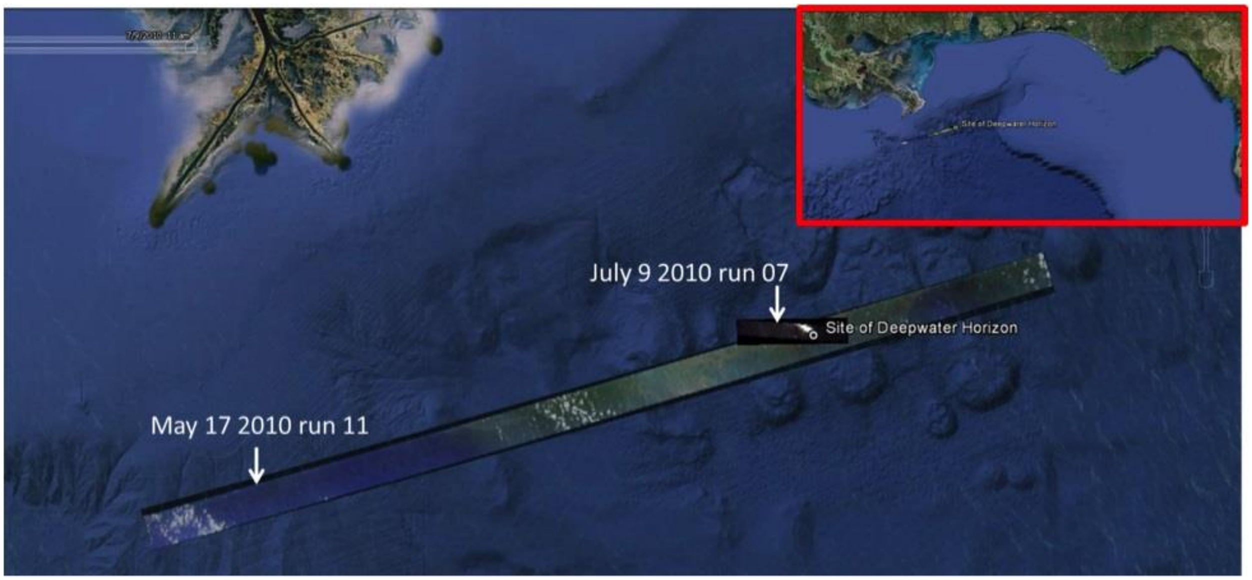

Figure 2: Location and orientation of 2 scenes used to compare USGS normalized difference technique and Spectral Line Height technique, May 17th 2010 (image f100517t01p00r11) and July 9th 2010 (image f100709t01p00r07). Inset shows proximity to the Mississippi coastline.

We developed a Spectral Line Height technique to identify areas where thick oil was present. The technique discriminates oil from adjoining water pixels. The SLH technique has the benefit of not requiring atmospheric correction. Effecting an accurate atmospheric correction can lead to data not being made available to responders during an oil spill for several hours after collection, or it may not be possible to provide an accurate correction at all. The presence of thick oil in the AVIRIS-generated color-composite images is indicated by green and yellow colors. Areas with no thick oil present appear as blue (Figure 3). We created a cloud filter based on spectral discrimination of clouds and ships. The SLH technique was not able to detect oil on land, wetlands, or on beaches. These are targets that are highly reflective across the NIR wavelengths used by the SLH algorithm, and therefore provide a biased baseline and no contrast with the peak reflectance due to oil. These backgrounds are identified as false positives.

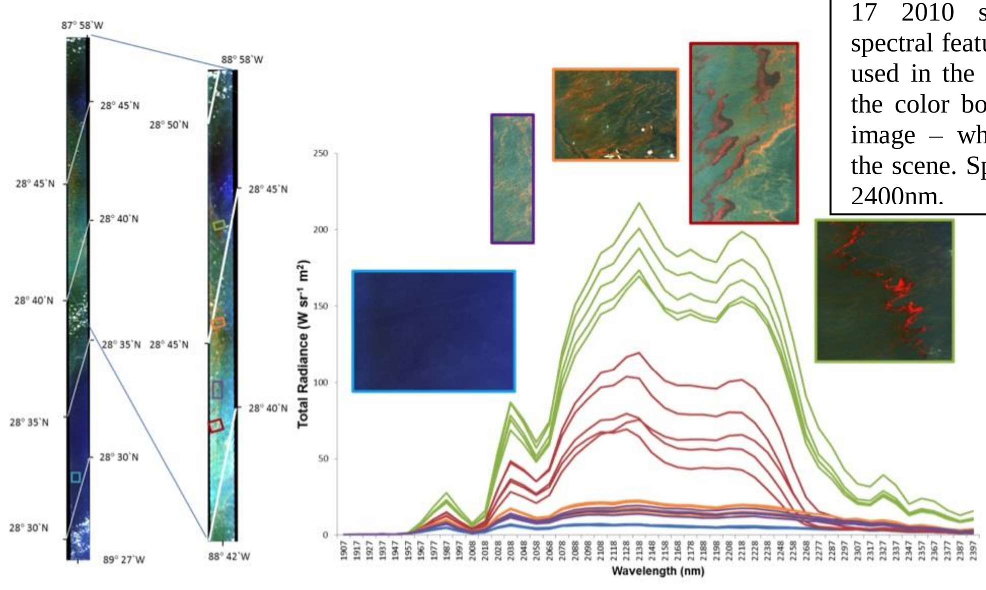

Figure 3: AVIRIS scene of May 17 2010 showing location of spectral features examined. Colors used in the spectral plot relate to the color boxes surrounding each image – which are noted within the scene. Spectra range is 1907 – 2400nm.

