Cooperative Institute for Marine and Atmospheric Studies

Fourth Annual Report

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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 re-competition 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 $22.0M. Task I which includes not only Administration but also Research Infrastructure (ship-time, computing resource access etc.), Education and Outreach was ca. $2.7M. The University of Miami contributed an additional $.24 M towards Administration. Task II, which supports CIMAS employees conducting research off- campus was ca. $ 8.1M.

Research project funding (Tasks III and IV) totaled ca. $11.2M. The largest portions of Tasks III and IV were the research projects within Themes (3, 1) Sustained Ocean and Coastal Observations & Climate Research Impact which together account for 65%. The smallest portions were in Themes (7, 5 and 4) Protection and Restoration of Resources, Ecosystem Modeling & Forecasting and Ocean Modeling, which together account for only 14 %. 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 somewhat 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 138 individuals at UM were directly provided salary support through CIMAS. Of these, 110 received over 50% of their support through CIMAS. Of the 110 research employees who received over 50% NOAA support, 63 worked at AOML, 38 at the SEFSC, 2 at RSMAS, 1 at the NHC, 4 at University of Puerto Rico and 2 in other locations..

Twenty two of these employees were Research Scientists including 2 part time former NOAA employees. The employees in the Research Associate and Research Scientist ranks have a diverse demographic profile. The population is 44% female. Foreign born individuals make up 51% of the total. The largest foreign sub-groups are Hispanics (23%) and Asian and Pacific Islanders (17%). The population of CIMAS remains relatively young in comparison with NOAA overall (or the local NOAA facilities – AOML, SEFSC and NHC) with an average age of 39. The demographic profile has remained relatively constant in recent years.

During this last year there were 71 peer-reviewed publications and another 51 non-peer reviewed technical reports or other publications resulting from CIMAS research. Results of a few individual projects are highlighted below. They were selected from various themes to be representative of the diversity of activities carried out within CIMAS and are sorted with respect to the high level NOAA scientific goal they primarily support. 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 individual CIMAS Research Themes.

SOME RESEARCH HIGHLIGHTS

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

The Western Boundary Time Series Project

The Western Boundary Time Series (WBTS) project maintains and analyzes one of the longest time series of water mass and transport data contributing to the global meridional overturning circulation (MOC). Numerical climate models have determined that variations in the northern components of the MOC relate to precipitation over the northern hemisphere, sea surface temperature distribution and hurricane intensity. Through innovative application and integration of different observational methods the project team has measured the temporal variability of both the warm upper and cold lower limbs of the MOC in the Florida Current and Deep Western Boundary Current, respectively. Research completed this year has determined the accuracy of the Florida Current volume transport to be within 1.7 Sverdrups and measured a decline in the Atlantic Meridional Overturning Circulation between 2004 and 2012 with a significant slowing in the transport south of the Lower North Atlantic Deep Water.

Simulation of the Argo Observing System

The Argo array (a major component of the Global Ocean Observing System) has been fully implemented and is now providing the oceanographic community with reliable three-dimensional global measurements of ocean temperature and salinity. These data are used to detect changes in the oceanic state and climate of the Earth, and this has large societal importance. Understanding the limitations of the Argo observing system is essential to meaningfully interpret these data. This project team has successfully estimated the uncertainties in oceanic state reconstructed from Argo data, identified those geographic regions in which reconstructions are less reliable and those where additional measurements are required.

PIRATA Northeast Extension (PNE)
Scientists involved with the PIRATA Northeast Extension (PNE) project described for the first time the mean vertical and cross-equatorial structure of the upper-ocean meridional currents in the Atlantic cold tongue region, using in situ observations including drifters, Argo, shipboard/lowered ADCP, and moored ADCP. The dominant circulation features in the long-term mean meridional velocity in the upper 100 m are the tropical cells (TCs) located approximately between 5°S and 5°N, with a near-surface poleward flow and subsurface equatorward flow that is stronger and shallower in the northernmost cell. From the central to the eastern Atlantic, the thickness of the TC surface limb decreases. In addition, the northern cell shifts further south of the equator from 23°W to 10°W. The project team has provided the first quantitative analysis of the heat budget in the northeastern tropical Atlantic.

Assessing the Sensitivity of Northward Heat Transport/Atlantic Meridional Overturning Circulation to Forcing in Existing Numerical Model Simulations
Comparison of the MOC estimates from observations and numerical models suggests that the misrepresentation of the MOC seasonal variations in the models is related to a strong baroclinicity in the modeled temperature/salinity fields below the surface mixed-layer. Analysis of data from two boundary arrays deployed along 34.5°S indicates that for periods shorter than 20 days basin-wide MOC variations are most strongly influenced by Ekman flows, while at periods between 20 and 90 days geostrophic flows tend to exert greater control over total transport variability of the MOC.

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) assimilates high-resolution, vortex-scale observations. The project team has demonstrated that it realistically represents the initial hurricane vortex structure both with simulated and real data. As a result HWRF forecasts initialized with HEDAS analyses have been found to be superior both in track and intensity to the NOAA operational HWRF model. The system has run in near real time since the 2010 hurricane season, and retrospectively for the 2008 and 2009 hurricane seasons. In 2013, some satellite products were assimilated for the first time in addition to observations from aircraft platforms.

A Study on the Asymmetric Rapid Intensification of Hurricane Earl (2010) Using the HWRF System
The high resolution model output from a real case forecast for a sheared storm is used for the first time to provide insightful understanding of the Rapid Intensification of a sheared storm. The diagnostics reveal that RI is triggered by an alternative pathway which is asymmetric intensification and very much different from the symmetric intensification mechanisms previously proposed. Especially in its early stages RI of a sheared a storm is the result of horizontal temperature advection taking place at upper levels when the configuration of

convective scale vertical motion and meso-scale vertical motion is such that warm advection toward the low level storm center is maximized.

Investigation of HWRF Model Error Associated With Surface-Layer and Boundary-Layer Parameterizations to Improve Vortex-Scale, Ensemble-Based Data Assimilation Using HEDAS

An idealized HWRF hurricane modeling system was developed for NOAA/NWS Hurricane Forecast Improvement Project (HFIP) with the capability to compare simulations directly to observed hurricane structures. By precisely controlling the environmental conditions, these hurricane simulations will enable the project team to investigate in detail how realistic NOAA's HWRF hurricane model is in its depiction of the structure of a hurricane, so that systematic improvements can be made not only to just obtain better track and intensity forecasts but more realistic simulation of the hurricane structure itself. An extensive analysis revealed that the model exhibits sensitivities to the parameterization of the surface and boundary layers that are comparable in magnitude to the expected sensitivities to vertical shear and sea surface temperature. Methods were proposed to calibrate the various sources of perturbations so as to obtain a better balanced ensemble.

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

Marine Optical Buoy (MOBY) Operations and Technology Refresh

The measurement of ocean color from satellites, because of the intervening atmosphere and low reflectance of light from the ocean versus the atmosphere, requires extremely high accuracy from the sensor. For the ocean color data record to be compared, merged, and maintained over a significant time period requires a common calibration point, maintained at the highest accuracy possible. The MOBY calibration site, supported by this work, provides that single reference point used by the international community of ocean color satellite systems to tie their measurements together. This allows the ocean color record to be maintained over generations of satellite instruments to provide a data record suitable for studies of climate and ecological change. This calibration site is not only used by the international community but provides critical support to the recently launched NOAA VIIRS.

Exploring nonlinear time series models for forecasting stock abundances in the Gulf of Mexico

Nonlinear modeling can improve stock assessment techniques. Improving stock assessments, and in particular forecasting subpopulation abundances, is necessary for sustainable harvesting of marine resources. With nonlinear modeling the forecasting is not constrained by the mechanistic assumptions that are required by traditional assessment methods. Nonlinear modeling relaxes these assumptions, but nonetheless captures dynamical trends in stock abundance.

Living on the (shelf) edge: using advanced glider technology to assess fishery resources along the South Atlantic continental shelf break

This project was conducted as a proof of concept for a multi-disciplinary approach to coastal marine research. Data sets of conductivity, temperature, chlorophyll fluorescence, CDOM, backscatter fluorescence, and dissolved oxygen were collected throughout the upper 200m of the water column across the Gulf Stream front. Passive acoustic recordings were collected through the entire transect resulting on a detection of a specimen far outside of its original detection range.

The importance of parrotfish on the maintenance and recovery of coral- dominated reefs

Herbivorous fishes are critical for healthy coral reef ecosystems, but how many and which types of herbivores are needed for coral persistence and recovery is largely unknown. This information is necessary for effective management of coral reef ecosystems including the management of reef fish fisheries. Results to date indicated that impacts of herbivores on coral populations will be modulated by physical and biological characteristics of individual reefs, and that these impacts are likely to be species-specific.

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

The overarching goal of this project is to improve the timeliness and quality of fishery stock assessments for reef fish populations in the SE United States and Caribbean. Reef fish are notoriously difficult to assess because their habitats are not conducive to the use of traditional sampling gear such as trawls. The three cruises we conducted in the performance period demonstrated the technical feasibility and operational robustness of the towed camera system, producing research-quality estimates of fish abundance and associated habitat characteristics in three marine protected areas on the west Florida shelf. This new technology has the potential to be transformational in providing such estimates anywhere bottom topography makes net sampling difficult or impossible.

Assessing the locations and status of reef fish spawning aggregations in the Florida Keys;

The goal of this project is to determine if there is a consistent relationship between seabed geomorphology and the locations of reef-fish spawning aggregations (FSAs) in the Florida Keys. Over 55% of the benthic habitat of the FKNMS remains unmapped, mostly in water deeper than 20 m, which is primarily where the FSAs of commercially important as grouper and snapper species were historically found. Through a combination of acoustic seabed classification, fisheries acoustic surveys, aerial and diver observations, the project team is investigating the current status of historical spawning aggregation sites as well as patterns of seabed features common to those sites. 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).

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, Extreme Weather Events, Climate Services and Ecosystem Approaches to Management as reflected in NOAA's Annual Guidance Memorandums, Research Plans and various Strategic Plans.
- Most recently (during the last project period) we established the Ocean Modeling and OSSE Center (OMOC) in collaboration with AOML.

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 in off-campus research teams primarily at NOAA's Miami facilities (AOML, SEFSC and NHC). The expertise of these CIMAS employees complements that already present within NOAA. CIMAS research scientists can also serve as project principal investigators and submit proposals to NOAA through Task III and to other agencies (or private entities) through Task IV as described below.

Research in CIMAS is also carried out under Tasks III and Task IV. These Tasks provide funding to both 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 competitive 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 through Task III.

III. PERSONNEL

Distribution of Personnel

CIMAS personnel participate in a wide range of NOAA-related activities. During the past twelve months a total of 138 persons were associated with CIMAS in various capacities. Of these, 110 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 110 who received over 50% NOAA support, 63 are located at AOML, 38 at the SEFSC, 2 at RSMAS and 1 at NHC. 2 work at distant NOAA facilities.

Table 1: CIMAS Research Personnel 2013 – 2014

Category	Number	BS	MS	Ph.D
Research Associate/Scientist	66	15	25	26
Part Time Research Associate/Scientist	8	4	2	2
Postdoctoral Fellow	10			10
Research Support Staff	26	1		
Total (> 50% NOAA support)	**110**	**20**	**27**	**38**
Full Time Administrative Staff	5			2
Task I Undergraduate Students	12			
Task I Graduate Students	11			
Visiting Scientist	4			
NOAA Association	63-AOML 38-SEFSC 2-RSMAS 7- (1) NHC, (4) UPR, (2) Other			
Obtained NOAA employment within the last year	1			

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 conducting University research. 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 closely parallel in pay, prestige and description the research faculty track 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 10 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 in the coming years.

Research Support Staff are temporary employees, hired for the duration of specific projects. These include persons with 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 during this last project period.

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.

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 the host institution, UM/RSMAS (R. Avissar), who chairs the Advisory board (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 over the lifetime of CIMAS. In this last reporting period one CIMAS researcher transitioned to a Federal position.

Demographics of CIMAS Employees

The CIMAS population is 56% male. Foreign-born individuals make up 51% of the personnel; of these Hispanics make up 23% of the ranks; Asian and Pacific Islanders, 17%. Only 3% are African-Americans despite our efforts to expand this group's participation. The population of CIMAS is relatively young with an average age of 39. The largest age decade is that between 30 and 40, for a total of 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 11 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 12 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. $22.0M 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
Year 4	2,731,785	8,062,381	10,643,803	532,443	21,970,412
TOTALS	**9,378,728**	**32,808,825**	**24,318,612**	**4,068,247**	**70,574,412**

The sources of that funding are shown in Table 2. The major source of funding continued to be OAR which provided 56% of the total. A major source of NOAA funding this reporting period was associated with the OAR portion of the Disaster Relief Appropriation Act of 2013 – "OAR" 14%. NMFS, NESDIS, NOS were second at 24%, 15%, and 3% respectively. "Other" accounts for 2%, the source of funding include awards from NASA and private industry as well as two sub-contractual awards from FIU to CIMAS investigators.

Table 2: Funding by Source

1 July 2013 - 30 June 2014		
Source	**Funding $M**	**% Total**
NESDIS	3.37	15%
NMFS	5.23	24%
NOS	0.75	3%
OAR	2.79	14%
OAR/AOML	7.35	33%
OAR/CPO	1.61	7%
OAR/OER	0.44	2%
Other	0.43	2%
GRAND TOTAL	**21.97**	**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 57%) or whatever rate is specified in the relevant RFP.** The rate according NOAA for Task III is in recognition of the funding CIMAS receives under Task 1 for Administration costs toward which that IDC would have contributed.

The total of Task I Funding was $ 2.73M, of which $0.66M was for the Administration component (this includes a 0.24M UM contribution) and the remainder for Research Infrastructure, Education and Outreach. This number is somewhat high due to advance funding of Task I during this reporting period. The distribution of NOAA Task 1 expenditures is shown in Figure 1.

The total NOAA-supported Task 1 budget was $ 2.73M. The category “Administration” 18% covers only a portion of the salary of CIMAS staff including its Director and Associate Director. The category "Other" 17% 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 25% of the total. Temporary Staff accounts for 28% which covers persons hired on a temporary basis to support research. Infrastructure accounts for 4% of total budget, this included the purchase of a salinometer.

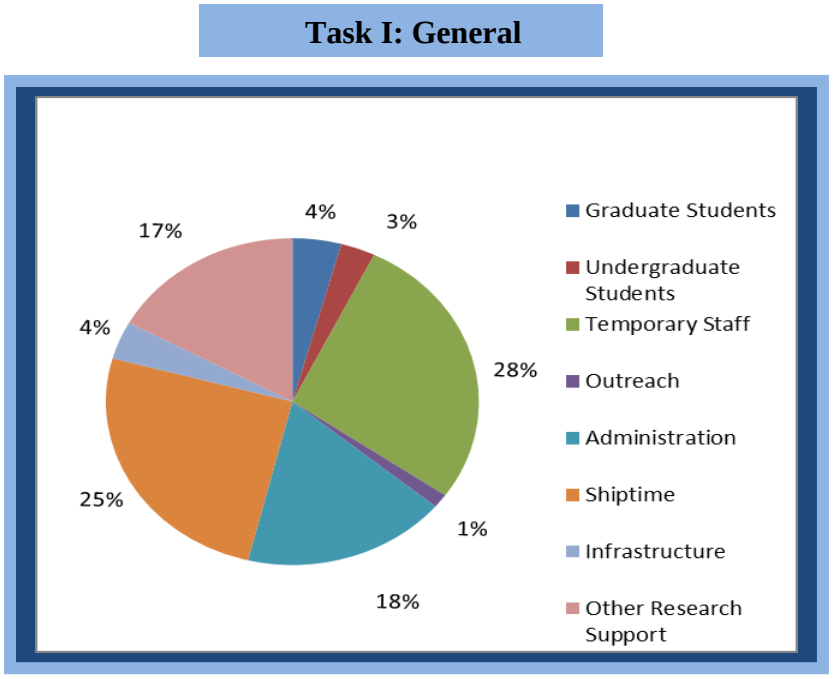

Figure 1: Distribution of Task1Funding

The funding provided for Task II employees totaled $8.1M over the past twelve months. The distribution of these funds by employee category is depicted in Figure 2.

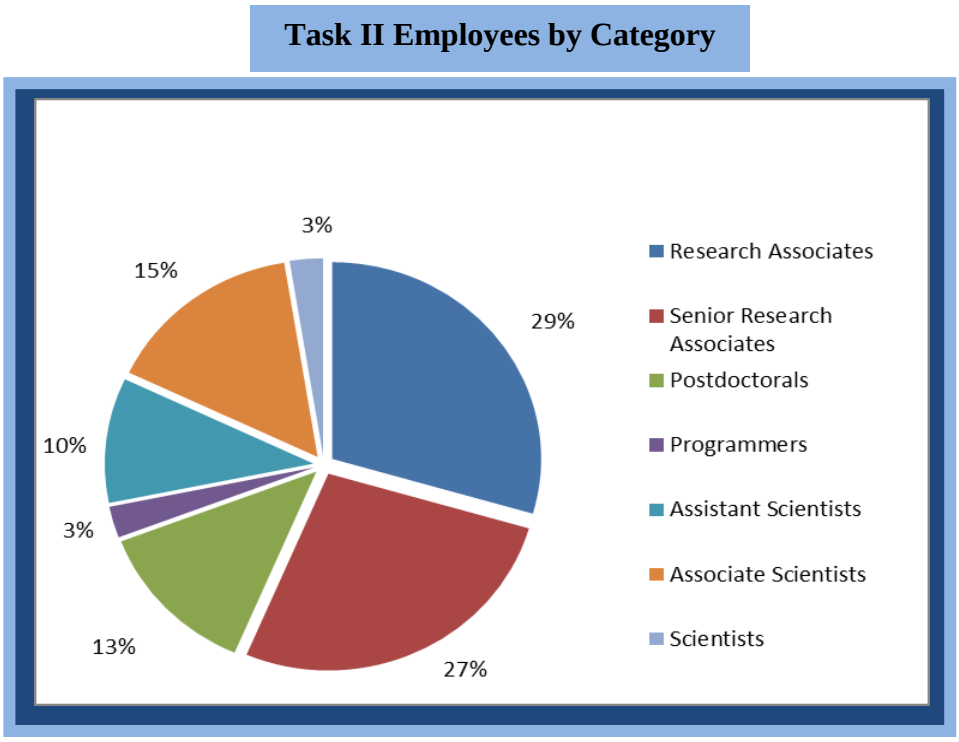

Figure 2: Distribution of Task 2: Funds by Employee Category

Funding By Theme

Project specific research funding (Tasks III and IV) under the new CA totaled ca. $11.2M as shown above in Table 1. Figure 3 shows the percentage of Task III and Task IV funding expended upon each CIMAS Themes during the twelve months. Of total CIMAS research funds, Theme 3: Sustained Ocean and Coastal Observations continues to account for the largest portion of the funding 40%. The smallest portion of funding was in Theme 5: Ecosystem Modeling and Forecasting – 3%.

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 include 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.

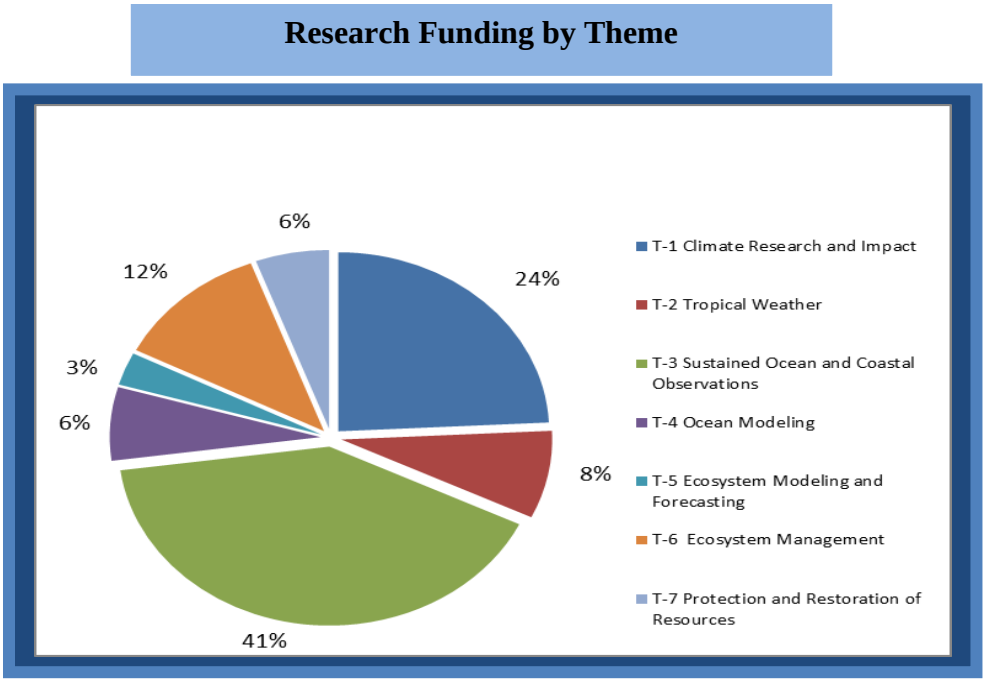

Figure 3: Percentage of Task 3 and Task 4 (Research) funding in the CIMAS Themes

Table 3 below tabulates NOAA funding received by CIMAS under the present Cooperative Agreement. This reporting period we received 5 awards under the Disaster Relief Appropriation Act of 2013 related to Hurricane Sandy activities totaling 5.43M. Additional "Sandy" awards will be included in subsequent reports.

Funding distributed through CIMAS to the Partner Universities during the present reporting period was $1.8M or 27% of Task III (Partner Universities are eligible through CIMAS only for Task III funding).

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 3: Recent NOAA Funding Directly to CIMAS

NOAA Award Number	Award Period	Total Funds
NA10OAR4320143	09/01/10 - 8/31/15	$ 62,216,594
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
NA12OAR4310105	08/01/12 - 07/31/14	$ 190,000
NA12OAR4310089	08/01/12 - 07/31/14	$ 130,000
NA12OAR4310083	08/01/12 - 07/31/16	$ 10,000
NA12OAR4310073	08/01/12 - 07/31/16	$ 10,000
NA14OAR4830103	02/01/14-01/31/16	$ 1,983,254
NA13OAR4830224	10/1/13 - 09/30/15	$ 1,301,395
NA13OAR4310131	9/1/2013 - 08/31/16	$ 68,282
NA130OAR4830217	10/1/13 - 09/30/15	$ 105,935
NA13OAR4830232	10/1/13 - 09/30/15	$ 1,027,950
NA14OAR4830119	04/1/14 - 03/31/14	$ 1,016,570

Table 4: Task III Projects Linked to CIMAS

PI	Funding Source	Project Title
Kourafalou	OAR	Extending the Gulf of Mexico to the North Atlantic in support of Development & Demonstration of a Relocatable Ocean OSSE System
Lee, S	OAR	CIMAS Contributions to OAR disaster Recovery Act Project
Pere, R	OAR/CPO	South Atlantic Meridional Overturning Circulation: Pathways and Modes of Variability
Shay, N	OAR	Evolving Data Fields for Use in OSSE Modeling
Zhang, X	OAR	Services to Support the Hurricane Forecast Improvement Project
Zhang, X	OAR	CIMAS Contributions to OAR disaster Recovery Act Project

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 and some "Sandy" decisions were made late in the year. Last, there are 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.

VI. RESEARCH REPORTS

THEME 1: Climate Research and Impact

Southwest Atlantic Meridional Overturning Circulation ("SAM") Project

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

Long Term Research Objectives and Strategy to Achieve Theme:
***Objectives*:** To sustain a 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 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. Observations and modeling studies have also 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. NOAA has maintained a 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. The SAM project represents a collaborative effort with partners in Argentina, Brazil, France, and South Africa to monitor the MOC-related flows in the South Atlantic and to improve our understanding of the key processes that cause this variability. Specifically the NOAA component of this international effort is focused on the western boundary currents, the Brazil Current in the upper layer and the Deep Western Boundary Current (DWBC) at depth. Study of the DWBC is of particular interest because it is believed to carry a significant percentage of the lower limb of the MOC, and prior to the SAM project, observations were insufficient to constrain its mean and variability in this crucial region. Long-term observations of these flows will be required to understand the mechanisms leading to changes in the MOC system in the South Atlantic, and the impact of those MOC changes on the global climate. The goal of the NOAA SAM program and the international collaborating programs is to measure the MOC in the South Atlantic with a trans-basin array from South America to Africa along 34.5°S. With approximately ten moorings on either side of the basin (as of December 2013) and more moorings scheduled for deployment in 2014, this trans-basin array ("SAMBA") is rapidly becoming a reality.

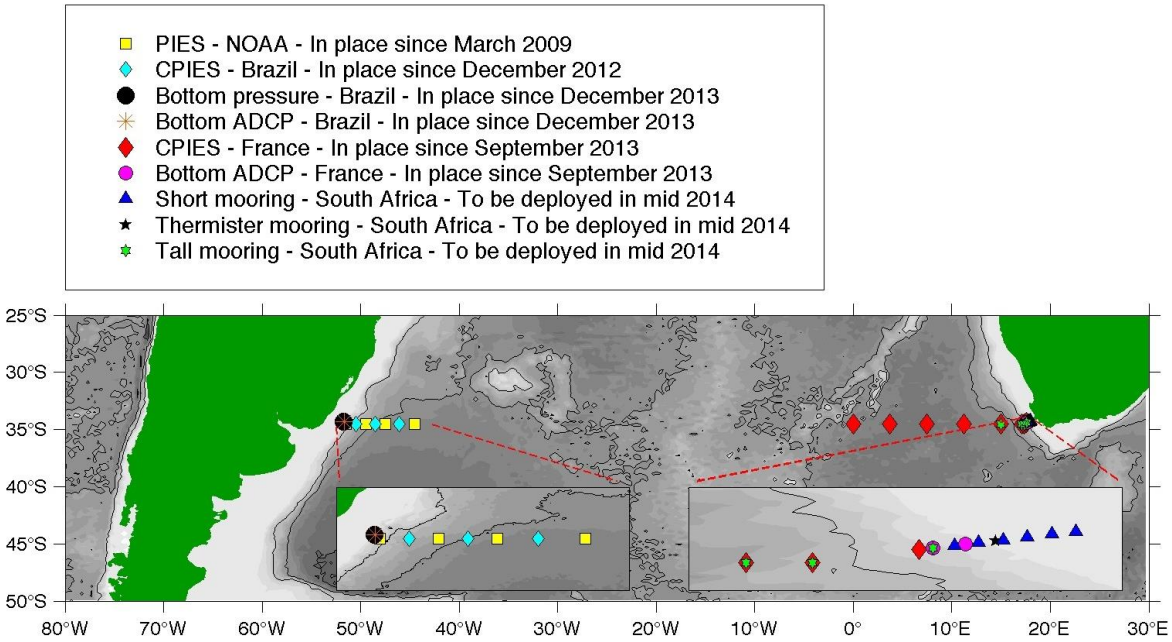

Figure 1: Map indicating the location of the four NOAA PIES making up the SAM array and the Brazilian CPIES added to the array in December 2012. Also shown are the new and planned additions to the experiment working towards the goal of the trans-basin array.

Research Performance Measure: During this performance period, data downloaded from the last cruise in the SAM region (December 2012) were quality controlled and processed, however limited ship time was available for planned data collection cruises and subsequent downloads. Planning for cruises (tentatively September 2014 and February 2015) is underway. The program goal is to acoustically download data every six months via cruises on either Argentine or Brazilian research vessels, and we intend to return to this schedule after what has been a financially challenging year.

The first 20 months of SAM data were compared with data collected at the eastern side of the basin by French collaborators, and the results were published (Meinen et al., 2013). Results from the study were also presented at the U.S. AMOC Meeting in Baltimore, MD in July 2013, at the IAPSO meeting in Gothenberg, Sweden in July 2013, and at the Ocean Sciences Meeting in Honolulu, HI in February 2014. Significant and exciting developments extending the SAM array are that scientists at the University of Sao Paolo are now funded to deploy additional bottom pressure recorder and ADCP mooring to augment the existing joint array on the western boundary, and the French have already deployed eight CPIES and two ADCP moorings on the eastern boundary.

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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 net northward heat transport in both the North and South Atlantic on seasonal to longer time scales, and to diagnose the cause(s) for inconsistency between the observed variability and that demonstrated in 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:
Monthly climatologies of temperature and salinity from observations and numerical models are used to estimate the Atlantic Meridional Overturning Circulation (AMOC) at 34°S. Observational estimates suggest that geostrophic transport plays an equal role to the Ekman transport in the AMOC seasonal variations at this latitude, whereas in present numerical model Ekman transport controls AMOC seasonality. The seasonality of the transport from observations is largely controlled by seasonal density variations at the western boundary, whereas in the models the eastern boundary dominates. The density seasonality at the western boundary is linked to the intensity of the Malvinas Current, which is poorly reproduced in the models. These results indicate that the weak seasonal cycle in model geostrophic transport can primarily be attributed to excessively strong (unrealistic)

baroclinicity below the surface mixed-layer, whereas observations show a strong vertical coherence in the velocity down to 1200 m.

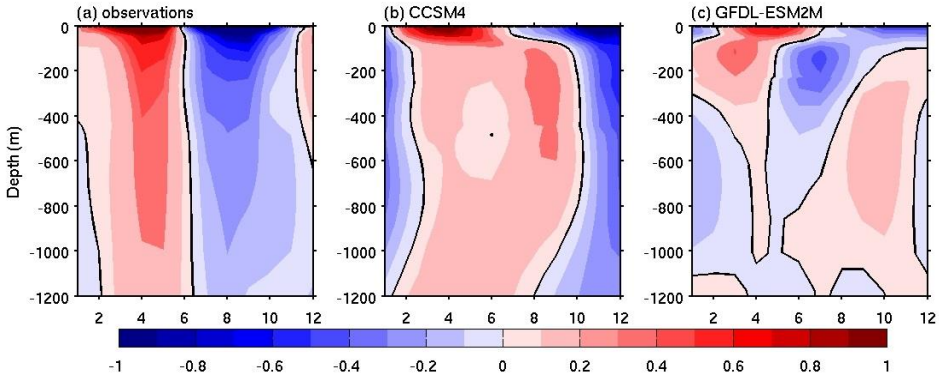

Figure 1: Month and depth distribution of zonally-averaged meridional velocity along 34°S in the upper ocean computed from (a) observations and two CMIP5 models (b) CCSM4 and (c) GFDL-ESM2M. Time-mean values at each depth have been removed to better demonstrate the seasonal variations. Units are 10^{-3} m/s.

Data from two boundary arrays deployed along 34.5°S are combined to produce the first continuous in situ time series observations of the basin-wide MOC in the South Atlantic. Daily estimates of the MOC between March 2009 and December 2010 range between 3 Sv and 39 Sv after a 10 day low-pass filter is applied. Much of the variability in this ~20 month record occurs at periods shorter than 100 days. Approximately two-thirds of the MOC variability is due to changes in the geostrophic (baroclinic plus barotropic) volume transport, with the remainder associated with the direct wind-forced Ekman transport. For periods shorter than 20 days the basin-wide MOC variations are most strongly influenced by Ekman flows, while at periods between 20 and 90 days the geostrophic flows tend to exert slightly more control over the total transport variability of the MOC. The geostrophic shear variations are roughly equally controlled by density variations on the western and eastern boundaries at all time-scales captured in the record.

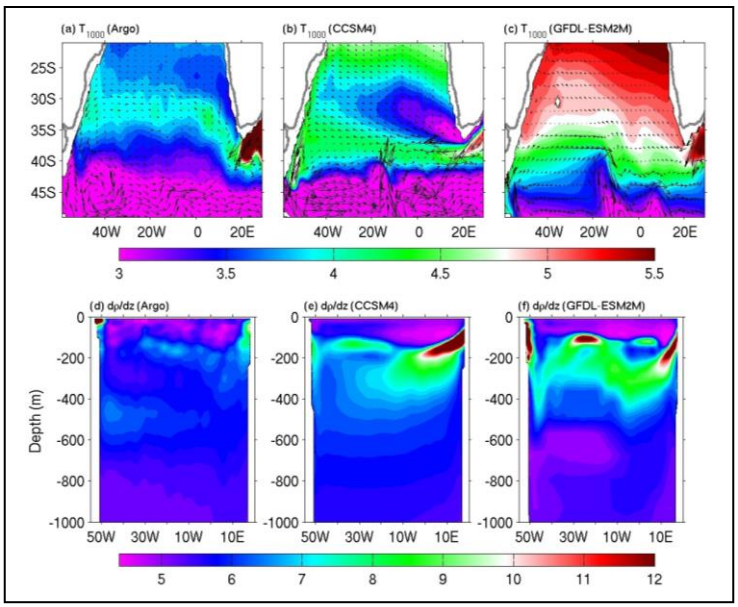

Figure 2: (Upper) Time-mean temperature at 1000 m depth from (a) Argo data, (b) CCSM4, and (c) GFDL-ESM2M. Vectors show the current at the same depth. (Lower) Vertical density gradient in the upper 1000 m for September derived from (d) Argo data, (e) CCSM4, and (f) GFDL-ESM2M.

Research Performance Measure: Improved understanding of the causes for differences seen between model and observations with respect to SAMOC seasonal variations. Research goals were fully met during the last year and significant analytical results presented at the OSTST meeting in October 2013 at Boulder, CO and the Ocean Science Meeting in February 2014, Honolulu, HI.

Elucidating Net Ecosystem Production and Calcification at the Atlantic Ocean Acidification Testbed

Project Personnel: I. Enochs (UM/CIMAS)
NOAA Collaborator: D. Manzello (NOAA/AOML)
Other Collaborator: W. McGillis (Columbia University)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** We have proposed developing and validating both instrumentation and an analytical methodology to sufficient to quantify a fundamental parameter of ecosystem functioning: benthic ecosystem metabolism. This quantity provides a key indicator of energy transfer and health within the ecosystem and the oxygen consumption and waste products released by the benthos. In turn, with our approach this quantity can be broken down into Net Ecosystem Calcification (NEC) and net ecosystem production (NEP) which are of particular interest in ocean acidification monitoring. Our approach relies on proven boundary layer techniques used to measure gradients of scalar quantities. We use precise autonomous oxygen and pH sensors to measure these gradients over seasons at the Atlantic Ocean Acidification Testbed (AOAT).

***Strategy*:** We use and adapted CROSS (Coral Reef Oxygen Sensing System) system adding pH as well as physical sensors. The difference in concentration (gradient) of the chemical (or physical) constituent of interest is directly proportional to the flux from the surface. We measure pH (hydrogen ion) and O_2 (oxygen) using an instrument module with dual inlets at different heights to determine the gradient. Alkalinity and total inorganic carbon are measured throughout the deployment. Acoustic Doppler Velocimeter (ADV), and Modular Acoustic Velocity Sensor (MAVS) are used to provide flow fields since the method assumes boundary layer flow. NEP can be directly determined from the O_2 gradient. NEC, a direct indicator of growth (and health) of calcifying organisms, is determined from the combination of O_2 and pH. The critical assumptions that go into the NEC calculation are derived in that we use the strong correlation between pH and carbonate ion concentration gradients to derive rates of calcium carbonate formation and dissolution.

CIMAS Research Theme:

***Theme 1*:** Climate Research and Impact (*Primary*)
***Theme 6*:** Ecosystem Management (*Secondary*)
***Theme 7*:** Protection and Restoration of Resources (*Tertiary*)

Link to NOAA Strategic Goals:

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

Coastal ocean acidification is a considerable threat to maintaining healthy coasts but we are not thoroughly prepared to quantify the effects particularly its impact of coral reefs and benthic shellfish.

This a non-invasive, and portable tool has the potential to monitor and understand changes from which effective adaptation mitigation strategies can be developed. Adding this monitoring capacity is critical for marine resource managers to prepare for and respond to the impacts of a changing climate, ocean acidification and the boundary-layer gradient method offers and innovative solution. The near bottom flux of a chemical constituent into or out of the sediment or biota on the seafloor is determined from the product of the vertical eddy diffusivity related to drag coefficient estimated from measurements of horizontal velocity at two closely spaced depths just above the seafloor and the concentration gradient of the constituent of interest measured over the same depth interval. We have been able to show that application of this method using oxygen sensors produces net photosynthesis and respiration rates that agree well with those determined by Eulerian and dome methods. Figure 1 shows a March 2014 time series of NEP and NEC. Figure 2 is the diurnal ensemble average of NEP and NEC. The method can potentially be applied to constituents for which no in situ chemical sensor exists but which can be measured from water samples. The package is a made of thin aluminum struts that stands 1 m high that carries an ADV, pH-O_2 measuring instrumentation, a MAVS time of flight 3-D velocimeter and a light sensor. It measures oxygen and pH flux every 30. The footprint of the measurement is an oval that is approximately 30-50 m^2

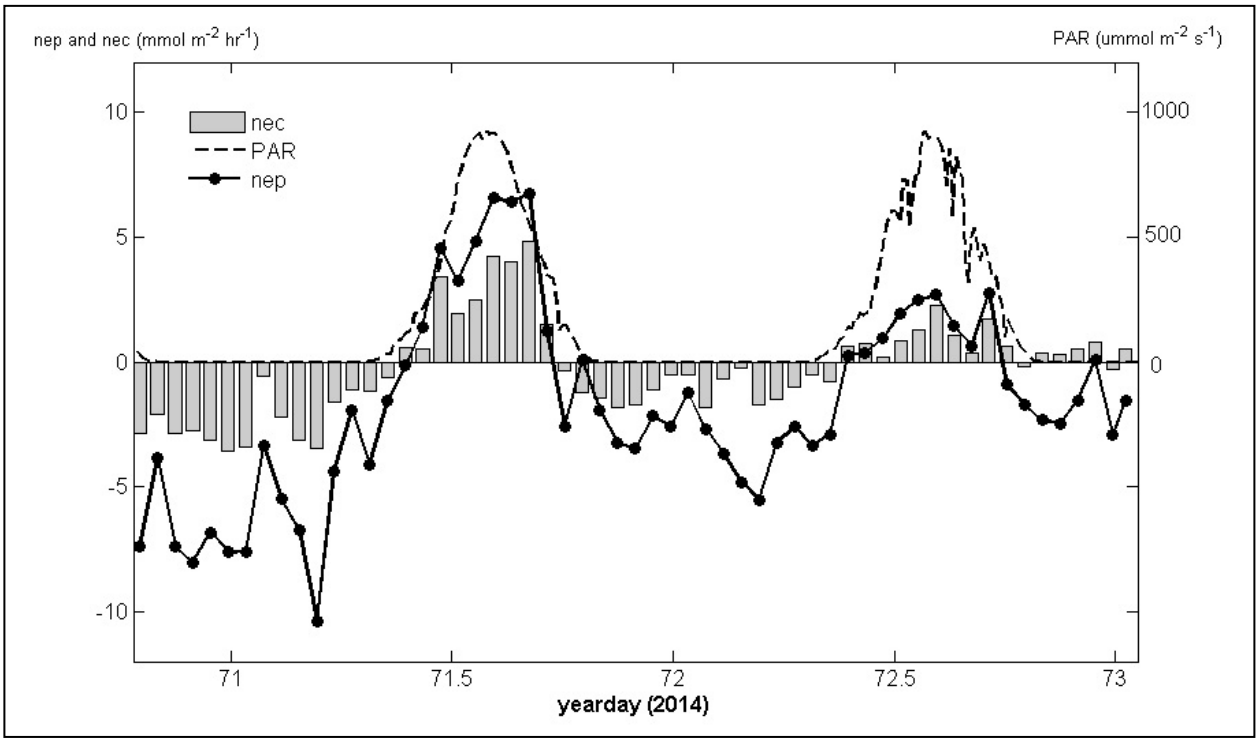

Figure 1: March 2014 Cheeca Rocks time series of metabolism measurements including net ecosystem calcification (nec), par, and net ecosystem productivity (nep).

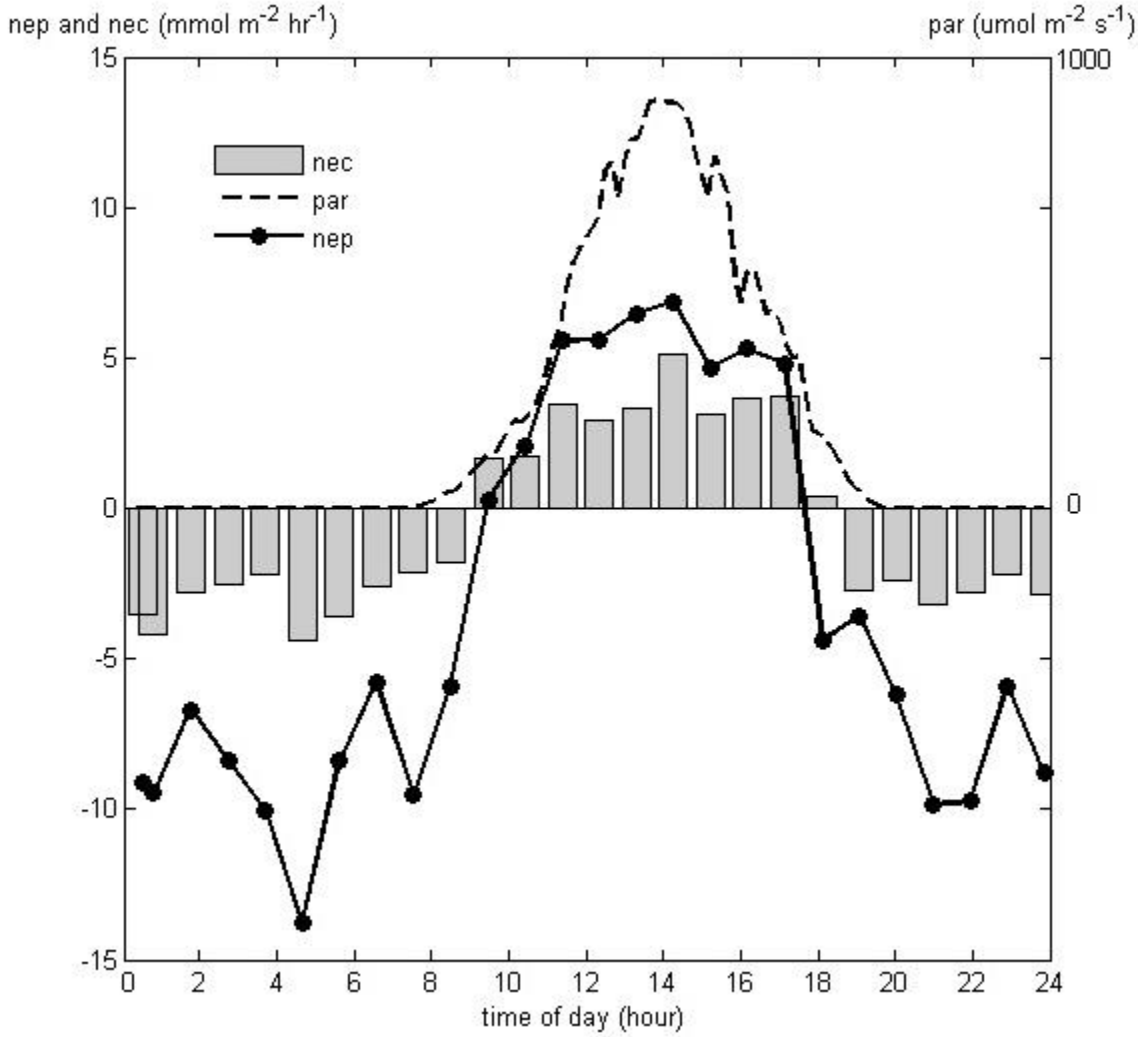

Figure 2: March 2014 ensemble diurnal of metabolism measurements including net ecosystem calcification (NEC), Photosynthetically Active Radiation (PAR), and net ecosystem productivity (NEP)

Research Performance Measure: The research objectives where met and we performed four week-long deployments on the Cheeca Rocks coral reefs during this project period. Sampling occurred in May 2013, July 2013, December 2013, and March 2014. For each field deployment, nep and nec in addition to light and meteorological conditions where measured.

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

Long Term Research Objectives and Strategy to Achieve Theme:
***Objectives*:** To monitor the meridional overturning circulation through observations of North Atlantic western boundary current.
***Strategy*:** To sustain a long term set of observations and integrate 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 Impact (*Primary*)
***Theme 3*:** Sustained Ocean and Coastal Observations (*Secondary*)
***Theme 4*:** Ocean Modeling (*Tertiary*)

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

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

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

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).

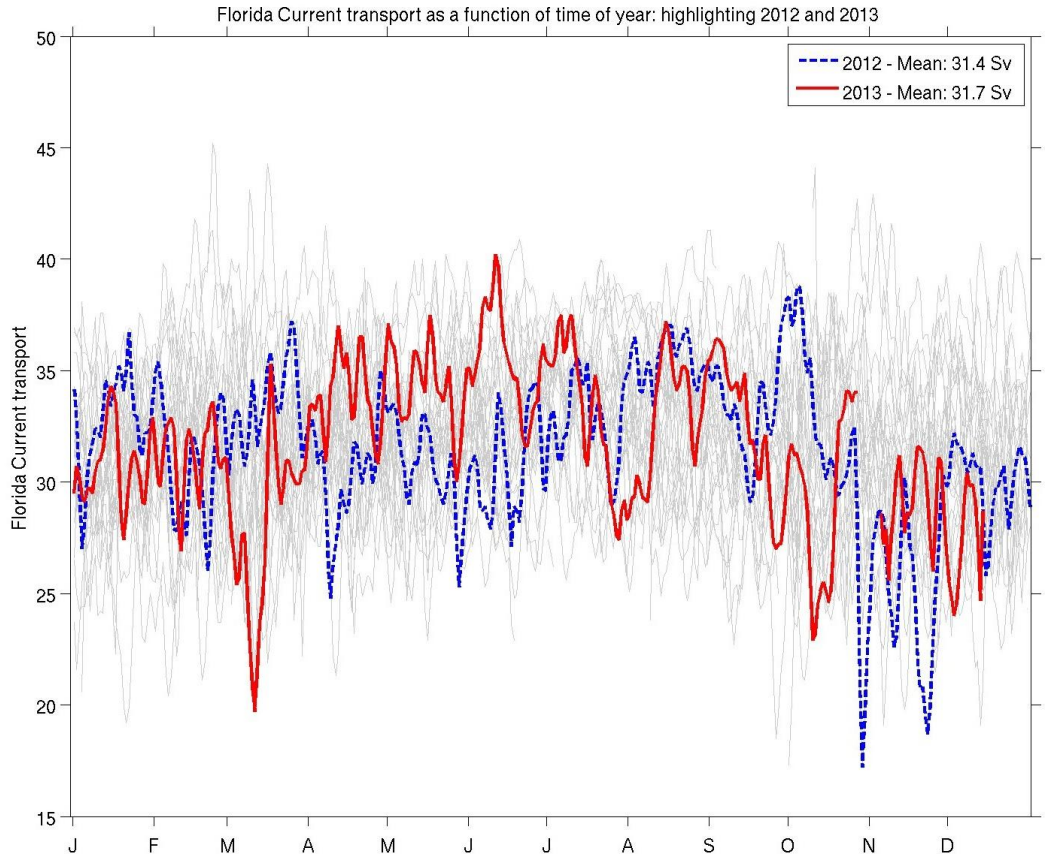

Figure 1: Volume transport of the Florida Current at 27ºN. The two most recent years are highlighted in color.

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 were 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 also conducts 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: We were compelled to reduce the number of Florida Current sections due to a shortfall in charter funds. There were also several short gaps in the Florida Current cable time series due to failures in the recording system. Nevertheless, 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.

Predicting the Effects of Natural and Anthropogenic Climate Variability on the Gulf of Mexico Using Downscaled Climate Models

Project Personnel: Y. Liu, S.-K. Lee, B. A. Muhling, and D. B. Enfield (UM/CIMAS)
NOAA Collaborators: J. T. Lamkin, W. Ingram, M. Schirripa (NOAA/SEFSC); G.J. Goni (NOAA/AOML)
Other Collaborators: M.A. 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 Impacts (*Primary*)
***Theme 5*:** Ecosystem Modeling and Forecasting (*Secondary*)

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

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

Research Summary:
Although the Atlantic bluefin tuna (BFT) is widely distributed, its spawning in the western Atlantic has been recorded predominantly in the Gulf of Mexico (GoM) from April to June with the optimal spawning temperature of 24 - 27°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) (Muhling et al. 2013, *Mar. Ecol. Prog. Ser.*, 486, 257-276, doi:10.3354/meps10397). A recent study, which used the IPCC-AR4 climate model simulations, showed that cooler areas in the northern GoM with high probabilities of larval occurrence could be substantially reduced by the end of the 21st century (Muhling et al. 2011, *J. Mar. Sci.*, 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, *J. Geophys. Res.*, 117, C05039, doi:10.1029/2011JC0075), 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 strengthened our preliminary 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). 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. In particular, the SST increase in the high-resolution model 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 downscaled CMIP5 climate models show that YC transport will be reduced during 21st century under both RCP4.5 and RCP8.5 scenarios, consistent with a similar rate of reduction in the Atlantic meridional overturning circulation (AMOC). 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 BFT.

SST variability obtained from these two downscaled MOM simulations under two different scenarios (EXP_4.5 and EXP_8.5) can be used to estimate the range for projected future temperature variability. However, because the natural climate variability is not included in the CMIP5 future projections, we added in natural climate IAS variability to the SST projections for the IAS region. Figure 1 shows the time series of SST in the GoM during 1900-2098 obtained from EXP_HIS, EXP_4.5 and EXP_8.5. By assuming the uncertainty from natural climate variability is consistent in both centuries, the standard deviation of the SST anomalies in the GoM for the period of 1900-2008 (EXP_20CR) is calculated and added to future SST projections (EXP_4.5 and EXP8.5) under both scenarios (light color region in Figure 1) as an uncertainty. As clearly shown in Figure 1, the uncertainty due to natural climate variability is very large. Based on the above analysis, the uncertainty from the natural climate variability has to be considered for projecting future climate change impacts within the IAS.

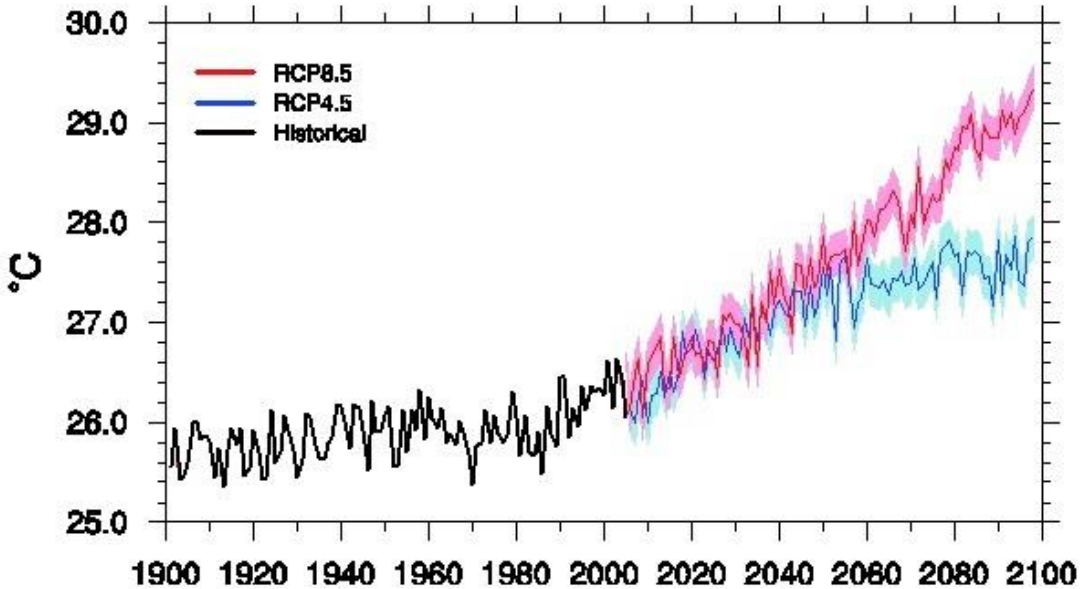

Figure 1: SST variability in the GoM during 1900-2098 obtained from EXP_HIS (black line), EXP_4.5 (blue line) and EXP_8.5 (red line). The standard deviation of detrended SST anomalies in the GoM for the period of 1900-2008 (EXP_20CR) is calculated (0.21) and added to future SST projections obtained from EXP_4.5 and EXP_8.5. The light blue and red color region is the uncertainty due to natural climate variability.

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

Global Drifter Program

Project Personnel: S. Dolk, 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 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 Units: OAR/AOML and 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 (see Figure 2). The DAC also marks drifters that have lost their drogue so that this information can be relayed in the GTS message.

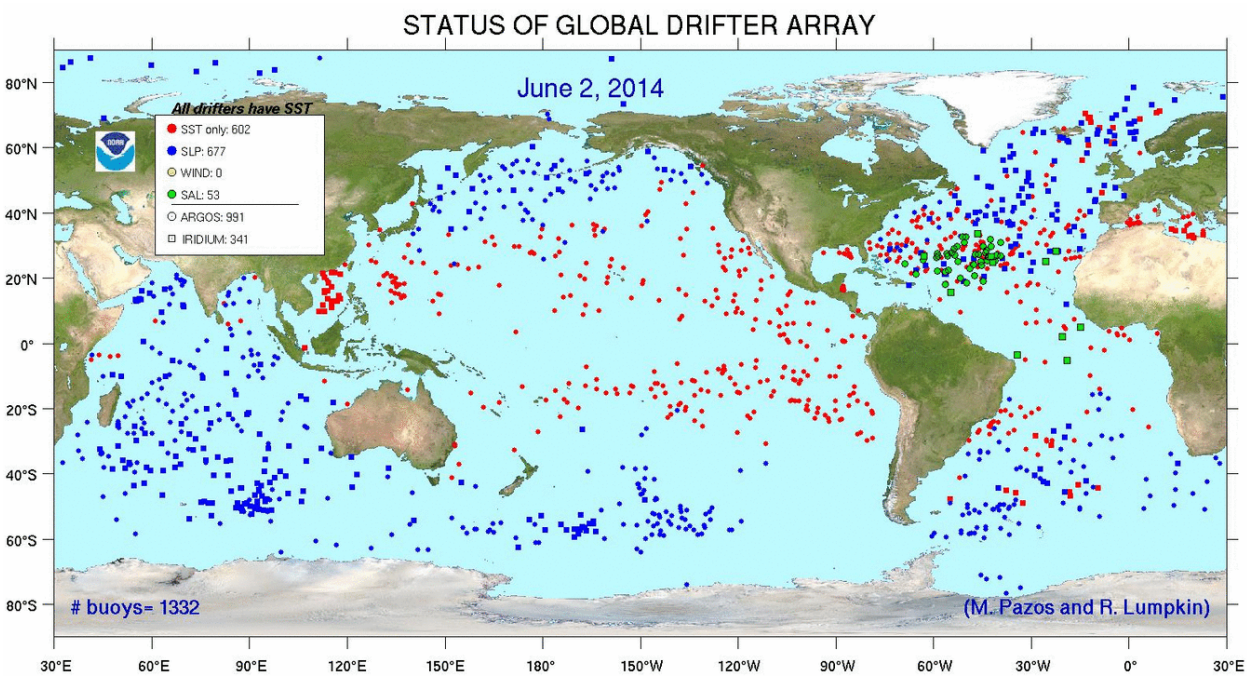

Figure 1: Status of the Global Drifter Array (updated weekly).

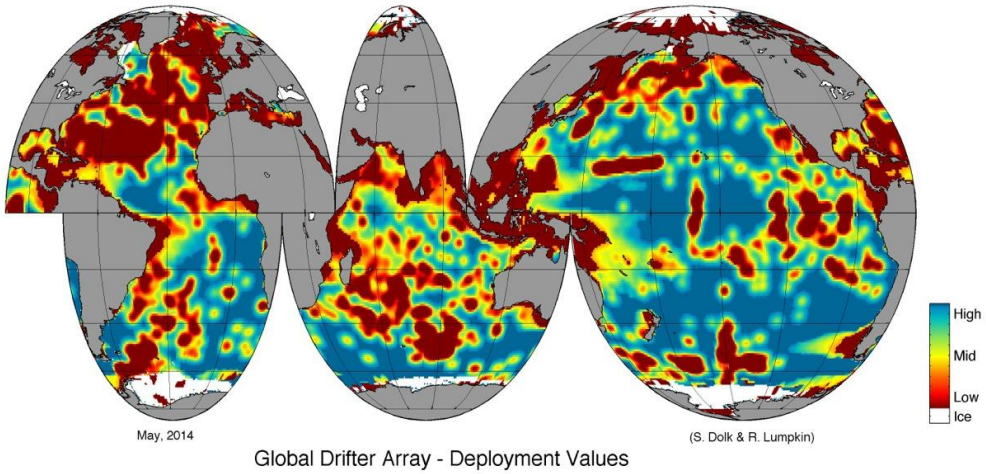

Figure 2: Deployment Value Map(s), (updated monthly).

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

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Coral Health and Monitoring Program (CHAMP)

Project Personnel: R. Carlton, I.C. Enochs, L.J. Gramer, K.P. Helmle, R. van Hooidonk, G. Kolodziej, and M. Jankulak (UM/CIMAS); T. Burton, D. Graham, and L. Olinger (UM Undergraduate)

NOAA Collaborators: J.C. Hendee, D.P. Manzello, 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 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 over the past centuries in order to identify baseline values, variability, and limiting environmental controls, 5) assess the effects of naturally-occurring CO_2 variation in the Florida Keys on the persistence of reef structures, biodiversity of their associated fauna, and growth/calcification 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 designated coral reefs; provide information to managers on small-scale geographic variations in thermal stress and cross-reef exchange with deeper ocean water, 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. Use state of the art climate models to forecast temperature and ocean acidification conditions on coral reefs on decennial to century scales.

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

Link to NOAA Strategic Goals:
***Goal 1*:** Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts* (*Primary*)
***Goal 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:
The Coral Health and Monitoring Program (CHAMP) encompasses a wide array of coral-related research efforts accomplished by CIMAS personnel along with NOAA collaborators. This past year, the CHAMP conducted extensive field operations related to two programs, the Coral Reef Early Warning System (CREWS) and the National Coral Reef Monitoring Plan (NCRMP).

The CREWS program installs and maintains in situ instrumentation in the near vicinity of coral reef ecosystems in Florida, the Caribbean and the Pacific. This year CREWS installed three new moored buoys, one in the Cayman Islands and two in Trinidad and Tobago. The program is shifting from the use of GOES (satellite) communications to digital cellular communications, which offer on-demand, instantaneous access to second-by-second data. Cellular modems are now featured at CREWS stations in Saipan (Commonwealth of the Northern Mariana Islands,

Figure 1: A photo of the newly-repainted Cheeca Rocks MAPCO2 buoy during its February/2014 overhaul.

USA), Belize, Little Cayman, and Tobago, with near-term rollouts planned for St. Croix (US Virgin Islands) and Puerto Rico.

CHAMP personnel, Ian Enochs, Renee Carlton, and Graham Kolodziej continued implementation of NCRMP, and climate/ocean acidification (OA) monitoring therein. NCRMP assets were deployed in St. Croix, at Cheeca Rocks and throughout the Florida Keys, as well as in South Florida. Site surveys for the deployment of MAPCO2 (Moored Autonomous pCO2) OA-monitoring buoys were conducted in American Samoa and Saipan by Ian Enochs and NOAA scientist Derek Manzello. Replicate units for monitoring bioerosion were constructed by CIMAS personnel and deployed by collaborators at NOAA/CRED throughout the Hawaiian Islands and the Commonwealth of the Northern Mariana Islands (CNMI) (Fig. 1).

CHAMP's NCRMP team continues to oversee data collection at sites throughout Florida, the Gulf of Mexico, the Caribbean and the Pacific. The most data-rich of these sites includes the MAPCO2 buoy located at Cheeca Rocks in the Florida Keys, the site of the Atlantic Ocean Acidification Testbed (AOAT). This buoy was the focus of many operations, including the buoy's annual retrieval to land for a complete changeout of instrumentation which took place in February. During that operation the Cheeca buoy became one of the earliest MAPCO2 buoys to install a newer-generation SeaFET pH sensor, replacing the older SAMI (Submersible Autonomous Moored Instrument) sensor. Ian Enochs, Mike Jankulak, Renee Carlton, and Graham Kolodziej continued support and monitoring activities at the AOAT. Activities included benthic monitoring, fish surveys, quantification of coral growth, collection and processing of calibration/validation water samples, as well as electronics replacement and servicing of the MAPCO2 mooring (Figs. 2 and 3).

Figure 2: In 2014, the Cheeca Rocks MAPCO2 buoy was outfitted with a newer-generation SeaFET pH sensor and battery for the first time.

Figure 3: The Cheeca Rocks MAPCO2 buoy is seen at its deployment site in April/2014 with its cover temporarily removed in order to connect a laptop to the system.

-At the Cheeca Rocks AOAT site, CIMAS scientist Kevin Helmle along with graduate students from Nova Southeastern University (NSU) collected nine coral cores nearby the MAPCO2 buoy to update coral skeletal records previously collected in 1997. Since that time, these corals have been exposed to severe temperature extremes, such as high temperatures in 2005 and cold temperature in 2010, which are recorded in the chemical composition of the skeleton and in the growth response through annual density banding. To address variability in coral growth and its trends at different latitudes, coral cores were also analyzed at the AOAT site in Puerto Rico. Annual records of extension, density, and calcification spanning the period of time from 1748 to 2009 were measured from 18 coral cores at two locations nearby the MAPCO2 buoy off La Parguera, Puerto Rico. Coral growth masterchronologies at the AOAT sites in Florida and Puerto Rico are used to identify long-term, century-scale, changes in coral extension, density, and calcification in response to oceanic changes such as warming sea surface temperatures and OA, climatic oscillations such as the North Atlantic Oscillation, Atlantic Multidecadal Oscillation, or El Niño Southern Oscillation, as well as anthropogenic impacts such as local land-based sources of pollution.

CIMAS scientist Ian Enochs along with Graham Kolodziej traveled to Maug, CNMI which is one of the few places in the world, possibly the only location in US waters where CO2-rich gas from subterranean sources naturally increases seawater acidity for surrounding reefs. The purpose of this project was to use unique equipment previously designed and built at AOML to spatially and temporally characterize the carbonate chemistry of this important ecosystem and to pair these data with benthic cover. This information will increase awareness and understanding of one of the rarest US reef ecosystems and will allow scientists and managers to understand how OA will alter ecosystem health and productivity.

Ian Enochs, along with collaborators from University of Miami, Mote Marine Laboratory, The Nature Conservancy, and NSU began a project to evaluate the potential for natural OA refugia to enhance the growth of reef corals to be out-planted for restoration purposes. In-house instrumentation and water chemistry analysis is being used to evaluate and monitor existing coral nursery and restoration operations. Elevated growth rates due to naturally high aragonite saturation states could increase the efficiency of restoration activities and allow for the advancement of these operations despite the ongoing deleterious effects of OA.

Ian Enochs and NRC Postdoc Paul Jones initiated reef monitoring associated with the Numeric Nutrient Criteria study. Supplementing ongoing and planned coastal monitoring efforts organized by AOML, this project involves monitoring three replicate reef sites at each of four reefs. Scientists have and continue to generate target species biometric data using the EPA Stony Coral Rapid Bioassessment Protocol and the Periphyton Rapid Bioassessment Protocol to assess nuisance algal growth. SCUBA surveys are conducted four times per year (over two years), to capture seasonal fluctuations in benthic community composition.

In the past year CHAMP's website (www.coral.noaa.gov) has debuted a new online query tool called the CHAMP Portal (www.coral.noaa.gov/champportal). In this, its beta release, the CHAMP Portal offers access to an extensive history of CREWS data dating back more than ten years and work is proceeding on the integration of data from other sources, including the NDBC's (National Buoy Data Center) C-MAN (Coastal-Marine Automated Network) stations in the Florida Keys and satellite products available through collaboration with the University of South Florida (Fig. 4).

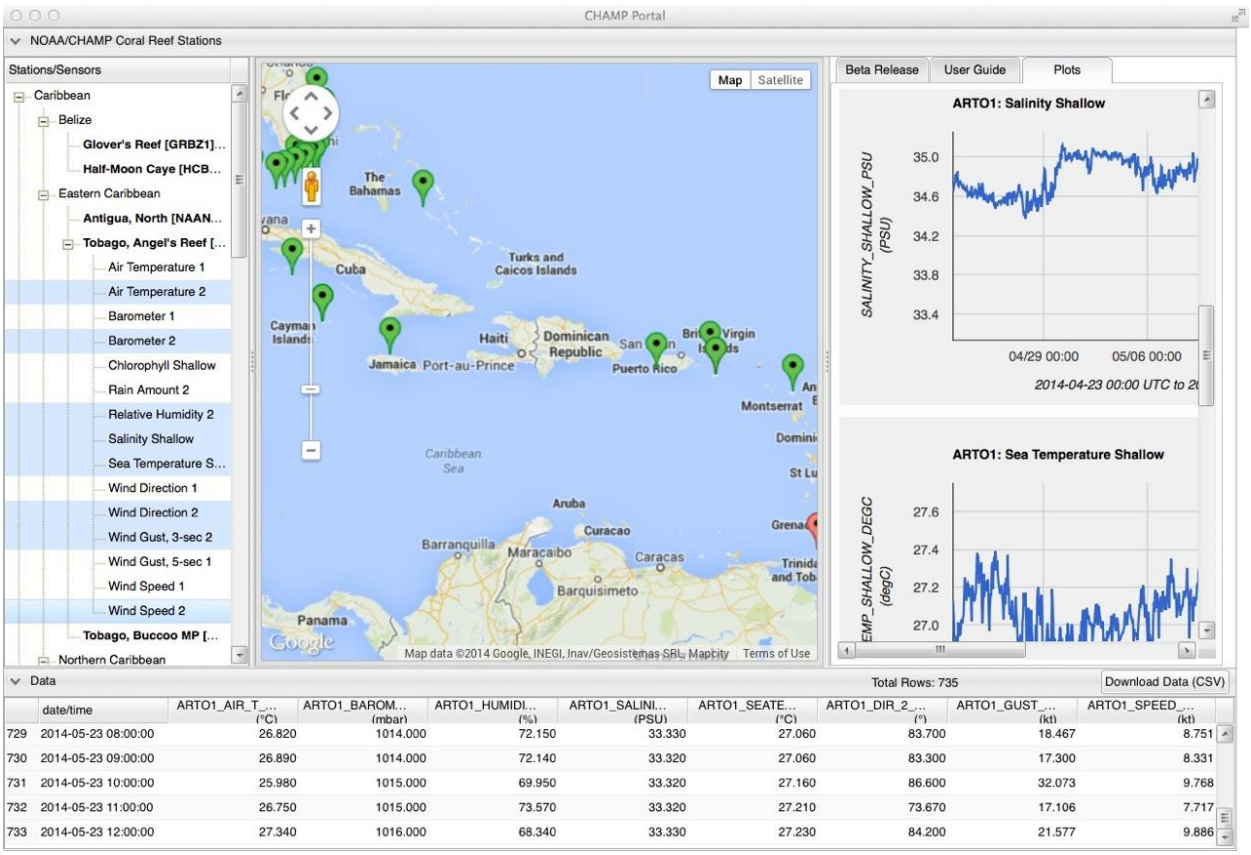

Figure 4: This screen capture of the CHAMP Portal query page shows it with the results of a query of recent meteorological and oceanographic data from the Angel's Reef CREWS station in Tobago. This station was installed in November of 2013.

CIMAS researcher Lew Gramer, has been engaged in three collaborations between NOAA, CIMAS, the University of South Florida, Florida Institute of Oceanography, NSU, and Keys Marine Lab: turbidity plume tracking on coral reefs using satellite data; oceanic upwelling and its impact on reef thermal environment and nutrient fluxes in south Florida; and a post-doctoral project expanding the ocean heat budget model of reef thermal variability from specific sites in the Florida Keys to wider

protected marine areas in Florida, the US Gulf of Mexico, and US Caribbean. For the upwelling project, in fall of 2013 and continuing in May and June of 2014, Gramer analyzed sea temperature and ocean currents records from approximately thirty coral reef monitoring sites in SE Florida, offshore of the Florida Keys, Miami-Dade, Broward, Palm Beach, and Martin Counties and a pattern of periodic, summer upwelling in the northernmost portion of the Florida reef tract was identified, with potentially significant implications for coral reef settlement and migration northward in a changing climate. A Hollings Scholar, Daniel Coleman of Tulane U., joined Gramer as an intern on this project in May 2014. Finally, Gramer began working in December 2013 on post-doctoral research as a continuation of his Ph.D. research. This research identified daily cross-reef circulation patterns tied to sea-surface heat fluxes, but which are dependent on sea-floor slope in neighboring waters (see Fig. 5). The post-doctoral work will extend this research on small-scale dynamics and their impact on the marine ecology, over broader areas of the Florida reef tract, and over other protected shelf-break ecosystems within the U.S. Gulf of Mexico and U.S. Caribbean in FY2014 and beyond.

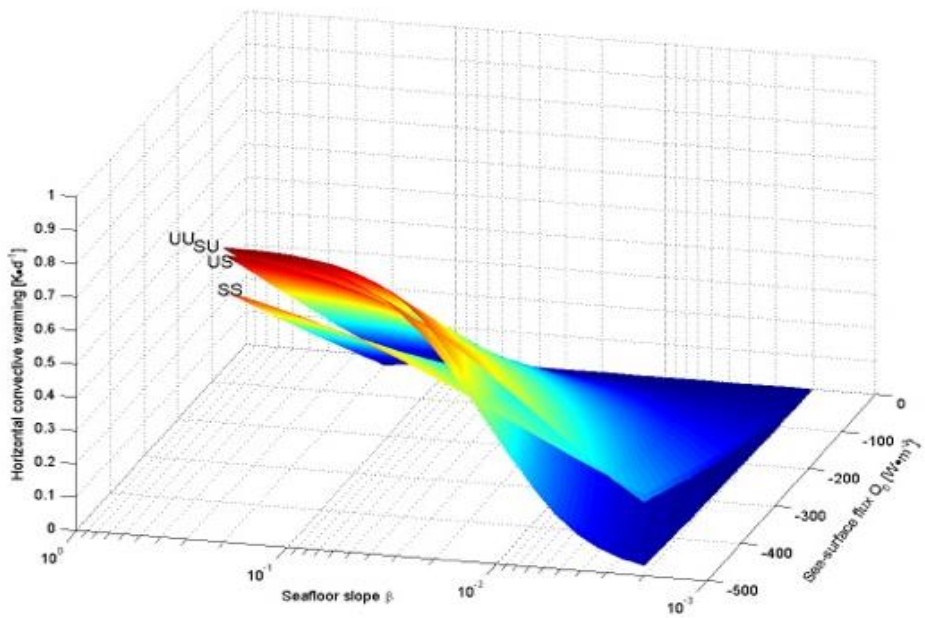

Figure 5: Predicted horizontal convective warming ($K \cdot day^{-1}$, vertical axis) of a reef-crest or reef slope, as a function of sea-surface cooling rate ($W \cdot m^{-2}$, axis into page) and the geometric slope of the neighboring seafloor, β (breadth-wise axis) under various momentum and thermal energy balances predicted by theory.

CIMAS scientist Ruben van Hooidonk utilized state of the art global fully coupled climate models from the 5th Intergovernmental Panel on Climate Change (IPCC) Assessment Report (AR5) to project both temperature stress and OA impacts on coral reefs in the coming century under four different carbon dioxide emission scenarios. These results have been included in chapter 30 of the 5th IPCC assessment report. In a collaborative effort with CIMAS scientist Sang-Ki Lee, these models have also been used to force a modular ocean model to create high resolution forecasts of reef futures in the Caribbean. These high resolution projections provide detailed projections that can inform reef managers and policy makers. To supplement these efforts, near real time monitoring products of OA are being developed using remote sensing. These products monitor pH, aragonite saturation state and total alkalinity in the wider Caribbean and the gulf of Mexico and will be made available to the wider public (Figs. 6 and 7).

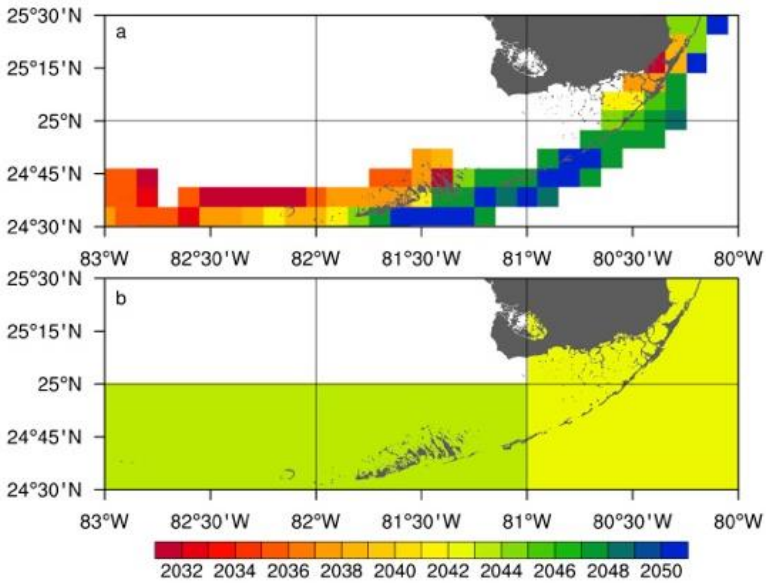

Figure 6: Comparison of coral bleaching projections made with a) a high resolution modular ocean model and b) with an ensemble of global circulation models.

Research Performance Measure: The CHAMP project addressed and met the defined objectives during 2013-2014 through a suite of research components that included ongoing data gathering as well as maintenance, data processing, and data delivery of existing CREWS stations throughout the Caribbean and Pacific. 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 from colony cores and samples along with bioerosion monitoring units have been collected and analyzed using x-radiography, optical densitometry, and micro CT technologies in order to address baseline values, spatial gradients related to carbonate chemistry, as well as variability over time.

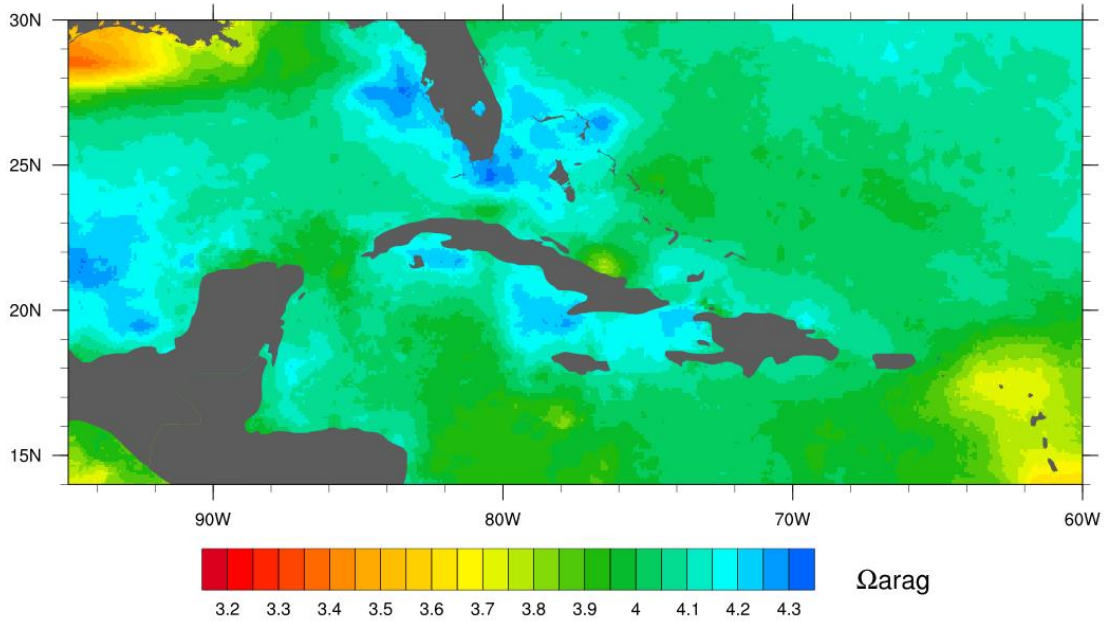

Figure 7: Sample output of the monitoring products; here aragonite saturation state is shown for August 2013.

VI. RESEARCH REPORTS

THEME 2: Tropical Weather

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

Project Personnel: A. Aksoy, K.J. Sellwood, and B.W. Klotz (UM/CIMAS)
NOAA Collaborator: S.D. Aberson (NOAA/AOML/HRD)

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

During the 2013 North Atlantic hurricane season, HEDAS has been run near real time as part of the NOAA Hurricane Forecast Improvement Project (HFIP) demonstration system. For the first time in 2013, HEDAS has begun to assimilate some satellite products in addition to the now-standard aircraft observations. These satellite products included Atmospheric Motion Vectors (AMVs), as well as thermodynamic profiles from the Atmospheric Infrared Sounder (AIRS) and Global Positioning System (GPS) Radio Occultation platforms. The preliminary results from this experiment were summarized in a poster at the American Meteorological Society's 31st Conference on Hurricanes and Tropical Meteorology that was held in San Diego on 31 March-4 April 2014.

One encouraging outcome of this experiment was that satellite observations were shown to compliment the spatial sampling capability of the aircraft observations. Figure 1 exemplifies this for wind observations, where the spatial distribution of various aircraft platforms is compared to that of the AMVs. It is apparent from this figure that AMVs sampled effectively in the upper-level outflow and vortex skirt just above the boundary layer where standard aircraft observations lack spatial density.

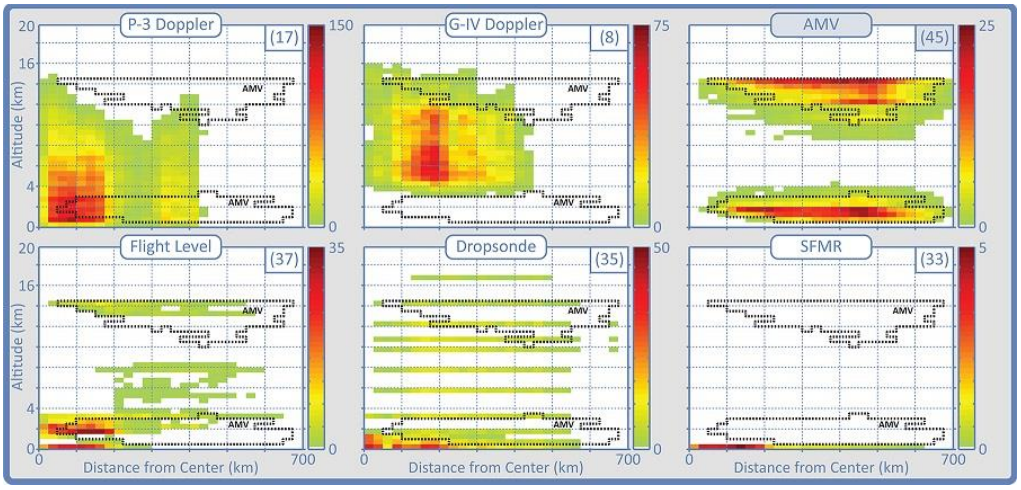

Figure 1: Observation density for wind observations from various platforms assimilated by HEDAS during the 2013 Atlantic hurricane season. Observation density is accumulated over all cases with available data and calculated in a storm-relative fashion. All platforms are on aircraft except for the AMVs shown in the upper right panel. In non-AMV panels, the two main regions that surround the higher AMV density are indicated with dotted contours. Observation density is azimuthally averaged within 500 m height and 25 km radius boxes. Number of cases that contributed data to a specific platform is shown in upper right its respective panel.

When deterministic HWRF forecasts initialized with HEDAS analyses with and without satellite observations are compared to the operational HWRF for the cases for which HEDAS was run during 2013 (Fig. 2), it is observed that both HEDAS flavors reduce mean forecast errors and the addition of satellite observations results in the lowest mean forecast error across all lead times out to 72 h. Although forecasts initialized with the HEDAS analyses do also appear to result in slightly more negative bias early on, this is also partially because HWRF initialization explicitly matches observed intensity at initial time while in HEDAS there is no such explicit treatment for initial intensity. While preliminary, these results not only demonstrate the advantages of state-of-the-art data assimilation at the vortex scale for hurricane intensity forecasting but also highlight some of the strengths of HEDAS as a versatile vortex-scale DA tool that is capable of producing high-quality analyses of the TC inner core and improving forecasts that are initialized with such analyses.

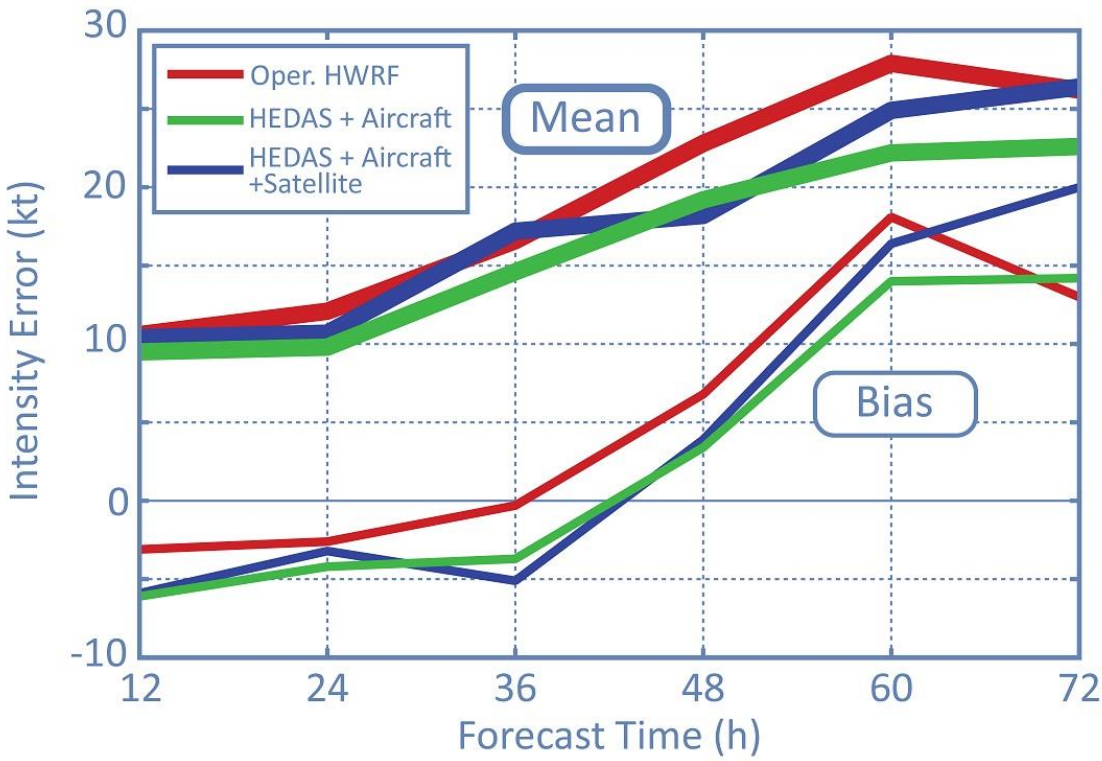

Figure 2: 12-72 h forecast intensity error (mean error and bias) for operational HWRF (red), HWRF initialized with HEDAS analyses that assimilated aircraft data only (blue), and HWRF initialized with HEDAS analyses that assimilated aircraft and satellite data.

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

Investigation of HWRF Model Error 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.W. Klotz (UM/CIMAS)
NOAA Collabortors: 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 composite steady-state hurricane structures 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
NOAA Technical Contact: Daniel Melendez

Research Summary:
The main goal of this project is to investigate the representation of model error in ensemble-based estimates of background error co-variances. The findings of this project are expected to be of significant scientific and practical value for both ensemble-based and ensemble/variational hybrid data assimilation systems used with NOAA's Hurricane Weather Forecasting and Research (HWRF) model. Specifically, processes within the surface-layer (SL) and boundary-layer (BL) parameterizations of the HWRF model are targeted because they are known to control vortex dynamics in the inner core of a hurricane and directly relate therefore to the forecast of intensity.

The major accomplishments of this project within the last year are as follows:

(1) An idealized end-to-end HWRF system was developed with the following attributes: (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) 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; and, (f) The capability to initialize with any axisymmetric vortex structure, including the observationally based composite vortex as explained above.

(2) 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". In addition to this control run, there are now perturbation experiments for a total of 13 parameters (see Table 1 for summary). These parameters can be generally categorized in three groups: Environmental, initial vortex, and model physics. For each parameter that is perturbed, eight perturbation experiments are carried out that sample the parameter range. The specific values for the various parameter perturbations used can be found in Table 1.

	PARAMETER PERTURBATION REALIZATIONS								
					Control				
1. Storm Environment									
- Zonal Westerly Shear (m/s)	0	4	6	7	**8**	9	10	12	16
- Westward Storm Speed (m/s)	0	2.5	3.75	4.375	**5**	5.625	6.25	7.5	10
- SST (C)	27	28	28.5	28.75	**29**	29.25	29.5	30	31
- Mositure Perturbations in PBL (%RH)	-20	-10	-5	-2.5	**0**	+2.5	+5	+10	+20
- Moisture Perturbations in ML (%RH)	-20	-10	-5	-2.5	**0**	+2.5	+5	+10	+20
- Temperature Perturbations in PBL (K)	-2	-1	-0.5	-0.25	**0**	+0.25	+0.5	+1	+2
- Temperature Perturbation in ML (K)	-2	-1	-0.5	-0.25	**0**	+0.25	+0.5	+1	+2
2. Initial Vortex									
- Vortex Size (RMW, km)	15	30	37.5	41.25	**45**	48.75	52.5	60	75
- Initial Intensity (kt)	65	75	80	82.5	**85**	87.5	90	95	105
3. Model Parameters									
- Vertical Eddy Diffusivity Multiplier	0.1	0.3	0.4	0.45	**0.5**	0.55	0.6	0.7	0.9
- Horizontal Diffusivity (namelist)	0	0.375	0.5625	0.6563	**0.75**	0.8438	0.9375	1.125	1.5
- Momentum Flux Multiplier	0.5	0.75	0.875	0.9375	**1**	1.0625	1.125	1.25	1.5
- Enthalpy Flux Multiplier	0.5	0.75	0.875	0.9375	**1**	1.0625	1.125	1.25	1.5

A wealth of metrics have been analyzed to identify model sensitivity to the above-mentioned parameters. One of these metrics was found to be very useful not only in identifying the sensitivities to various parameters but also in calibrating parameter ranges so as to result in comparable model sensitivity when perturbed. Known as the response function, the sensitivity of the model simulations to the perturbations in Table 1 are summarized in Figure 1. From this figure, it appears that parameters that influence model simulations the most are vertical wind shear and SST, although model physics perturbations such as eddy diffusivity and surface flux coefficients are also among the most impactful parameters. The radius of maximum wind exhibits large sensitivity to even small perturbations, but the sensitivity quickly saturates for larger perturbations. Smallest impact is seen from horizontal diffusion and initial intensity. It should be also noted here that the vertical axis is plotted on a logarithmic scale, meaning that the most impactful parameters have impacts greater by 1-2 orders of magnitude compared to the least impactful parameters.