Research Performance Measure: This project helped develop a simple method for rapid identification of thick oil at the surface using hyperspectral images collected with the AVIRIS sensor (NASA Jet Propulsion Lab) over areas contaminated with Deepwater Horizon oil during summer of 2010. Full fluorescence spectral characterization of the Macondo 232 oil in various stages of weathering and emulsification have been completed and provides the information needed to design in situ fluorometers for routine monitoring of future spills.

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

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:
Acroporid corals have declined by more than 90% on reefs throughout the Caribbean in the past 30 years and are listed as 'Threatened' species under the U.S. Endangered Species Act. Data collected for this project directly supported the critical habitat designation and recovery plan development by NMFS. Additionally, the protocol developed based on this project is being implemented to other reef areas through state and territorial partners.

The overall objectives of this project are to document the dynamics of the remaining Elkhorn populations in the upper Florida Keys and compare its performance to other Caribbean locations. Individually tagged *Acropora palmata* colonies are surveyed periodically to document their condition. Based on these observations, we can estimate basic population parameters including recruitment, growth and mortality, along with the causes of mortality and the sources of recruitment (asexual or sexual). These data were directly used in a population model developed by a colleague at Scripps Institute of Oceanography and the projections will assist in the development of a recovery plan by NMFS. Data from the Florida Keys population indicates continued decline of the adult *A. palmata* population, and an alarming failure of asexual and sexual recruitment. This decline was the direct result of the 2005 hurricane season. Recovery from this disturbance has been slow and the population continues to suffer losses from disease and predation. *Acropora palmata* in Curacao suffered 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 indicate that in the Florida Keys population, the 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 by SCUBA divers as a management tool. We found that the live coral tissue lost to snail predation was 80% less following the removals (Figure 1). Based on the snails found at subsequent surveys, we can project that it will take 4-5 years for snails to return to their original abundances. The dive time to accomplish this effect is estimated to be 72 seconds per elkhorn colony suggesting that predator removal by divers can effectively conserve *A. palmata* colonies in targeted areas.

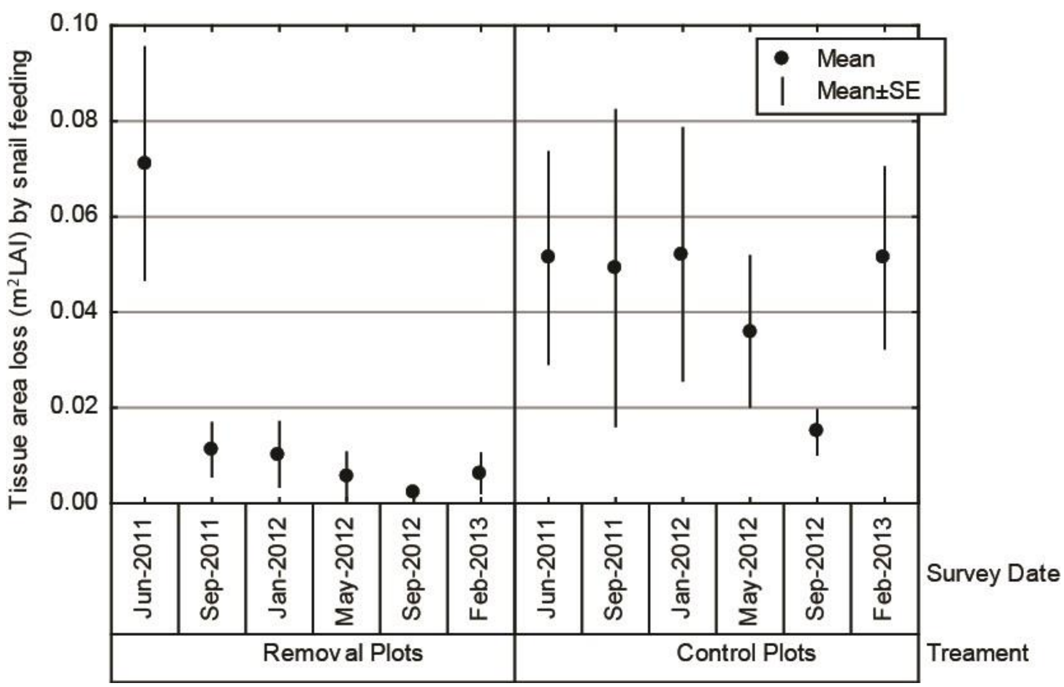

Figure 1: The mean (± standard error) tissue area (estimated square meters using Live Area Index or LAI) lost to snail feeding on tagged *Acropora palmata* colonies in the predator removal and control treatments from the start of the experiment in Jun 2011. Tissue loss was decreased by 80% following the removals and has remained low throughout the experiment.

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 two year predator removal experiment is planned to conclude July 2013. Survey sites around Curaçao were re-surveyed in May 2013.

VII. EDUCATION AND OUTREACH

With respect to Education and Outreach, CIMAS has just begun to reach beyond UM/RSMAS to the wider set of Partner Universities. The major example in Formal Education is the USF Marine Resource Assessment program supported through CIMAS by an award from the National Marine Fisheries Service.

Formal Education Activities

The USF Marine Assessment Graduate Program

An update of the entire program period is provided below to create a complete record of the the MRA 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. There are presently five different courses have been developed and taught to USF students, NOAA employees and Florida Fish and Wildlife employees by USF faculty and NOAA/NMFS employees:

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).
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)

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)
This course was taught for the second time during Fall 2012 by Cameron Ainsworth of USF-CMS (24 students, including 2 agency employees - 8% agency)

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)
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)

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)
This course was taught for the second time during Spring 2013 by Kendra Daly and Mark Luther of USF-CMS (13 students, including 2 agency employees - 15% agency)

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).

Through the Rosenstiel School, CIMAS continues to be active in education at the graduate, undergraduate and high school levels. 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. 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 but often highlight them on the CIMAS website. Also many CIMAS personnel are active in setting up and maintaining the web sites at both AOML and SEFSC.

RSMAS Graduate Education

For many decades, the Rosenstiel School of Marine and Atmospheric Science has offered graduate instruction leading to the Doctor of Philosophy (PhD) and Master of Science (MS) degrees through academic divisions that include Marine Biology and Fisheries, Marine and Atmospheric Chemistry, Marine Geology and Geophysics, Meteorology and Physical Oceanography, and Applied Marine Physics. Though graduate students typically concentrate in one of these curricular areas, interdisciplinary study is encouraged and coursework can be tailored to the individual student. In addition, we offer the Master of Arts (MA) and MS degrees in Marine Affairs and Policy for students who wish to pursue careers in marine policy and management. Currently there are about 200 students enrolled in these RSMAS graduate programs, 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. Because the students were not necessarily CIMAS employees we do not report these hirings in our annual report.

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. This program now has an enrollment of about 40 students.

RSMAS 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. In academic year 2012, a record number of students enrolled in the program. The students take a dual major and have the highest GPA and SAT scores of any undergraduate program at the University of Miami. 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.

RSMAS contributions to the MAST Academy and other local High Schools

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) 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. David Die, CIMAS Associate Director, who is also 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 has been 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 directly 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 the LMRCSC students. Moreover the participation of US Caribbean universities in CIMAS benefits the LMRCSC by enhancing the recruitment of a diverse student body.

Topical Workshops Conducted Through CIMAS on Behalf of NOAA

Support for Science Management Conference: Gulf of Mexico Fisheries: An Agenda for the Future, September 14-15, 2012:

Commercial and recreational fisheries account for approximately $9 billion of annual value to the Gulf of Mexico region, and employ tens of thousands of people in direct and allied businesses. Fisheries of the region are recovering from previous overfishing episodes, with restrictive measures being implemented at the federal and state levels. Additionally, fisheries of the region face threats from habitat loss, impacts of the 2010 Gulf oil spill and other factors such as sea level rise and ocean acidification. Effective management of fisheries resources requires timely and comprehensive scientific assessments combined with access to high quality fishery dependent and fishery-independent data. Under this grant from the National Marine Fisheries Service, we supported the first-of-its-kind Gulf of Mexico Fisheries Symposium to bring together fishery managers, administrators, scientists and stakeholders to discuss the state of Gulf fisheries and the nature and priorities for additional scientific research to better support sustainable fisheries.

During September 14-15, approximately 200 of the region's most influential fisheries participants convened in St. Pete Beach Florida to discuss topics ranging from the state of Gulf Fisheries, fishery research priorities, aquaculture's role in fisheries sustainability, recreational statistics programs, and the importance of improving habitats. A detailed discussion concerning research priorities for future investments was a tangible product from the two day deliberation. This set of priorities will be used by various entities to determine which programs will benefit from funding from various sources including the RESTORE Act, which is funded by settlements from the Deepwater Horizon incident. Further information about the symposium is available at: www.GulfFisheriesSymposium.com

Figure 1: Symposium panel discusses fishery research priorities for the Gulf of Mexico: L-R: Guy Harvey, Charles Wilson - CSO GRI, Steven Murawski - College of Marine Science USF, James Bohnsack – National Marine Fisheries Service SEFSC, Luiz Barbieri – Florida Fish and Wildlife Research Institute, Bob Hueter – Mote Marine Lab.

The Gulf of Mexico Fisheries Symposium was sponsored by NOAA, the Florida Fish and Wildlife Commission, the University of South Florida, the Florida Institute of Oceanography, Mote Marine Laboratory, the Guy Harvey Ocean Foundation and Guy Harvey Magazine.

Figure 2: Guy Harvey and University of South Florida graduate student volunteers assisting with symposium, including L-R, Emily Chancellor, Jacquelin Hipes, Jennifer Granneman, Marcy Cockrell, Sarah Grasty, Elizabeth Herdter, and Susan Snyder.

Figure 3: Logo created for the Gulf Fisheries Symposium by famed marine wildlife artist Guy Harvey.

Workshop to Inform the Science Pertaining to the Extinction Risk for 82 Species of Corals Petitioned for Listing Under the Endangered Species Act:
NSU hosted and coordinated logistics for a scientific workshop in support of the status review of 82 corals for potential listing under the Endangered Species Act (ESA). The review of the status of the 82 coral species was major undertaking because of the large number, and geographically dispersed nature, of coral species involved. The CIMAS workshop focused on Caribbean corals and coral reefs. Nine experts presented within two themes: General Coral Reef Ecology and Threats and Climate Change and Climate Impacts on Coral Reef Ecosystems. The information from the experts along with lively discussion from the audience provided valuable information in support of the proposal to list 66 or the 82 corals as under the ESA in December 2012. The workshop met all objectives. The information provided by the experts and audience, and summarized in a CIMAS-report delivered to the NMFS. It provided valuable support for NMFS' proposal to list 66 of the 82 candidate corals.

Establishing a Coral Reef Ecosystem Ocean Acidification Monitoring Program Workshop:
Coral reef monitoring historically has offered only limited capacity to assign specific attribution to agents of change. As the international community works to develop coordinated ocean acidification monitoring efforts within coral reef environments, there is an urgent need to strategically engineer these networks to better serves as research platforms which incorporate a diagnostic capability useful in testing predictions based upon our understanding of paleo-OA events, experimental findings, process investigations, and model projections. This demands a suite of biogeochemical and ecological measures jointly monitored to detect not only changes in water chemistry, but also changes in aspects of coral reef community structure and function that are particularly sensitive to OA. In August, 2012 a Coral Reef Ocean Acidification Monitoring Portfolio Workshop was hosted by the NOAA Ocean Acidification Program and the National Coral Reef Institute at the Nova Southeastern University Oceanographic Center. The workshop convened researchers and project managers from around the world engaged in coral reef ecosystems ocean acidification monitoring and research. The workshop sought to define a suite of metrics to include as part of long-term coral reef monitoring efforts that can contribute to discerning specific attribution of changes in coral reef ecosystems in response to ocean acidification. The working group discussed how this portfolio of observations could leverage existing and proposed monitoring initiatives and which basic measurements would need to be included. A report is currently being developed that will offer the key workshop recommendations for achieving the most valuable coral reef ocean acidification monitoring indices that should be integrated into long-term monitoring and should best aid in discerning changes in coral reef ecosystems in response to ocean acidification.