Similar to the response function, spread measures by how much experiments vary for the given range of parameter realizations. Since various parameters result in varying magnitudes of spread, and since the units of spread vary depending on the metric chosen, normalization is applied by dividing individual time-averaged spread values by the maximum spread for the given parameter. Overall (normalized) spread is then computed to be the average over a set of metrics. In Figure 2, these

"original" values of overall average spread are shown in light gray bars for the various parameters perturbed. From Figure 2 original spread values (light gray bars), one gets an indication that the various perturbed parameters do indeed impact the variability across the simulations to varying degrees. However, the parameter ranges that have resulted in these spread values shown are chosen somewhat arbitrarily, as little direct observational evidence exists for the true natural variability for most of the perturbed parameters. Consequently, even when normalized, the original spread values do not convey a fair assessment of the impact of the various parameters on the simulations. Better fairness in that regard can only be achieved if parameter ranges are calibrated to result in comparable average variability over the metrics considered.

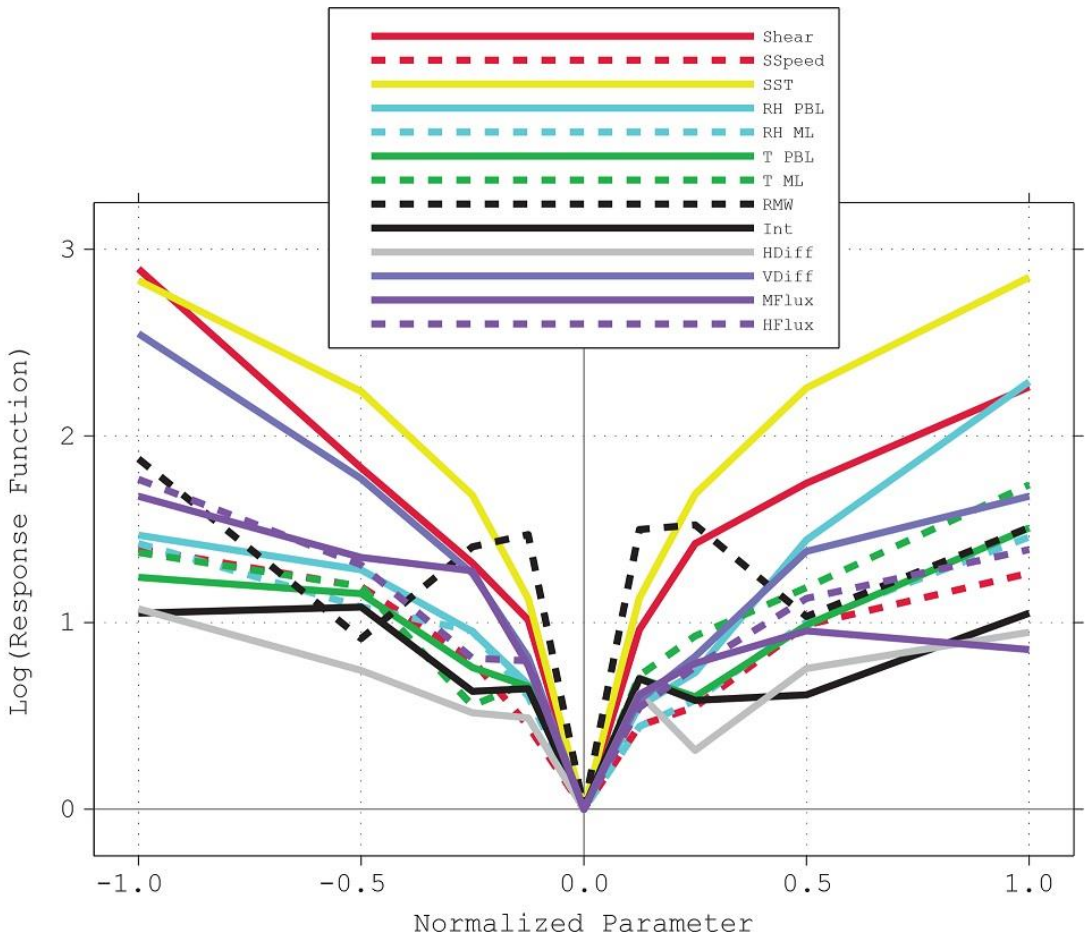

Figure 1: Overall response function for all perturbed parameters. Response functions are accumulated for 18 metrics as discussed in the text. Parameter realizations are normalized by their respective maximum range to allow for direct comparison.

The response function is proposed as a means to calibrate perturbations from various sources to obtain a well-balanced ensemble. To this end, it is hypothesized that in a well-calibrated ensemble, various sources of perturbations should result in comparable magnitudes of the response function across their specified range of values. In other words, the fact that the response function values in Figure 1 are noticeably different for various perturbed parameters at the same normalized perturbation values points to the need for calibration. A logical next step, then, is to reverse-compute the relative range values that would lead to the same response function value.

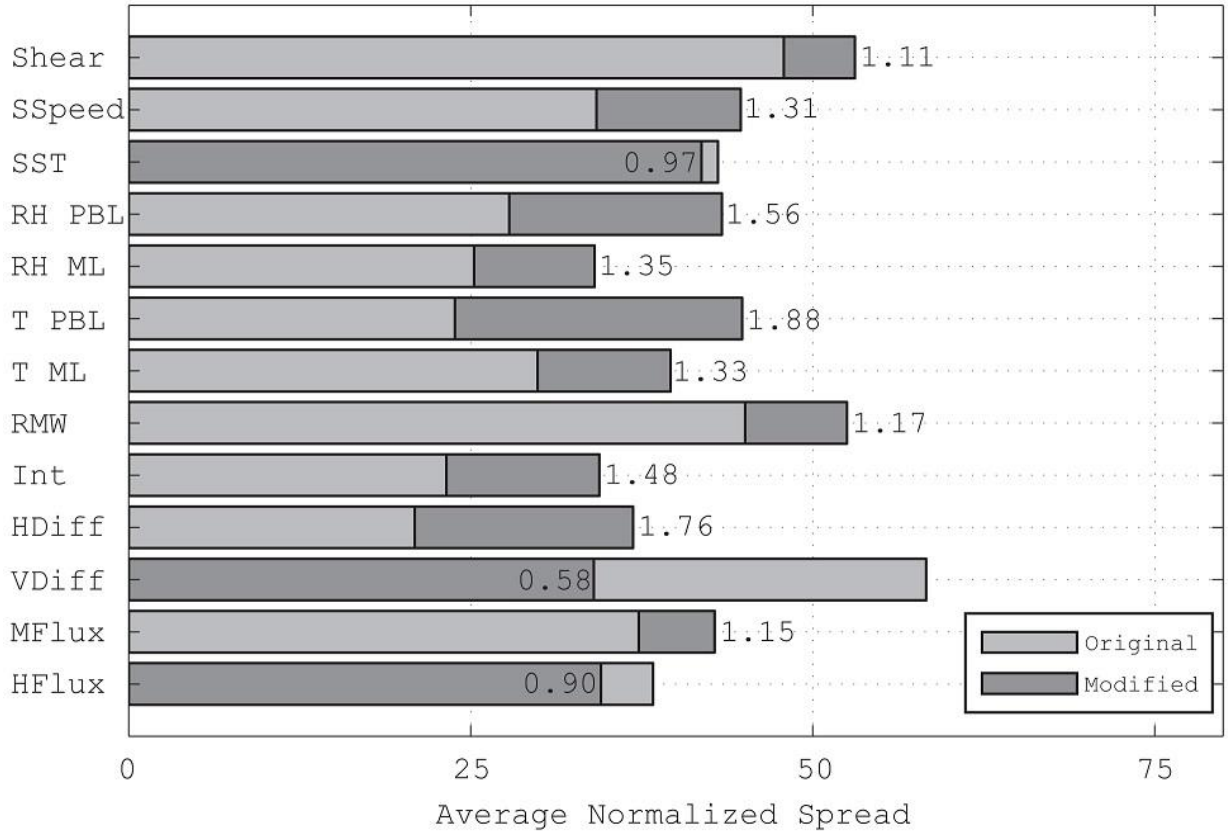

Figure 2: Overall average spread for all perturbed parameters. For each parameter shown in rows, spread values are accumulated over the same 18 metrics as in Fig. 1. For each metric, the maximum spread (of all parameters) is used to normalize spreads to a scale of 0-100 before accumulating over metrics. Spread values in light gray reflect the "original" overall spread that each parameter generates over their respective range of values. Dark gray bars show spreads that were "modified" as explained in text. The modification factors are displayed next to respective bars.

This can be done by interpolating the observed response function relationships for a pre-determined response function threshold value to determine the parameter ranges that would correspond to a fixed response function value. To demonstrate the sensitivity of such interpolations to the response function value and interpolation method, this calculation is repeated for a range of response function threshold values 0.1-2 as well as for three different methods of interpolation (linear, cubic, and spline) and shown in Figure 3. The goal here is to (a) demonstrate that the interpolation methodology is robust, and (b) obtain a range of threshold values where the modification of spread is most optimal. The immediate outcome in Figure 3 is that, when spread is modified using the response function, the resulting variability of it across perturbed parameters is almost always reduced, at times by almost a half. This is a direct indication that the overall modified spread values of various parameters become more similar, a direct outcome we expect from calibration. Furthermore, the three interpolation methods yield generally similar behavior across the response function threshold range tested, which suggests that the technique is robust. Finally, a global minimum in the standard deviation values for the threshold range of 0.5-1.0 provides guidance as to what threshold value to use to carry out the calibration.

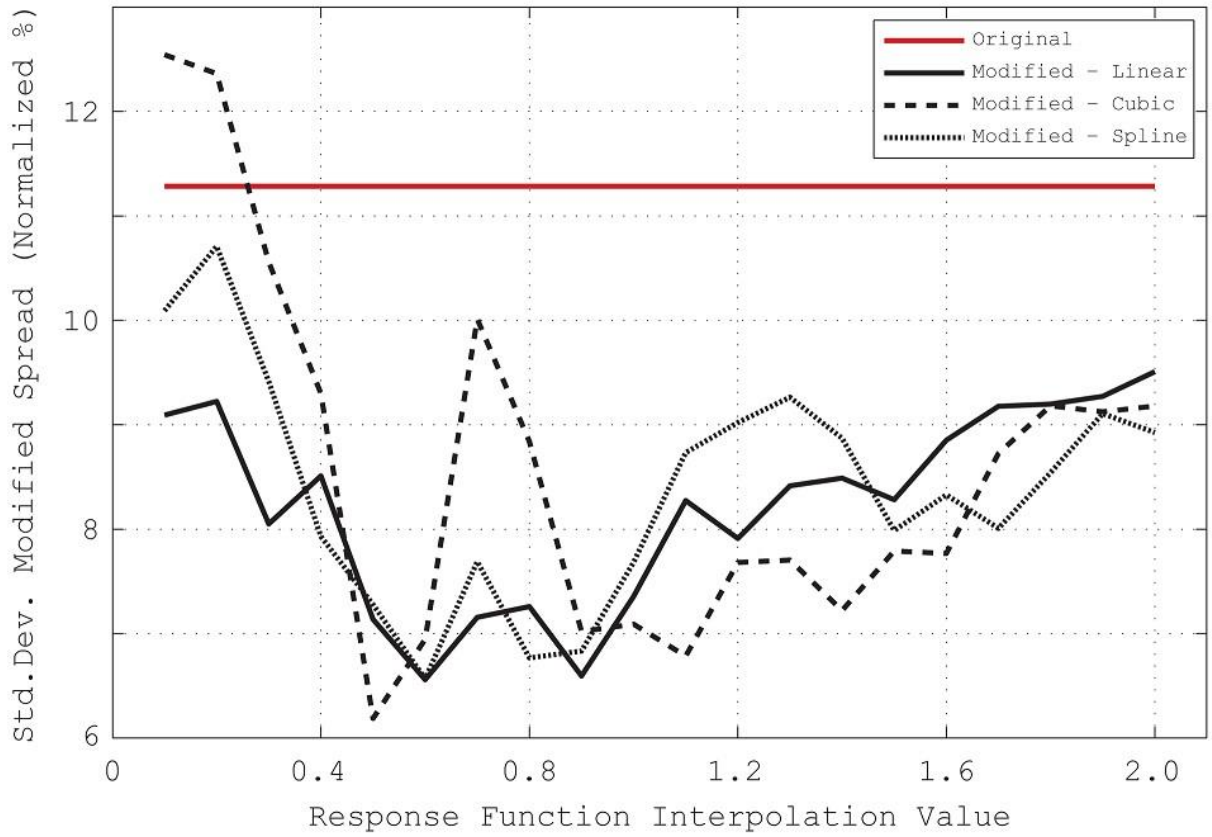

Figure 3: The standard deviation (across parameters) of overall modified average spread as a function of response function threshold and interpolation method. The original standard deviation is shown in red.

Finally, in Figure 4, the calibration procedure is also evaluated in terms of the mean modified spread it yields. Here, as before, the calculation is carried out for a range of response function threshold values 0.1-2 as well as for three different methods of interpolation (linear, cubic, and spline). We again find that, for almost all threshold values tested and all three interpolation methods, the spread modification results in higher mean spread compared to the original spread. Furthermore, there does appear to be a range of threshold values that generate higher mean spread.

Combined with the minimum of standard deviation of spread, we conclude that the maximum of mean of spread suggests a similar range for response function threshold values, 0.5-1.0. To test the direct impact of employing a calibration threshold in this range, we chose the threshold value of 0.6 and re-calculated average spread based on the modified normalized spread values obtained. The results of this test are shown in the dark gray bars in Figure 2. Compared to the original spread distribution, the modified spread values are indeed more similar across perturbed parameters. Moreover, a higher overall spread is achieved for most of the parameters.

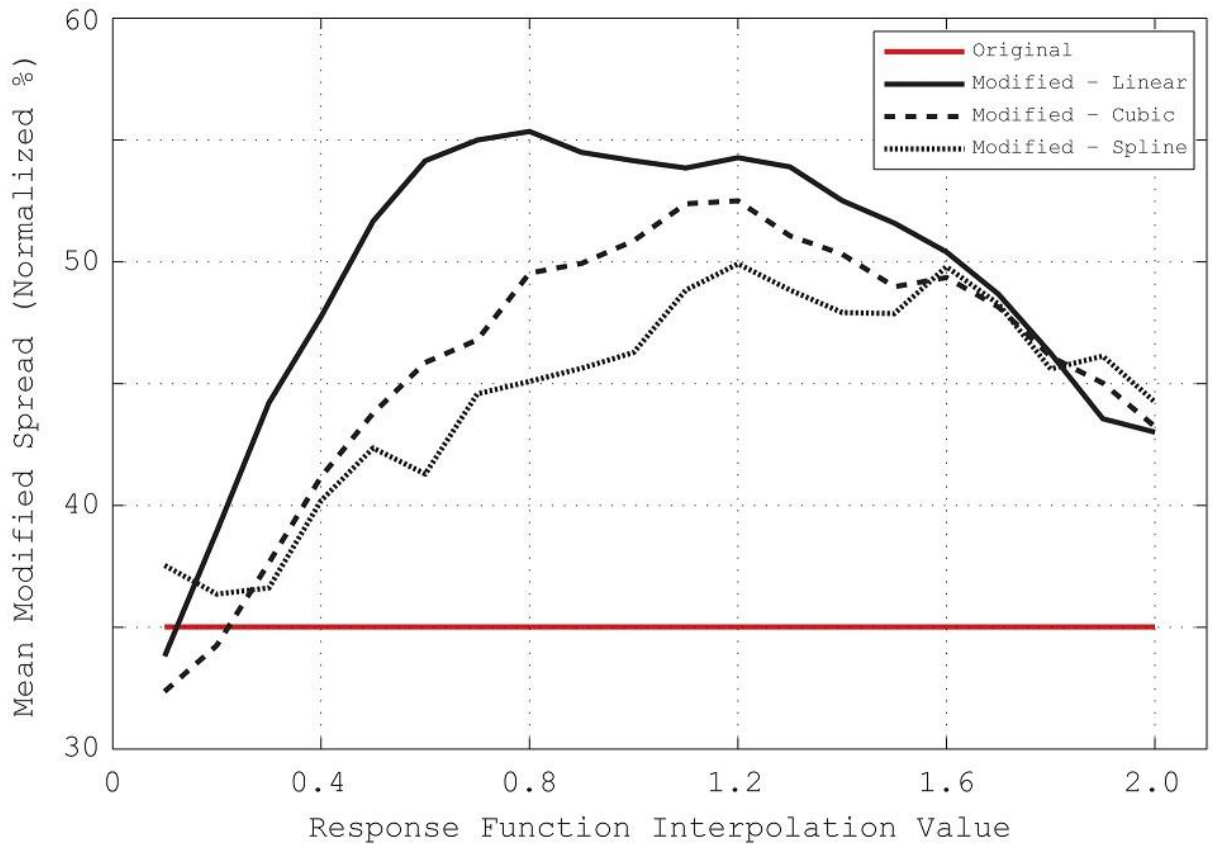

Figure 4: The mean (across parameters) of overall modified average spread as a function of response function threshold and interpolation method. The original mean is shown in red.

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

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Impact of Geostationary Hyperspectral Sounder on Prediction of Tropical Cyclones

Project Personnel: A. Aksoy, B. Annane, L. Bucci, and Javier Delgado (UM/CIMAS)
NOAA Collaborators: R. Atlas, and T. Vukicevic (NOAA/AOML); T. Schmit, and Z. Li (NOAA/NESDIS)

Long Term Research Objectives and Strategy to Achieve Them:
Objectives: To systematically evaluate the impact a geostationary hyperspectral sounder will have on the accuracy of tropical cyclone track and intensity predictions.
Strategy: To conduct rigorous regional Observing System Simulation Experiments (OSSEs).

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 event*

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

Research Summary:
Observing system simulation experiments (OSSEs) are numerical experiments conducted with data-assimilation systems (DAS) and numerical prediction models to assess the impact that a proposed observing system, in this case a geostationary hyperspectral sounder, will have on a forecast. Our study focuses entirely on its impact on tropical cyclone intensity and track prediction. The hyperspectral sounder observations were simulated from a 1 km Nature Run using a different numerical model (WRF-ARW). For these experiments we developed an OSSE system (Figure 1) to automate the execution of data assimilation systems using the Gridpoint Statstical Interpolator (GSI) DAS or the Ensemble Kalman Filter (EnKF) DAS and the Hurricane Weather Research and Forecasting (HWRF) numerical model. The system collects observations, creates analyses, launches forecasts, and generates diagnostic information to quickly evaluate the impact the hyperspectral sounder had on tropical cyclone prediction. Several experiments were conducted using different observation and OSSE system configurations. Figure 2 shows that some configurations have improved tropical cyclone intensity prediction but degraded track predictions. Further evaluation is needed to achieve conclusive results about the potential impacts of a geostationary hyperspectral sounder.

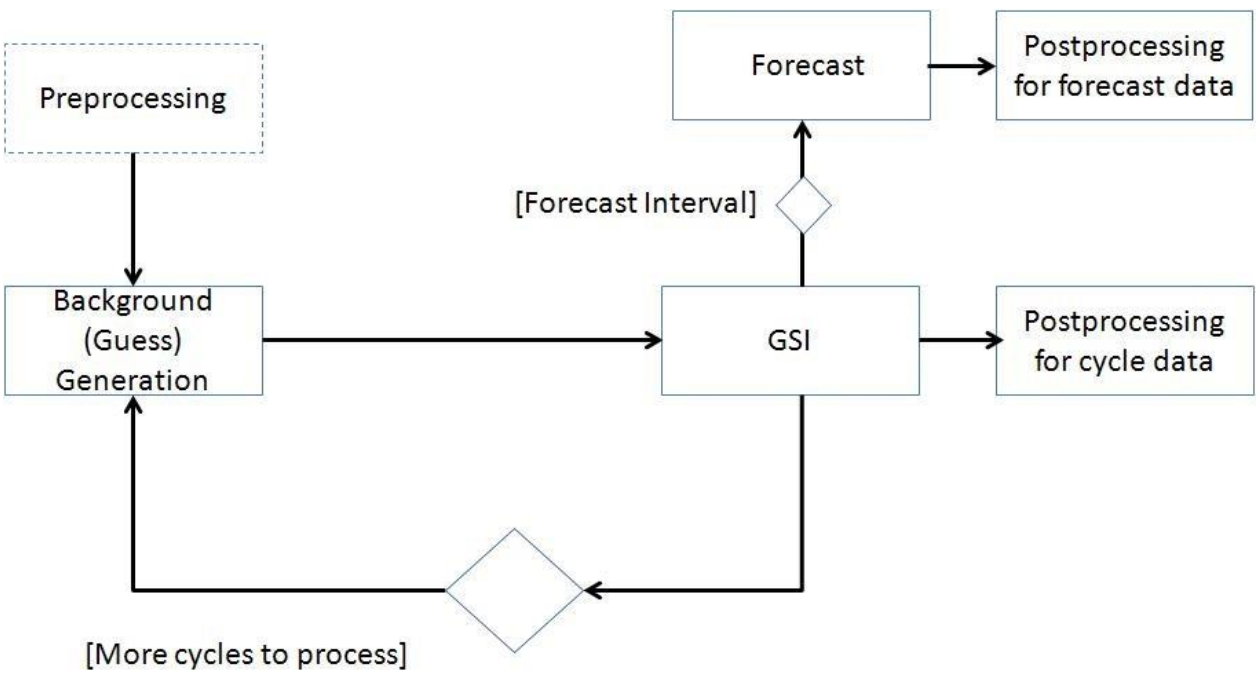


Figure 1: Workflow followed by the implementation of the GSI-HWRF OSSE system.

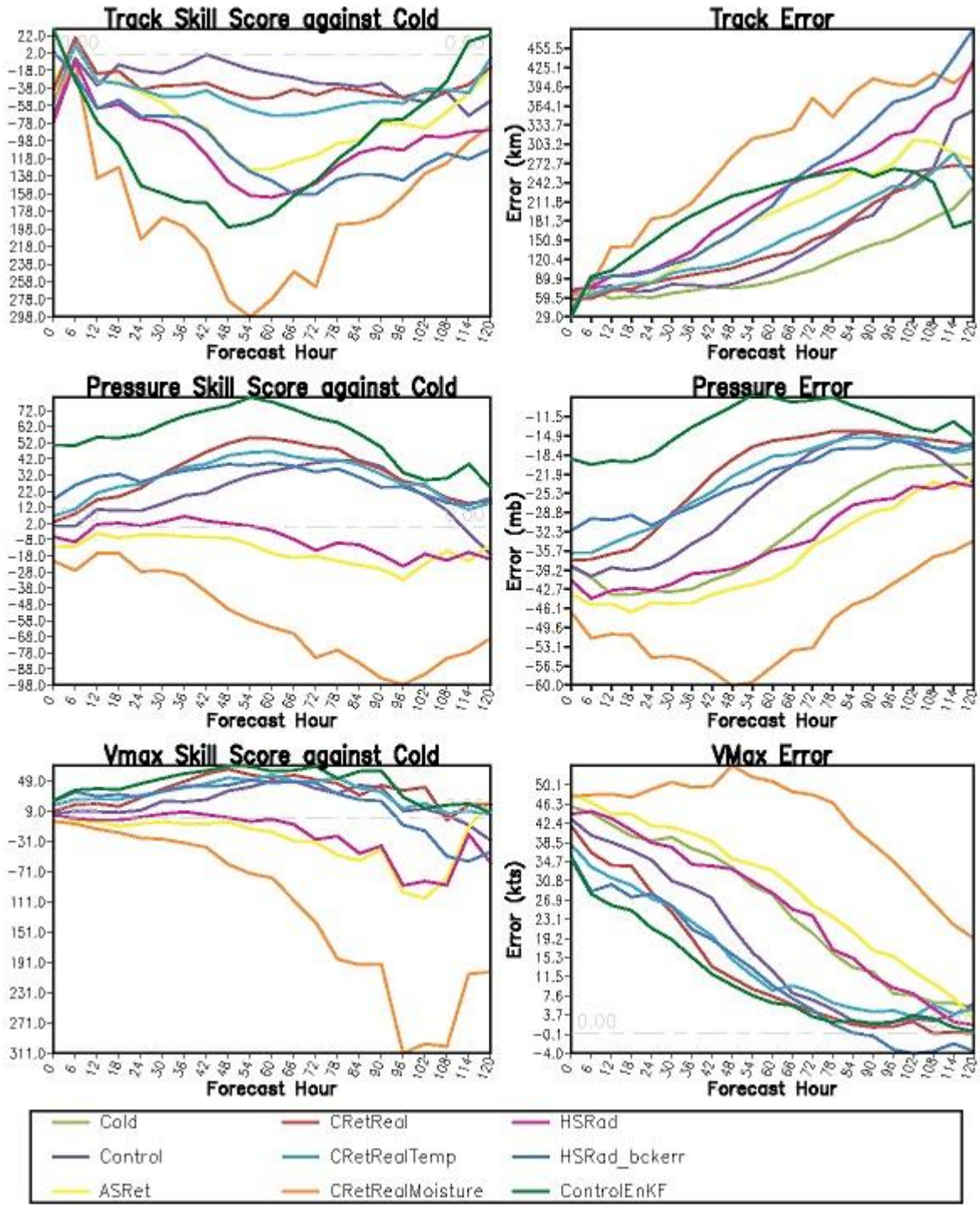


Figure 2: Track, minimum sea level pressure, and maximum 10m wind speed errors of the tropical cyclone are calculated against the respective Nature Run tropical cyclone values. Skill scores for each experiment were calculated against the "Cold" experiment (no data assimilated). The results for 6 hyperspectral sounder experiments are shown.

Research Performance Measure: The research program is on schedule.

Evaluation of the Optical Autocovariance Wind Lidar (OAWL) and its Potential Impact on Numerical Weather Prediction

Project Personnel: A. Aksoy, B. Annane, L. Bucci, J. Delgado (UM/CIMAS)
NOAA Collaborators: R. Atlas, and T. Vukicevic (NOAA/AOML); M. Hardesty (NOAA/ESRL)
Other Collaborators: T. Clune, E. Kemp, B. Rosenberg, J.-C. Jusem, and J. Jacob (NASA/GSFC); L.P. Riishojgaard, Z. Ma, and M. Masutani (JCSDA); D. Emmit, S. Wood, and S. Greco (SWA); S. Tucker (Ball Aerospace)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To systematically evaluate the relative advantages and potential impact of two alternative wind lidar techonologies, the Optical Autocovariance Direct Detection Wind Lidar (OAWL) and Winds from the International Space Station for Climate Research (WISSCR).
***Strategy*:** To conduct global and regional Observing System Simulation Experiments (OSSEs).

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*

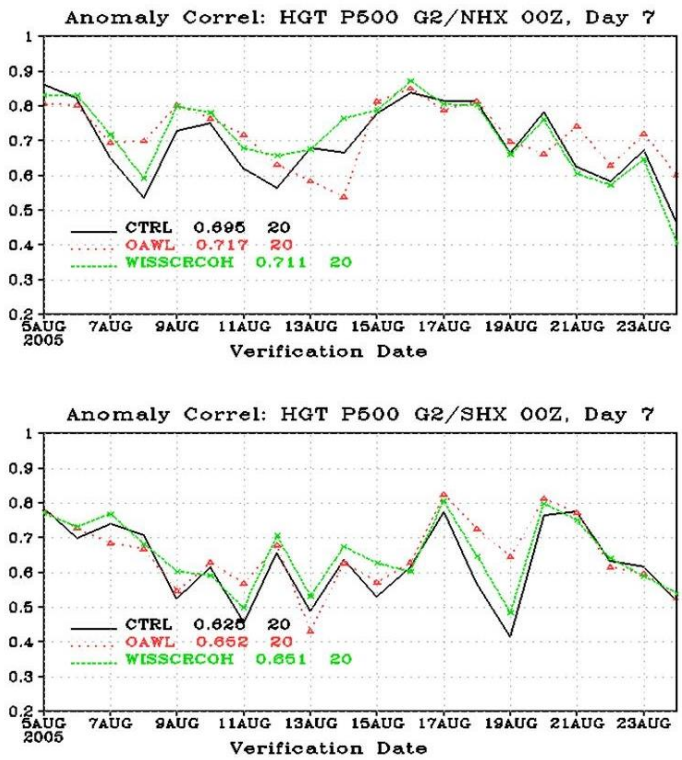
NOAA Funding Unit: OAR/AOML
NOAA Technical Contact: Alan Leonardi

Research Summary:
A study has been conducted to evaluate the potential impact of the Optical Autocovariance Wind Lidar (OAWL) on numerical weather prediction. The primary goal was to assess the advantages and disadvantages of using the OAWL technique in place of the current technology proposed for use in the WISSCR mission. To this end the OSSE team developed an agreed upon conceptual instrument model for OAWL, generated unique very realistic simulations of OAWL and WISSCR_COH data from three separate nature runs, performed an extensive lidar data product evaluation (a pre-OSSE), and performed OSSEs using two global OSSE systems and one state of the art regional OSSE system.

The first global OSSE was conducted using the GEOS-5 DAS/fvGCM OSSE system, in part to determine if this system could be used to assess the relative value of the two different lidar systems. The results of this OSSE indicate little improvement when lidar wind profiles are assimilated, even in the cases where idealized data with unusually high quality and quantity are used. However, this OSSE system had never undergone a rigorous validation, and there are a number of inconsistencies between the data assimilation and nature run components. These inconsistencies appear to be responsible for the lack of meaningful impact and we concluded that this system could not be used to address the relative impact of differing lidar instruments.

The next global OSSE was conducted with a current state of the art OSSE system that used the ECMWF T511 nature run and the NCEP GFS for data assimilation and forecasting. This OSSE demonstrated that both lidar systems improved tropical wind analyses and forecasts, with the largest

impact occurring in the upper troposphere. The percentage beneficial impact of OAWL was found to be more than three times as large as that for WISSCR_COH in reducing errors in wind analyses at both upper and lower levels of the troposphere. Substantially larger impact for OAWL is also true at nearly every forecast interval out to 7 days for tropical wind. Both lidars also demonstrated beneficial impact on 500 mb height forecasts for both the Northern and Southern Hemisphere Extratropics. The impact is largest in the Southern Hemisphere, where the percentage increase in forecast skill (as represented by the anomaly correlation) is nearly identical for both lidars. In the Northern Hemisphere Extratropics, the beneficial impact of OAWL (+3.1%) is larger than that for WISSCR_COH (+2.3%). This OSSE did show considerable case-to-case variability, with examples of negative as well as positive impact of OAWL relative to WISSCR_COH and of either lidar relative to the control.



The final OSSE that we performed utilized a 1 km resolution WRF ARW nature run embedded within the ECMWF T511 nature run, and NOAA's Hurricane Prediction System, currently consisting of the HWRF forecast model coupled with the GSI analysis. In the limited hurricane forecast experiments that we have performed thus far, the OAWL data has proved more useful than WISSCR data. The results of this OSSE indicate considerable potential for lidar wind data to improve hurricane forecasts, but more work is required to increase the sample size and understand large positive and negative impacts. However, these experiments have only examined the effect of improving initial conditions. Both lidars could also provide data to improve the model physics and thus contribute to improved predictions through this effect as well.

Figure 1: Time series of the 500-hPa geopotential height anomaly correlation scores on Day 7 for CTRL (black), OAWL (red)and WISSCR_COH (green) forecasts verifying daily in the (Up) Northern and (Down) Southern Hemispheres. Forecasts for each run were initialized at 0000 UTC and verified against the Nature Run.

The most general conclusion from this study is that the OAWL instrument operating at .355 micrometers would be capable of making significant improvements to atmospheric analyses and numerical forecasts.

Research Performance Measure: All major objectives have been met.

A Study on the Asymmetric Rapid Intensification of Hurricane Earl (2010) Using the HWRF System

Project Personnel: H. Chen (UM/CIMAS)
NOAA Collaborators: S.G. Gopalakrishnan, T.S. Quirino, and F.D. Marks, Jr. (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To provide physical understanding of rapid hurricane intensification in a highly sheared environment.

***Strategy*:** To study the asymmetric rapid intensification of Hurricane Earl (2010) using the HWRF system by diagnosing the high resolution model output.

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/HRD
NOAA Technical Contact: Alan Leonardi

Research Summary

For the first time the asymmetric, three-dimensional, rapid intensification of a tropical cyclone, Hurricane Earl (2010), has been simulated using the operational, ocean-coupled, HWRF modeling system and verified not only with best track estimates, but also against inner core observations which were available during the pre-conditioning and RI stages of the storm.

Apart from the routine track and 10-m wind speed, the model reproduced some salient, observed features of a sheared vortex such as the asymmetric convective pattern and tilt of the storm both at the pre-conditioning and RI stages for the Earl case. The size prediction, in terms of the RMW, especially after the initial spin up process, was close to the observation. We believe that in the absence of high-resolution observations in space and time this forecast is useful in providing further insights on the RI process.

Both the HWRF forecast and the observations indicate that strong convection is highly asymmetric in the pre-conditioning and RI stages with most of the strong convection concentrated in the downshear/downshear-left quadrants. In contrast, the vertical vortex tilt evolves from a large tilt in the pre-conditioning and early RI stages to almost vertical alignment in the later RI stage.

The hourly hodograph of vortex tilt from the HWRF forecast reveals that the tilt is still large when RI starts at 57 h, and begins to decrease rapidly, suggesting that vertical alignment of the vortex is the result of RI rather than the trigger.

Analysis of the 2-min HWRF forecast output shows that, despite the asymmetry in convective activities, RI onset is associated with a sudden warming in the upper troposphere above the 8-km altitude, without which RI would not have occurred resulting in a final pressure as much as 45 hPa higher.

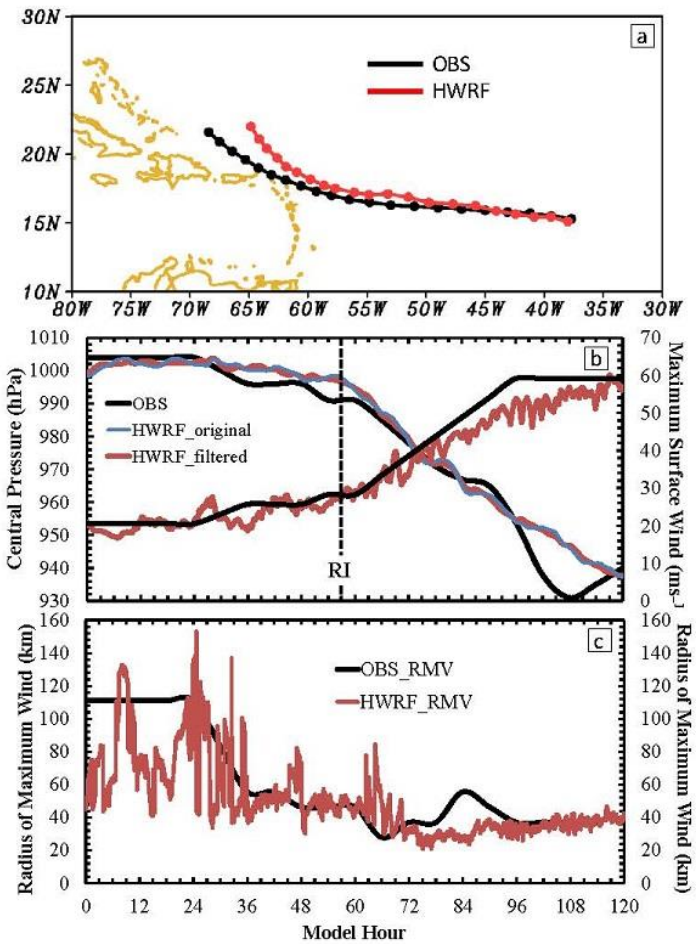


Figure 1: (a) HWRF-forecast (red line) and observed track (black line) at 6-h interval; (b) time series of HWRF-forecasted (2-min-resolution; red line) and observed (6-h-resolution; black line) maximum surface wind (V_{max}, m s^{-1}) and central pressure (P_{min}, hPa) for the period of 26/18-00 to 31/18-120. For HWRF-forecast pressure, a semidiurnal filter is applied to the central pressure time series (blue line) to remove storm-unrelated pressure change (red line); (c) time series of HWRF-forecasted (2-min-resolution; red line) and observed (6-h-resolution; black line) RMW (km). The black dashed line in (b) indicates RI onset.

An in-depth analysis reveals that there are three stages associated with RI of Earl: pre-conditioning stage (i.e. 51 h -57 h), early RI stage (i.e. 57 h – 65 h) and late RI stage (i.e. > 65 h). In the pre-conditioning stage, most of the deep convection concentrates in the downshear-left quadrant and a new circulation center develops at upper level associated with the deep convection, which sets up the configuration for the cooperative interaction between the convective-scale subsidence and shear-induced meso-scale subsidence for the next stage. Nevertheless, random CBs in different quadrants prior to pre-conditioning stage are found to moisten the environment near the vortex and wind speed increases in response to these random CBs. Yet, the wind speed only intensifies temporarily without the warming having developed in the upper level as a result of CBs occurring in the optimum quadrants. In the early RI stage, the vortex is tilted but the warming due to convective-scale subsidence and shear-induced meso-scale subsidence is advected towards the low-level storm center by the upper-level circulation. The asymmetric intensification process due to horizontal temperature advection at upper level lowers the surface pressure efficiently and initiates RI while bringing the vortex into vertical alignment. In the late RI stage, the vortex is aligned and subsidence in the eye contributes to the intensification of the warm core, a symmetric intensification process.

It should be emphasized that although cloud-resolving models show some promise in RI predictions for individual cases, there is much less skill in forecasting intensity with limited fidelity over several TC forecasts. Both storm-to-storm and cycle-to-cycle variability are not uncommon. For instance, while the overall predictions of the intensification for the Earl case were reasonable, even the subsequent forecast cycle produced a delayed intensification. Additionally, while the current cycle of HWRF retrospective forecast reproduced the RI of Earl well, after the RI (after about 96 h into the forecast) there were some differences in minimum sea-level pressure with the observed central pressure deepening much faster until 108 h and then filling while the HWRF forecasted central pressure kept deepening. It is unclear at this time if these differences are due to an eye wall replacement cycle which is known to have predictability issues in numerical models. Our preliminary

analysis, based on some of the surface wind behavior, shows that the HWRF system did not capture this subtle change, at least in this particular cycle. All these issues raise an important question on the predictability of convection, even in an organized system such as a hurricane. The HWRF system has been operationally run at cloud-permitting scales for a couple of seasons over the North Atlantic and Pacific basins and over the North Indian Ocean. Retrospective runs have also been made over several seasons.

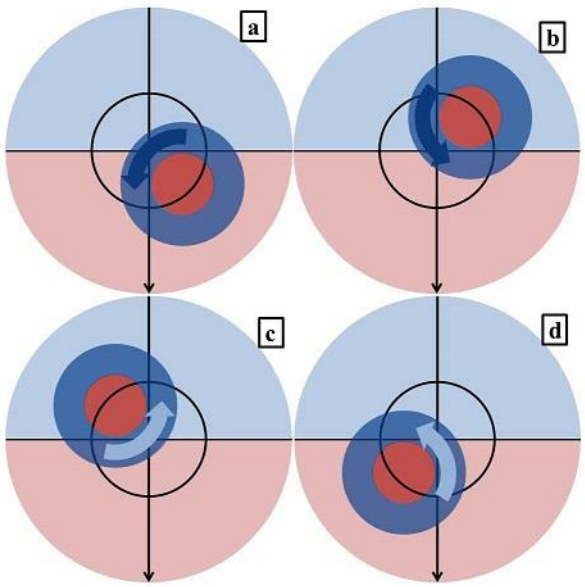


Figure 2: Schematic depiction of configuration of shear-induced mesoscale subsidence (light blue semicircle), mesoscale ascent (light red semicircle), CBs (dark red circle), and convective-scale compensated subsidence (dark blue ring). The black circle indicates the RMW at the surface, and the black arrow shows the shear direction (northerly shear). The thick blue arrow indicates the upper-level flow associated with CBs. For CBs located in (a) downshear-left and (b) upshear-left, convective-scale subsidence is superposed on the mesoscale subsidence. For CBs located in (a) upshear-right and downshear-right, convective-scale subsidence is superposed on the mesoscale ascent.

Research Performance Measure: All research objectives are met on schedule and publication is under revision now.

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Improving the Scalability of a Hurricane Forecast System in Mixed-Parallel Environments

Project Personnel: J. Delgado (UM/CIMAS)
NOAA Collaborator: T. Quirino (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To reduce the execution time of HWRF hurricane forecasts.
***Strategy*:** To modify the HWRF hurricane modeling framework so that high resolution storm-following nests for different, independent storms can be efficiently integrated by multiple sets of computational processors.

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 current research version of the Hurricane Weather Research and Forecasting (HWRF) weather modeling software framework in use at HRD allows multiple high resolution regions of interest (e.g. the area in which a tropical storm occurs) called *nests* to be created within a larger, coarser resolution domain. This allows us to forecast at relatively high resolution with a reasonable amount of processing power. In the standard HWRF implementation, these nests are sequentially modeled (i.e. integrated) by a single set of processors. However, there is a limit on the number of processors that can be used to integrate a domain/nest of a given size. Moreover, while we have seen improvements in hurricane prediction accuracy using a large domain with multiple storm-following nests, we could not complete those simulations within the operational time constraints. To address this issue, we devised a modification of the HWRF framework permitting the nests to be integrated concurrently by different sets of processors in order to make it possible to run these kinds of simulations operationally.

As with all parallel programs, execution of this model is divided into computation and communication components. HWRF consists of *tightly coupled* communications, which refers to the fact that the communications occur frequently throughout the weather simulation. As a result, communication takes a significant portion of the execution time. We have succeeded in parallelizing the computational portion of HWRF and have observed that the execution time of these portions of code has been reduced substantially. The methodology we used is depicted in Figure 1. The original implementation is on the left hand side and our modified version is on the right hand side. Figure 2 shows how the execution time for a 5-day forecast increases as the number of storms increases when using 300 processors to integrate each storm. As can be seen, the parallel version significantly reduces execution time. However, there is additional overhead as the number of storms increases. This is mainly due to the additional time required for I/O and internode communication. Our ongoing work is to optimize these portions of the code in order to further reduce execution time.

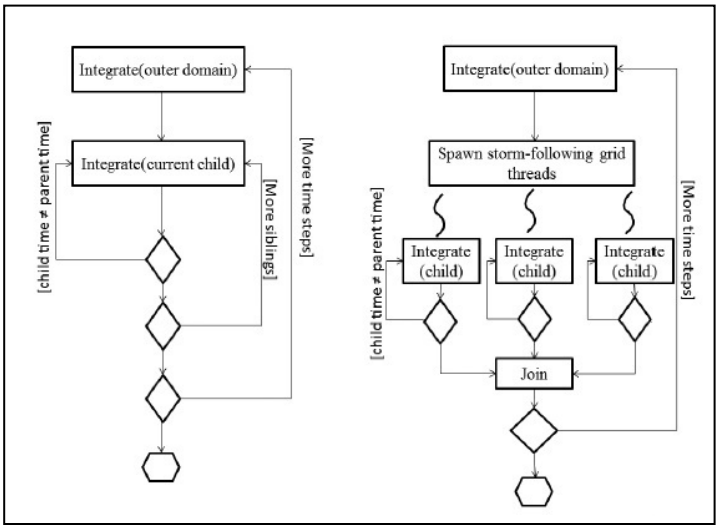

Figure 1: Original (left side) vs. modified (right side) HWRF integration workflow. On the left side, the original framework integrates grids sequentially. On the right side, the modified framework integrates storm-following grids in parallel.

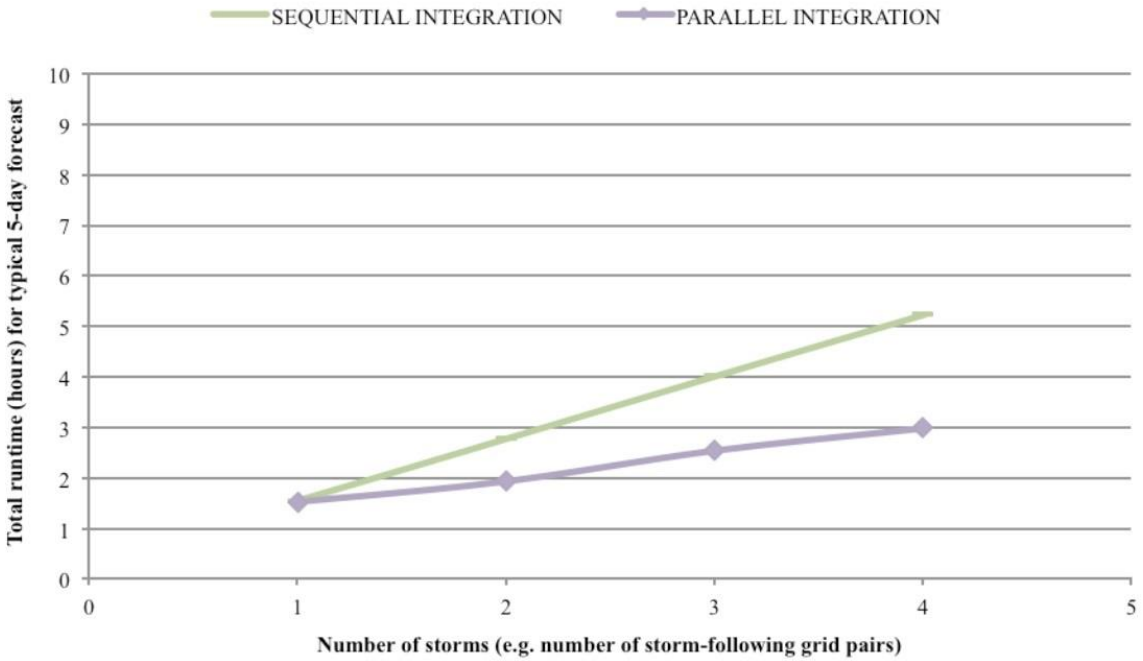

Figure 2: Execution time of a typical 5-day forecast using sequential (green) and parallel (purple) nest integration as a function of the number of storms.

Research Performance Measure: The performance improvements we have seen thus far are what we expected at this stage of the project. We knew that the communication and I/O intensive nature of HWRF would limit the impact of our changes and have concluded that it is necessary to address this in order to fully benefit from our modifications.

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Development of an Objective Scheme for Predicting Tropical Cyclone Genesis

Project Personnel: J.P. Dunion (UM/CIMAS)
NOAA Collaborator: J. Kaplan (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 an objective scheme for predicting the likelihood of tropical cyclone genesis in the North Atlantic for both 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 capabilities of the Tropical Cyclone Genesis Index (TCGI), and conduct 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: OAR
NOAA Technical Contact: Dr. Alan Leonardi

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 was conducted during the summer of 2013. Verification of TCGI was made using a 2011-2013 dataset of North Atlantic tropical disturbances and skill was found to be competitive with TC genesis forecasts made at the NOAA National Hurricane Center (Fig. 1).

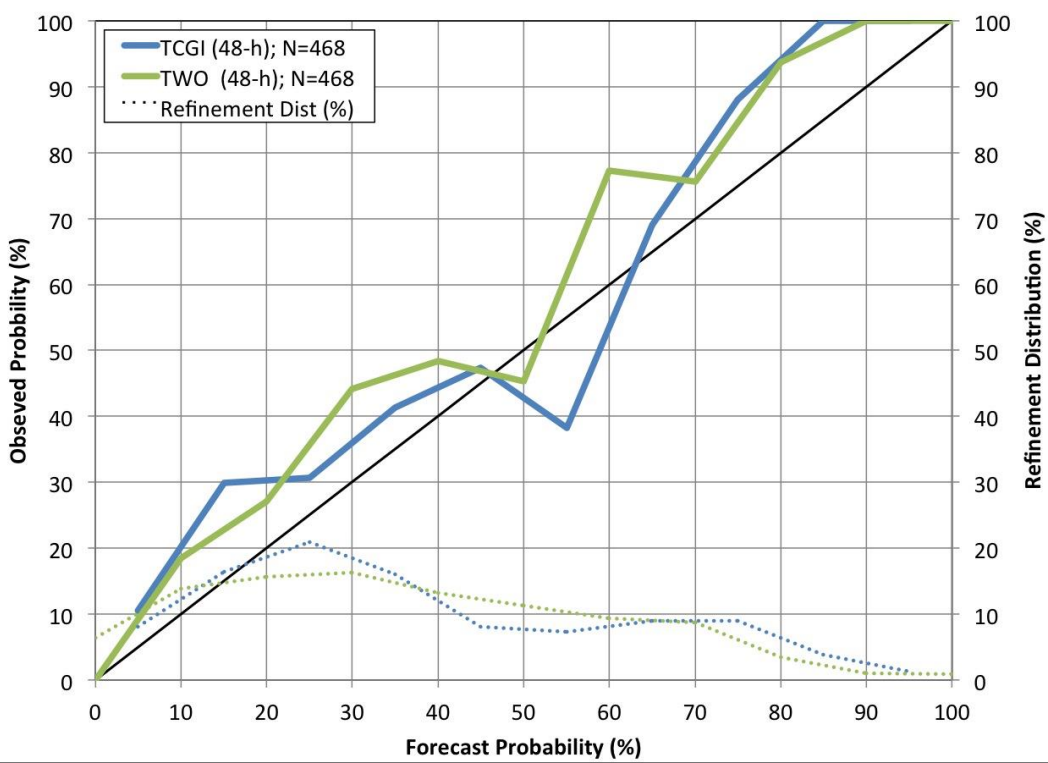

Figure 1: Reliability diagram for TCGI and a homogeneous sample of NHC TWO TC genesis forecasts (61 developing and 27 non-developing disturbances). The solid blue/green (red) lines indicate the relationship between the 48-hr (120-hr) forecast and verifying genesis percentages, with perfect reliability indicated by the thin diagonal black line. The dashed lines indicate how the forecasts were distributed among the possible forecast values.

Research Performance Measure: This project is year two of a two-year effort. Accomplishments to date focus on our overall objective of creating a real-time TC Genesis Index for operational use and include:

1. PI Dunion presented year-2 project results at the AMS 31st Conference on Hurricanes and Tropical Meteorology Conference in San Diego, CA, (April 2014): *Development of a Probabilistic Tropical Cyclone Genesis Index (TCGI) for the North Atlantic*.
2. PI Dunion submitted a Year-2 mid-year report (29 March 2013), a Year-2 final report (30 September 2013), and a final project report (28 February 2014) to NOAA JHT.
3. The proposal team completed the development of code to run the TCGI scheme in real-time during the 2013 Atlantic hurricane season.
4. Real-time tests of TCGI (0-48h and 0-120h) on North Atlantic tropical disturbances were performed on NOAA NESDIS computers at CIRA with output being made available via an ftp site.
5. A forecast verification of TCGI was made using a dataset of 2011-2013 dataset of North Atlantic tropical disturbances.

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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 the usefulness of aircraft observations to high resolution hurricane modeling systems and to develop advanced model diagnostic techniques to support 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 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 outputs of forecasts of multiple storms. 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 provided to the model development team.

Observations of axisymmetric structures of the vortex-scale, convective-scale and boundary layer were summarized in our earlier papers (Zhang et al. 2011a; Rogers et al. 2012). Since then 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 documented by Zhang et al. (2013a). Current observational work is focused on case studies with focus on rapid intensifying storms (Montgomery et al. 2014; Rogers et al. 2014).

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 showing significant improvements in simulated structure (Fig. 4). 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.

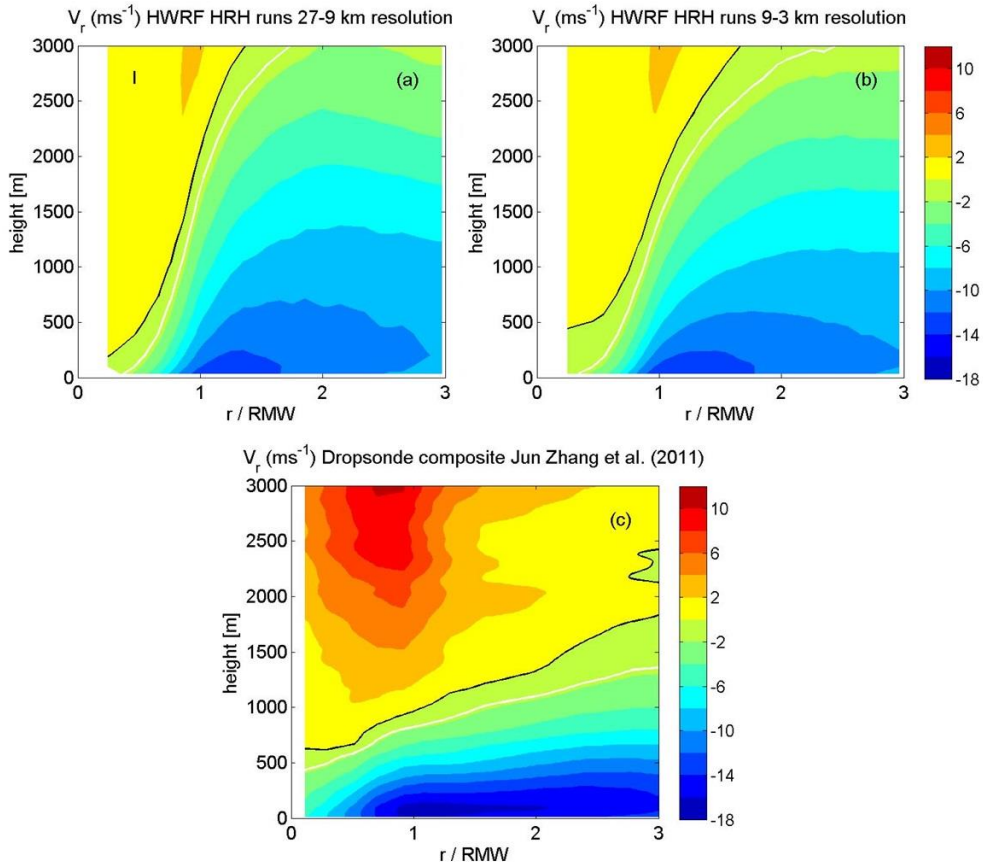

Figure 1: Composite mean radius-height plot of axisymmetric radial wind from the HRH 69 runs using the 2010-versional HWRF model for (a) 27-9 km resolution; (b) 9-3 km resolution; and (c) from dropsonde composite (Zhang et al. 2011a). Radial dimension plotted as normalized radius r*, where r* is the 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.

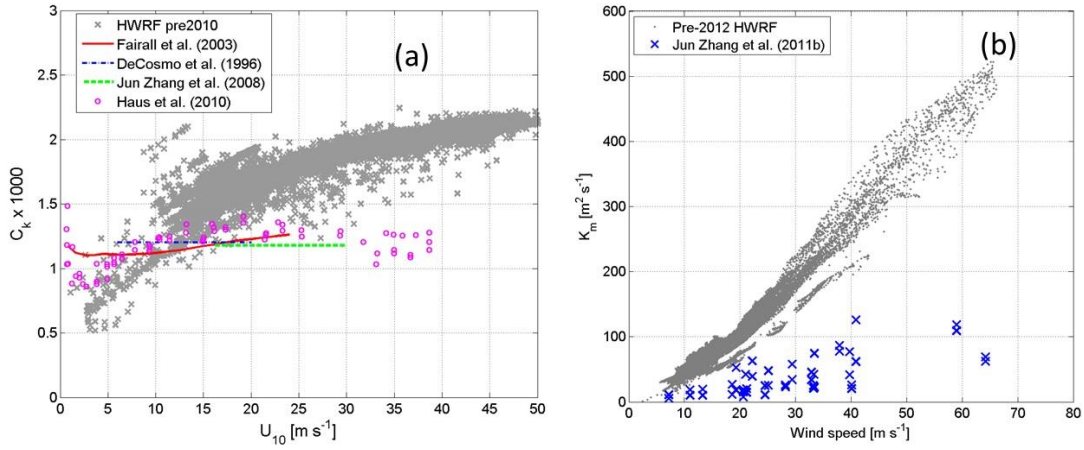

Figure 2: Plot of (a) exchange coefficients for enthalpy transfer as a function of surface wind speed from an idealized simulation with the HWRF model operationally used prior to 2010 seasons and (b) vertical eddy diffusivity for momentum flux as a function of wind speed, from an idealized simulation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

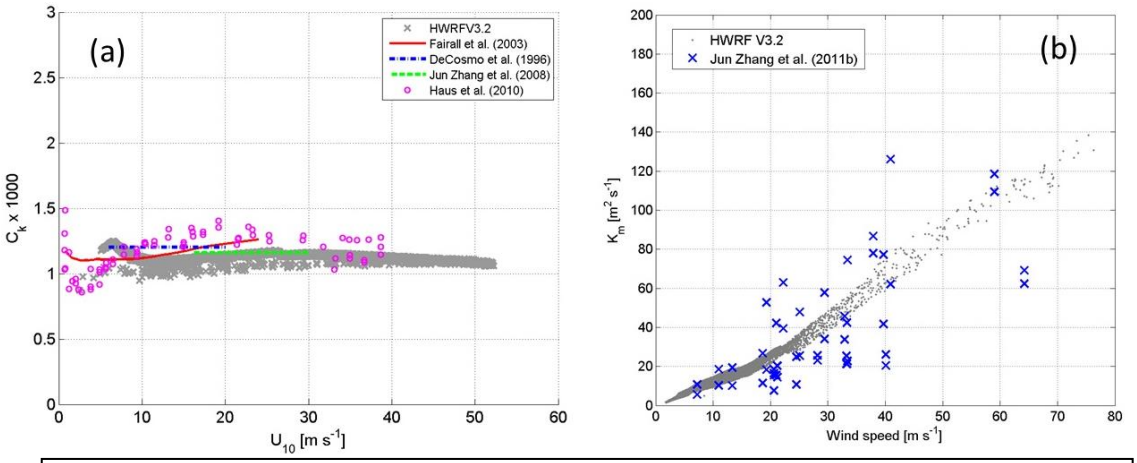

Figure 3: Plot of (a) exchange coefficients for enthalpy transfer as a function of surface wind speed and (b) vertical eddy diffusivity for momentum flux as a function of wind speed, from an idealized simulation with the 2012 version HWRF model used and from the observational studies.

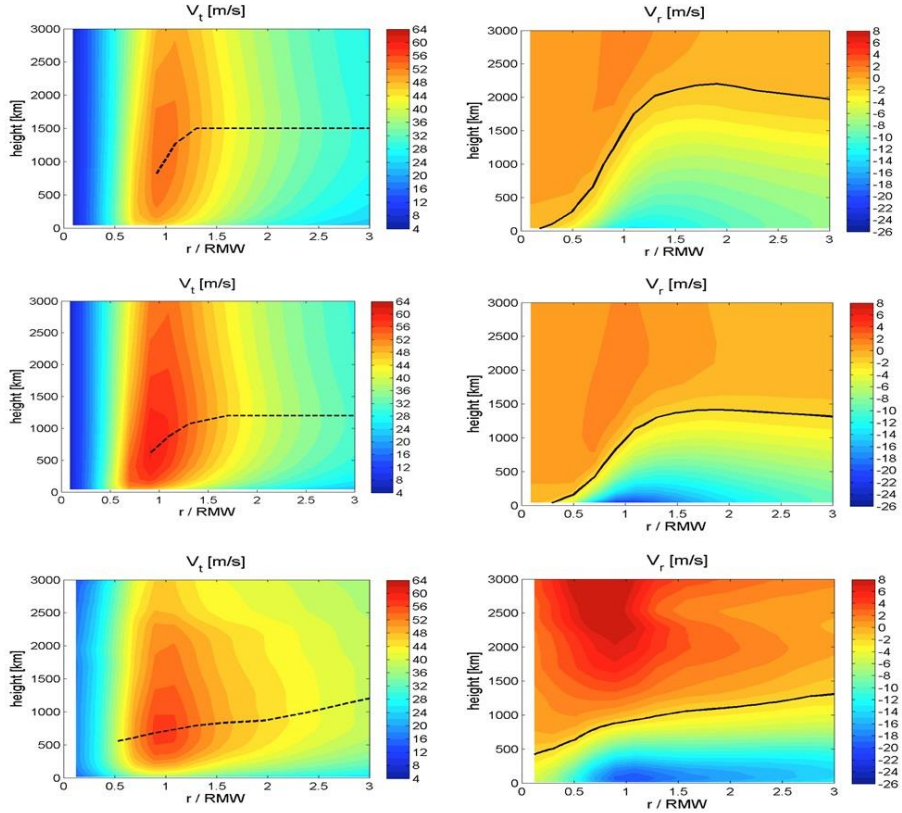

Figure 4: Plots of tangential wind (left) and radial wind (right) as a function of normalized radius and height. The upper panels are composites of HWRF simulations with 2011 version boundary layer scheme, the middle panels are composites of HWRF simulations with 2012 version boundary layer scheme, and the lower panels are from sonde composites. The dashed line represents the height of the maximum tangential wind speed and the solid line represents the inflow layer depth.

Research Performance Measure: The program is on schedule. In this most recent cycle, four peer-reviewed articles have been published in *Monthly Weather Review, Tropical Cyclone Research and Review* and *Quarterly Journal of Royal Meteorological society*. One additional paper has been submitted to *Monthly Weather Review.*

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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 improvements in forecasts of hurricane track, structure and intensity, due to the assimilation of new and future observations.
***Strategy*:** To advance the development and conduct evaluations of Observing System Simulation Experiments (OSSEs), in global and regional hurricane 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:
With respect to the global model OSSE, we collaborated with the NOAA Earth Systems Research Laboratory (ESRL). The purpose was to evaluate the impact of assimilating simulated dropwindsonde data from the Global Hawk unmanned aircraft on hurricane forecasts. Our main conclusion was that the assimilation of dropwindsonde data into NOAA's Global Forecast System (GFS) consistently improved track forecasts out to 4 days, and that the most effective deployments sampled both the hurricane and its regional environment. A manuscript documenting these results has been prepared for peer review.

With respect to the regional model OSSE, a second Nature Run simulation of a hurricane has been prepared. As with the first nature run (see Nolan et al. , 2013), a high-resolution configuration of the Advanced Research Weather Research and Forecasting model (WRF-ARW) yielded a physically realistic tropical cyclone that forms between Haiti and Cuba, and intensifies over the eastern Gulf of Mexico prior to landfall over western Florida. The three-dimensional nature run output has been made available to all interested investigators, including outputs every 5 minutes available on the vortex-following grid of 1 km horizontal spacing throughout the life cycle of the tropical cyclone.

Initial regional assimilation experiments with hyperspectral sounders and spaceborne Lidar have been conducted and diagnostic work is under way using an array of verification metrics relevant to the tropical cyclone and its environment.

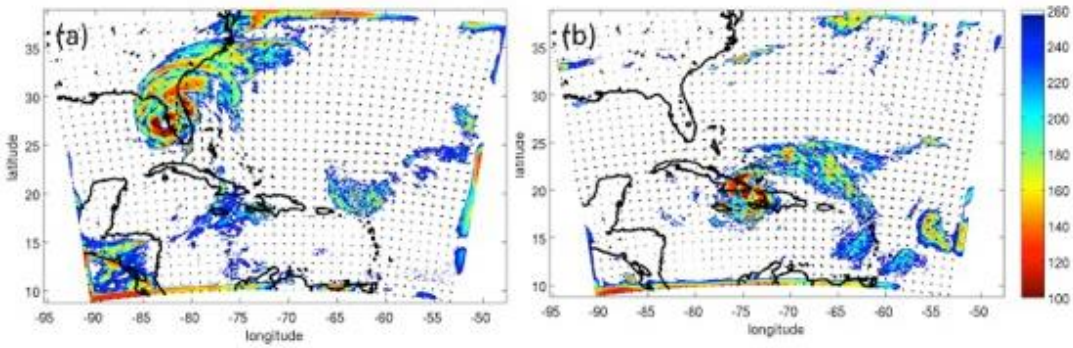

Figure 1: Simulated outgoing longwave radiation (OLR) and surface wind vectors (scaled to 40 m/s) on the 9 km WRF grid at (a) formation and (b) landfall of the tropical cyclone in the new Nature Run.

Research Performance Measure: All the objectives have been met on schedule.

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Real-Time Hurricane Wind Analysis

Project Personnel: B. Annane, S. Otero, and R. St. Fleur (UM/CIMAS)
NOAA Collaborators: M. Powell, and S. Murillo (NOAA/AOML/HRD)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To improve our understanding of the wind distribution in tropical cyclones.
***Strategy*:** To apply advanced computing methodologies to integrate cyclone data and to make the data more readily available to scientists in real-time.

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

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

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

Research Summary:
The HRD Real-time Hurricane Wind Analysis System (H*Wind) is a distributed system that ingests real-time global tropical cyclone observations measured by land-, sea-, space-, and air-borne platforms adjusting them to a common framework, 10m marine exposure. These observations are stored in a relational database, and then graphically displayed via an interactive Java application

where scientists can quality control, objectively analyze, and visualize the information. The H*Wind system consists of five sub-components: data collection, database, quality control interface, analysis package, and product generation package.

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

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

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

In February 2014, the NOAA Technology Partnerships Office approved the transition of H*Wind technology and product archive for commercialization by a US private sector firm, allowed under the Technology Transfer Act of 1986 (15 US Code 3710). Although AOML/HRD retains a license to use H*Wind to support existing internal research, AOML no longer sustains H*Wind for public use and its H*Wind website was taken off-line.

Research Performance Measure: All objectives have been met on schedule.

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An Eighteen-Year Tropical Cyclone Global Positioning System Dropwindsonde Dataset

Project Personnel: K. Sellwood (UM/CIMAS)
NOAA Collaborator: S. Aberson (NOAA/AOML/HRD)

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. 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 research regarding hurricane boundary layer structure and air sea interactions. 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 during NASA's Hurricane Severe Storm and Sentinal (HS3) missions in 2013 have also been added to the archive and will continue to be updated as this program continues. The value of such a comprehensive data base is evident in a series of manuscripts which study the near surface structure of tropical cyclones by compositing the dropsonde data over many storms. See Figure 1.

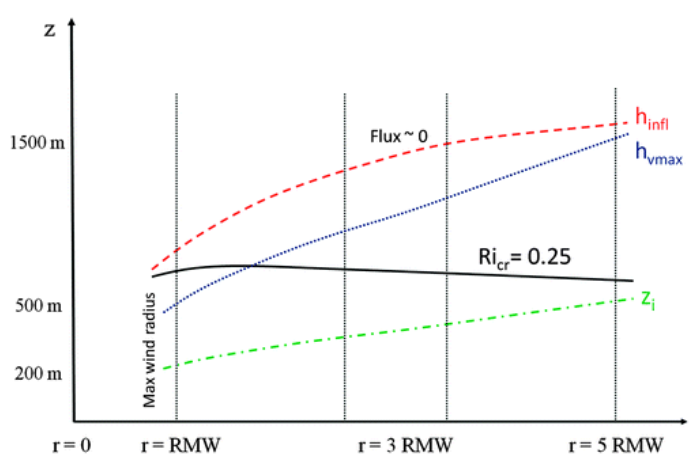


Figure 1: Schematic diagram of the characteristic height scales of the hurricane boundary layer. The height scales are based on the composite analysis of the dropsonde data. The h_{infl} is the inflow layer depth (red dashed line), z_i is the mixed layer depth (green dashed–dotted line), and h_{vmax} is the height of the maximum wind speed (blue dotted line). The solid black line represents the height where the bulk Richardson number is equal to 0.25. These height scales provide a means of evaluating the hurricane boundary layer structure in numerical forecast models. Figure courtesy of Jun Zhang (UM/CIMAS).

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.

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 decodes the data which is transmitted and formats it so that can be easily interpreted. This program also provides a best estimate of the high-resolution observation times and locations that are essential for data assimilation with advanced hurricane forecasting models. Dropwindsonde data processed using this code has been assimilated into HRD's experimental version of the Hurricane Weather Research and Forecasting model (HWRFx) in near real time since 2010 and retrospectively for the 2008 through 2012 Altantic hurricane seasons. The retrospective cases illustrate that including these data in the initial condition provided a significant improvement in the forecast of tropical cyclone track and intensity out to 60 hours. See Figure 2. These 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.

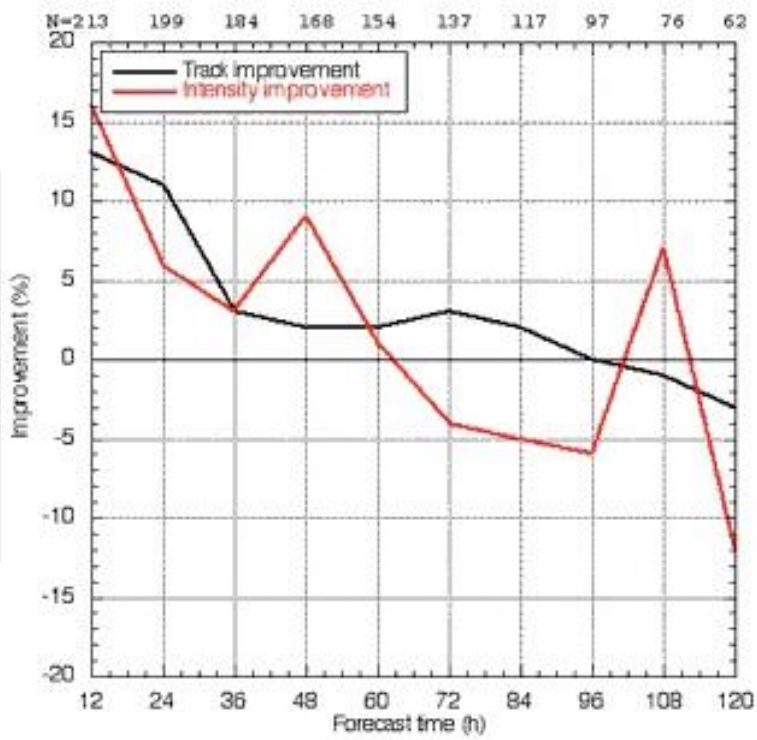


Figure 2: Percent improvement in hurricane track and intensity for 12-120 hour forecasts from HWRF model with dropwindsonde and flight level observations assimilated into the initial condition. The number of cases at each forecast time is given at the top of the figure. There is up to a 15% improvement in both track and intensity out to 60 hours compared with model forecasts which do not incorporate these observations.

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

Studies in Support of NOAA's NESDIS Operational Ocean Heat Content Product Suite

Project Personnel: L.K. (Nick) Shay (UM/RSMAS)
Other Collaborators: E. Maturi, and D. Donohue

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 the Pacific Ocean Basins to NOAA NESDIS for 24/7 operations. A key aspect of this product is that the isotherm depths (20 and 26^oC), ocean mixed layer depth, and OHC will be carefully evaluated from *in-situ* data from floats, drifters, expendable bathythermographs (XBT) transects, long-term Pirata and TOGA TAO moorings and airborne XBTs (AXBTs, AXCTDs) including data recently acquired from the Deep Water Horizon monitoring over about 90 days following the incident and measurements from the ONR ITOP experiment in the western Pacific Ocean basin.

***Strategy*:** To build realistic climatology for a two-layer model and evaluate a daily global OHC product based on satellite altimetry-derived sea surface height anomalies (SSHA) from available missions (Jason, SARAL, and Cryosat-2) with observations from various in situ platforms. This product (North Atlantic and Pacific) has been transitioned to NOAA NESDIS for 24/7 operations. The building of the South Pacific product suite is ongoing.

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

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

Funding 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 3.0 and latest WOA for the two and a half layer model using a 15-day running mean to insure continuity between the months for mean isotherm depths and reduced gravities. Thermal profiles acquired from various platforms including floats, XBT transects (see Figure 1), moorings and AXBTs for a fourteen-year period. In addition, the airborne measurements from the Deep Water Horizon response in 2010 were also entrained into the Atlantic and Pacific Ocean basins analysis to improve the satellite-derived algorithm. Altimeter-derived SSHA (including those from SARAL) have been blended and objectively from various platforms using the Mariano and Brown (DSR, 1992) approach to estimate space based values of isotherm (and mixed layer) depths and OHC values. Based on these measurements, we have found high correlations and low RMS differences between observed and space-based estimates of the product fields based on the SMARTS and SPORTS climatology for the North Atlantic and Pacific Ocean basins, respectively. Super Typhoon (ST) Haiyan in November 2013 also provided an example of how SPORTS calculated OHC benefitted tropical cyclone intensity forecasting. Accurately estimated OHC from a couple days before the storm revealed high OHC under what would be the eventual track of ST

Haiyan. These high OHC values indicated favorable ocean conditions for Haiyan's intensification in the western Pacific Ocean. In addition, SPORTS is being applied to three typhoons observed extensively from aircraft and buoys during the ONR-sponsored experiment that was conducted during the *Interaction of Typhoons with the Ocean Program* (ITOP) conducted in 2010 in the western Pacific Ocean including the ST Megi. Initial estimates for the South Pacific Ocean product are encouraging as well. We expect to have the product ready to be declared operational in early 2015 at NESDIS.

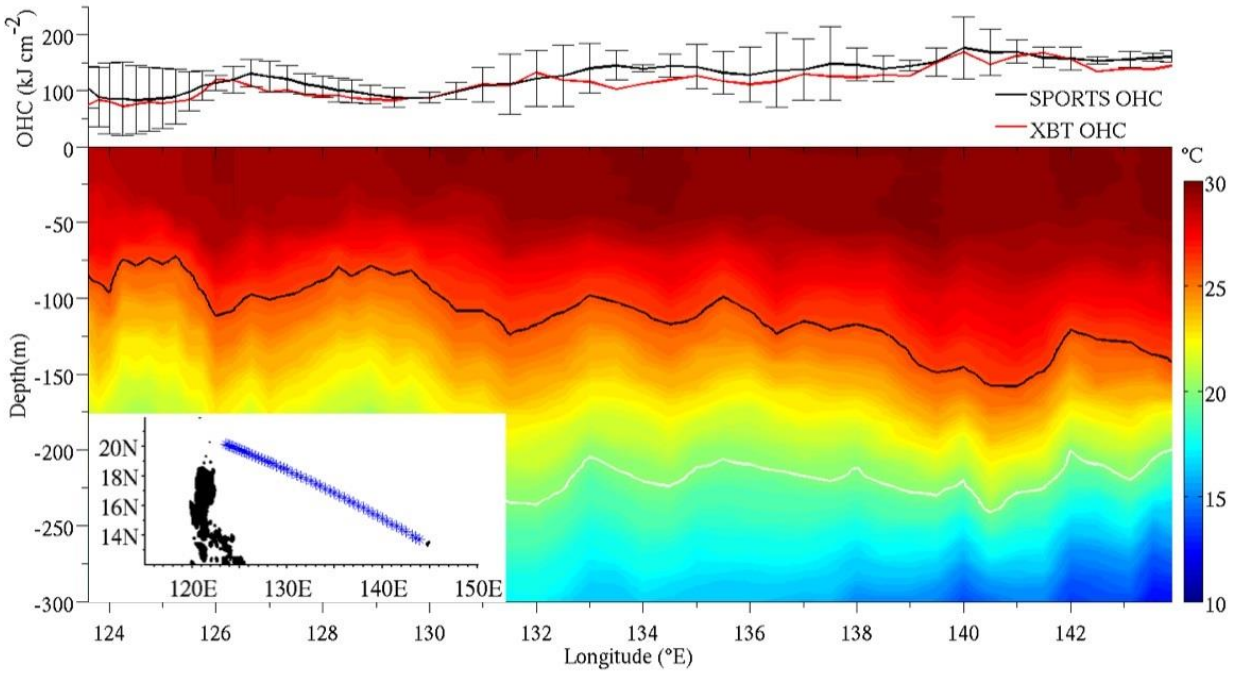


Figure 1: XBT transect and SPORTS data averaged over a three-year period (2008-2010) for the month of September. Upper panel shows average OHC calculated from SPORTS (black line) with ±2σ error bars and average OHC calculated from the XBT (red). Lower panel shows averaged temperature profiles from the XBT transect with the 26°(20°) isotherm in black (white). The XBT transect path is shown in the inset in the lower left corner**.**

Research Performance Measure: These new products originally developed by Mainelli (2000) and Shay and Brewster (2010) have been successfully transitioned to NOAA NESDIS and to NHC for Statistical Hurricane Intensity Prediction Scheme (SHIPS) and used at the Joint Typhoon Warning Center. In general, the addition of OHC values, reduced intensity forecast error about 5 to 6% above the SST influence on hurricane intensity over the North Atlantic Ocean Basin for example. However, it has been shown that deep warm mixed layers (high OHC) become even more important in the western parts of the basins. OHC reduced intensity forecast error by an additional 22% during hurricane Ivan's passage in 2004. With this newer and enhanced (and evaluated) product (including the injest of SARAL SSHA), we expect that the OHC will reduce uncertainties even more, and the product fields will be available year round through NOAA NESDIS with an archive dating back to 1998 for improved analyses and forecasts for weather and climate studies.

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 formulate new wind and rain models in the SFMR algorithm that removes the high surface wind speed bias in heavy rain and to evaluate performance of these changes
***Strategy*:** To use rain data from independent sources to improve the rain-absorption model function by developing a new Z-R relationship and k-R relationship for the SFMR. To evaluate the new algorithm performance and its ability to reduce the bias in heavy rain.

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: NOAA/OAR/USWRP/JHT
NOAA Technical Contact: Jiann-Gwo Jiing

Research Summary:
The airborne stepped frequency microwave radiometer (SFMR) estimates surface wind speed and rainrate in most conditions, but is particularly useful in tropical cyclones. However, due to a several factors, retrieval accuracy is degraded in conditions where weak-to-moderate winds are coupled with heavy precipitation. Typically, winds are overestimated in such conditions.

The bias associated with these conditions was previously quantified and a bias correction model was developed. While this bias correction model is important and necessary, it is really only a temporary solution. To truly address the problem of overestimating the surface wind speeds in heavy precipitation, the SFMR algorithm requires updating to correspond to the quantified bias. The wind versus emissivity model was addressed first, whereby data in non-precipitating conditions were considered. This restriction eliminates any effects the rain has on the emissivity that the SFMR detects. With some additional changes to the method of determining the components of the emissivity (i.e. total emissivity is equal to the smooth surface emissivity plus the frequency dependent excess emissivity), the previous wind versus emissivity model and the updated model correspond very well to each other. In fact, the differences between the two functions are within the noise range of the measurement, despite the small sample size used to derive the current operational model. Figure 1 provides the comparison of these two models along with the scatter of the data used to develop the updated version. As indicated in the figure, the 4.74 GHz channel was used specifically for the updated model methodology because this channel has the least impact from precipitation.

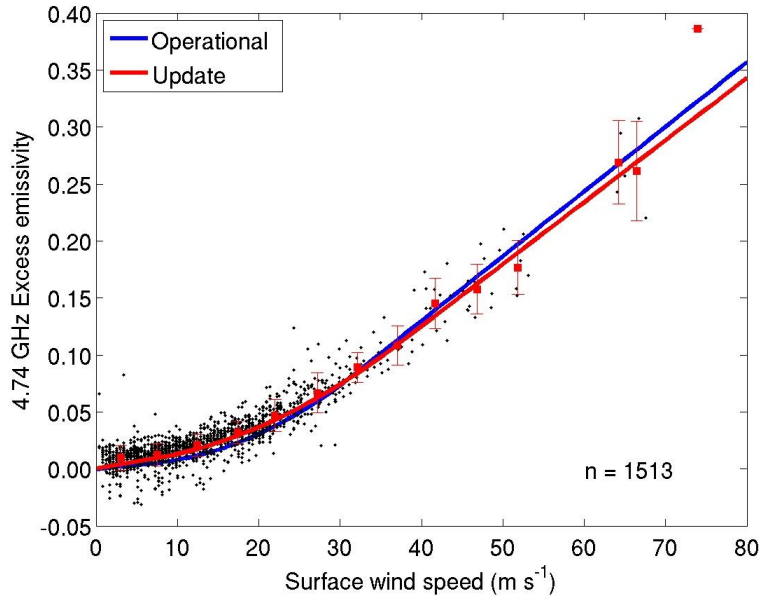


Figure 1: Total excess emissivity at 4.74 GHz is provided as a function of surface-adjusted dropsonde wind speed (U_{sfc}). The red and blue lines represent the function for the updated and operational versions, respectively. The error bars associated with the red squares (bin-averaged data) represent the standard deviations for each bin.

Because the current and the updated wind versus emissivity functions are very similar, the problem with wind speed overestimation must be originating from the rain absorption portion of the SFMR algorithm. To address this problem, data from the NOAA P-3 Tail Doppler radar (TDR) and Precipitation Imaging Probe (PIP) were used to independently determine a new radar reflectivity versus rainrate (Z-R) relationship. This Z-R relationship was then used to determine an updated absorption versus rainrate (k-R) function that is more suitable for the SFMR. Figure 2 displays the current and updated k-R relationship as a function of SFMR frequency. Clearly, the updated version does not increase the effect of absorption with increasing rainrate as quickly. When averaged over all frequencies, there is factor-of-two difference between these two versions.

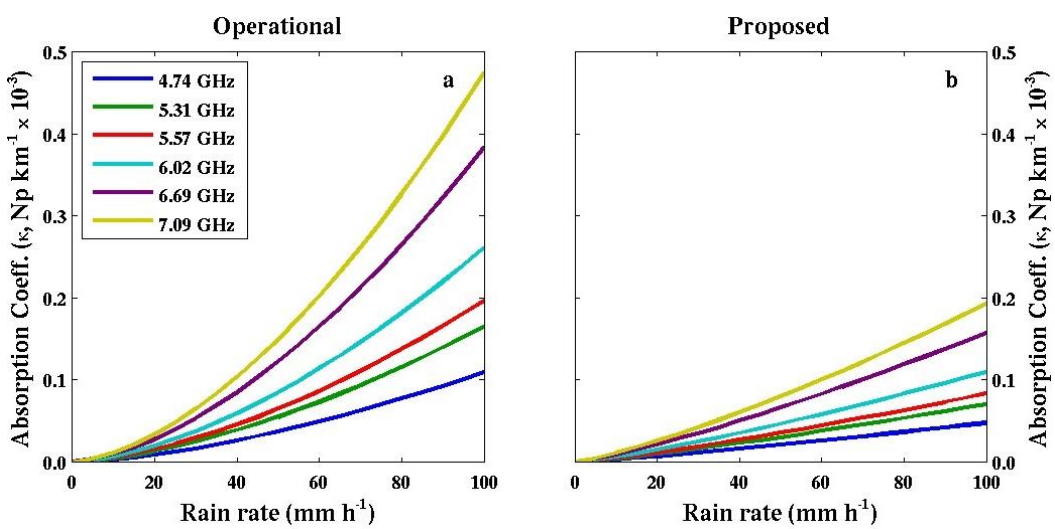


Figure 2: Operational (a) and updated (b) absorption coefficient as a function of SFMR channel frequency is shown in relation to rainrate. The spread in the proposed absorption coefficient indicates there is less effects due to absorption as rainrate increases.

With the new emissivity and absorption models in place, an evaluation of their performance reveals that there are several areas of significant improvement. One particular area is the ability to obtain rainrates higher than 60 mm hr^{-1}. Figure 3 provides a histogram of the range of rainrates from each model version. The key point from this figure is that the maximum rainrate is on the order of 90 mm hr^{-1} for the updated version whereas it is only near 60 mm hr^{-1} for the current version. The updated values are more comparable to other sources of rain measurements than those of the current version. In terms of improving the wind speed, which was the main goal of this work, non precipitating regions have a +2.5 m s^{-1} high bias at wind speeds less than hurricane strength using the current algorithm but the updated algorithm reduces this bias to less than 0.5 m s^{-1} on average. Specifically examining the conditions of weak wind speeds and heavy precipitation, results indicate that a current bias of +5 m s^{-1} is reduced to about +3.5 m s^{-1}. While the algorithm update does not fully remove the high bias, it moves the estimate in the right direction. Figure 4 provides the histograms for the current and updated results and indicates improvements in all conditions. Therefore, while the high bias is not fully removed, the estimated wind speeds better compare to other trusted sources of surface wind speed estimates.