Public Outreach and Informal Educational Activities Associated with Specific CIMAS Research Projects

Measuring the Value of Climate Variability on the Agricultural Sector: Climate Prediction Applications Science Workshop
D. Solís and D. Letson (UM/RSMAS)
Conference website: http://www.rsmas.miami.edu/academics/divisions/marine-affairs-policy/cpasw/

PIRATA Northeast Extension

R.C. Perez, V. Hormann, G. Rawson, Z. Barton (UM/CIMAS)

R. Perez, V. Hormann, and R. Lumpkin participated in K-12 outreach events to increase public awareness about oceanographic research, including the Exploring Marine Science Day for 6-7th grade girls (RP, VH), the National Ocean Science Bowl Eastern Florida Regional Competition (RP), the Ocean Tracks project (RL), and the Adopt-a-Drifter Program (RL).

Gulf of Mexico Integrated Ecosystem Assessment

G.S. Cook (UM/CIMAS)

G.S. Cook represented CIMAS and NOAA at the NOAA education center during the 2013 Miami-Dade County Fair.

Aquarius Reef Base

J.W. Fourqurean, T.A. Potts and M.R. Heithaus (FIU)

- Thomas Potts (FIU) presented information on Aquarius Reef Base at the Sea-Space Initiative in Washington, DC in February 2013. The SSI is a series of global workshops designed to facilitate collaboration amongst ocean- and space-related fields and industries.
- Thomas Potts (FIU) worked with members of the Chief of Naval Operations Strategic Studies Group in Islamorada, Florida in April 2013 to propose collaborative efforts between the Navy and Aquarius Reef Base in an effort to leverage manned undersea capabilities across all domains.
- Thomas Potts (FIU) wrote an article entitled, "Aquarius Lives On" for *Alert Diver Magazine*, May 2012.
- James Fourqurean and Thomas Potts (FIU) collaborated on a non-fiction article about the Aquarius undersea laboratory with Joe Levit for the student classroom magazine, *National Geographic Explorer* to be published in June 2013.
- Thomas Potts (FIU) and staff members from Aquarius Reef Base collaborated with Bartley Price in the production of a video segment that aired on ABC news program, *Nightline* on February 6, 2013.

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

S. Dong (UM/CIMAS)

- Dong. S., 2012: Causes for model-data differences in seasonal variations of the South Atlantic meridional overturning circulation". 2012 AMOC annual PI meeting, Boulder, CO, August 15-17, 2012.
- Dong. S., 2013: "The South Atlantic MOC from CMIP5 models". NOAA/AOML/PHOD Informal Research Report, Miami FL, February 6, 2012.

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

B. 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.

Development of an Objective Scheme for Predicting Tropical Cyclone Genesis
J.P. Dunion (UM/CIMAS)

- Guest Scientist, Discovery Channel (Curiosity Series): Megastorm: Hurricane Sandy (November 2012)
- Guest Speaker, Marlborough Elementary School, Marlborough, CT (January 2013)
- Guest Speaker, University of Wisconsin-Madison/CIMSS (March 2013): *Development of a Probabilistic Tropical Cyclone Genesis Prediction Scheme*

Re-analysis of the Atlantic Basin Tropical Cyclone Database in the Modern Era
C.W. Landsea (NOAA/NHC), F D. Marks (NOAA/AOML/HRD), H.E. Willoughby and S. Delgado (FIU)

- Delgado, S., 2013: Reanalysis of the 1955 Atlantic Hurricane Season, FIU Earth and Environment Graduate Symposium, Miami FL (Talk given 15 Feb. 2013).

- Delgado, S., 2013: Recent Revisions to HURDAT. Florida Commission on Hurricane Loss Estimation Methodology, Tallahassee, FL (Talk scheduled for 18 June 2013)

Surface water pCO_2 measurements from ships
K. Sullivan, D. Pierrot, F. Bringas, G.-Ha Park, L. Barbero (UM/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.

The GO-SHIP CO_2 Repeat Hydrography Program
K. Sullivan, L. Barbero G. Berberian, J. Hooper and K. Seaton (UM/CIMAS); C. Langdon (UM/RSMAS)

- Pierrot, Wanninkhof, and Langdon are actively involved in the international coordination and data quality control efforts such as SOCAT and GO-SHIPS repeat hydrography.
- Barbero and Wanninkhof are leading a synthesis effort of Gulf of Mexico carbon data under auspices on the North American Carbon Program and the Ocean carbon and Biogeochemistry Program (OCB).

- Zhang (NOAA/AOML) is actively involved in the Joint IOC-ICES Study Group on Nutrient Standards (SGONS) and attended an international nutrient workshop organized by SGONS at NIOZ in Nov. 2012.

Ship of Opportunity Program

C. Gonzalez, S. Dong, Z. Barton, R. Domingues, M. Goes, G. Rawson, Q. Yao, J. Soto, R. Roddy, K. Seaton, and R. Sabina (UM/CIMAS)

- Google Earth application for global ocean observation visualization.
- SOOP project web page at AOML: *www.aoml.noaa.gov/phod/soop*
- TSG web page for the University of Virginia Semester at Sea MV Explorer: *www.aoml.noaa.gov/phod/tsg/sas/*

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)

- 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.