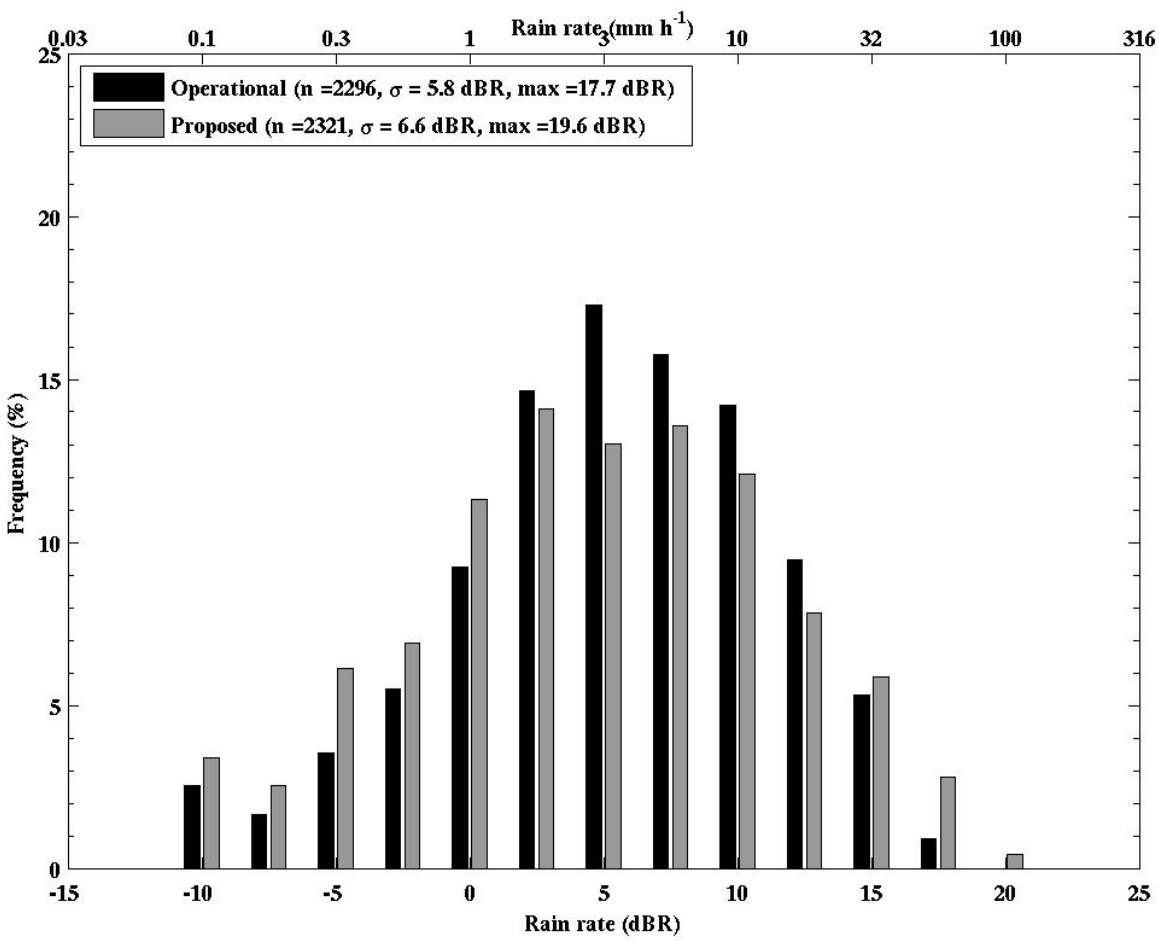


Figure 3: Histograms of the operational (black) and updated (gray) rainrates are shown. These rainrates are displayed in dBR but the equivalent rainrate values in mm hr^{-1} are also provided for reference along the top axis. The range of achievable rainrates is expanded under the updated version, where the maximum rainrate increases by nearly 2 dB or ~30 mm hr^{-1}.

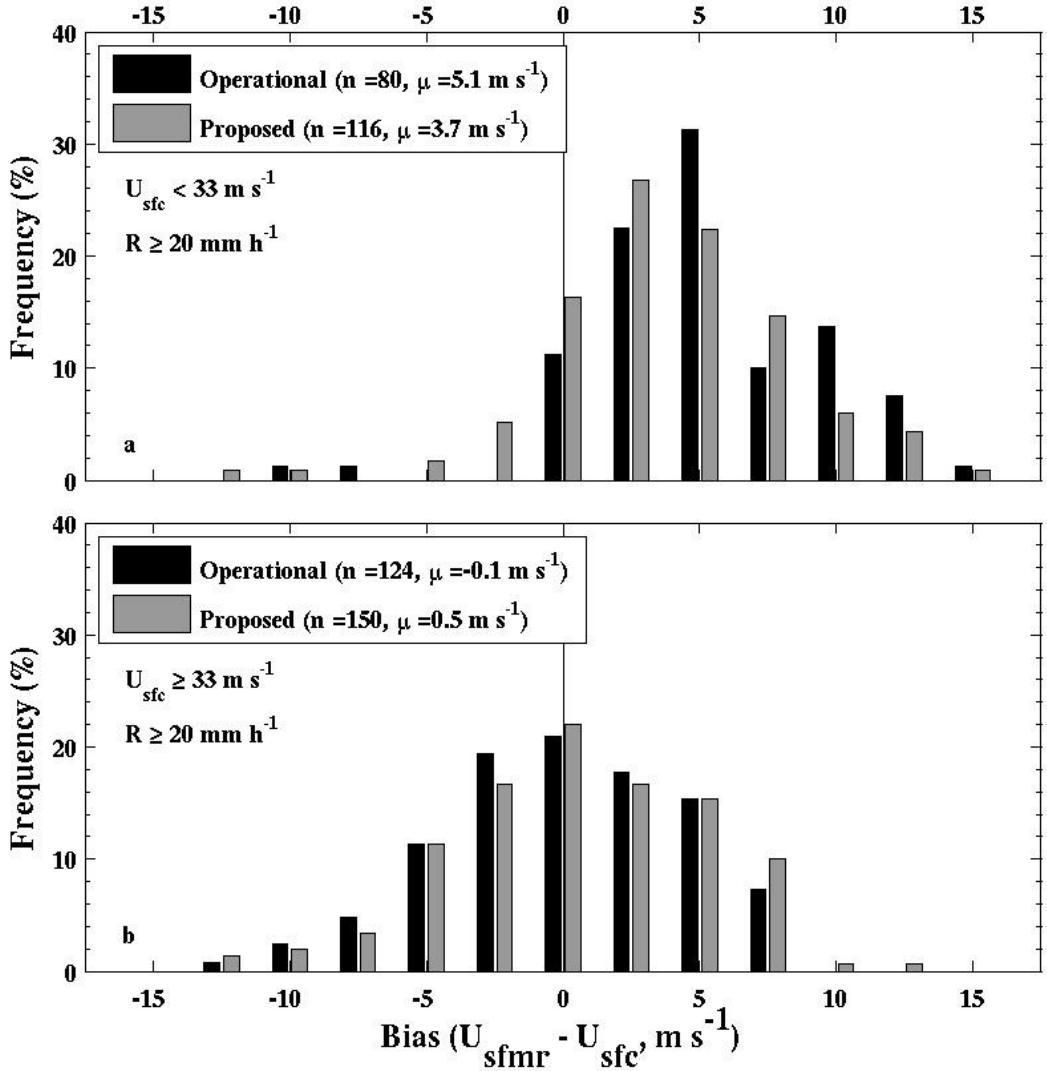


Figure 4: Histograms of the operational (black) and updated (gray) wind speed bias for heavy rain conditions (rainrate > 20 mm hr^{-1}) at wind speeds less than hurricane force (a) and wind speeds within the hurricane wind speed regime (b).

Research Performance Measure: All research goals have been met. The algorithm needs approval from the JHT committee before it can become operational, but all goals related to this work have been completed.

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)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To reanalyze the years 1955–1964, inclusive, of the HURDAT Atlantic 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*
***Goal 1*:** Climate Adaptation and Mitigation – *An informed society anticipating and responding to climate and its impacts.*

NOAA Funding Unit: OAR/AOML/HRD
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.

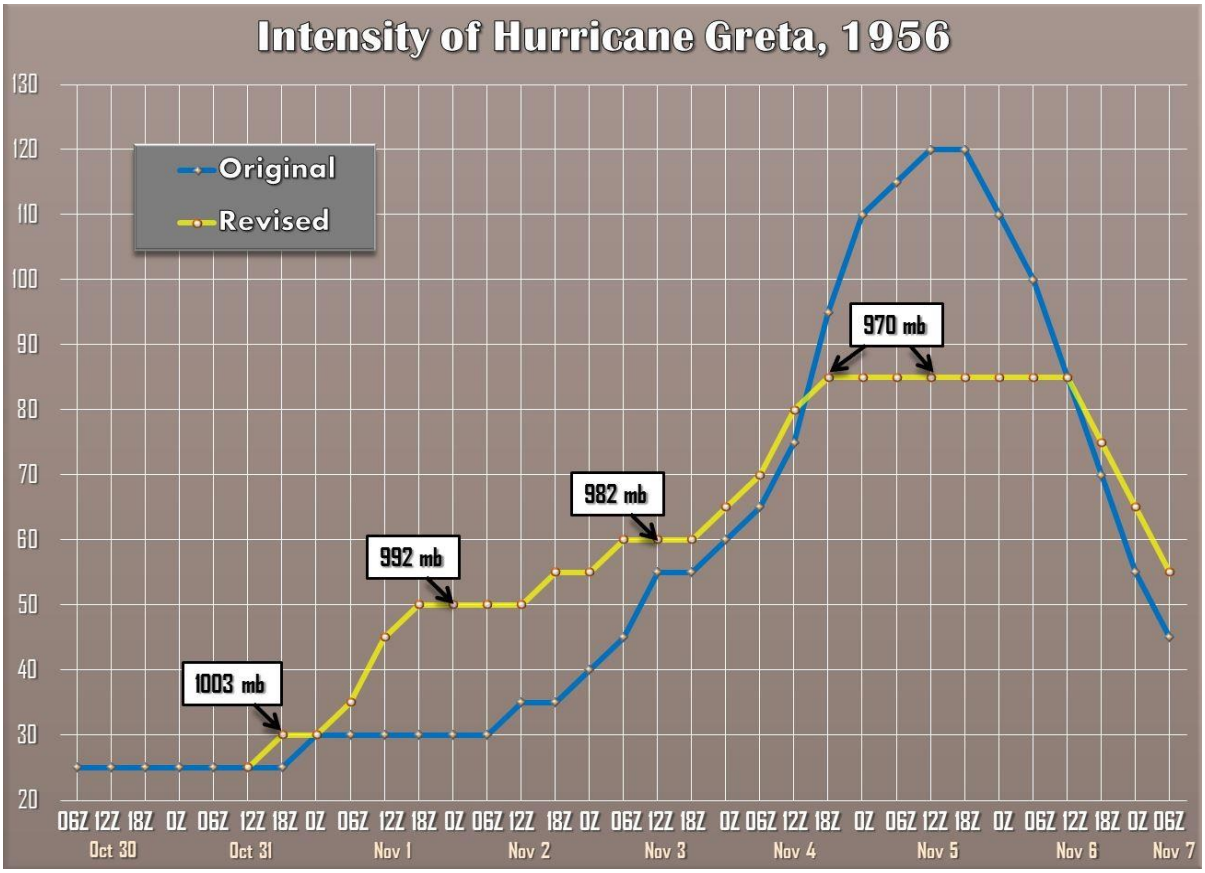


Figure 1: Original (blue) and revised (yellow) intensities (wind speed in knots) of Hurricane Greta of 1956, illustrating changing assessments of hurricane intensity due to reanalysis.

Reanalysis of all Atlantic tropical cyclones from 1955 through 1963 are complete and have been reviewed with C.W. Landsea, Mr. Delgado's contact at the National Hurricane Center. We expect the final year, 1964 to be finished before fall. A summary of significant results since June of 2013 follows:

The year 1960 was quiet for the Atlantic, but active for the United States. Five of that year's seven tropical cyclones made US landfall. The most significant was Hurricane Donna, but its reanalysis was done before the current phase of the project. Another major change to 1960 was a decrease the intensity of Hurricane Ethel from 140 kt to 100 kt. The 140 kt value was a surface wind estimate from the reconnaissance aircraft. It was inconsistent with a measured central pressure of 976 mb.

1961 was a very active year for the Atlantic, but only one hurricane struck the US. It was also a year of milestones since it marked the first use of satellite images. Anna was the first hurricane in the Atlantic to be imaged, and Esther was the first tropical cyclone to be found based upon satellite imagery. The system developed rapidly over the eastern Atlantic. When it was photographed it was already a tropical cyclone, but the Weather Bureau waited until a ship and reconnaissance aircraft corroborated the picture. The reanalyzed peak intensity of Esther increased to 135 kt from original 125 kt in HURDAT. A new tropical storm was added to 1961. It occurred in November over the central Atlantic.

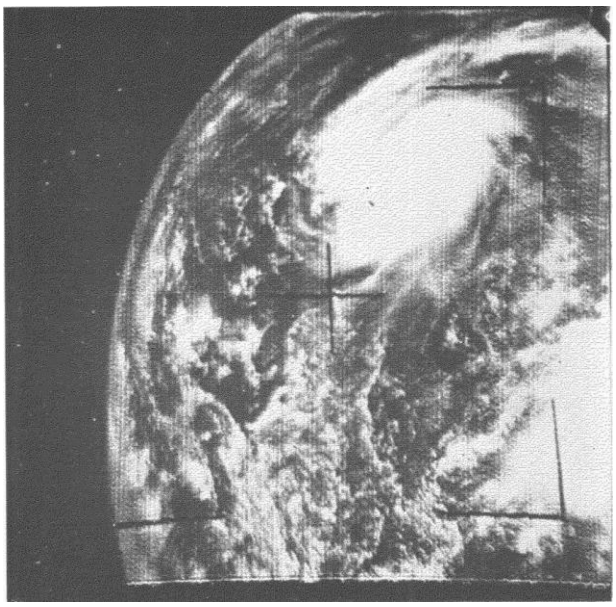


Figure 2: TIROS (Television Infrared Observing Satellite) image of Hurricane Anna on 21 July 1961, the first tropical cyclone to be observed operationally from space.

The reanalysis introduced relatively minor track and intensity alterations to the HURDAT record of the 1963 hurricane season. The track of hurricane Beulah was extended 8 days to show its entire extratropical stage. Cindy and Debra were demoted from hurricanes to tropical storms because available data did not support hurricane intensity. After careful examination, the peak intensity of Flora remained 125 kt at landfall in Haiti and category 3 at first landfall in Cuba.

Research Performance Measure: The 1955-1963 reanalysis should be complete in June. Mr. Delgado will defend his FIU masters' thesis in early July and graduate in August. He will continue working at FIU to complete analysis of 1964 in late summer and (funds permitting) will travel to the National Climatic Data Center in Ashville NC in July to assess availability of satellite imagery to support the reanalysis.

The year 1962 was also quiet. In the original HURDAT, no tropical cyclone made US landfall in 1962. Alma passed close enough to produce tropical-storm force winds in the Carolinas Outer Banks. Daisy produced strong winds, high waves and heavy rain as a non-tropical cyclone over the North East. Three new tropical cyclones have been identified in 1962. One made landfall in the Outer Banks in late June and another other occurred late in the year, developing from a long-lived extratropical cyclone that produced hurricane-force winds and caused some damage in the Southeast. The intensity of Hurricane Ella was decreased from 100 kt to 90 kt, which means that it is no longer considered a major hurricane. The eye diameter of this system had expanded to 100 nm when the lowest central pressure was measured.

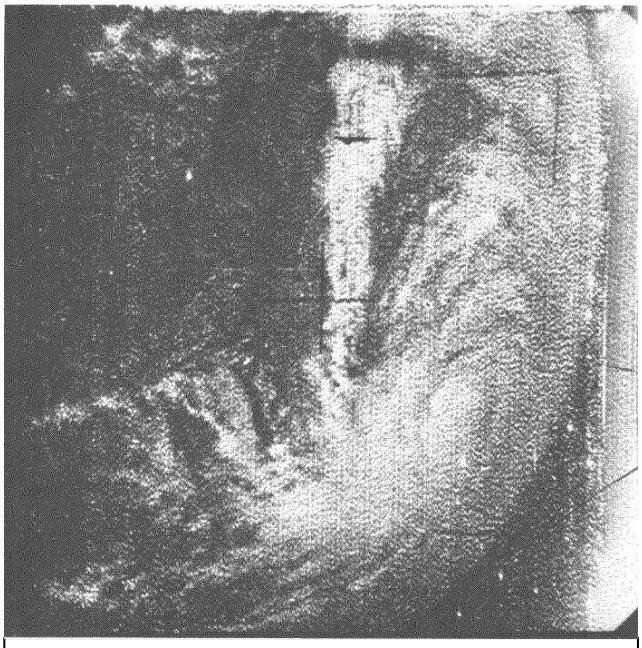


Figure 3: TIROS (Television Infrared Observing Satellite) image of Tropical Storm Esther on 10 September 1961, the first tropical cyclone to be discovered in satellite imagery.

Services to Support the Hurricane Forecast Improvement Project

Project Personnel: X. Zhang, A. Aksoy, J. Zhang, K. Sellwood, B. Klotz, R. St. Fleur, and R. Gall (UM/CIMAS)

NOAA Collaborators: S.G. Gopalakrishnan, T.S. Quirino, and F.D. Marks, (NOAA/AOML/HRD); V. Tallapragada and HWRF team (NOAA/NCEP/EMC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** Our overall objective is for CIMAS and its collaborating groups to further advance the capabilities, accuracies and reliability of numerical hurricane forecasting in FY14-15 under HFIP.

***Strategy*:** To achieve this objective, we will focus on (1) experimenting with alternative physics packages; (2) exploring the assimilation of satellite data through regional OSSE system; (3) implementing new capabilities in the operational HWRF model; (4) collaborating with NWS and other federal scientists, and research scientists from other organizations on furthering HFIP's plans and objectives; (5) managing the technical aspects and R2O and O2R transitions of the HFIP program.

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

NOAA Technical Contact: Alan Leonardi

Research Summary

NOAA undertook the Hurricane Forecast Improvement Project (HFIP) to reduce numerical forecast errors in track and intensity, extend forecast guidance to 7 days, and increase the skill of predicting rapid intensity changes (i.e., decrease the false alarm ratio for rapid intensity change). CIMAS and its collaborators in NOAA and elsewhere have advanced the capabilities, accuracy and reliability of numerical hurricane forecasting through: (1) experimenting with alternative physics packages; (2) exploring the assimilation of satellite data through regional OSSE system; (3) implementing new capabilities in the operational HWRF model; (4) collaborating with NWS and other federal scientists, and research scientists from other organizations on furthering HFIP's plans and objectives; (5) managing the technical aspects and R2O/O2R transitions of the HFIP program.

We achieved recent progress in the following five areas: (1) HWRF model development including multiple movable nests, new flexible vortex initialization and recalibrated physical parameterization based on observations [Table 1 and Figure 1]; (2) annual AOML/HRD IFEX hurricane observation program [Figure 2, experiments of foci are varied from year to year but the goals are same, Rogers et al. 2013]; (3) data assimilation and observing strategy analysis [Table 2]; (4) verification and diagnosis on full spectral scale (large to convective scales) forecasts from HWRF model and software capacity developed for such research, DIAPOST and HPOST; (5) HFIP project management conducted annual workshop, published annual report, allocate and maintain real-time reservation system, held biweekly HFIP telecon, and assisted HFIP project office manage funding.

Table 1: Three major components of the basin-scale HWRF forecast

Initialization	Forecast System	Products & Dissemination
• Static terrestrial initialization • Initialization & Cycling • Vortex initialization (Relocation & modification) • Data assimilation	• Trigger mechanism • Resource allocation • Submission & monitor system (jobs & resources management)	• Vortex- and large-scale post-processing • Diagnostic & forecast products • Web products • Product real-time dissemination • Tape archive • Grib file generation

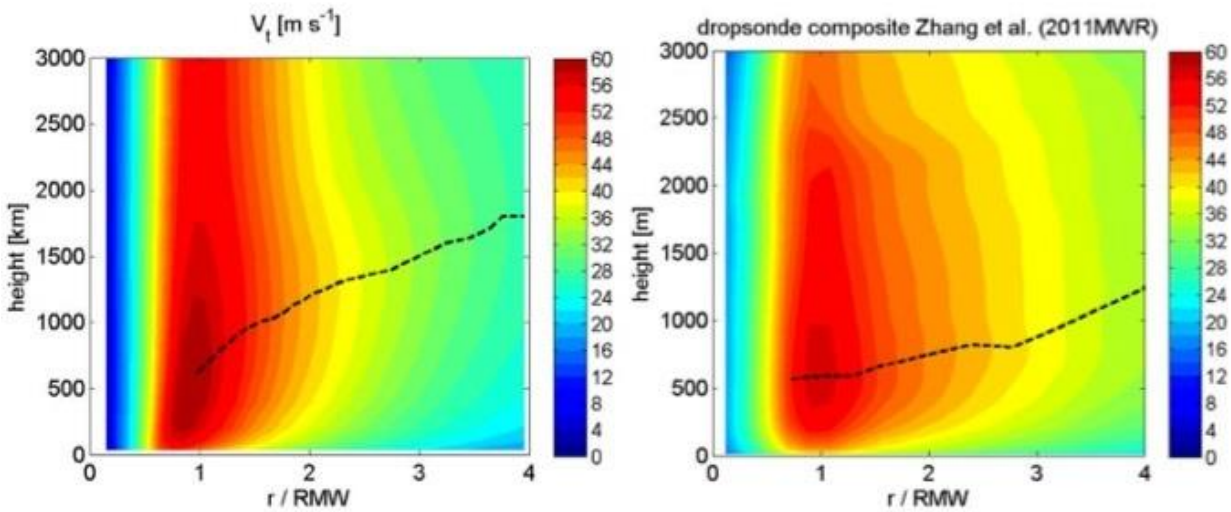


Figure 1: (Left), composite of the tangential wind speed (Vt) using simulations of Hurricane Earl (2010) with the 2012 version HWRF model; (Right), as in left but for GPS dropsonde composite of Vt. The black dashed line represents the height of maximum Vt.

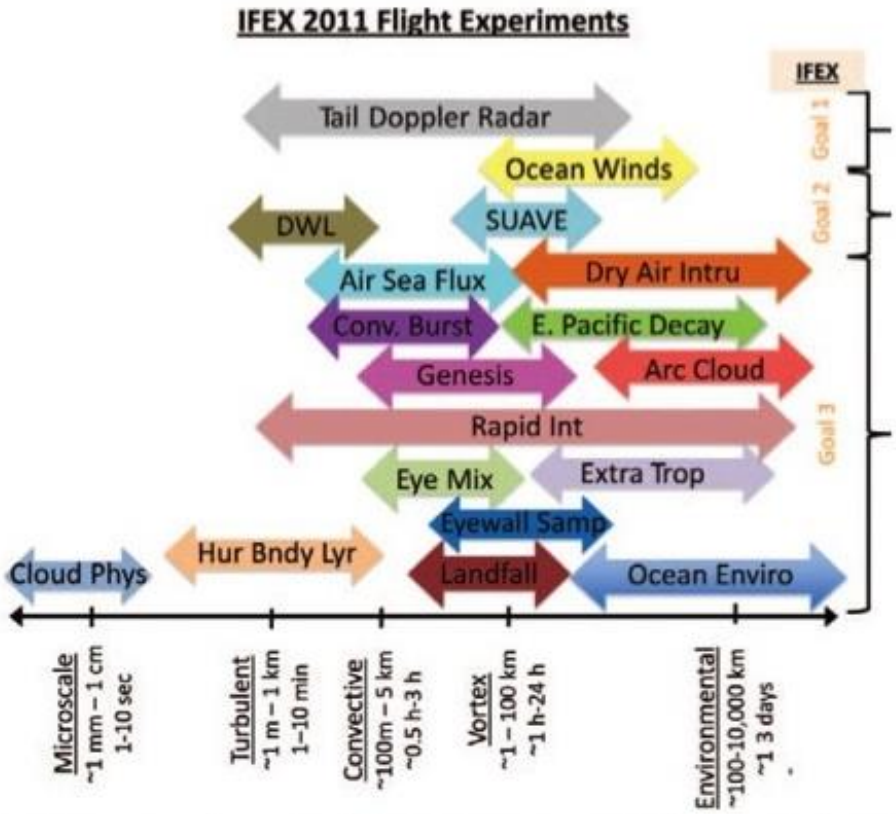


Figure 2: List of experiments proposed for the 2011 IFEX Hurricane Field Program, plotted as that portion of the spatial spectrum the experiments primarily addresses (here, DWL = Doppler wind lidar and SUAVE = special unmanned aerial vehicle experiments). Also noted are the primary IFEX goals addressed by each experiment.

Table 2: Summary of the Number of Observations Admitted by HEDAS

Platform	Num. Obs.	Num. Cases	Avg. Num. Obs.
Flight Level	77,304	37	2,089
SFMR	15,805	35	452
Dropsondes	21,420	33	649
Doppler Superobs	267,310	21	12,729
Satellite AMVs	113,701	45	2,527
Satellite AIRS Retrievals	80,589	23	3,504
Satellite GPS-RO Retrievals	4,992	24	208
Total	**581,121**	**45**	**12,914**

Research Performance Measure: All CIMAS and AOML research objectives for HFIP are being met on schedule.

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

Project Personnel: X. Zhang, and R. St. Fleur (UM/CIMAS)
NOAA Collaborators: S.G. Gopalakrishnan, T.S. Quirino, and F.D. Marks, Jr. (NOAA/AOML/HRD); 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 and AOML/HRD
NOAA Technical Contact: D. Melendez and Alan Leonardi

Research Summary:
The experimental basin-scale HWRF modeling system developed in collaboration with EMC can support any number of high-resolution movable nests centered on storms that may exist in the Atlantic or the East Pacific basin (Figure 1). It not only provides simultaneous high-resolution forecasts for multiple storms, but also has the potential to improve the representation of storm-storm interactions, synoptic scale circulation, and the TC life cycle from genesis to decay. Because the operational HWRF system is limited by its configuration, the basin-scale HWRF system may be applied to unique research problems about TCs and their prediction, such as storm-storm interaction, model bias diagnostics, physics scheme improvement, localized multiple-vortex initialization and regional data assimilation techniques.

Similar to the operational HWRF modeling system, the basin-scale HWRF system consists of three key components: initialization, forecast system, and post-processing and the production system. The existing vortex initialization scheme in HWRF modeling system was extended to the basin-scale HWRF system so that any number of TCs may be seamlessly initialized at 3 km resolution in the same domain. The design incorporating multiple movable nests, their feedbacks and interactions has taken into account operational requirements for concurrent integrations that can be produced for any number of storms in the basin. The design can further be applied on the next-generation multi-scale regional or global modeling systems for hurricane forecasting.

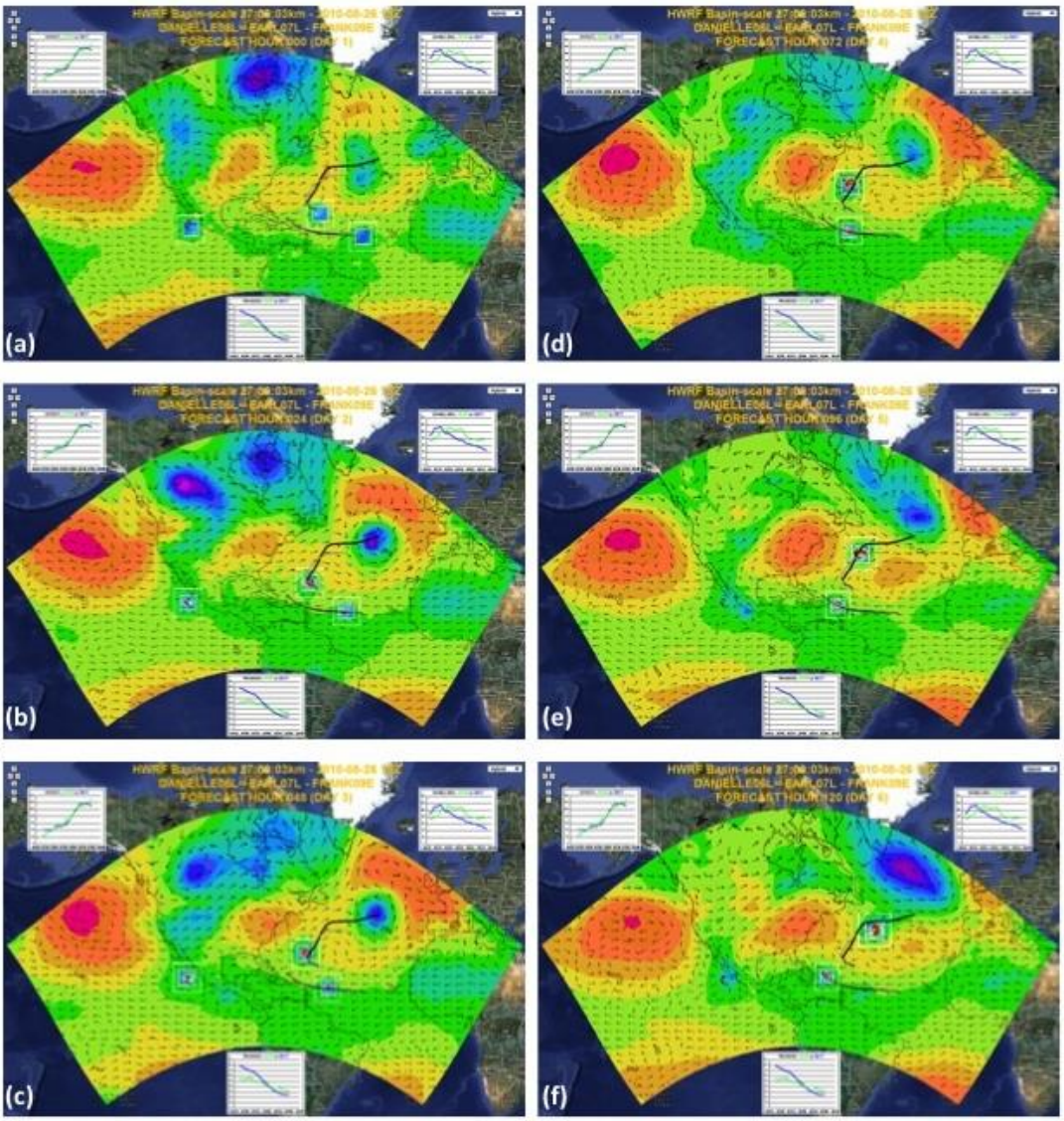


Figure 1: Earl-Danielle-Frank real-time 3-km forecast at 18 UTC 26 August 2010. (a) 0h; (b) 24h; (c) 48h; (d) 72h; (e) 96h; (f) 120h. The insert panels show the intensity forecasts of Hurricanes Earl (upper left), Danielle (upper right), and Frank (low middle).

With the basin-scale HWRF system, we have systematically tested three seasons (2011-2013 hurricane seasons) in the Atlantic (Figure 2) and the East Pacific (Figure 3) basins. The results show the system can improve the track forecast about 7-12% in both basins. The improvement on intensity forecast is mixed. We identified some TCs like Hurricane Leslie and Hurricane Mariam with significantly larger intensity errors. We conclude that these intensity errors are caused by the lack of adequate underlying oceanic representation for these slow moving TCs (Figures 4 and 5). This finding implies that oceanic representation is a critical component in the operational TC forecast system even though acting on this finding will be complex and expensive. We further demonstrate the benefit of the basin-scale domain from the Hurricane Sandy forecast verification. Hurricane Sandy track forecasts by the basin-scale HWRF system were consistently better than those produced by the operational HWRF system because the basin-scale HWRF system can better represent the mid- and low-latitude interaction, forecast more accurately the synoptic-scale and/or planetary-scale

evolvement, which steered the movement of Hurricane Sandy. Although both operational HWRF and basin-scale HWRF were forced by same large-scale GFS forecast, the superior of the Sandy forecasts by basin-scale HWRF suggests the need for a transition from a storm-centric to a basin centric and eventually a global to local scale forecast system for hurricanes.

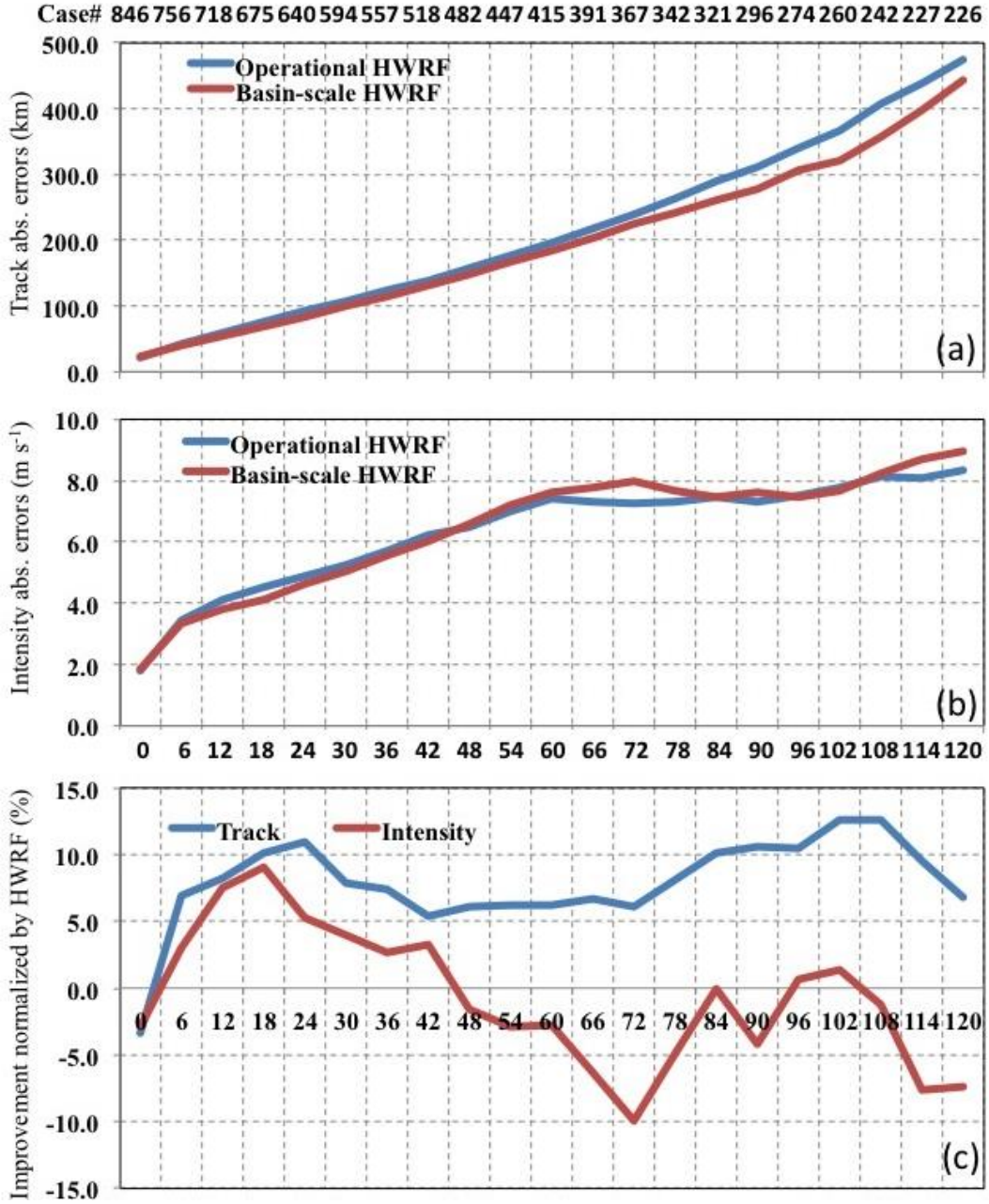


Figure 2: Track and intensity verification of three hurricane seasons during 2011-13 in the Atlantic basin. (a) Track; (b) Intensity; (c) Track and intensity improvement normalized by operational HWRF. (d)(e)(f) same as (a)(b)(c) in the left column correspondingly.

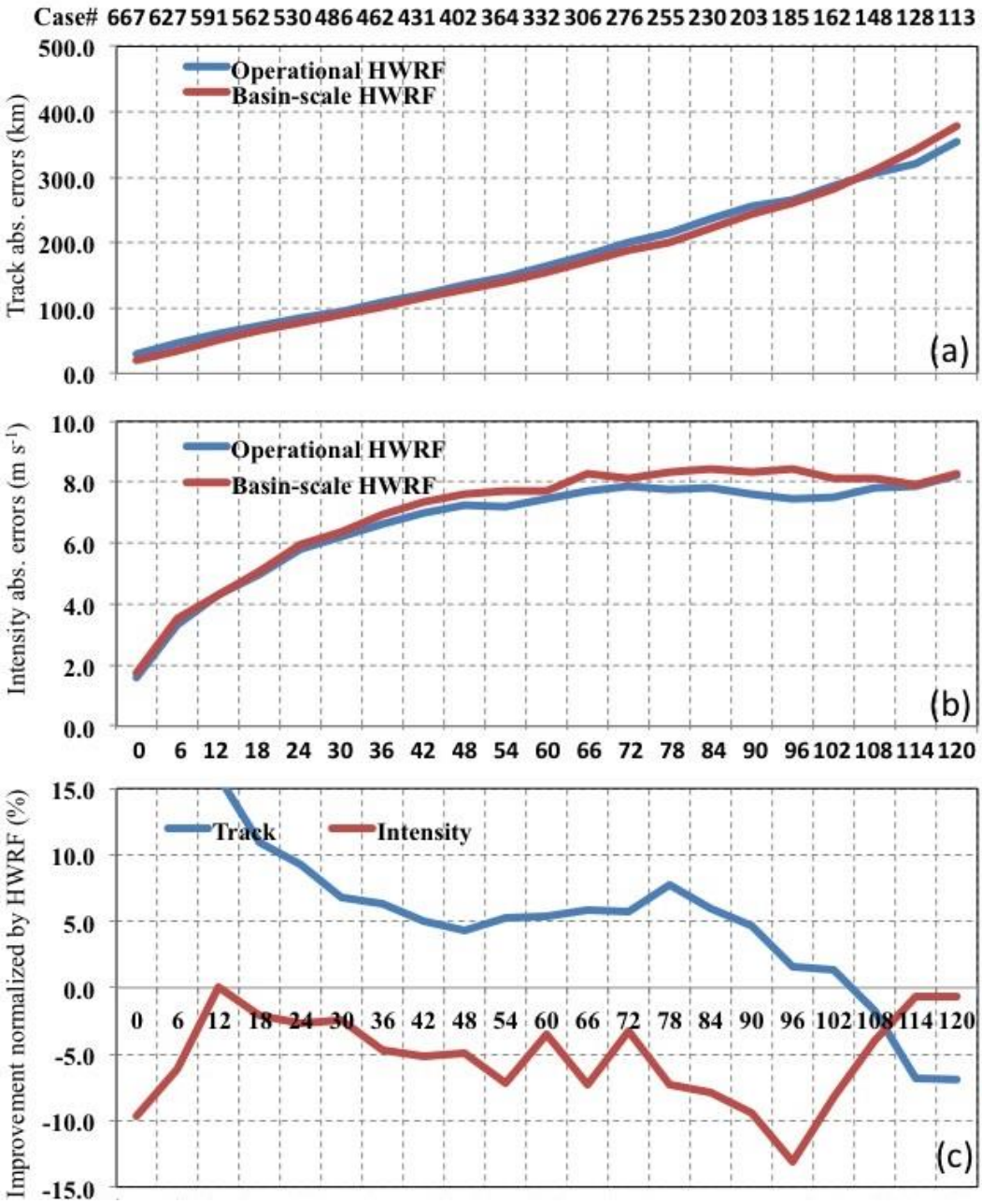


Figure 3: Track and intensity verification of three hurricane seasons during 2011-13 in the East Pacific basin. (a) Track; (b) Intensity; (c) Track and intensity improvement normalized by operational HWRF. (d)(e)(f) same as (a)(b)(c) in the left column correspondingly.

In conclusion, we have proven the scientific and forecast advantages of extending the operating domain and concurrently accommodating multiple TCs within the basin-scale HWRF system. The system can potentially extend operational forecasts from 5 days to 7 days to include the genesis stage. The basin-scale system can also serve as an experimental lab for developing the next-generation global-to-local scale TC forecast model.

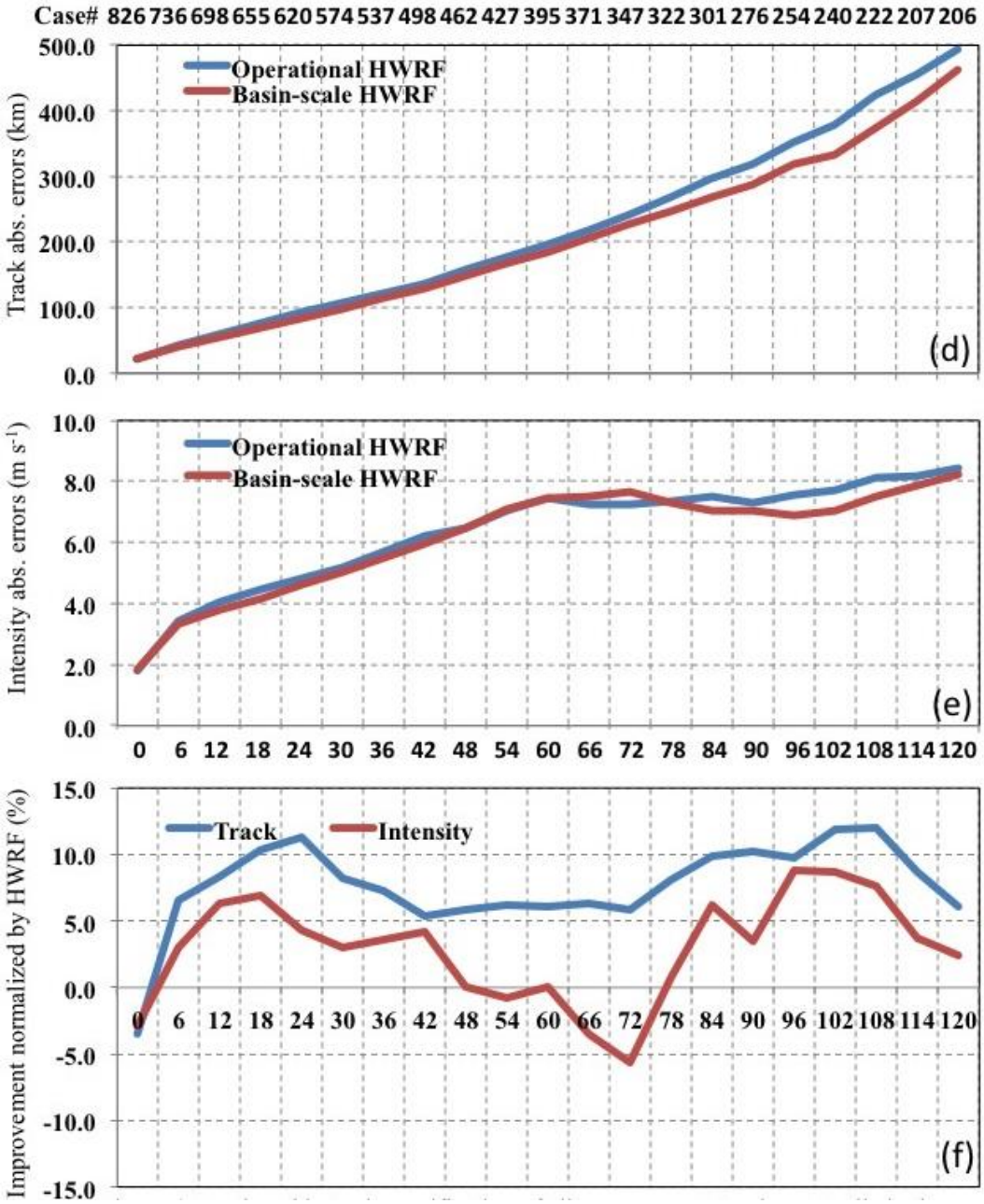


Figure 4: Track and intensity verification of all cases except Hurricane Leslie in three hurricane seasons during 2011-13 in the Atlantic basin.. (a) Track; (b) Intensity; (c) Track and intensity improvement normalized by operational HWRF. (d)(e)(f) same as (a)(b)(c) in the left column correspondingly except Hurricane Leslie cases.