Biogeochemical Measurements - Atlantic Ocean Acidification Test Bed: Cheeca Rocks

C. Langdon (UM/RSMAS)

- The PI is working with a group of young film producers from the Savannah College and Art and Design on project to portray the threat that ocean acidification poses to the health of coral reefs both in Florida and around the world.

Global Drifter Program

S. Dolk, V. Hormann, R. Perez and E. Valdes (UM/CIMAS)

- In an effort to better assess drogue presence, E. Valdes reanalyzed data from 14,000 drifters, utilizing a program created by R. Lumpkin. This program incorporated anomalous downwind motion and drifter transmission frequency anomalies to more accurately determine drogue loss and improve the quality of surface current data.

- In conjunction with the Adopt A Drifter Program, S. Dolk and R. Lumpkin participated in an educational outreach program. *Ocean Tracks: Investigating Marine Migration in a Changing Ocean* is an educational program designed to engage high school students to utilize authentic scientific data through a newly developed interactive web-interface. S. Dolk and R. Lumpkin attended the advisory panel meeting to evaluate phase one of this collaborative project.

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

L.K. (Nick) Shay (UM/RSMAS)

Public awareness through invited presentations, website.

- Shay, L. K., B. Jaimes, J. K. Brewster, P. Meyers, C. McCaskill, E. W. Uhlhorn, F. D. Marks, G. R.Halliwell, O. M. Smedsted and P. Hogan. (2012): Resolving eddy shedding processes from the Loop Current during Deep Water Horizon (2010): Implications for coupled forecast intensity models. *30th AMS Hurricane and Tropical Meteorology Conference*, 16-20 April, Ponte Vedra, FL (Abstract)

- Shay, L. K., (2012) Systematically merged Atlantic regional temperature and salinity (SMARTS) climatology for operational hurricane forecasting. 21 Sept 2012, NOAA NESDIS, World Weather Research Bldg, Silver Springs, MD (Invited).
- Shay, L. K., (2012) Aircraft based surveys of the Loop Current during Deep Water Horizon and hurricane Isaac, BOEM Loop Current Dynamics System Workshop, 30-31 Oct, Raleigh, North Carolina (Invited)
- Shay, L. K., **(**2012) Advancing Technologies to improve oceanic analyses and products. *In Hurricane Symposium*, Annual Meeting of the American Meteorological Society, 22-27 January, New Orleans, LA, (Invited).
- Shay, L. K., B. Jaimes, J. K. Brewster, S. Paul and T. Richards, (2012) Improving the oceanic data acquisition system for research aircraft during Deep Water Horizon oil spill. 66th Interdepartmental Hurricane Conference, Office of the Federal Coordinator of Meteorological Services, 4-8 March, Charleston, SC

Hydrodynamic Modeling in Support of the Oil Spill Response in the Gulf of Mexico
V. Kourafalou (UM/RSMAS); M. Le Hénaff (UM/CIMAS); G. Halliwell (NOAA/AOML)

- Presentation at the *Ocean Sciences Meeting AGU/ASLO/TOS*, Salt Lake City, UT.
- Presentation at the *5th Lagrangian Analysis and prediction of Coastal and Ocean Dynamics (LAPCOD)*, Miami Beach, FL.
- Presentation at the American Geophysical Union 2012 Fall Meeting, San Francisco, CA (December 2012).
- Presentation at the *2nd International Coordination Workshop GODAE OceanView COSS-TT*, Lecce, Italy (January 2013).
- Presentation at the *2013 Gulf of Mexico oil spill and ecosystem science conference.* New Orleans, LA. (January 2013).
- PI Kourafalou presented project results at the meeting of NOAA/AOML, NOAA/Office of Response and Restoration and the U.S. Coast Guard on observational and modeling needs to address potential threats along the South Florida coasts from oil spills in Cuba and the Bahamas, Miami, FL (January 2012).
- PI Kourafalou was the local host and presented project results at the *Workshop on Hydrodynamic Modeling in Support of Potential Oil Spills in SE Florida*, a partnership of Florida Institute of Oceanography Universities, the U.S. Coast Guard and NOAA (Office of Response and Restoration and AOML), Miami, FL (October 2012).

Evaluation of Management Strategies for Fishery Ecosystems
E.A. Babcock and D.J. Die (UM/RSMAS)

- Dr. Babcock teaches an undergraduate class on Marine Conservation Biology and Fisheries in the Galapagos (U.M. M.S.C. 423) every Spring semester. This course has inspired several undergraduate students to become interested in Fisheries Biology as a career.

Creation of a Species Distribution Model for the Bryde's Whale, Balaenoptera edeni edeni, Residing in the Gulf of Mexico and Improve the Quality of Data Collected during Atlantic Marine Assessment Program for Protected Species (AMAPPS) Vessel and Aerial Surveys
R. Duncan (UM/CIMAS)

- R. Duncan volunteered for SEFSC's Open Day on May 25, 2013 at the Marine Mammal Program display table.