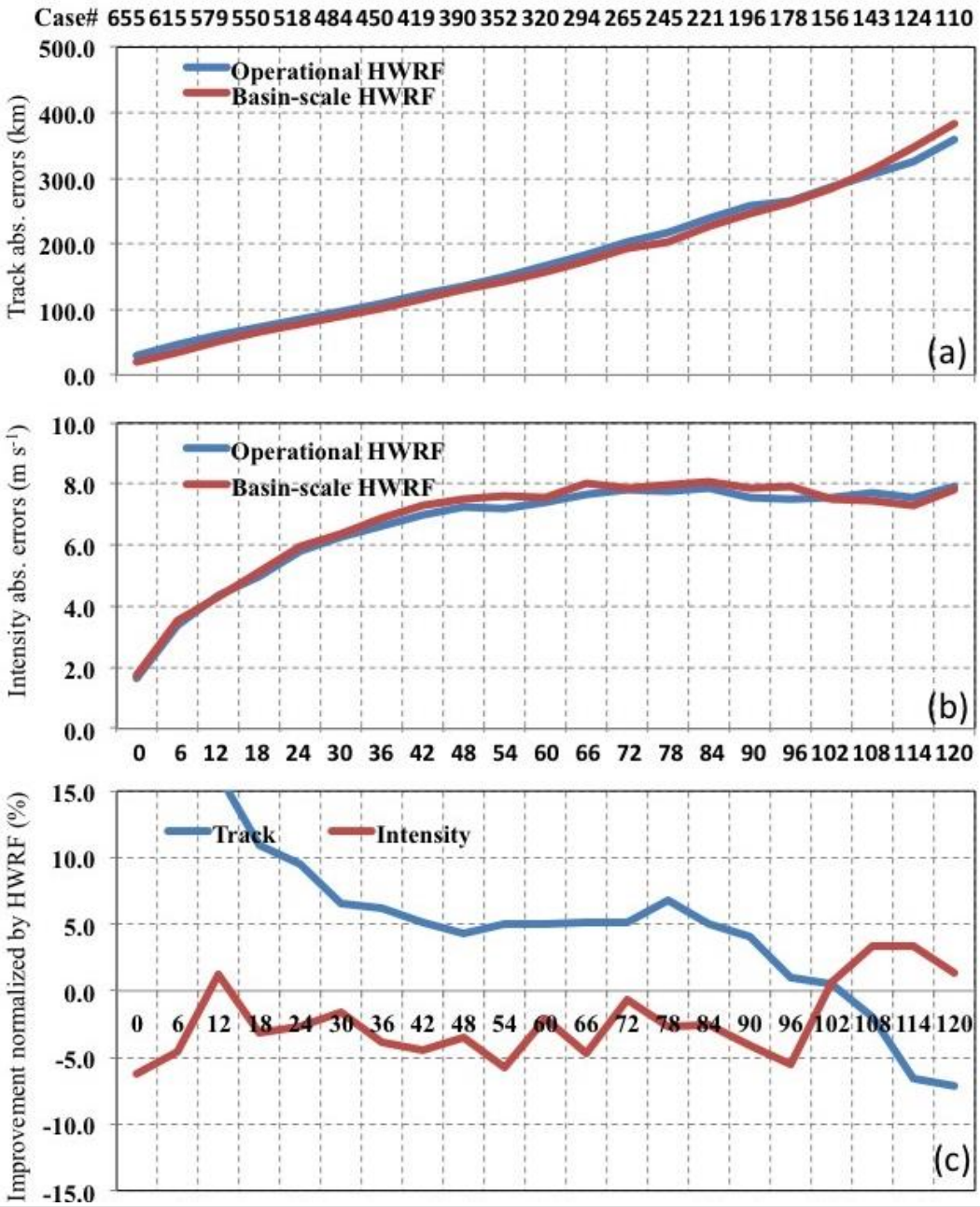
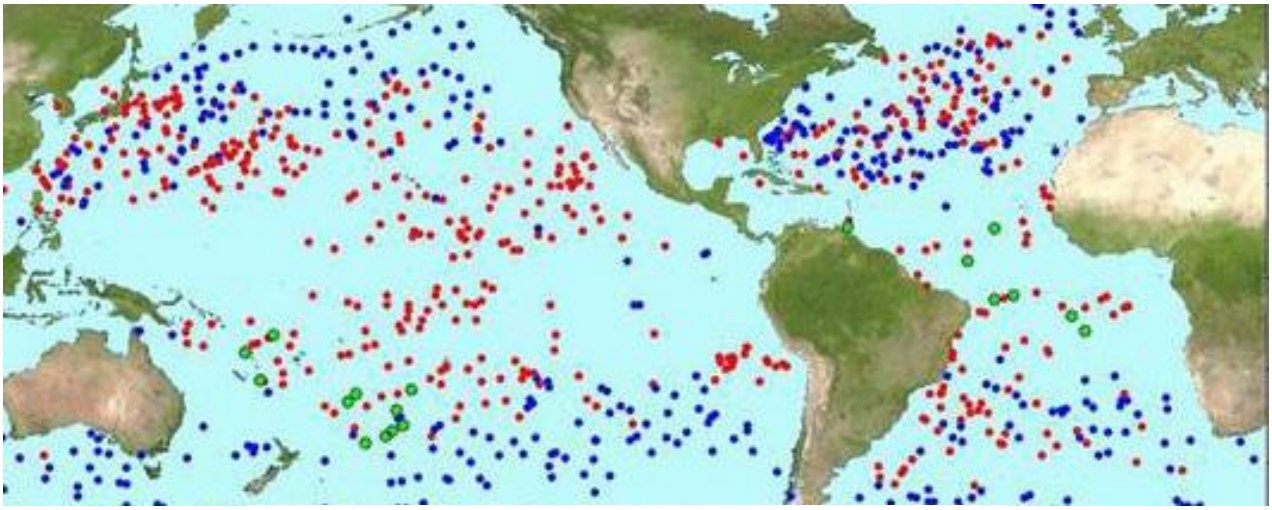


Figure 5: Track and intensity verification of all cases except Hurricane Miriam in three hurricane seasons during 2011-13 in the East Pacific basin.. (a) Track; (b) Intensity; (c).\ Track and intensity improvement normalized by operational HWRF. (d)(e)(f) same as (a)(b)(c) in the left column correspondingly except Hurricane Miriam cases.

Research Performance Measure: All research objectives were met on schedule. The system will be tested by HFIP as a real-time demonstration system during the 2014 hurricane season.



VI. RESEARCH REPORTS

THEME 3: Sustained Ocean and Coastal Observations

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

Project Personnel: D. Pierrot, L. Barbero, and K. Sullivan (UM/RSMAS/CIMAS)
NOAA Collaborator: R. Wanninkhof (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:
***Objective*:** Develop and implement a monitoring network for ocean acidification in the Gulf of Mexico, East Coast U.S., and open-ocean waters.
***Strategy*:** To reoccupy coastal transects, and ships of opportunity to quantify the changes in and causes of ocean acidification.

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

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

NOAA Funding Unit: OAR/OAP
NOAA Technical Contact: Libby Jewett

Research Summary:
This effort implements the North Atlantic Ocean, East and Gulf Coast Ocean Acidification (OA) observing system 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).
- 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 are developed as part of the effort. Assistance with analyses and protocols is provided to other groups including those studying OA impacts on coral reef systems. The work involves partners at AOML, CIMAS, and NOAA/NMFS/NEFSC.

During the performance period we interpreted results from an oceanographic research cruise studying OA in the Gulf of Mexico, GOMECC2, and compared the observations with the first occupation in 2007. The comprehensive determination of inorganic carbon system parameters provides input to determine the aragonite saturation state. A significant result was the finding the Gulfstream has very low saturation states on its Western edge that influences ocean acidification along the Eastern Seaborne (Figure 1).

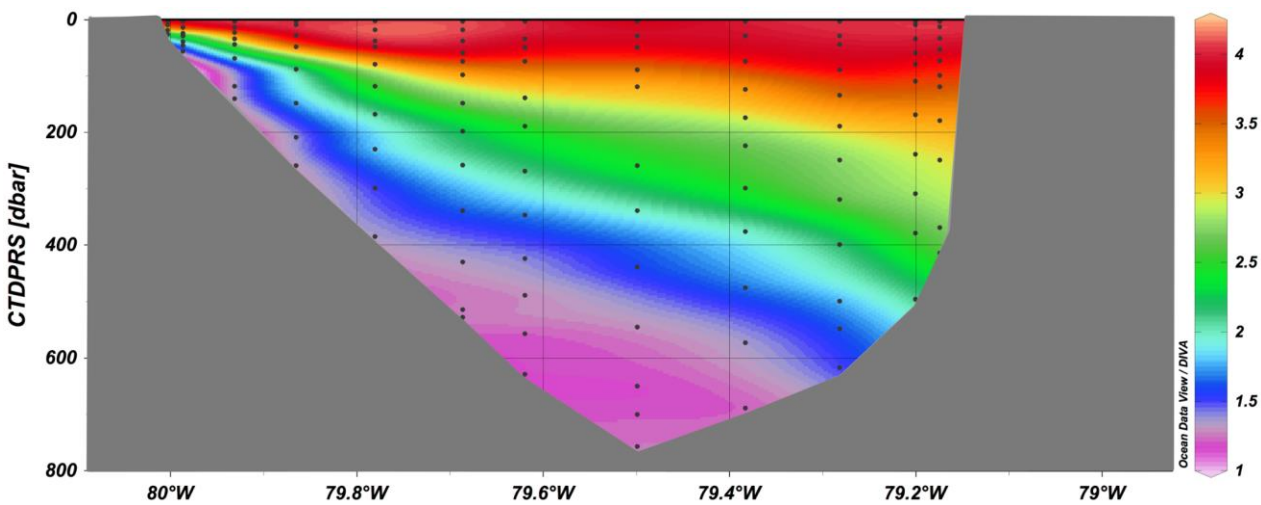


Figure 1: Aragonite saturation state in the Florida Straight (27˚N) on the GOMECC-2 cruise. The very low saturations states at the bottom and Western side of the Straight have significant impacts on saturation levels further up the coast.

As part of the OA effort we are establishing a monthly climatology of surface water ocean acidification parameters in the Gulf of Mexico 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.

Research Performance Measure: Provision of quality-controlled that is being used to determine patterns and rates of OA in the realm. The data from the GOMECC-2 cruise has been submitted on time to the NODC and will be released to the public in July 2014, after the 2-year embargo.

The GO-SHIP CO_2 Repeat Hydrography Program

Project Personnel: L. Barbero, G. Berberian, J. Hooper, K. Sullivan (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: OAR/COD/CPO
NOAA Technical Contact: Joel Levy

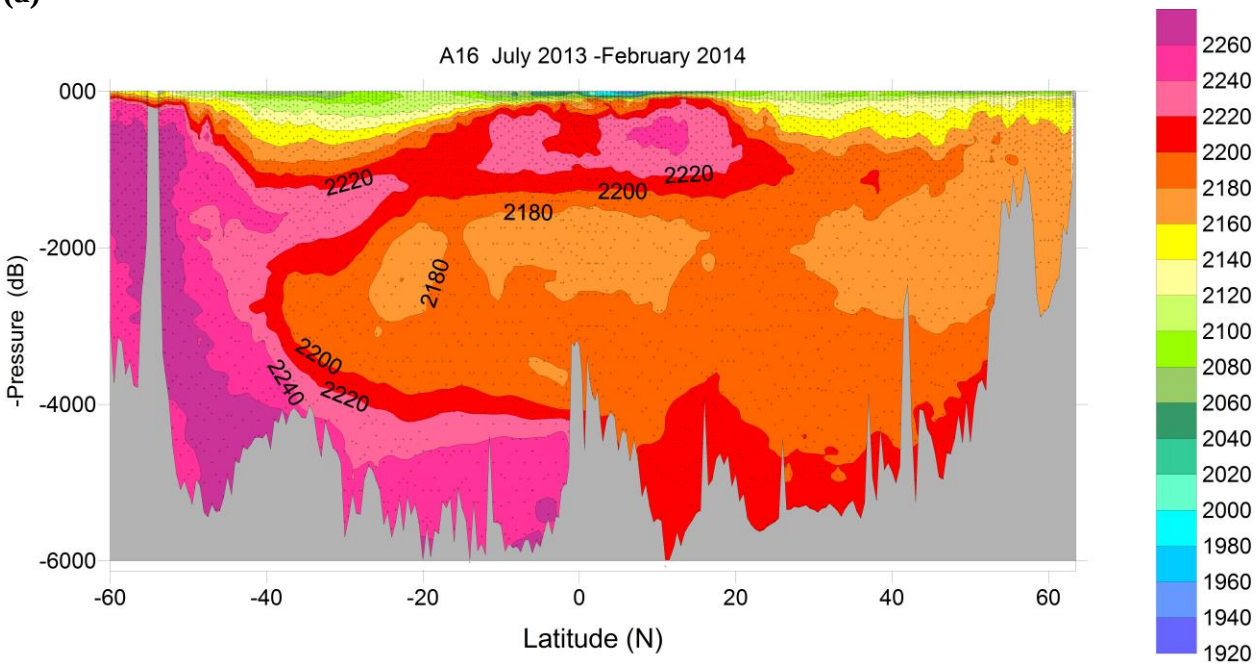
Research Summary:
The CLIVAR/CO_2 Repeat Hydrography Program is a global re-occupation of select hydrographic sections to quantify changes in storage and transport of heat, fresh water, carbon dioxide (CO_2), oxygen, nutrients, chlorofluorocarbon tracers and related parameters. The effort started in 2003. In 2014 the Atlantic meridional A16 transect from 63 ˚N to 60 ˚S was completed in full.

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-2014 we completed meridional sections from 63 ˚N to 60 ˚S called A16 with full physical and chemical characterization of over 250 water column profiles. 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 A16 cruise is provided in Figure 1a while Figure 1b shows the differences with results obtained in 2003/2005. The invasion of anthropogenic CO_2 in the top 500 m is apparent.

(a)



(b)

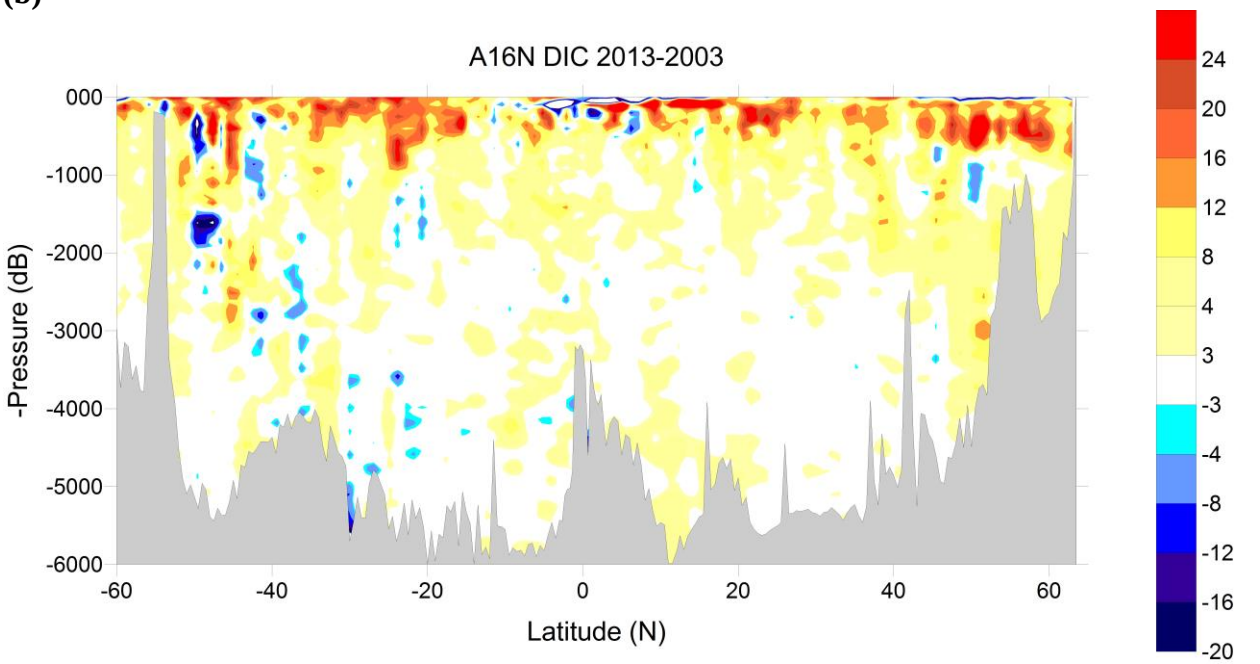


Figure 1: (a) Cross section of dissolved inorganic carbon (DIC) for the A16 cruise in 2013/14; (b) the difference with respect to the 2003/05 cruises.

Research Performance Measure: The Repeat Hydrography Sections are progressing according to the timeline mandated by the CLIVAR CO_2 Repeat Hydrography Committee (http://ushydro.ucsd.edu/cruises). The COD performance measure for FY14 (completing the re-occupation of the A16S cruise) was met.

Florida Area Coastal Environment (FACE) Program

Project Personnel: M. Gidley, and C. Brown. (UM/CIMAS)
NOAA Collaborators: NOAA: J. Stamates, J. Bishop, T. Carsey, C. Featherstone, and C. Sinigalliano (NOAA/AOML); R. Kotkowski, and M. Doig (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 inlet flow measurements 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*
***Goal 4*:** Resilient Coastal Communities and Economies - *Coastal and Great Lakes communities that are environmentally and economically sustainable*

NOAA Funding Unit: NOAA/AOML and external supplements by wastewater utilities
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 and chemical sensing of plumes, and microbiological measurements. This year, we initiated a project with the Florida Department of Environmental Protection to develop numeric nutrient criteria for the coastal ocean. The project includes twelve bimonthly water quality cruises in the coastal ocean off of Broward and Miami-Dade Counties, as well as acoustic Doppler current profiler instrumentation operating in the area. The water quality cruises are conducted in conjunction with parallel coral reef survey cruises conducted by Dr. Paul Jones and Dr. Ian Enochs also at AOML. Some preliminary results are shown in Figure 1, where nutrient (nitrate+nitrite) concentrations at four coral reef sites from three cruises are shown. This project will continue through 2015.

Another project whose field program has been completed during this time period was the NOAA/CRCP funded study of the nutrient loads 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 (ADCP) instrument, while water samples are collected for analysis of nutrients, salinity, and other analytes. These data have been 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. From those data we can generate an estimated monthly loading through the two inlets for a variety of

nutrients (Figure 2). These results will be analyzed in the context of other point sources of pollution into the coastal ocean.

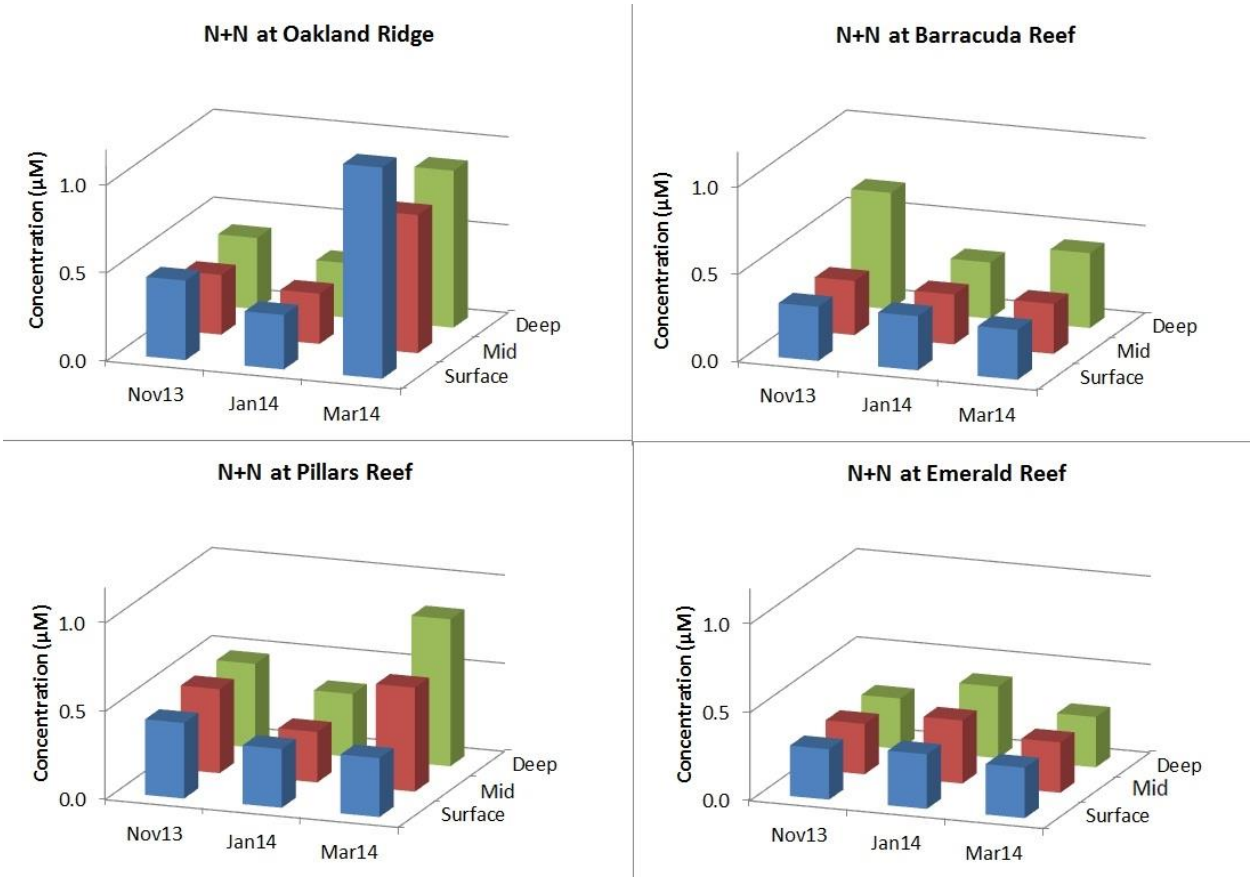


Figure 1: Concentrations of key nutrient Nitrite + Nitrate (NO2 + NO3, or "N+N") from three depths (surface, mid, and deep) from three bimonthly cruises at four coral reef sites. Deep site concentrations are those that directly impact the reefs.

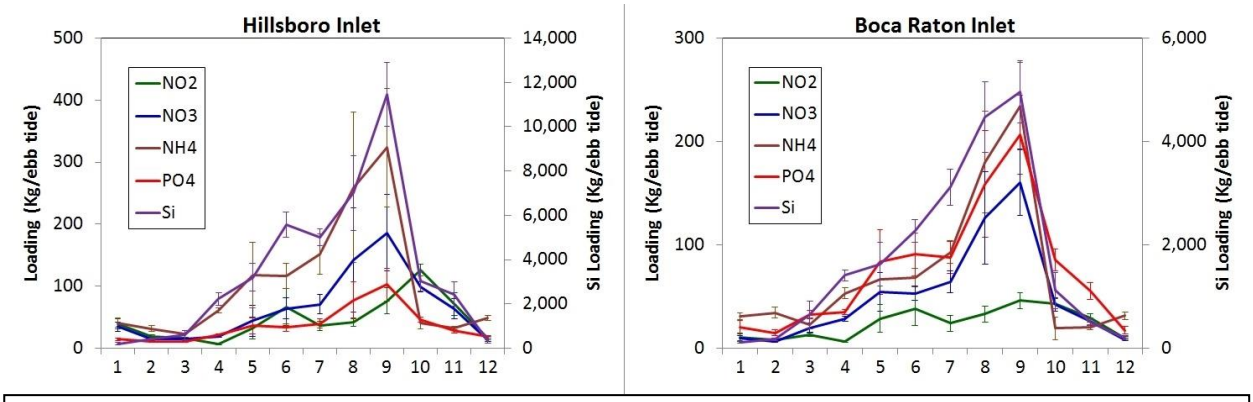


Figure 2: Estimated loadings through the indicated inlets into the coastal ocean,for five key nutrients. Silicate values ("Si") are denoted by the right axis, all others by the left axis. Vertical bars denote one standard deviation in the concentrations.

Research Performance Measure: A field program to provide water quality and coral reef habitat data in support of the development of numeric nutrient criteria for the coastal waters of southeast Florida has been initiated. A separate project investigating loadings form the Hillsboro and Boca Raton inlets into the coastal ocean has been completed and is being provided as a NOAA Technical Report. FACE provides relevant NOAA Technical Reports on the FACE website: http://www.aoml.noaa.gov/themes/CoastalRegional/projects/FACE/ faceweb.htm.

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Aquarius Reef Base Maintenance and Monitoring

Project Personnel: J. Fourqurean, T. Potts, R. Garcia, O. Rutten, M. Hulsbeck, T. Dunmire, and H. Stark (FIU)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To ensure the operational readiness of Aquarius Reef Base, the world's only saturation diving research laboratory and habitat

***Strategy*:** To perform necessary maintenance and upgrading to provide the infrastructure to support underwater research in coral reef ecology, biogeochemistry, physical oceanography, animal behavior studies and oceans observations at the Aquarius habitat site on Conch Reef in the Florida Keys National Marine Sanctuary

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)*

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

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

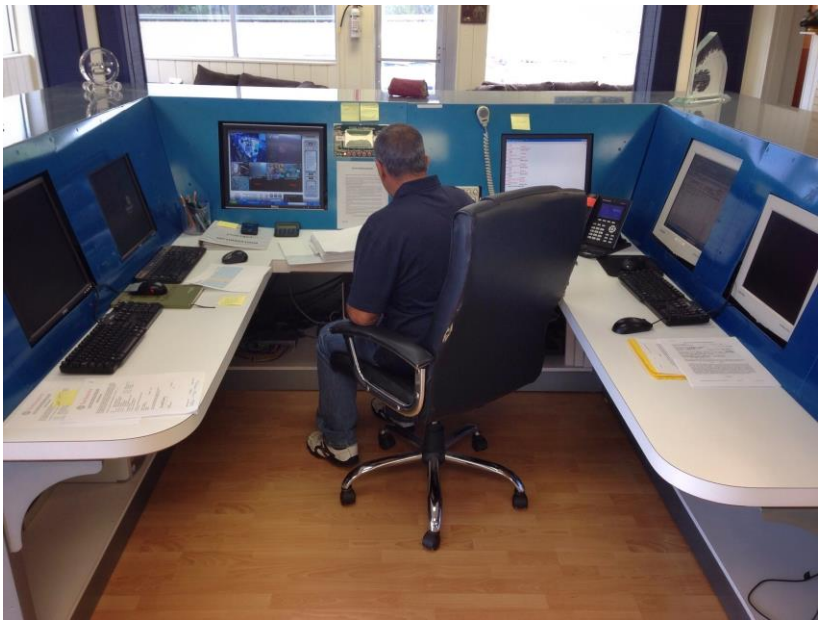
Research Summary:

The Aquarius Reef Base is comprised of the undersea habitat and associated baseplate, Life Support Buoy, a shore base (location to be determined and new lease negotiated) and fleet of operational and research vessels. These assets provide a state-of-the-art diving facility for coral reef science along with synchronous ocean observing, a test bed for technology development, and advanced communications that allow for telepresence research, education, and outreach.

Saturation diving is conducted from the Aquarius undersea laboratory, which is the only undersea laboratory specifically devoted to science operating in the world today (Figure 1). Located on Conch Reef, 4.5 km offshore of Tavernier Key and 14 km from the shore base located in Key Largo, four scientists and two staff technicians typically live and work out of Aquarius for up to ten days. The laboratory is located in 20 m of water, and aquanauts diving to a depth of 33 m achieve bottom times that are nearly 10 times longer than no-decompression scuba diving from the surface. Aquarius provides workspace, power, and data communications that support experimentation, observation, and technology testing that would be difficult, if not impossible, to conduct if supported solely from the surface.

Figure 1: Aquarius undersea lab sits in 20 m of water, 4.5 km off Tavernier, Florida in the Florida Keys.

During missions, a watch desk and support staff is based at a Key Largo operations facility (Figure 2). A life support buoy transmits real-time data from Aquarius and work sites to the shore-based watch desk, including:



- Status of generators and compressors
- Life-support parameters inside Aquarius
- Voice and video from Aquarius to shore
- Science data from the seafloor and Aquarius to shore
- Ocean observations in real-time (salinity, temperature, oxygen, waves, currents, and various optical properties

Figure 2: Watch desk located at shore base.

Data from seafloor experiments can be transmitted in real-time, including voice and images, to anywhere in the world via the Internet. A conventional cellular telephone also provides worldwide communication capability (Figure 3).

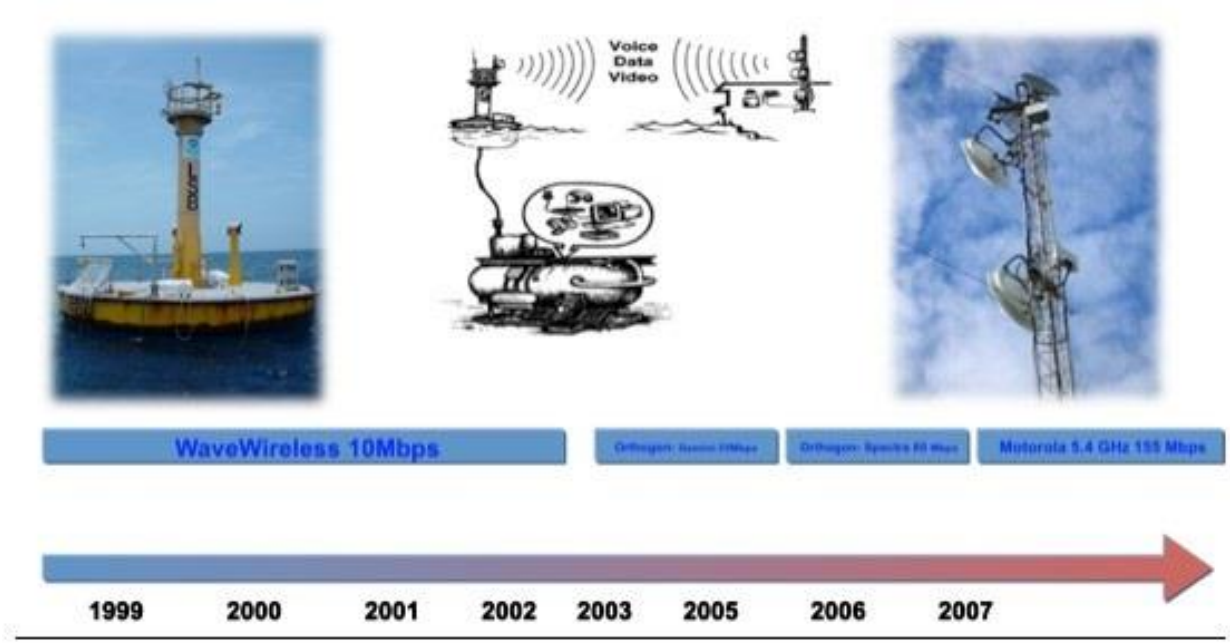


Figure 3: Aquarius telecommunications.

Research Performance Measure: During the reporting period, Aquarius Reef base relocated its land facility to a new, properly-zoned location on Snake Creek in Islamorada in the Florida Keys. This move included re-establishment of the necessary research infrastructure, including the wireless data bridge, high-pressure and low-pressure compressors and gas storage systems, boat dockage, recompression chambers, and workshops. The new land base is up and functioning efficiently.

All prescribed maintenance tasks necessary to keep the offshore habitat functional were completed and logged in a timely manner. New hull inspections and surveys of safety practices were completed. Safety training and re-certifications were completed by all personnel.

Two saturation missions were hosted by ARB during the reporting period: the first was a NASA astronaut training 7-day mission, and the second was a graduate student-led science mission exploring the behavioral choices made by herbivorous fish on the coral reef in response to changing threat of predation.

The successful relaunch of the Aquarius program during the reporting period allowed for the scheduling of 5 saturation missions for the coming year, including one 31-day education/outreach mission, one FIU-led science mission, one US Navy training mission and two NASA astronaut training missions.

Ship of Opportunity Program

Project Personnel: S. Garzoli, C. Gonzalez, S. Dong, Z. Barton, R. Domingues, M. Goes, G. Rawson, Q. Yao, R. Roddy, K. Seaton, and R. Sabina (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:

Overview

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.*

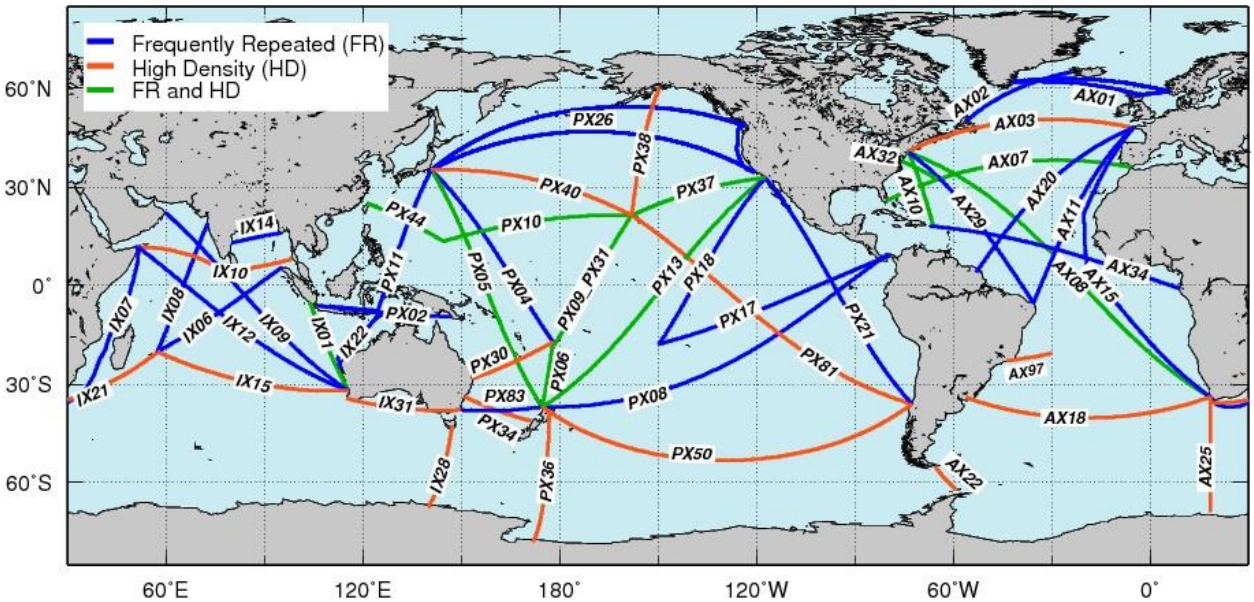


Figure 1: OceanObs09 XBT transects recommended by the scientific community to be occupied in frequently repeated mode (FR, in blue), high density mode (HD, in orange) or both (in green).

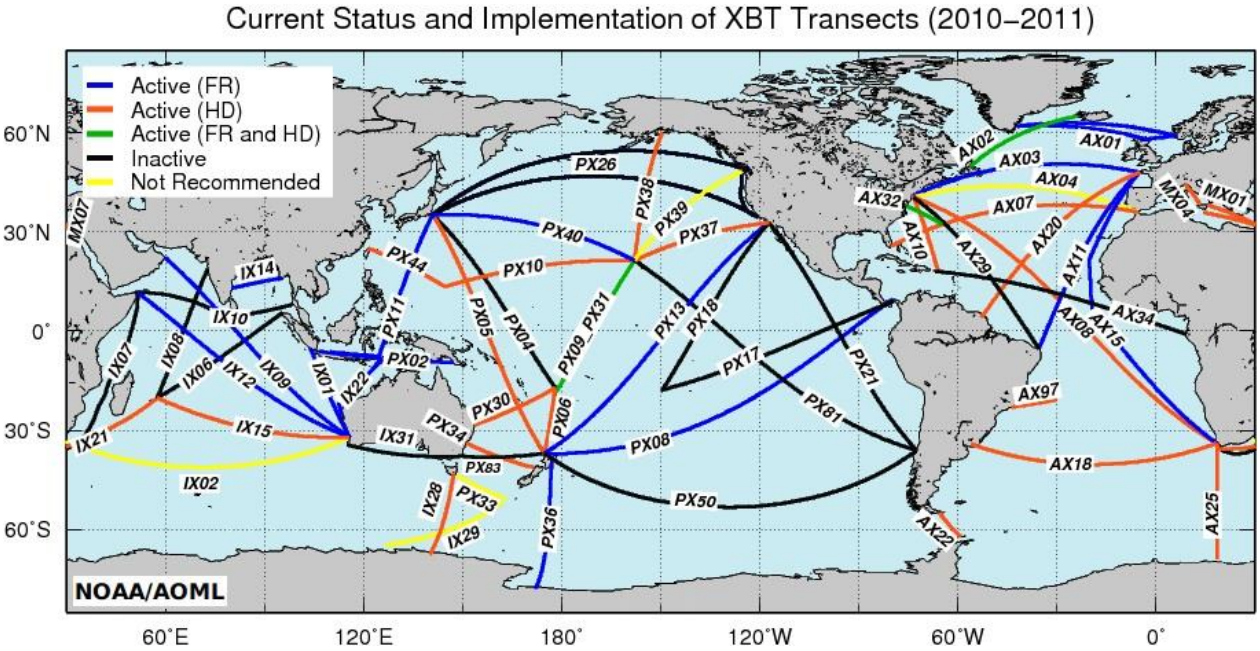


Figure 2: Current status and implementation of XBT transects recommended by the international community. Transects in black were not sampled during 2010-2011. Other colors indicate transects sampled in frequently repeated mode (FR, in blue), high density mode (HD, in orange) or both (in green). XBTs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

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, MX01, MX02, and MX04. 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.

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.

Instrument Development

XBT biases have been shown to impact historical observations of ocean heat content and possibly estimates of heat and volume transport in the ocean. In partnership with Sippican/LockheedMartin, NOAA/AOML and CIMAS are leading efforts to produce a climate quality XBT probe, which is projected to feature improved thermistor calibrations and pressure switches. As part of the efforts, 96 XBT deployments collocated with CTD stations were performed during the PNE2013b cruise (Nov 11 and Dec 08, 2013) with the objective of testing how a stricter quality control during the production of the probes and the post-processing of the data can improve the XBT thermal bias. Three XBT probe types were tested: (i) Standard, (ii) Experimental, and (iii) Tight Weight Tolerance (TWT) probes; and three pos-processing corrections were applied for thermistor calibration: (i) Wire imbalance, (ii) Manufactory thermistor calibration, and (iii) Thermal time constant corrections. The main results obtained (Figure 3) showed that the manufactory thermistor calibration is the most efficient post-processing correction to decrease the thermal bias, improving the accuracy from the original 0.1C to a 0.02C. In addition, and the TWT and screened thermistor probes are respectively 66% and 62% more accurate that the Standard XBT probe.

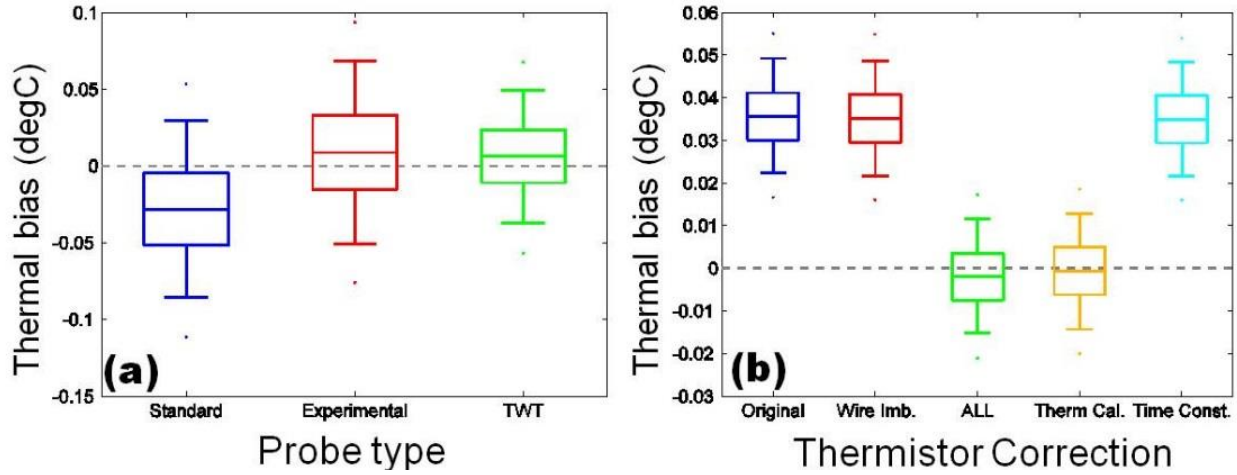


Figure 3: Box plots of estimated thermal bias distributions (deg C) for each (a) probe type and (b) thermistor correction. Note that the TWT probe and the Thermistor Calibration correction resulted in the lowest biases.

Other Engineering developments

Several developments to the equipment used in SOOP operations were implemented. System components and the firmware of the Auto Launchers have been updated. An Auto Launcher Hub that allows for several Auto Launchers to be controlled by a single computer has been developed. The Auto Launcher Hub also opens up the opportunity for the Auto Launchers to be deployed as a stand alone system, which will not require ship riders. The new Hub has been successfully tested on two AX7 cruises, which was used to allow for two separate Auto Launchers to be used simultaneously.

During an AX07 realization, it has been discovered that a browning out of the power on the ship could lead to a miscommunication between the computer and the Mk21. With this issue, the Mk21 would need to be reset often before an XBT drop, and it would invalidate the data if the browning out occured during a deployment. This issue has been resolved by incorporating an on-line UPS on the XBT gear, which gives constant and clean power to the equipment. New UPS's have been added to the major XBT transects maintained by AOML, including AX07, AX08, AX10, and AX18.

An investigation about adapting the Auto Launcher for use with the proposed Climate Quality XBT was also undertaken. This investigation addressed the feasibility of adding new components to the system to log launch height, barometric pressure, probe serial numbers and to develop an automated calibration process.

Software Development

The development and update of AMVERSEAS (the software used to acquire and transmit oceanographic and marine meteorological observations) has continued. The major upgrades and new features introduced are described here. (1) The AMVERSEAS system has been upgraded to comply with the Windows 7 United States Government Configuration Baseline (USGCB). With this upgrade, adjustments in the security configurations through the Windows 7 User Access Control are not required, and the software can be operated normally. (2) The Marine Mammal Sighting Report has been added to the software. This report will help to determine the distribution and behaviors of marine mammals globally. The data collected will be integrated into the National Marine Mammal Laboratory's Platforms of Opportunity database, which has data dating back to 1958.(3) The “Buoy

Deployment Logger" feature has been added to the software, which will be used for saving buoy deployment information that should be sent to the Global Drifter Center. (4) Upgrades in the "XBT Data Recorder" included: (4a) adding the capability to connect up to four auto launchers with the system; (4b) adding the capability of transmitting compressed packs with a predefined number of profiles; and (4c) including the "Cruise Report Generator" functionality. Additional upgrades in the "XBT Data Recorder" with the objective of assisting the ship's rider included: (4d) the addition of the bathymetry database, (4e) the addition of the temperature climatology of the World Ocean Atlas 2013, (4f) and the implementation of the "Night mode" function (Figure 4).