The Effect of the Florida Current on the Dispersal of Larval Fish at 27N Latitude
S. Privoznik, B. Muhling, A. Ender and E. Malca (UM/CIMAS)

- Plankton samples were utilized as part of Undergraduate Hollings Scholar Nadia Makara's summer internship at the Early Life History Laboratory (mentors: Trika Gerard and Estrella Malca)

Applying Bio-physical Monitoring and Capacity Assessments to Mesoamerican Reef Marine Protected Areas
E. Malca and B. Muhling (UM/CIMAS)

- This project was presented at the International "Larval Fish Conference" in Bergen, Norway July 2012. In addition to undergraduate & graduate students from ECOSUR in Mexico, Victor Gudiel Corona, University of San Carlos, Guatemala is utilizing samples to carry out his professional degrees in Marine Biology.
- 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

Assessing the locations and status of reef fish spawning aggregations in the Florida Keys
A. Gleason (UM/RSMAS)

- Results were communicated regularly to FKNMS partners and the public, including (1) sending regular updates to FKNMS managers, (2) a presentation to the FKNMS Advisory Council and (3) providing interviews regarding our ongoing research on a FL Keys radio-broadcast fishing show
- Details of mutton snapper spawning aggregations off Key West were provided to guide decision-making by a SAFMC-affiliated Interdisciplinary Planning Team considering alternatives for mutton snapper management (SAFMC Options Paper - Regulatory Amendment 14 to the Fishery Management Plan of the Snapper Grouper Fishery of the South Atlantic Region)

Neonate Loggerhead Dispersal, Behavior and Survivorship in the Western North Atlantic* and *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
K.L. Mansfield (FIU)

- Florida International University: *FOUND: the sea turtle lost years*. Eat Think and Be Merry science series, North Miami, FL (April 2013).
- 33rd Annual International Symposium on Sea Turtle Biology and Conservation: *Tag selection and techniques for satellite tagging small hard-shelled sea turtles.* Invited speaker and expert panelist in special satellite tagging session. Baltimore, MD (January 2013).

- Florida Fish and Wildlife Commission: *Satellite tracking neonate loggerhead sea turtles.* Florida Sea Turtle Permit Holder Meeting. Tallahassee, Florida (February 2013).
- Mansfield, K.L., J.A. Wyneken. *First satellite tracks of neonate green turtles (Chelonia mydas) using a new tag attachment method.* Oral presentation. 33rd Annual International Symposium on Sea Turtle Biology and Conservation in Baltimore, MD (February 2013).
- Gumbo Limbo Nature Center: *FOUND: the sea turtle lost years.* Public lecture series, Boca Raton, FL (January 2013).

Coral Recovery/Restoration Research

D.E. Williams, C.M. Cameron, A. Bright, B. Huntington, (UM/CIMAS)

- Collaborated with and provided presentation on coral spawning/larval research with Teen Research Underwater Explorers (TRUE Dive team; truediveteam.org), a group of high school scientific divers based in Tampa FL.

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**[1]
Dr. John Proni	Florida International University[1]
Dr. Eric Chassignet	**Florida State University**
Dr. Markus Huettel	Florida State University
Dr. Gustavo Goni	N OAA/AOML/Physical Oceanography
Dr. Frank Marks	NOAA/AOML/Hurricane Research Division
Dr. Alan Leonardi	NOAA/AOML/Ocean Chemistry Division[2]
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

[1]No longer with FIU. Replacement needed.
[2]No longer in position. New Acting Director will substitute.

EXECUTIVE ADVISORY BOARD

[1]No longer at UVI. Replacement needed

IX. AWARDS AND HONORS

Western Boundary Time Series Project
Rigoberto Garcia (UM/CIMAS)

- Award for AOML outstanding research paper for the article *“Florida Current transport variability: An analysis of annual and longer-period signals”*. Deep Sea Research, Part I, 57, 835-846, 2010. Authors: Meinen, C.S., M.O. Baringer, and R.F. Garcia.

Multimodel Ensembles for Hurricane Forecasts
Prof. T.N Krishnamurti and Robert O. Lawton

- T.N. Krishnamurti received the Sir Gilbert Walker Gold Medal of the India Meteorological Society, 2012.

Relationship of the Atlantic Warm Pool with the Atlantic Meridional Overturning Circulation
Sang-Ki Lee, Liping Zhang, David B. Enfield (UM/CIMAS)

- The paper by Wang, C., S. Dong, A. T. Evan, G. R. Foltz, and S.-K. Lee, 2012, Multidecadal co-variability of North Atlantic sea surface temperature, African dust, Sahel rainfall and Atlantic hurricanes, *J. Climate*, 25, 5404-5415, was highlighted by *Nature Geoscience* in the issue of April 2012.

Is There An Optimal ENSO Pattern That Enhances Large-scale Atmospheric Processes Conducive to Major Tornado Outbreaks in the U.S.?
Sang-Ki Lee, David B. Enfield and Hailong Liu (UM/CIMAS)

- Paper by Lee, S.-K., R. Atlas, D. B. Enfield, C. Wang and H. Liu, 2013, Is there an optimal ENSO pattern that enhances large-scale atmospheric processes conducive to major tornado outbreaks in the U.S.?, *J. Climate* 26, 1626-1642, 2013, was highlighted in February 2013 issue of *Bulletin of the American Meteorological Society* as Paper in Note.

Real-Time Hurricane Wind Analysis
Bachir Annane, Sonia Otero, Russell St. Fleur (UM/CIMAS)

- The H*Wind Team was nominated for Federal Employees of the Year to the South Florida Federal Executive Board for recognition in the Professional Excellence category, in May 2013.

Development of Multiple Moving Nests within a Basin-Wide HWRF Modeling System
Xuejin Zhang and Javier Delgado (UM/CIMAS)

- Xuejin Zhang was awarded NOAA Team Member of the Month for May 2013

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.

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

C. Atluri, R. Domingues, E. Forteza, S.L. Garzoli, M. Goes, V. Halliwell and R. Sabina (UM/CIMAS)

- Certificate of Appreciation from AOML issued to Elizabeth Forteza, Vicki Halliwell, and Reyna Sabina: For months of dedication in maintaining the 24/7 US Argo operations during a critical manpower shortage ensuring that there were no gaps in this critical environmental data system.

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.

Evaluation of Management Strategies for Fishery Ecosystems

E.A. Babcock and D.J. Die (UM/RSMAS)

- Ph.D. student Holly Perryman won the RSMAS T.A. Excellence Award for a Graduate Class, June 2012.

Agreement between the University of South Florida College of Marine Science and NOAA Fisheries support for the Marine Resource Assessment program

E.B. Peebles and C.H. Ainsworth (USF)

- Orian Tzadik (MRA student) –1st place, best presentation, USF-CMS 2013 Graduate Student Symposium.

X. POSTDOCTORAL FELLOWS AND GRADUATE STUDENTS

CIMAS-Supported Postdoctoral Fellows and Graduate Students

Postdoctoral Fellows
Barbero-Munoz, Leticia
Enochs, Ian
Chen, Hua
Gruss, Arnaud
Hormann, Verena
Le Henaff, Matthieu
Liu, Hailong
Liu, Yanyun
Phillips, Nicole
Song, Zhenya
van Hooidonk, Ruben
Wang, Xin
Yang, Hoaping
Zabola, Joaquin

Graduate Students
Task I
Fiorentiono, Laura
Johnston, Michelle
Vaughan, Nathan
Shiroza, Akihiro
Yurex, Simeon

Task III
Ailloud, Lisa
Bhatia, Kieran
Conner, Allison
Danger, Nick
Drury, Crawford
El-Toury, Sharein
Ender, Alexander
Harford,William
Jay Fisch
Nuttal, Matt
Omori, Kristen
Perryman, Holly
Rolando Santos
Smith, Matthew

Task III Cont'd
Thyberg, Travis
Woosley, Ryan
Zink, Ian

Employees
Dolk, Shaun
Domingues, Ricardo
Gramer, Lewis J.
Jankulak, Michael
Malca, Estrella
Privoznik, Sarah
Rawson, Grant
Seaton, Kyle
Soto, Jaime

Other Participants in CIMAS Projects

Postdoctoral Fellows
Adam, Thomas
Huntington, Brittany
Min, Dughong
Simon, Anu
Toro-Farmer, Gerardo

Graduate Students
Abercrombie Mary I.
Barnes, Brian
Chancellor, Emily
Cockrell, Marcy
Cossuth, Joshua
Delgado, Sandy
Drexler, Michael
Granneman, Jennifer
Grasty, Sarah
Hariharan, Sam
Herdter, Elizabeth
Hipes, Jacquelin
Jaimes, Benjamin
Kiel, Courtney
Kilborn, Joshua
Lee, Corinne

Graduate Students Cont'd
Lindo-Atichati, David
Liu, Dianting
Marshall, Darren
McCaskill, Claire E.
Meng, Tao
Meyers, C.
Mullikin, Elizabeth
O'Connor, Brendan
Snyder, Susan
Tzadik, Orian
Vega-Rodriguez
Wallace, Amy
West, Lorin
Zelinsky, David

XI. RESEARCH STAFF

Aichinger Dias, Laura	Research Associate II
Aksoy, Altug	Assistant Scientist
Amornthammarong, NatchanonAssistant	Scientist
Annane, Bachir	Senior Research Associate III
Atluri, Charita	Senior Research Associate I
Barbero Munoz, Leticia	Assistant Scientist
Barton, Zachary	Research Associate I
Berberian, George	Research Associate II (PT)
Blondeau, Jeremiah	Senior Research Associate II
Bright, Allan	Senior Research Associate I
Brown, Cheryl	Research Associate II
Bucci, Lisa	Senior Research Associate I
Cameron, Caitlin	Research Associate II
Carlton, Renee	Research Associate II
Chen, Hua	Postdoctoral Associate
Cook, Geoffrey	Assistant Scientist
Delgado, Javier	Senior Research Associate I
Diaz, Jose E.	Research Associate II
Dolk, Shaun	Research Associate III
Domingues, Ricardo	Research Associate II
Dong, Shenfu	Associate Scientist
Duncan, Roxanne	Research Associate I
Dunion, Jason	Senior Research Associate III
Enochs, Ian	Assistant Scientist
Enfield, David	Scientist (PT)
Erickson, Kristin L.	Research Associate III
Festa, John	Senior Research Associate III (PT)
Forteza, Elizabeth	Research Associate III
Gall, Robert	Scientist

Garcia, Rigoberto F.	Senior Research Associate II
Garzoli, Silvia	Scientist (PT)
Gidley, Maribeth	Assistant Scientist
Goes, Marlos	Assistant Scientist
Gonzalez, Caridad	Research Associate III
Gramer, Lewis J.	Research Associate III
Gruss, Arnaud	Postdoctoral Associate
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.	Systems Administrator
Johnson, Darlene R.	Senior Research Associate I
Klotz, Bradley	Research Associate III
Le Henaff, Matthieu	Assistant Scientist
Lee, Sang-Ki	Scientist
Liu, Hailong	Senior Research Associate II
Liu, Yanyun	Postdoctoral Associate
Lorsolo, Sylvie	Assistant Scientist
Malca, Estrella	Research Associate III
Manzello Derek	Associate Scientist
Melo, Nelson	Senior Research Associate II
Muhling, Barbara	Associate Scientist
Otero, Sonia	Senior Research Associate II
Park, Geun-Ha	Assistant Scientist
Peng, Tsung-Hung	Scientist (PT)
Perez, Renellys	Associate Scientist
Phillips, Nicole	Postdoctoral Associate
Pierrot, Denis P.	Associate Scientist
Privoznik, Sarah	Research Associate I
Rawson, Grant T.	Research Associate III