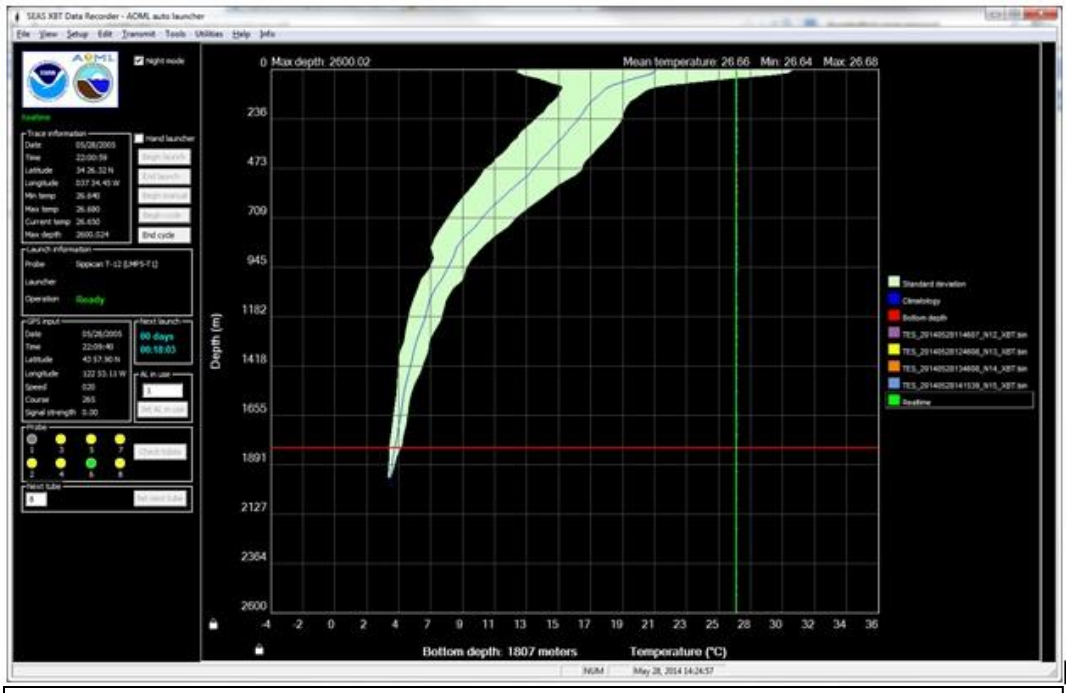


Figure 4: New features of the AMVERSEAS XBT Data Recorder, showing the "Night Mode" display with the climatological temperature profile (green shading).

Data Managemen.

Procedures to encode XBT profiles into the BUFR format have been enhanced in order to integrate and manage metadata more effectively. Currently, all profiles processed and QCed at AOML are being placed on the GTS in the BUFR format. Profiles are tracked from the pre-BUFR level to the GTS output, and the latter is compared with the original bulletin in both its encoded and decoded forms.

AOML participated, in collaboration with the National Oceanography Centre (UK), in the validation of BUFR common sequence 3 15 007, for the representation of temperature, salinity, depth (CTD) and current profile data. This is one of the templates in the context of the migration to table-driven code forms proposed by the Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM).

AOML is also generating annual and semestrial XBT reports that summarizes and documents the XBT deployments by AOML and other national and international partners (Figure 5). These reports are created using profile information from multiple data repositories such as from AOML, the National Oceanographic Data Center (http://www.nodc.noaa.gov/), and Coriolis

(http://www.coriolis.eu.org/), and are made available through the XBT Science website (http://www.aoml.noaa.gov/phod/goos/xbtscience).

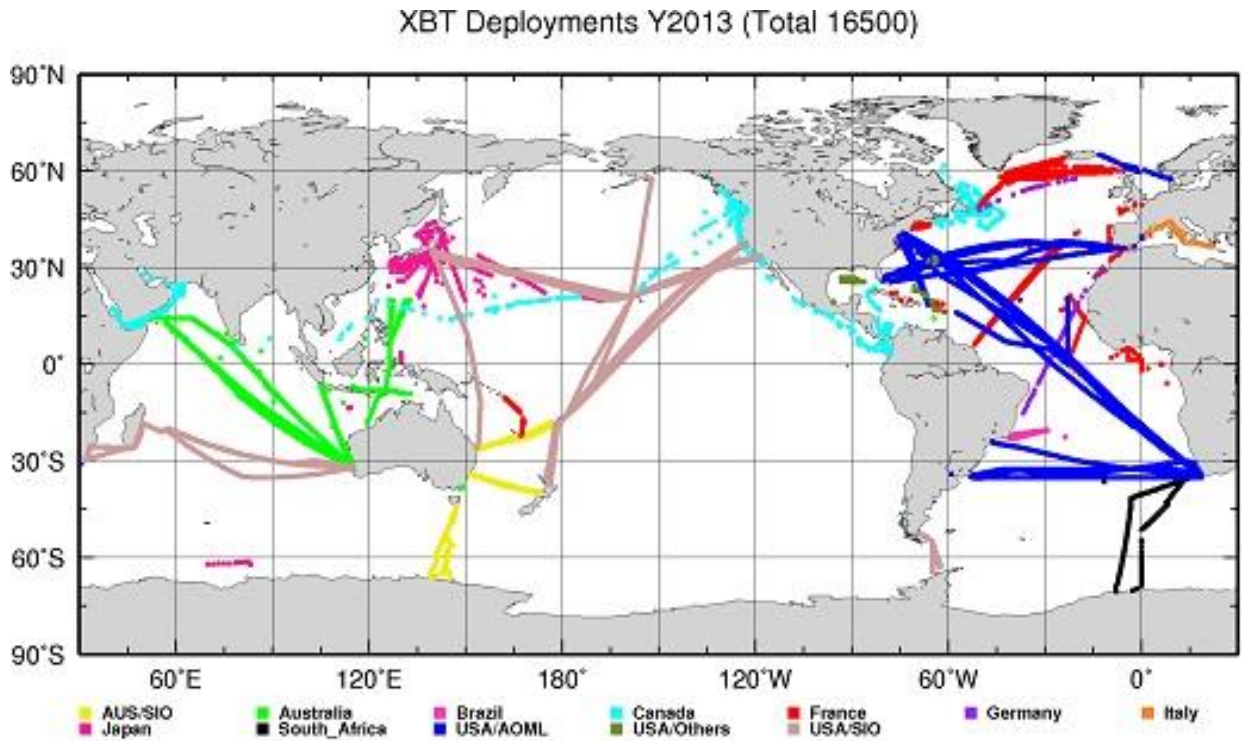


Figure 5: XBT deployments during calendar year 2013 by different countries/institutions.

Antarctic Circumpolar Current

An investigation using temperature data from the AX25 repeat XBT transect (from South Africa to Antarctica) in combination with other hydrographic and satellite observations reported a mechanism by which local winds alter the structure of the Antarctic Circumpolar Current (ACC) flow in the region. These changes in the local ACC structure were found to be due to anomalies of opposite signs in the transports of the Subantarctic Front (SAF) and of the Antarctic Polar Front (APF) caused by latitudinal shifts of the westerlies (Figure 6). These results demonstrate that the structure the ACC transport can be longitudinally modulated by local winds, even though the net transport of this current is set by integrated winds over the Southern Ocean. The manuscript by Domingues et al. entitled "Wind forced variability of the Antarctic Circumpolar Current south of Africa between 1993-2010" has been published on the Journal of Geophysical Research – Oceans.

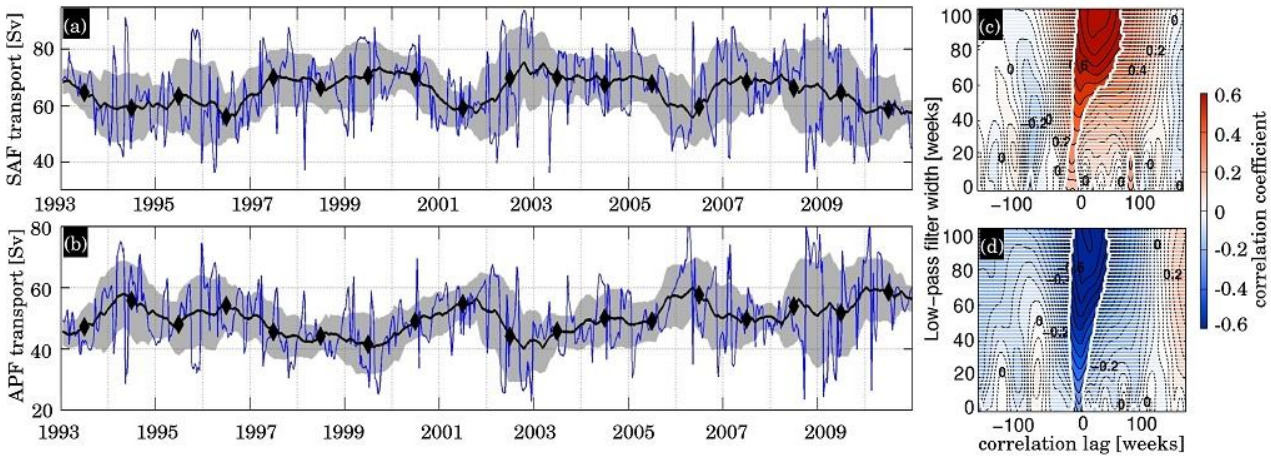


Figure 6: Transport time-series for the (a) Subantarctic Front (SAF) and (b) Antarctica Polar Front (APF), showing the one-year running mean (black line) and standard deviation (gray shaded area), and the annual means (black diamonds). Correlation coefficients between the averaged wind stress between 35°S-45°S and: (c) the SAF transport; (d) the APF transport. (c) and (d) show the correlation coefficient as a function of the lag in weeks between the two time series (x-axis) and of the low-pass filter width applied (y-axis). Non-significant correlations (p>0.05) are illustrated by the white dashing.

South Atlantic MOC Studies

Data from the trans-Atlantic XBT transect (AX18) is being used to estimate the strength of the meridional overturning circulation (MOC) and the meridional heat transport (MHT) (Figure 7). XBTs are particularly useful in the South Atlantic, where data coverage is sparse. Studies using XBTs deployed along AX18, nominally at 35°S, since 2002 (AX18) have significantly improved our understanding of the South Atlantic MOC and MHT. A 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.

Analysis of XBT and Argo data shows that the South Atlantic is responsible for a northward MHT with a mean value of 0.57 ± 0.15 PW, no significant trend is observed from 2002 to 2014. The MOC varies from 14.4 to 25.5 Sv with a mean value of 18.6 ± 2.6 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 -10.1 ± 6.0 Sv at 24°S and -19.8 ± 4.0 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 22.4 ± 4.3 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 all, 2012). Since the publication of this manuscript, three more cruises were conducted. An updated transport, including the three cruises after the publication, is 0.68 ± 0.17 Sv.

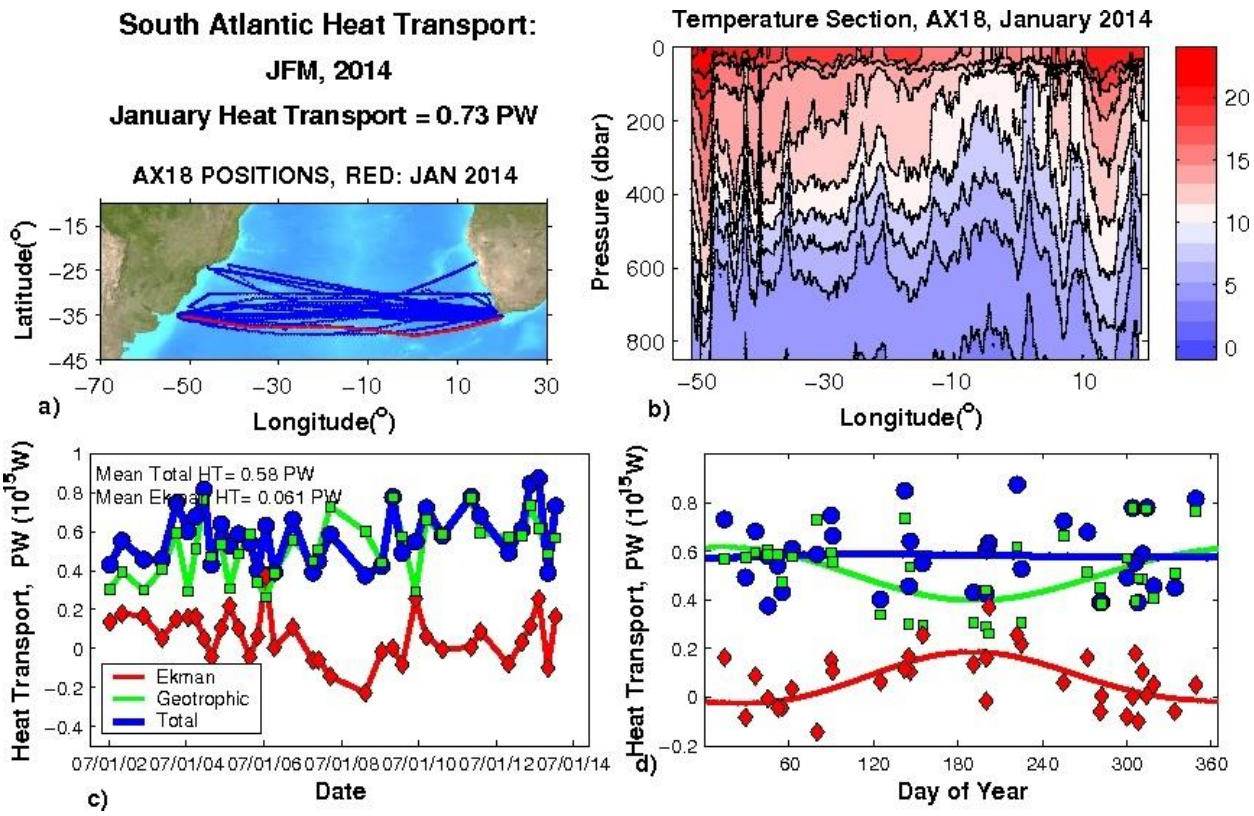


Figure 7: Meridional Heat transport at nominally 35°S computed from XBT data collected along AX18 starting in 2002. (Top left) Location of the repetitions of this transect; (Top right) Vertical temperature section from the last cruise (January 2014); (Bottom left) Time series of the different components of the meridional heat transport (Red: Ekman, Green: Geostrophic, and Blue: total); (Bottom right) Annual cycle of the different components.

The MOC and MHT estimates from AX18 have been used to validate the methodology used to derive the MOC/MHT from satellite altimetry measurements, which is used to examine the temporal and spatial variability of the MOC/MHT during periods not sampled by AX18. The comparison of the MOC time series from AX18 with numerical models outputs demonstrated that the models are unable to capture the seasonal variation of the MOC. This incited recent studies to investigate the potential causes for model-data differences, and the results indicated models are biased with strong baroclinicity. An manuscript lead by Dr. Shenfu Dong entitled "Seasonal Variations in the South Atlantic Meridional Overturning Circulation from Observations and Numerical Models" is currently under revision on the Geophysical Research Letters.

One study also used a high-resolution ocean assimilation product to simulate an XBT-based observational system across the South Atlantic, with the goal of estimating how uncertainties in the MOC and MHT estimates along AX18 can be reduced in a feasible, cost-effective manner. Results from this work showed that an increase in the western boundary sampling to 20 km would improve the accuracy of the current SAMOC estimations by ~ 1Sv. The reference velocity for the barotropic mode is likely to be the most significant source of error in the MOC and MHT calculations due to the extensive continental shelf along 34°S. It is found that at least climatological reference velocites are necessary in the boundaries to reduce the mean bias in the calculation. It is also shown that the variability of the barotropic mode can be accurately estimated using satellite altimetry and XBT data

in the top 800m (Figure 8). A manuscript entitled "An improved XBT-based monitoring system for the South Atlantic Meridional Overturning Circulation at 34°S" is currently under revision on the Journal of Geophysical Research.

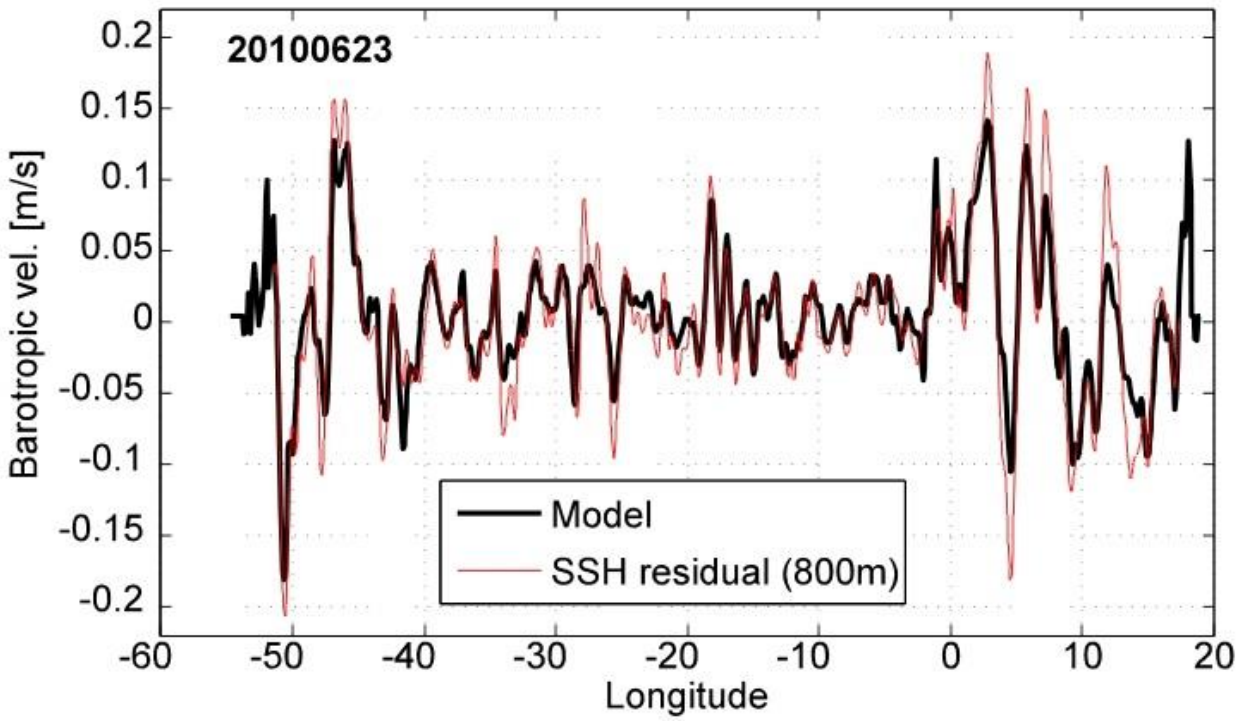


Figure 8: Barotropic velocity (m/s) along 34°S on December 23, 2010, calculated using the HYCOM assimilative model velocities (black), and its estimate using the non-steric sea surface height (red), calculated from the residual of sea surface height and the dynamic height referenced at 800m.

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 transport (Figure 9; *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.

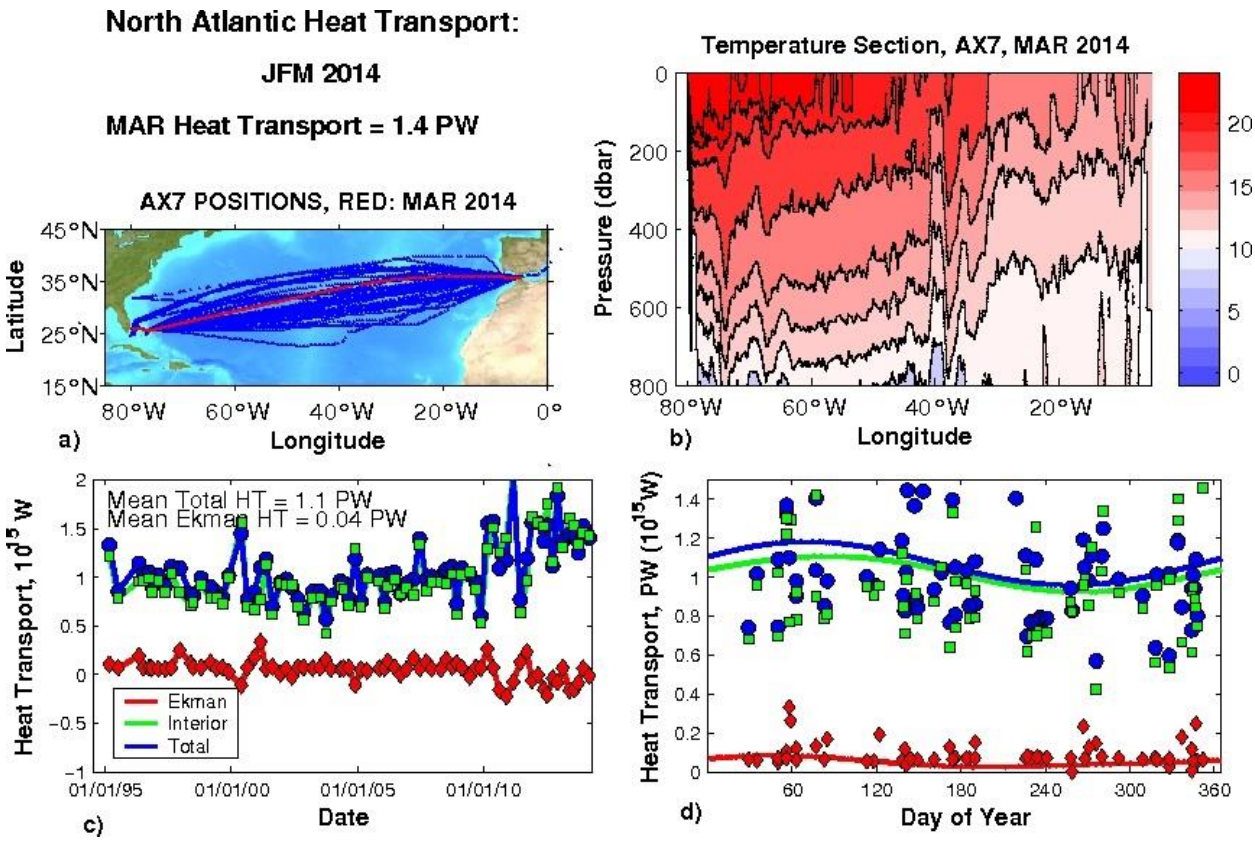


Figure 9: Meridional Heat transport at nominally 30°N computed from XBT data collected along AX7 starting in 1995. (Top left) Location of the repetitions of this transect; (Top right) Vertical temperature section from the last cruise (March 2014); (Bottom left) Time series of the different components of the meridional heat transport (Red: Ekman, Green: Geostrophic, and Blue: total); (Bottom right) Annual cycle of the different components.

Research Performance Measure: All operational research goals were met during this year with respect to the percentage recovery of good data based upon rigorous internal quality control. All scientific goals were met with respect to timely assimilation of the data generated into operational NOAA modeling efforts.

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Sediment on Reefs and Adjacent Coastal Areas: Information Tools for Managers in American Samoa, South Florida, CNMI

Project Personnel: L.J. Gramer, (UM/CIMAS)
NOAA Collaborators: J.C. Hendee, and M. Shoemaker (NOAA/AOML)
Other Collaborators: B. Barnes, and C. Hu (USF)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives: To: 1) integrate in situ, remote-sensing, and other environmental data so as to better understand the impacts of high-turbidity water on the health and life cycles of organisms in targeted reef ecosystem, 2) compile ecological forecasts for coral reef ecosystems to help to

understand them, and to aid in decision support for Marine Protected Area and other natural resource management, 3) develop climatologies and near real-time anomaly products for remote and in situ sensing of turbid-water conditions on monitored coral reefs.

Strategy: Construct and deploy *in situ* instrumentation near key coral reef areas, to calibrate and validate remote sensing algorithms; provide information to management on small-scale variations in turbidity, chlorophyll *a*, and thermal stress, based on an improved understanding of the physical environment and narrowband reflectance of ocean water near these reefs; provide a data archiving and artificial intelligence toolbox to facilitate the acquisition and integration of high-quality turbidity data from these and other reef areas in targeted priority jurisdictions.

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

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

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

Research Summary:
The project will provide managers with historical maps of turbidity, and alerts and maps for near real-time tracking of sediment plumes, in coastal waters of three CRCP priority jurisdictions: American Samoa (incl. Faga'alu), south Florida (including reefs immediately offshore of port expansion/tunnel projects, and beach refurbishment projects), and CNMI. Climatological relative turbidity maps at 250m spatial resolution are being made available to management partners in all three jurisdictions as a product of Year 1 (see example in Figure 1). Targeted field observations will be planned and carried out in Years 2 and 3, to refine these products to provide absolute turbidity (NTU) for priority sites as well, per manager requirements.

In Year 2, sensor deployment/recovery will be done at sites in CNMI, collaborating with regional IOOS partners of the NOAA Coral Health and Monitoring Program, to enhance the product suite there with absolute suspended solids information. Remote conferencing with managers in all three jurisdictions continues, with the aim of ensuring that management expectations for information on coastal sediment concentration are being appropriately met. In Year 3, field calibration moves to American Samoa, in collaboration with local partners and in concert with planned NCRMP activities. Knowledge gained from work in the other jurisdictions will be directly applied to the benefit of American Samoa managers.

Alerts/Google Earth maps were available Year 1 for all three areas, so managers can become familiar with these tools early in the project.

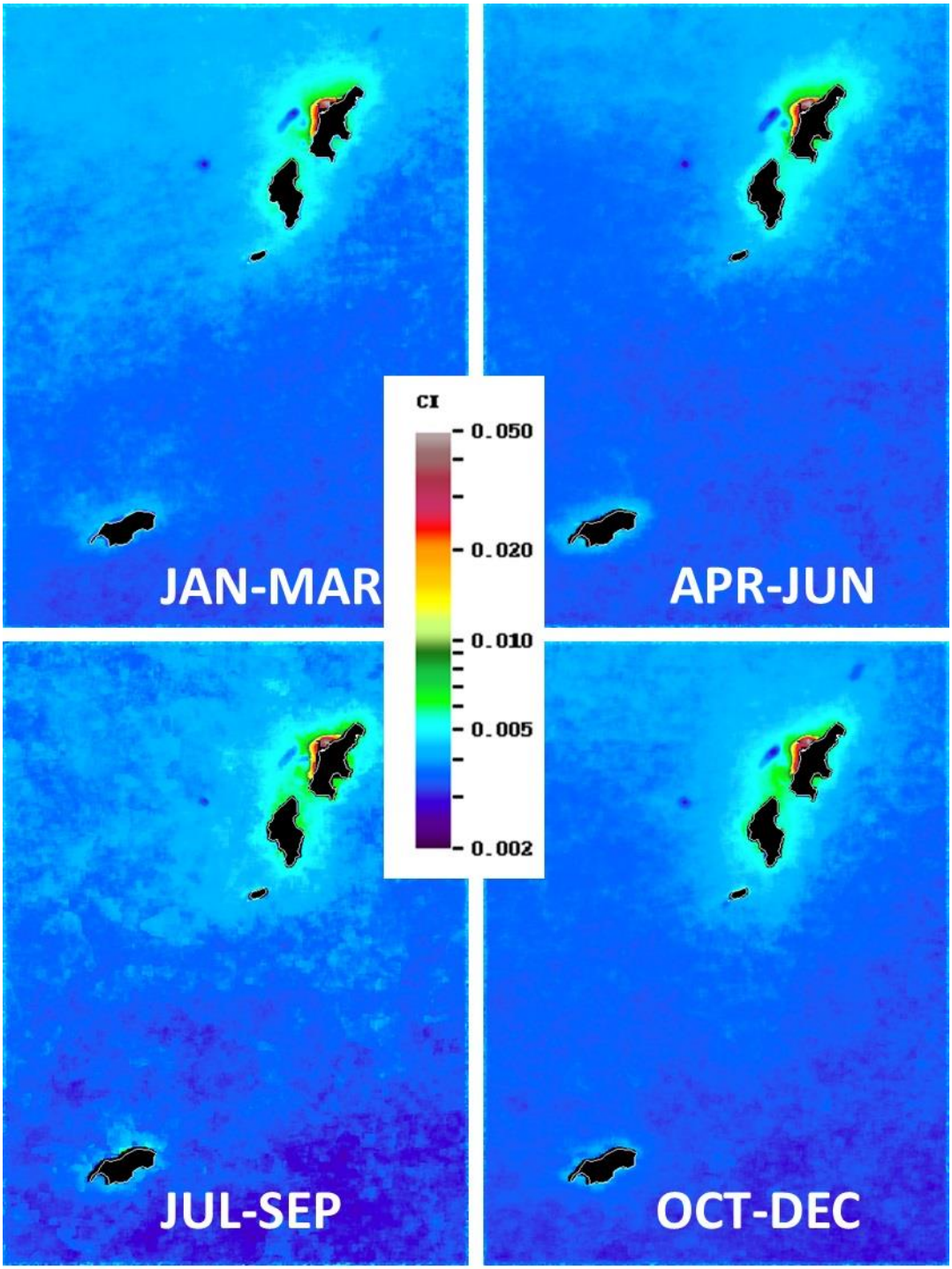

Figure 1: Climatological mean relative turbidity for the waters surrounding the islands of the Commonwealth of the Northern Mariana Islands (CNMI), for all four seasons. Calculated from MODIS ocean color data 2002-2014, using a Color Index-derived ("CI") relative turbidity algorithm.

Research Performance Measure: The three year project has met all year one milestones.

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 3*:** Sustained Ocean and Coastal Observations

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

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

Research Summary:
We used a combination of recreational and commercial fishing vessels to (1) catch pelagic fishes known to interact with pelagic longline fishing gear, (2) attach pop-up satellite archival tags (PSATs) to them and (3) release them to study their horizontal and vertical movements for periods up to 180 days. Over 300 PSATs have been deployed by the NOAA-SEFSC Migratory Fisheries Biology Branch and about 78% of them reported summarized data via the Argos satellite system. In addition, we have physically recovered >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. Recent examples of PSAT analysis include descriptions of sailfish, white marlin, and yellowfin tuna habitat use. Specifically, time spent at depth and temperature relative to the uniform temperature mixed layer. The Delta T metric represents an important input variable for habitat standardization models, which are used to predict vertical distributions and abundance needed for stock assessments.

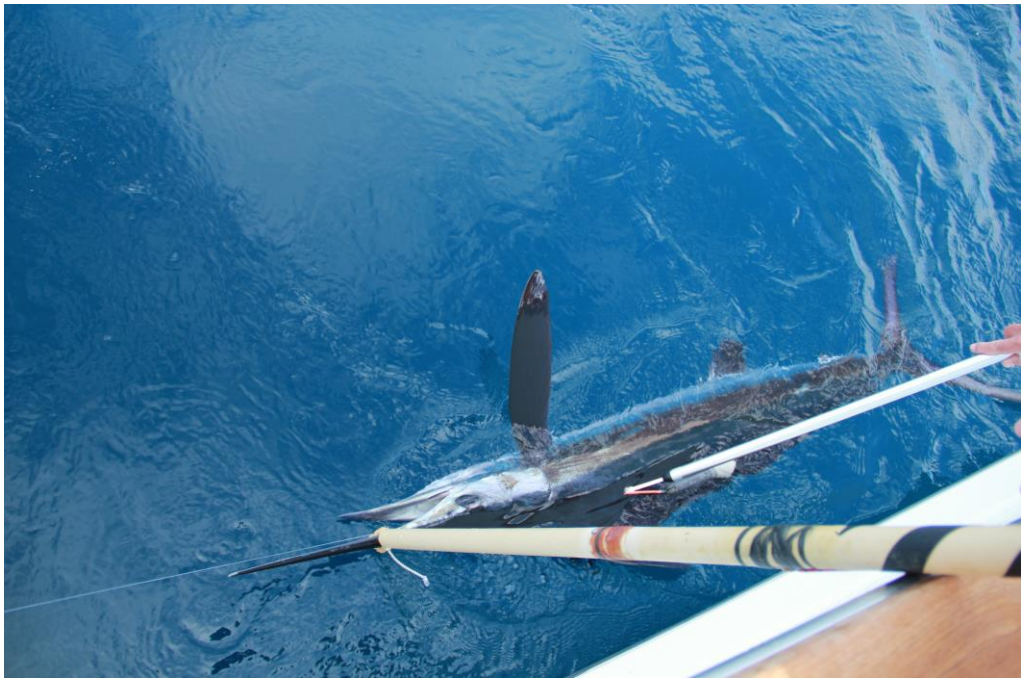

Figure 1: Attaching pop-up satellite archival tag into dorsal musculature of white marlin. (Photo credit: Ann Barse)

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.
- A number of peer reviewed papers have resulted over the last few years. They can all be accessed at: http://www.sefsc.noaa.gov/fisheriesbiology.jsp.

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Calibration/Validation Support for NPP VIIRS Data Product Continuity

Project Personnel: C. Hu (USF)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** (1) To assess VIIRS data product continuity from its predecessors, diagnose reasons for discrepancy; (2) To improve VIIRS data product continuity through algorithm development.

***Strategy*:** To use field and laboratory measured data to evaluate VIIRS data products for coastal oceans, and to use algorithm tuning to improve data product continuity.

CIMAS Research Theme:

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

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

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

NOAA Funding Unit: NOAA/NESDIS
NOAA Technical Contact: Dr. Menghua Wang (menghua.wang@noaa.gov)

Research Summary:
In situ Rrs data were collected between April 2012 and October 2013 in Tampa Bay and off the coast of central west Florida using an above-water spectrometer and community accepted protocols. A total of 80 quality controlled Rrs spectra were collected. These data were used to evaluate VIIRS performance in Florida's coastal waters. It was found that VIIRS yielded reliable Rrs data in the green and red bands, but erroneous Rrs data in the blue bands (410 and 443 nm). These results are summarized in Figure 1 below.

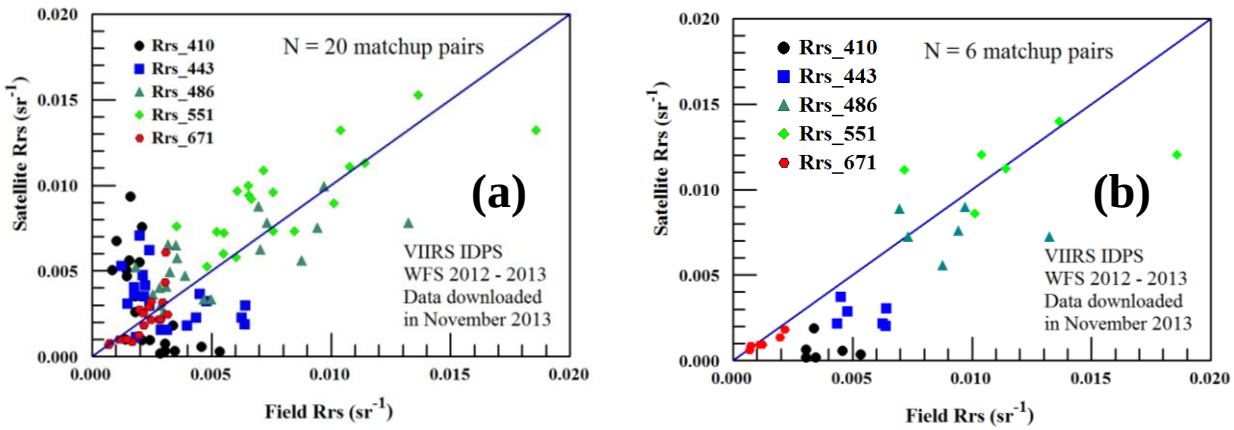

Figure 1: Validation of VIIRS Rrs data products for coastal waters off Florida (station locations shown in Figure); (a) Quality Flags (QF) are not applied; (b) QF flags are applied.

VIIRS typical total radiance at solar zenith angle of 45° was estimated and found to be very similar to MODIS typical total radiance. VIIRS signal-to-noise ratios under typical total radiance were found to be lower than MODIS.

Research Performance Measure: This is a 2-year project and currently it is still in Year 1. The accomplishments have already met the original objectives.

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: G. Rawson, and L. Visser (UM/CIMAS)
NOAA Collaborators: E. Johns, and C. Kelble (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 inter-annual 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 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 Florida Keys National Marine Sanctuary (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 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.

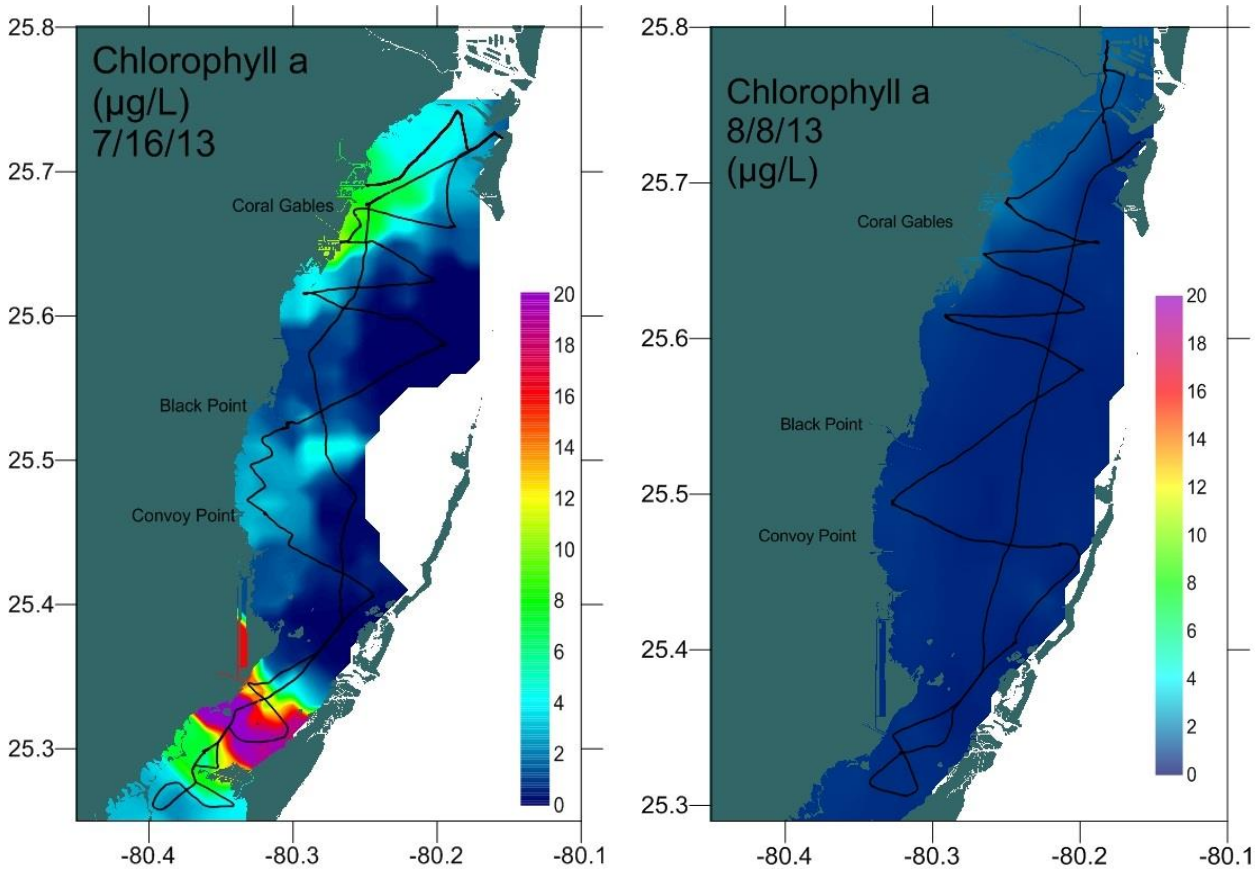

Figure 1: (a) Surface Chlorophyll a (µg L^{-1}) map from data collected in Biscayne Bay on July 16, 2013 and (b) Surface Chlorophyll a (µg L^{-1}) map from data collected in Biscayne Bay on August 8, 2013 both as part of the SFP. An algal bloom occurred in Biscayne Bay mid-June and persisted for several weeks. We conducted four surveys in response to the bloom and monitored its progression throughout the Bay. The first figure shows the most intense chlorophyll levels we measured during this time, and the second figure shows the dissipation of the bloom as the waters returned to typical conditions. 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 2013 – 30 June 2014) has been on data collection, as the regular bimonthly SFP cruises had been temporarily discontinued after the August 2012 surveys due to funding cuts, and then resumed again in July of 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.

Juvenile Sportfish Monitoring in Florida Bay, Everglades National Park

Project Personnel: R. Cascioli, and L. Visser (UM/CIMAS)
NOAA Collaborators: J. Browder (NOAA/SEFSC); B. Huss, and C. Kelble, (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

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

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

CIMAS Research Theme:

***Theme 3*:** Sustained Ocean and Coastal Observations (*Primary*)
***Theme 5*:** Ecosystem Modeling and Forecasting
***Theme 6*:** Ecosystem Management
***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 and OAR/AOML
NOAA Technical Contact: Theo Brainerd and Alan Leonardi

Research Summary:

This project is a component of the Restoration Coordination and Verification (RECOVER) Monitoring and Assessment Plan of the Comprehensive Everglades Restoration Program (CERP). The Comprehensive Everglades Restoration Program is the largest and most expensive ecosystem restoration ever attempted. The primary goal is to restore the quantity, quality, timing, and distribution of freshwater to as near historic levels as feasible in the greater Everglades Ecosystem. Restoration activities will have a significant effect on the downstream coastal ecosystem that supports a significant portion of south Florida's economy, including the recreational fishery within Florida Bay.

The spotted seatrout, *Cynoscion nebulosus*, is an important recreational sportfish in Florida Bay and spends its entire life history within the Bay. Salinity and freshwater influx affect spotted seatrout distribution both directly through physiology and indirectly by affecting habitat (i.e. seagrass), prey and predator distributions and species compositions. Therefore, juvenile spotted seatrout are a good indicator to assess the effect of CERP on Florida Bay's recreational fishery.

Juvenile spotted seatrout populations have remained low throughout central Florida Bay, but not in the west sub-region from 2008 through 2013. There has been a statistically significant shift to lower juvenile spotted seatrout populations in the central bay since 2008. The cause of this shift is not

certain, but 2008 had the highest salinities observed during the MAP sampling, which may have resulted in a shift in seatrout populations. The highest densities and frequencies of occurrence overall occurred in 2006 in Whipray and in West. A notable increase in spotted seatrout densities in north-central Florida Bay occurred in the fall of 2005, following a substantial decrease in salinity as a result of hurricanes.

Three sub-regions showed juvenile spotted seatrout population inversely correlated with salinity, but the West did not (Fig. 1). The west sub-region lacked any correlation with salinity suggesting that salinity may not be the major influence on juvenile spotted seatrout here and other factors may play a role in seatrout abundance. This could be in part, because the salinities in the west are more stable.