Richter, Lee	Research Associate I
Roddy, Robert	Research Associate III (PT)
Sabina, Reyna	Research Associate III (PT)
Seaton, Kyle	Research Associate II
Sellwood, Kathryn J.	Research Associate III
Shideler, Allison	Senior Research Associate I
Song, Zhenya	Postdoctoral Asociate
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
van Hooidonk, Ruben	Postdoctoral Associate
Visser, Lindsey	Research Associate II
Volkov, Denis	Associate Scientist
Wang, Xin	Senior Research Associate I
Wicker, Jesse A.	Research Associate III
Williams, Dana E.	Associate Scientist
Willis, Paul	Research Associate II (PT)
Yang, Haoping	Postdoctoral Associate
Yao, Qi	Senior Research Associate I
Zabalo, Joaquin	Postdoctoral Associate
Zhang, Jun	Associate Scientist
Zhang, Liping	Senior Research Associate I
Zhang, Xuejin	Associate Scientist

XII. VISITING SCIENTISTS PROGRAM

Dr. Shane Elipot
National Oceanography Centre, Liverpool
Joseph Proudman Building
6 Brownlow Street, Liverpool, L3 5DA, UK
17 – 21 September, 2012

Dr. Nancy Maynard
NASA Emeritus
NASA Goddard Space Flight Center
Greenbelt, MD
1October, 2012 (to continue through 2015)

Dr. Elizabeth Jewett
Director, NOAA Ocean Acidification Program
National Oceanic and Atmospheric Administration
SSMC 3, Rm 11806
1315 East West Hwy.
Silver Spring, MD 20910
9 October, 2012

9 October, 2012 *"Introduction to the NOAA Ocean Acidification Program"*

Prof. Dr. Edmo J. D. Campos
Professor Titular - Physical Oceanography
Oceanographic Institute - University of Sao Paulo
Pca. do Oceanografico 191 - Cid. Universitária
05508-120 S. Paulo, SP, Brazil
28 December, 2012 – 25 February, 2013

Dr. Janice R. Trotte-Duhá
Ministerio da Ciencia, Technologia e inovacão
Secretary of Research and Development Policies and Programs
Esplanada dos Ministérios, Bloco E
CEP: 70067-900, Brasilia, DF
28 – 29 January, 2013

XIII. PUBLICATIONS

Table 1: Publication Record 2012-2013

	Institute Lead Author	**NOAA Lead Author**	**Other Lead Author**
	2012-2013	**2012-2013**	**2012-2013**
Peer Reviewed	38	26	32
Non-Peer Reviewed	8	6	0

Refereed Journal Articles

Aksoy, A. (2013), Storm-Relative Observations in Tropical Cyclone Data Assimilation with an Ensemble Kalman Filter. *Mon. Wea. Rev.*, 141, 506-522, doi:http://dx.doi.org/10.1175/MWR-D-12-00094.1.

Aksoy, A., S.D. Aberson, T. Vukicevic, K.J. Sellwood and S. Lorsolo (2013), Assimilation of high-resolution tropical cyclone observations with an ensemble Kalman filter using NOAA/AOML/HRD's HEDAS: Evaluation of the 2008-2011 vortex-scale analyses. *Mon. Wea. Rev.*, 141, 1842-1865, doi:http://dx.doi.org/10.1175/MWR-D-12-00194.1.

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Babcock. E.A., R. Coleman, M. Karnauskas and J. Gibson (2013), Length-based indicators of fishery and ecosystem status: Glover's Reef Marine Reserve, Belize. *Fisheries Res.*, doi:10.1016/j.fishres.2013.03.011, in press.

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Bernard, A. M., M.S. Shivji, R.R. Domingues, F.H. Hazin, A.F. Amorim, A. Domingo, F. Arocha, E.D. Prince, J.P. Hoolihan and A.W. Hilsdorf (2013), Broad geographic distribution of roundscale spearfish (*Tetrapturus georgii*) (Teleostei, Istiophoridae) in the Atlantic revealed by DNA analysis: implications for white marlin and roundscale spearfish management. *Fisheries Res.*, 139, 93-97.

Bignami, S., I.C. Enochs, D.P. Manzello, S. Sponaugle and R.K. Cowen (2013) Ocean acidification alters the otoliths of a pan-tropical fish species with implications for sensory function. *Proceedings Nat. Acad. Sci*., 110(18) 7366-7370, doi:10.1073/pnas.1301365110.

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Brandt, P., R.J. Greatbatch, S.-H. Didwischus, M. Claus, V. Hormann, A. Funk, J. Hahn, G. Krahmann, J. Fischer and A. Körtzinger (2012), Ventilation of the equatorial Atlantic by the equatorial deep jets, *J. Geophys. Res.*, 117, C12015, doi:10.1029/2012JC008118.

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Gopalakrishnan, S.G., F. Marks, J.A. Zhang, X. Zhang, J.-W. Bao, V. Tallapragada (2013), A Study of the Impacts of Vertical Diffusion on the Structure and Intensity of the Tropical Cyclones Using the High-Resolution HWRF System. *J. Atmos. Sci.*, 70, 524-541, doi:http://dx.doi.org/10.1175/JAS-D-11-0340.1.

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Manzello, D.P., I.C. Enochs, N. Melo, D.K. Gledhill and E.M. Johns (2012), Ocean acidification refugia of the Florida Reef Tract. *PLoS ONE* 7(7), e41715, doi:10.1371/ journal.pone.0041715.

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Misra, V., S. DiNapoli and M. D. Powell (2013), The track integrated kinetic energy of the Atlantic tropical cyclones. *Mon. Wea. Rev*., 141, 2383-2389, doi: http://dx.doi.org/10.1175/MWR-D-12-00349.1.

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Sabine, C.L. et al. (2013), Surface Ocean CO_2 Atlas (SOCAT) gridded data products. *Earth Syst. Sci. Data*, 5, 145-153, doi:10.5194/essd-5-145-2013.

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Wang, X., and C. Wang (2013), Different impacts of various El Niño events on the Indian Ocean Dipole. *Clim. Dyn.*, doi: 10.1007/s00382-013-1711-2, in press.

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