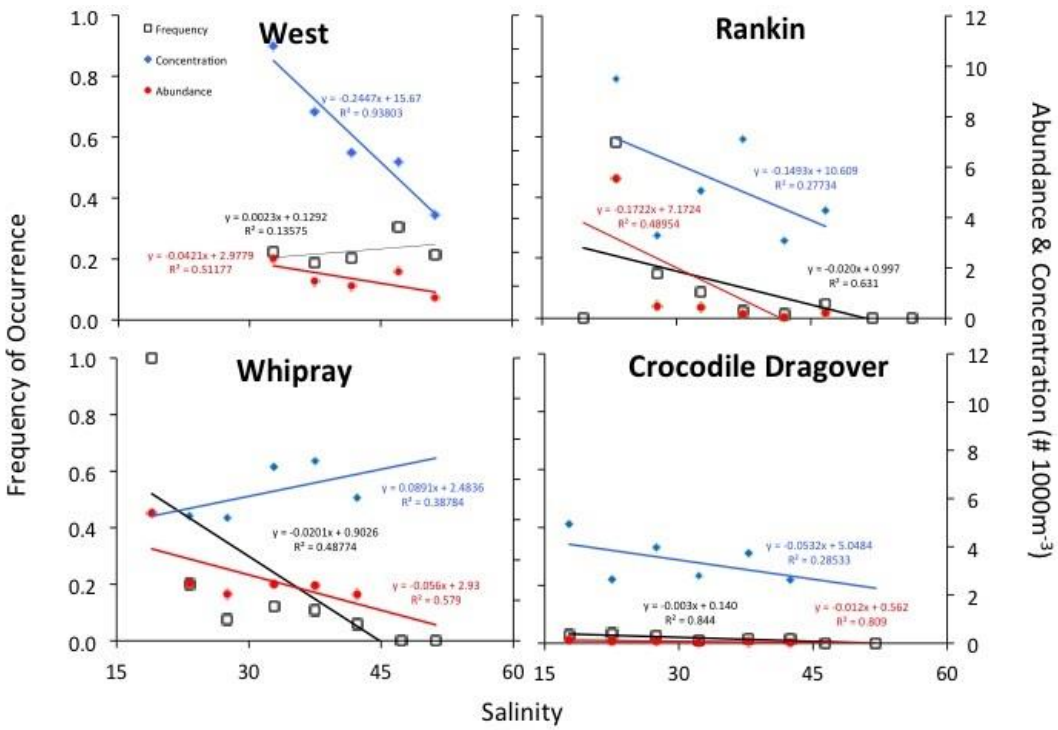

Figure 1: Scatter plots depict the relationship between the juvenile spotted seatrout population and salinity within each sub-region. The black boxes are frequency of occurrence, the blue diamonds are concentration and the red circles are density. Only significant linear regressions are depicted.

There was a significant positive linear relationship of spotted seatrout density, frequency of occurrence, and concentration, between seagrass percent cover throughout Florida Bay (Fig. 8). This suggests that as percent cover increases juvenile spotted seatrout are caught more frequently and at higher densities. The spatial distribution of seagrass in Florida Bay varies by region, with a strong east west gradient. The west sub-region has the highest seagrass percent cover with a decreasing trend towards Crocodile Dragover. Juvenile spotted seatrout frequency of occurrence follows a similar spatial pattern to seagrass percent cover.

A logistic regression was employed on the data collected from 2004 to 2010 to quantify the impact of salinity, temperature on juvenile spotted seatrout frequency of occurrence. Juvenile spotted seatrout are unlikely to be observed at temperatures below 20°C, reflecting the seasonal spawning cycle. In hypersaline waters, juvenile spotted seatrout are only found in areas with moderate temperatures.

Overall, this probability plot shows that juvenile spotted seatrout prefer low salinity and moderate temperatures.

Perhaps most importantly, our analyses this year with our new water-quality-model-based HSI confirmed that simulated NSM conditions provided a sound restoration target for juvenile spotted seatrout abundance in each of our Florida Bay sampling sub-regions. Furthermore, the HSI model sufficiently discriminated between the alternatives of the Central Everglades Project design and future without CEPP, with regards to differences in juvenile spotted seatrout abundances.

Research Performance Measure: We have quantified a significant relationship with juvenile spotted seatrout to salinity that has allowed for the development of a testable hypotheses regarding the effect of CERP on juvenile spotted seatrout distributions. This project data (and the Project Principal Investigator) provided critical contributions to the relevant components of the congressionally mandated 2013 System Status Report, indicating that this project is contributing to science-based management within CERP.

We have begun the development of a revised performance measure for juvenile sportfish in the southern coastal systems. The preliminary steps of this process have focused on the development of Habitat Suitability Index (HSI) models that will be used to predict the habitat suitable for juvenile *C. nebulosus* and other sportfish from submerged aquatic vegetation and water quality parameters. The performance measure will then examine the area of suitable habitat under current conditions compared to the area of suitable habitat predicted from the natural system model and climate change scenarios. The change in area of suitable habitat will be used to derive a quantitative performance measure with a target that CERP can aim to achieve in light of likely climate change scenarios.

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Developing the Operational Calibration/Validation Components for VIIRS SST Retrievals

Project Personnel: P. Minnett, and R. Evans (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/NOAA
NOAA Technical Contact: Alexander Ignatov

Research Summary:

The VIIRS sensor was launched on the S-NPP 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 in situ matchups. VIIRS matchups with measurements form drifting and moored buoys, and ship-board infrared radiometers, have been collected and analyzed to assess the VIIRS SST retrieval performance. Our focus in the past year has been to develop an enhanced atmospheric correction algorithm that improves accuracies towards the edges of the swaths. VIIRS has a wider swath than the heritage sensor MODIS, meaning there is complete coverage of the globe twice per day, without gaps between the swaths of adjacent orbits. However, the SST retrieval problem is more severe towards the edges of the swaths because the atmospheric path length is more than twice that at nadir, and the emission angle of the infrared radiation leaving the sea surface is much greater. We have devised new algorithms that improve the accuracies of the VIIRS SSTs across the entire swath, with a marked improvement in accuracy at satellite zenith angles >45° (Figure 1). Part of the effort to assess the accuracies of the retrieved SSTs, that is the validation component of our project, is the deployment of very well calibrated ship-board radiometers on both research ships and commercial vessels. An M-AERI Mk2 was installed on the *Celebrity Equinox* of Royal Caribbean Cruises Ltd. in May 2014 (Figures 2 and 3). It is working well in an autonomous mode, with instrument monitoring being achieved via a satellite internet connection.

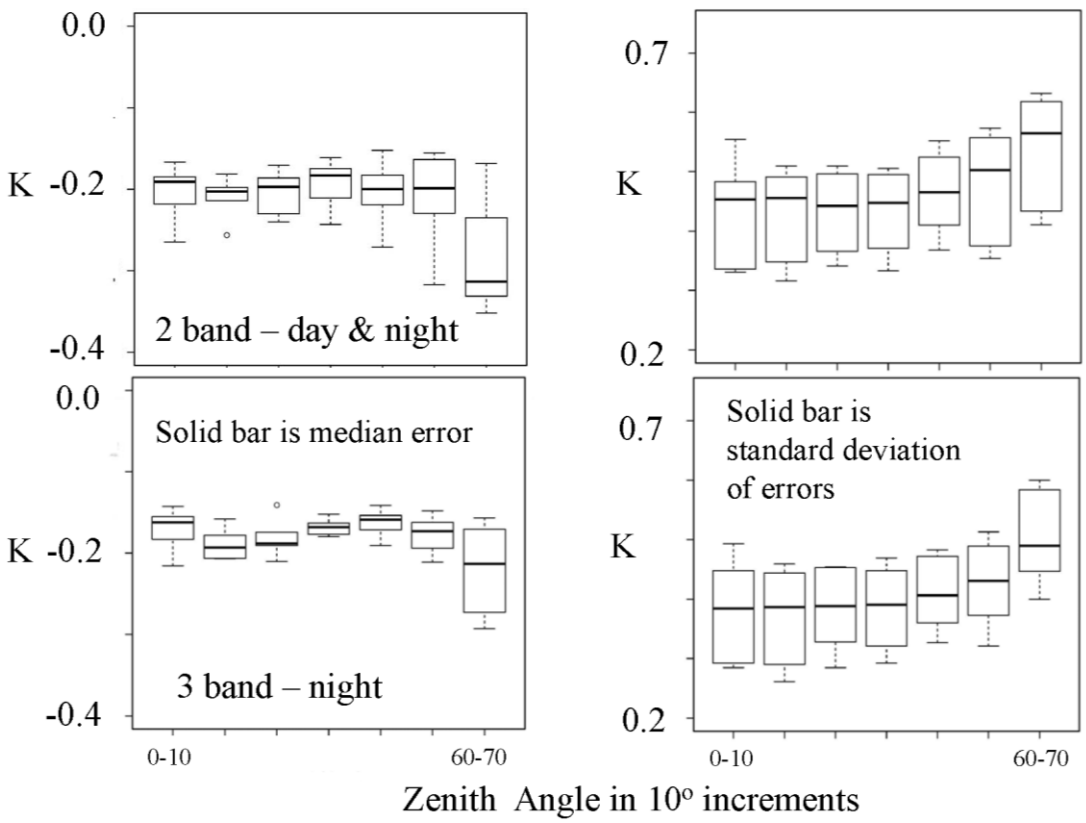

Figure 1: Residual median errors (left panels) and standard deviations of errors (right panels) of VIIRS SSTs as functions of the satellite zenith angle. The top row is for SSTs derived using our improved atmospheric correction algorithm applied to measurements in two spectral bands which can be used both day and night. The bottom row is for an improved atmospheric correction algorithm applied to measurements in three spectral bands which can be used only at night. Even though there is a degradation in the accuracy of the SSTs at high zenith angles, this is much better than with previous algorithms.

Figure 2: A M-AERI Mk2 being installed in an environmental enclosure on the *Celebrity Equinox*. When complete, the instrument will be in a sealed, weather-proof enclosure; the pipes on the side of the enclosure are connected to a small air-conditioning unit that provides cooled, dry air to the enclosure.

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 and NOAA/NESDIS/STAR.

Figure 3: The *Celebrity Equinox* with the position of the M-AERI Mk2 shown by the yellow arrow.

PIRATA Northeast Extension (PNE)

Project Personnel: R.C. Perez, S. Dolk, and G. Rawson (UM/CIMAS)
NOAA Collaborators: R. Lumpkin, G. R. Foltz, C. S. Meinen, and C. Schmid (NOAA/AOML); M. Strick (NOAA/PMEL)
Other Collaborators: D. Amaya (Texas A&M Univ.)

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/AOML's contribution to PIRATA is to organize and conduct annual cruises to service moorings of the PIRATA Northeast Extension (PNE), 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 (TIWs), and ventilation of the oxygen minimum zone.

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 November-December 2013, the PNE servicing cruise was conducted aboard the NOAA ship Ronald H. Brown. This cruise departed from Bridgetown, Barbados and terminated in Recife, Brazil (Figure 1). The chief scientist of this cruise was Gregory Foltz (NOAA/AOML) and Shaun Dolk, Renellys Perez (co-chief scientist), and Grant Rawson were the CIMAS personnel in attendance. During the cruise, temperature, salinity, pressure, velocity, and dissolved oxygen concentration were measured in the upper 1500 m of the ocean from 69 conductivity-temperature-depth (CTD) casts, primarily along 23°W. Additional temperature, salinity, and pressure data continues to be acquired from two Argo floats that were deployed during the transit to the first PNE mooring, and surface currents are being monitored from 20 drifting buoys that were deployed between the equator and 9°N along 23°W. Several buoys were deployed into strong northwestward flow associated with the crest of a TIW and will gather surface temperature and velocity information that will help to quantify the role of TIWs in the equatorial Atlantic heat and momentum budgets.

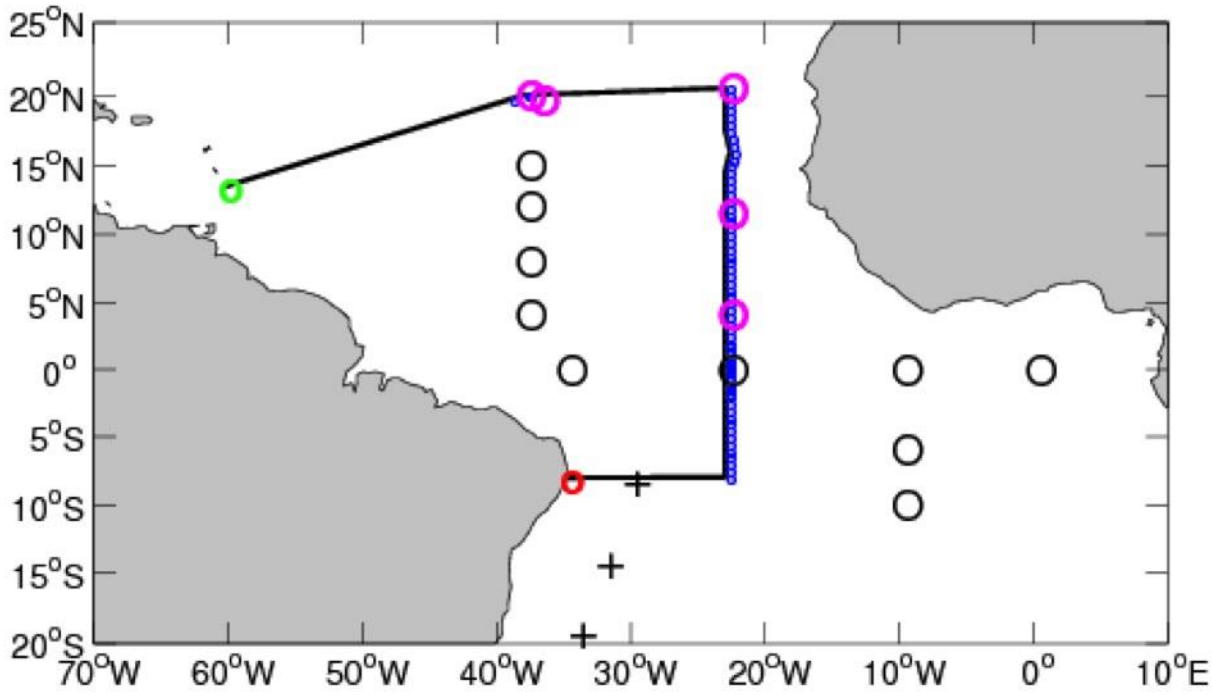

Figure 1: Locations of the PIRATA backbone array moorings (black circles), Southwest Extension moorings (black crosses), and Northeast Extension moorings (pink circles), including an experimental T-Flex mooring at 20°N, 38°W. Green and red circles indicate the beginning and end ports of Bridgetown, Barbados, and Recife, Brazil, respectively. Blue circles show the locations of 69 CTD casts performed during the cruise.

In addition to the standard measurements from CTD casts, special emphasis was placed on resolving the vertical structure of currents in the upper 100 m of the ocean. Quantification of the upper-ocean vertical structure of currents is important for understanding the role of the ocean in sea surface temperature and salinity variability, but in the past has been elusive because of limited direct velocity measurements. To accomplish this goal, the NOAA/AOML and CIMAS team increased the vertical resolution of the upward-looking Acoustic Doppler Current Profiler (ADCP) attached to the CTD frame and the downward-looking ADCP mounted on the ship's hull. With the help of PMEL technicians, two single-depth current meters were mounted on the 4°N, 23°W PNE mooring at depths of 5 m and 20 m to augment measurements from the existing current meter at 10 m. Figure 2 shows early data from these newly deployed current meters.

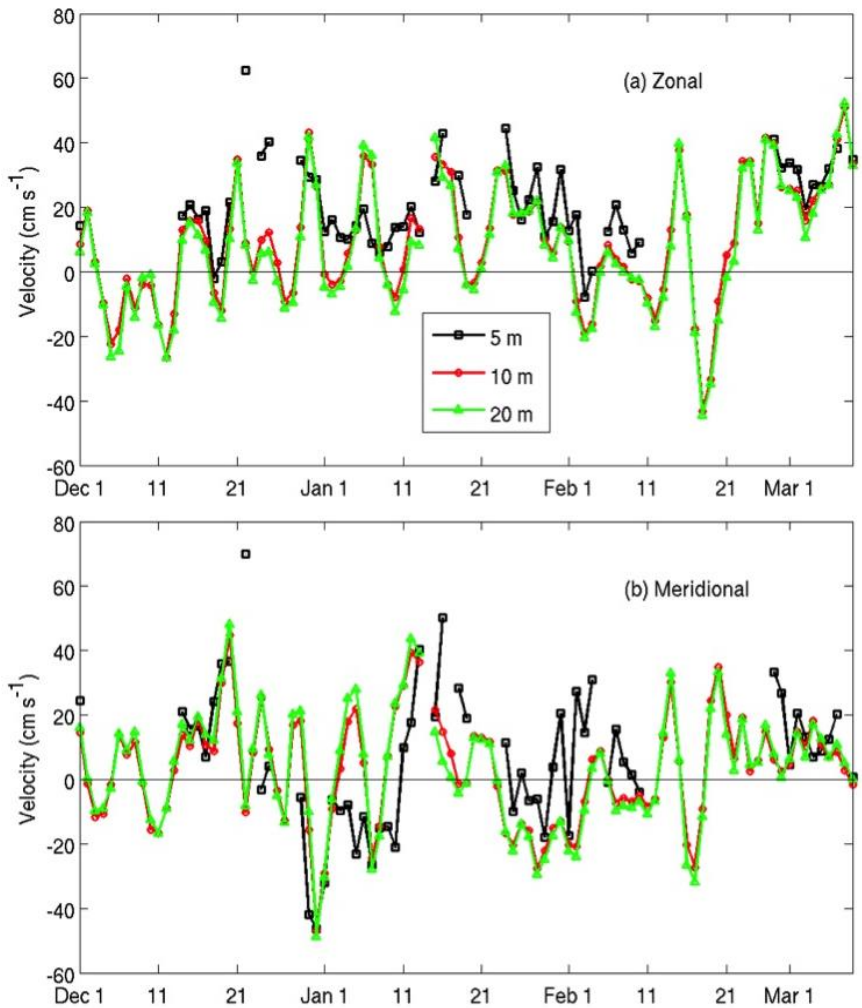

Figure 2: Daily-averaged real-time data during December 2013 – March 2014 from current meters deployed on the 4°N, 23°W PIRATA Northeast Extension mooring during the PNE2013b cruise. Current meters were attached to the mooring line at depths of 5 m, 10 m, and 20 m.

Research Performance Measure: All major objectives are being met. Three PNE-related papers have been published in Climate Dynamics, Journal of Climate, and Journal of Geophysical Research. Results were presented at the October 2013 TAV/PIRATA meeting in Venice, Italy and the 2014 Ocean Sciences Meeting.

Surface Water pCO_2 Measurements from Ships

Project Personnel: D. Pierrot, K. Sullivan, and L. Barbero (UM/CIMAS); F.J. Millero (UM/RSMAS)
NOAA Collaborators: G. Goni, and R. Wanninkhof (NOAA/AOML)

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

CIMAS Research Theme:
***Theme 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/COD/CPO
NOAA Technical Contact: Joel Levy

Research Summary:
The ship-based surface pCO_2 program is designed to provide sustained measurements of regional oceanic carbon sources and sinks on seasonal timescale by measuring surface water and marine boundary pCO_2 on ships of opportunity. It is a collaboration of investigators at the NOAA laboratories AOML and PMEL; and the following academic institutions: Columbia University, the University of Miami, and the Bermuda Institute of Ocean Sciences. 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. In FY-14 the NOAA funded participants maintained instrumentation and reduced the data from seven ships and posted the data. Flux maps, based on extrapolation routines using remotely sensed wind and sea surface temperature (SST) have been created to estimate global seasonal sea-air fluxes. An appreciable focus continues to be global

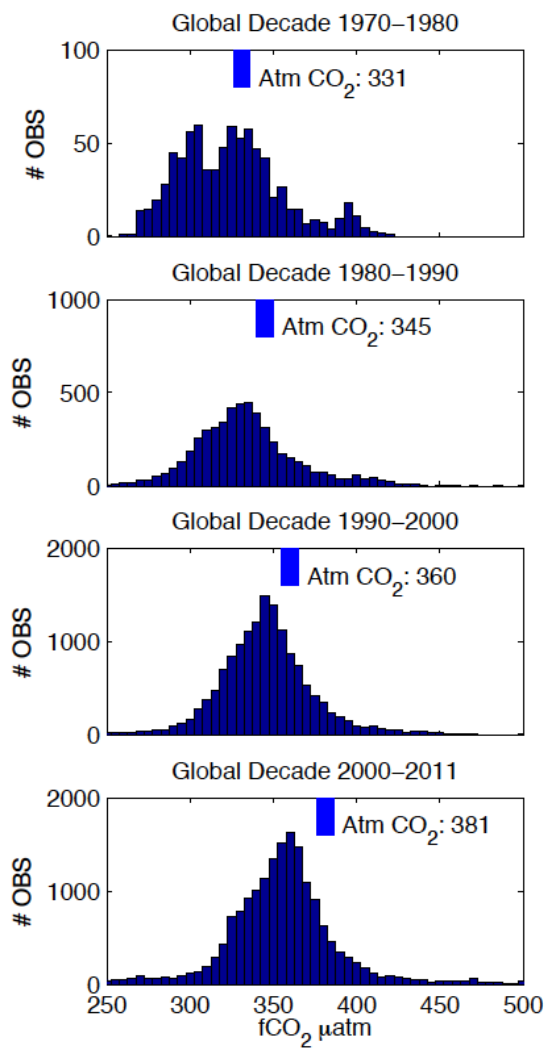

Figure 1: Distribution of surface water CO_2 levels as in the SOCAT-2 database. The corresponding atmospheric CO_2 levels are marked at the top of each panel. The mean water values in the 70's, 80's, 90's, and 2000' were 324; 332; 346; and 354 µatm, respectively. This suggests that either ocean CO_2 increases are lagging atmospheric values or that non-representative sampling is occurring.

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 2013 and efforts to produce SOCAT version 3 is underway (Fig. 1).

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 SKOGAFOSS are transmitting TSG data. All of the seven ships send complete daily files of pCO_2 to shore via internet.

Research Performance Measure: Produce and update a global surface water CO_2 database.

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

Project Personnel: C. Atluri, Z. Barton, S. Dong, E. Forteza, S.L. Garzoli, M. Goes, V. Halliwell, R. Sabina (UM/CIMAS)
NOAA Collaborators: C. Schmid, U. Rivero, P. Pena, and M. Baringer (NOAA/AOML)

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

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

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

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

Research Summary:

The Argo array is part of the Global Climate Observing System/Global Ocean Observing System (GCOS/GOOS). Argo 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:

- 430 floats were deployed by the USA.
- 62 of these floats were deployed jointly by AOML and CIMAS.
- 2,362 US floats actively reported data during this period.
- 82,732 profiles have been distributed on Global Data Centers.
- 69,973 profiles were sent to GTS by the US DAC where 78% of them were distributed during the first 24 hours since the profiles were obtained.
- The US Argo Data Assembly Center (US DAC) at AOML has increased the operational capacity and now collects and process data 3 times a day to improve the time between the collection of the profile and the real availability of the data to the weather service and the research community.
- The US DAC maintains a website: http://www.aoml.noaa.gov/phod/argo/index.php that provides documentation and information about the operations at the US Argo DAC, which is updated daily (e.g. Figure 1).
- Four new Argos Float type decoders have been implemented by the dynamically programmed code, which processes 40 other float types. Software to convert the incoming prv files to hex files has been improved to decode the Checksum accurately in case of more than 1 hex message exists.
- New Software to accommodate multiple Oxygen sensors has been developed extensively to accommodate the missing functionality. Existing floats have been renamed to new instrument types based on their distinct format types. The new software can now handle 19 Oxygen format types.
- 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 been tested rigorously and moved to operations. The program is also improved to accommodate the access to directory structure of the floats, which minimizes the indexing time.
- Using CLS web services for download of csv files: A new program is developed to download the CSV files from CLS servers instead of an FTP of PRV files. The program also converts the CSV files to hex files which is later used for decoding of the Argos data.
- Real-Time Quality Control and Product Production Software: Previously, real-time adjustments of pressure and salinity, quality control and file production for data distribution was done by individual programs, because the various steps were introduced over time. Several of these programs were inefficient and difficult to modify. The need to transition to the new NetCDF format 3.0 for Argo profiles was used as an opportunity to consolidate these programs. This program will be made operational in the near future.

- A new software development for decoding very high resolution near surface profiles reported by Iridium floats as sts files was started. These data will be very useful for sea surface temperature and salinity measurements from satellites.
- A system for accelerated data processing is being developed for the purpose of making data from floats deployed near tropical cyclones available faster, with the purpose to make these data much more useful for hurricane forecasting.
- US Argo Atlantic deployments were coordinated and done by AOML. During the past year several deployments of Atlantic Argo floats were made by CIMAS and NOAA personnel on scientific cruises and from ships of opportunity. Vessels are constantly sought out to assist with the deployment of Argo floats. Planning and logistics for these cruises are done in coordination with WHOI to ensure the number of floats available for the cruise, and ensuring that the ship and the scientific parties have space and are able to deploy the floats. An opportunity arose to deploy floats in an area that was historically limited for deployments due to the limitations of the floats. With a new version of the floats, this is becoming less of a problem and as such, we were able to deploy into the Gulf of Mexico. Four exploratory floats were deployed aboard NOAA's R/V Okeanos Explorer.

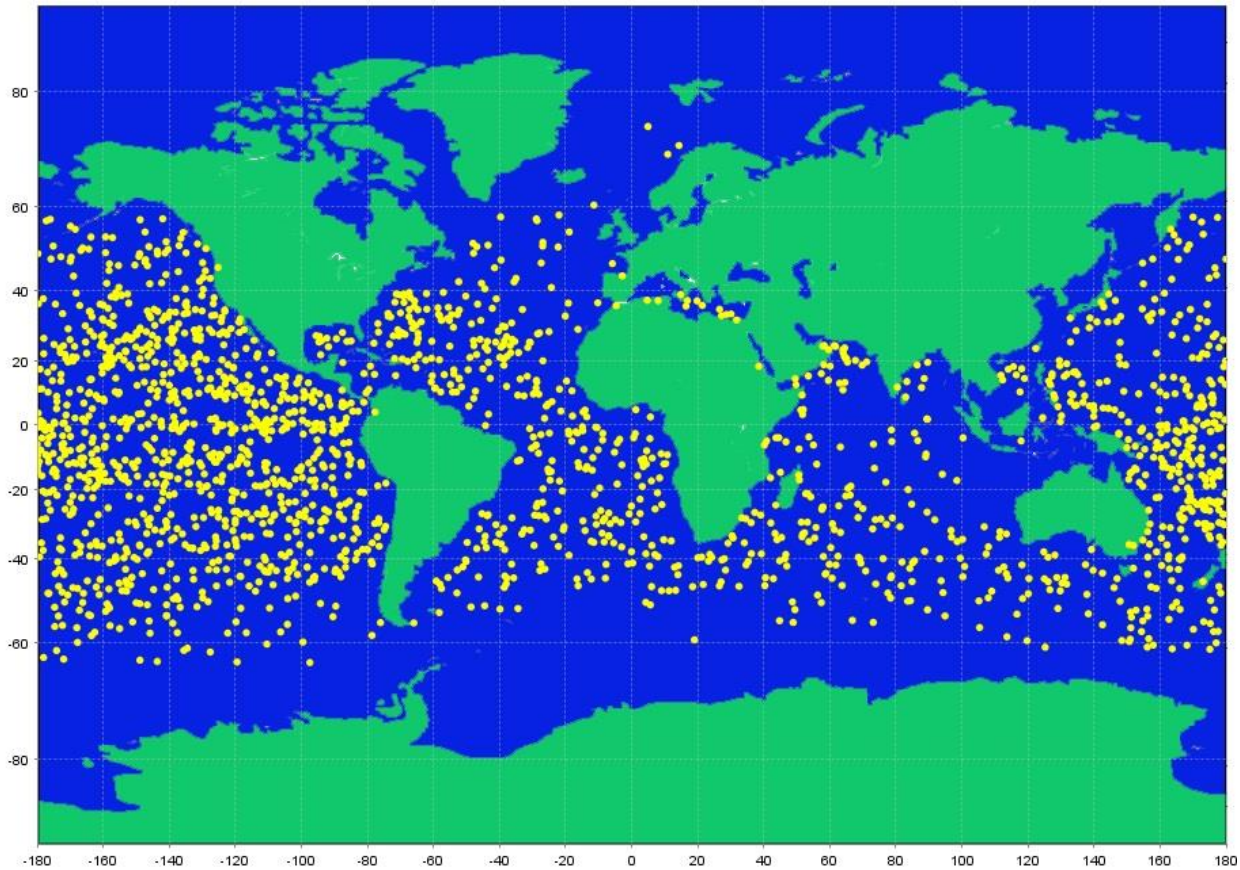

Figure 1: Location of US Argo floats in June 2014.

Representative results from scientific studies relying upon Argo data:
Monthly climatologies of temperature and salinity from observations and numerical models are used to estimate the Atlantic Meridional Overturning Circulation (AMOC) at 34 S (Figure 2). Observational estimates suggest that the geostrophic transport plays an equal role to the Ekman transport in the AMOC seasonal variations at this latitude, whereas in the models the Ekman transport controls the AMOC seasonality. The seasonality of the geostrophic transport from observations is largely controlled by the seasonal density variations at the western boundary, but in the models the eastern boundary dominates. The observed density seasonality at the western boundary is linked to the intensity of the Malvinas Current, which is poorly reproduced in the models. The results indicate that the weak seasonal cycle in the model geostrophic transport can primarily be attributed to excessively strong baroclinicity below the surface mixed-layer, whereas the observations show a strong vertical coherence in the velocity down to 1200 m.

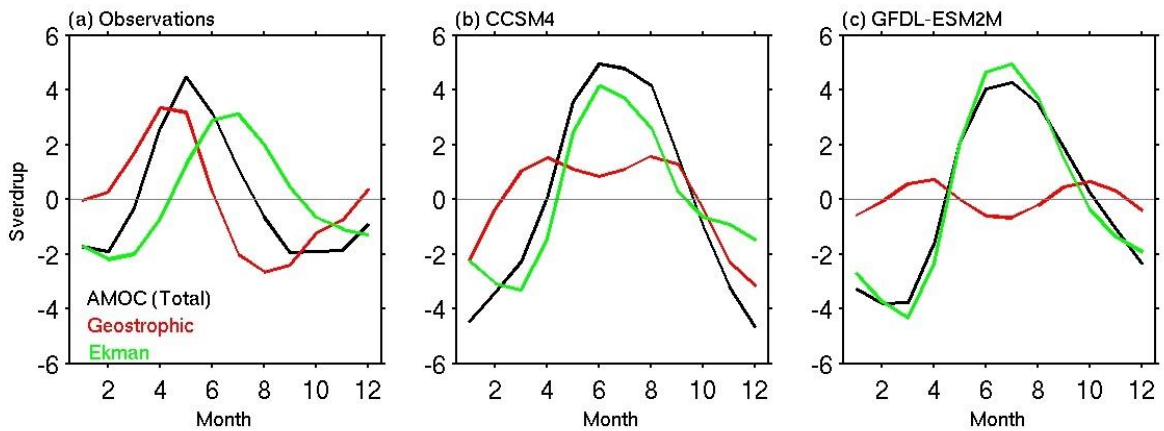

Figure 2: Seasonal variations of the AMOC at 34°S (black) and contributions from the geostrophic (red) and Ekman (green) components estimated from (a) observations (Argo, Roemmich and Gilson 2009; WOA13, Locarnini et al. 2013, *NOAA Atlas NESDIS 73*; and SCOW, Risien and Chelton 2008, *J. Phys. Oceanogr. 38*) and two CMIP5 models (b) NCAR CCSM4 (e.g. Gent et al. 2011, *J. Clim. 24*; Danabasoglu et al. 2012, *J. Clim 25*) and (c) GFDL-ESM2M (e.g. Dunne et al. 2012, *J. Clim. 25*; Parsons et al. 2014, *GRL 41*). The time-mean values for the total AMOC and each component have been removed.

The decadal sub-surface salinity changes are investigated across the Subtropical South Atlantic Ocean using ocean reanalysis products as well as climate model experiments (Figure 3). Results show that there is a recent significant salinity increase at the core of the salinity minimum at intermediate levels. The main underlying mechanism for this sub-surface salinity increase is the lateral advective (gyre) changes due to the Southern Annular mode variability, which conditions an increased contribution from the Indian Ocean high salinity waters into the Atlantic. An initial analysis is performed to validate the ability of SODA and ECCO2 reanalysis to represent the recent (2000s) climatology of the Antarctic Intermediate Water (AAIW) mean. The reanalysis outputs are compared to the Argo climatology of Roemmich and Gilson (2009, *Prog. Oceanogr. 82*). The two products produce different climatologies of salinity minimum in the 2000s. ECCO2 shows less bias towards observations, since it assimilates both surface and profiles data, which confirms the value of assimilating Argo's temperature and salinity data in models to improve the representation of water masses.

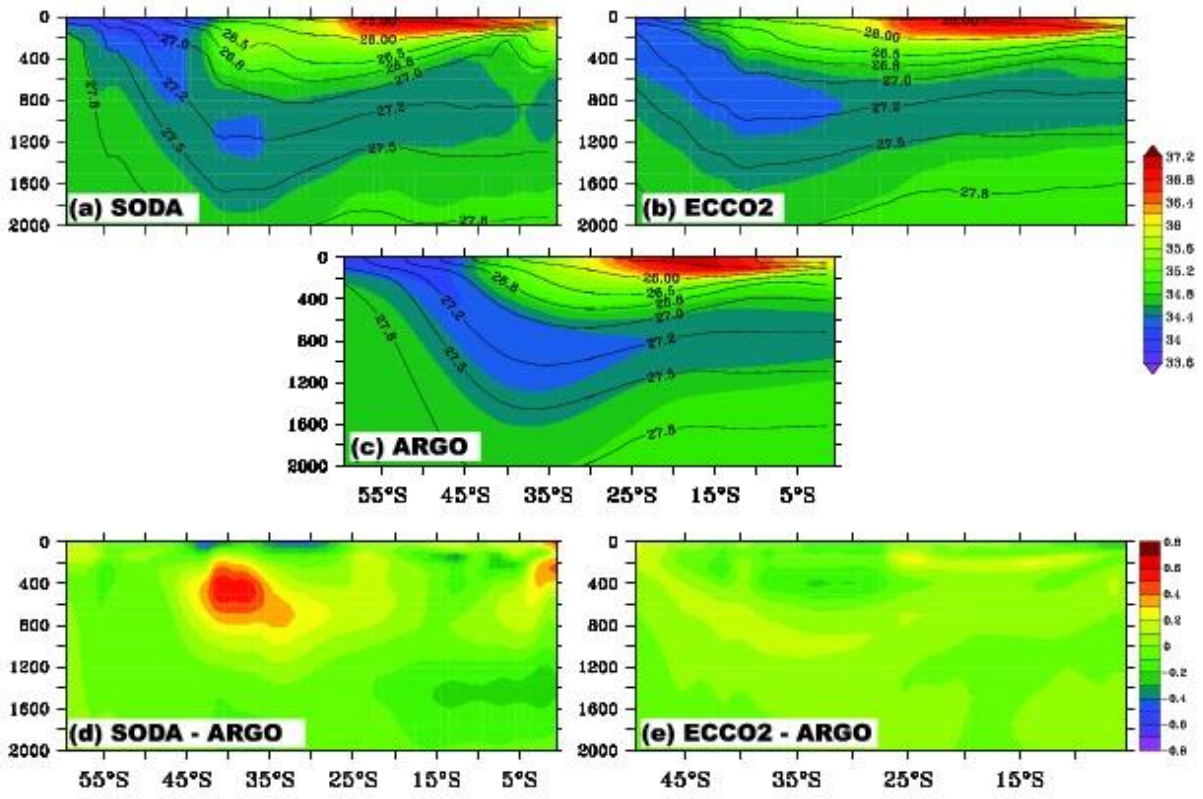

Figure 3: Meridional section of the climatological average (after 2004) of salinity at 25°W in the South Atlantic. Depth is in meters. Relevant potential density surfaces (σ_θ in Kg/m3) are overlaid. Panel a) is for SODA, b) for ECCO2, c) for Argo climatology [Roemmich and Gilson 2009], d) SODA - Argo and e) ECCO2 - Argo.

Historical and new observations, including hydrographic sections, Argo data and chlorofluorocarbon measurements, are examined together with two different analyses of the Ocean General Circulation Model for the Earth Simulator (OFES) to trace the pathway of the Deep Western Boundary Current (DWBC) through the South Atlantic (Figure 4). Together, observations and model outputs indicate that after crossing the equator, the DWBC flows with the characteristics of NADW and a total volume transport of approximately 14 Sv (1 Sv = 10^6 m^3/sec). It crosses 5°S mostly along the western boundary and breaks up into rings near 8-11°S. When this very energetic eddying flow reaches the Vitória-Trindade ridge (~20°S), the flow branches due to conservation of potential vorticity. The main portion of the flow continues along the continental shelf of South America in the form of a strong reformed DWBC, while a smaller portion, about 20%, is advected towards the interior of the basin. It is hypothesized that this eastward motion results from eddy thickness flux divergence due to overlying Agulhas Ring decay and enhanced mixing caused by the energetic eddy field at the Vitória-Trindade ridge.

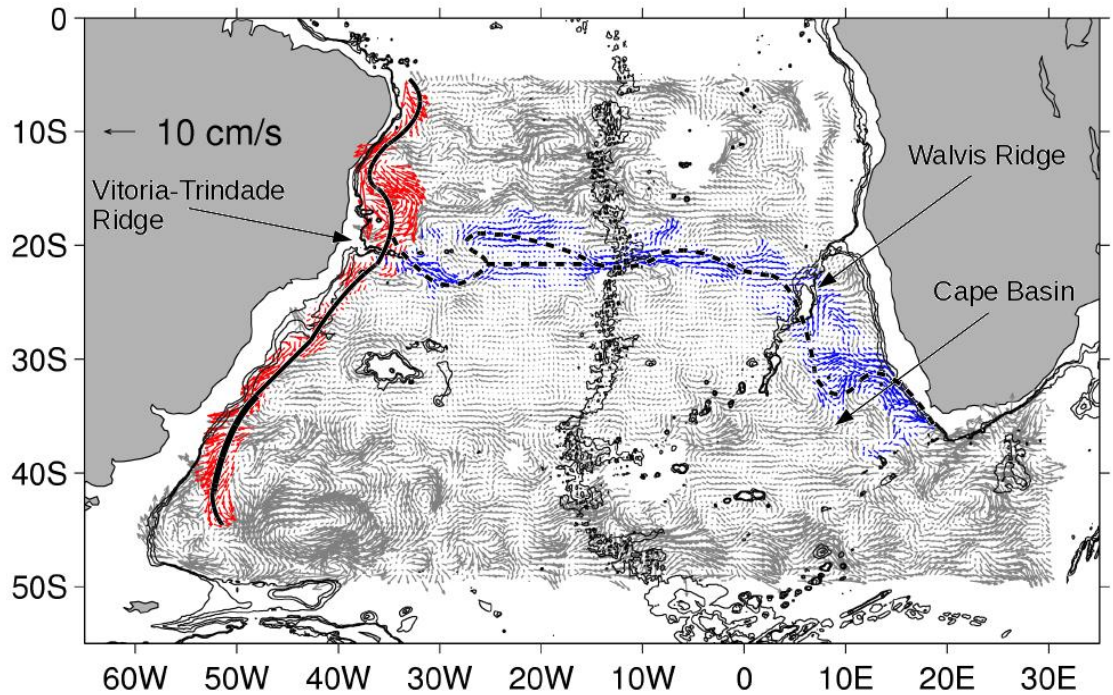

Figure 4: Velocity field at 2000 dbar derived from the Argo data, as derived following a method developed by Schmid (2014, *DSR*, in press). Red highlights the strong southward flow along the western boundary; blue indicates the eastward velocity originating near the Vitória-Trindade ridge. Isobaths: 2000, 2500 and 3000 m. Solid curves highlights the pathway of the DWBC along the South American coast. Dashed lines indicate regions where the pathway is less well developed as it moves to the interior of the basin.

Research Performance Measure: This program has attained all objectives and continues to operate within the planned timelines.

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Remote Sensing in Support of Climate Research

Project Personnel: R.C. Perez (UM/CIMAS)
NOAA Collaborator: G.J. Goni (NOAA/AOML)
Other Collaborator: J.A. Trinanes (U. Santiago de Compostela)

Long Term Research Objectives and Strategy to Achieve Them:

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

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

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

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

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

Research Summary:
A key outcome of this project is to develop and implement the technologies needed to provide raw and processed quality satellite products to scientists, decision-makers and the general public. The range of primary satellite products include sea surface height, sea surface temperature, ocean color and surface winds.

One of the activities conducted during this year supports a NOAA/NESDIS effort to install and operate a 2.4 meter X-band antenna which would be located at NOAA/AOML. The new satellite receiving system will collect telemetry from a new generation of Earth observation satellites and will provide near real time geophysical, atmospheric and oceanic information to government, commercial, academic and public users. The new station will be protected from the environment by a radome and 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), VIIRS (Visible Infrared Imager Radiometer Suite), onboard NPP (NPOESS Preparatory Project), and the upcoming Joint Polar Satellite System (JPSS). Raw data will flow to UW/SSEC, where it will be converted to Level1B to be delivered to NOAA/NCEP for numerical weather prediction assimilation. A local processing server will create real-time products onsite at AOML. Examples of information collected by the proposed system include critical weather (e.g. hurricanes), sea surface temperature, ocean color, cloud cover, and ozone profile data. These products have proven extremely useful in monitoring, modeling and forecasting meteorological and oceanographic processes.

We already manage an L-band antenna that collects and distributes operational data from the POES (Polar Operational Environmental Satellites) constellation. The raw telemetry from these satellites and the derived-Level1 products are routinely pushed to NOAA/NESDIS Office of Satellite Data Processing and Distribution for operational applications. We also provide DCS (Data Collection System) operational data from the satellites of the POES constellation and SARAL (Satellite with ARgos and ALtiKa) to the Argos program.

Our servers provide data and metadata complying with common open standards that promote interoperability and Service Oriented Architectures (SOA). Our approach is to serve a suite of spatiotemporal products through interoperable techniques, which would be able to access and use remote layers via Open Geospatial Consortium (OGC) Web Services (OWS). Users will be able to easily combine local and remote raster and vector layers, change the projection, display and customize plots, retrieve the data and incorporate the desired layers within their own computer

environment. Based on XML Schema, our system facilitates the creation of tailored interfaces, which adjust the contents to the user needs. From the user's perspective, customized interfaces can be easily deployed at a minimum cost and used for both, coastal, meso- and large-scale applications. The suite of protocols and tools include THREDDS, ERDDAP, OPENDAP and OGC Web Services. The range of products has been extended with the addition of new regional and global parameters (e.g. NPP color fields).

Following an algorithm described in Baker-Austin et al., 2013, Nature Climate Change, 3, 73-77, we have implemented a global risk model focused on non-cholera vibriosis. Diverse studies show that SST and salinity are two main environmental factors influencing the number of infections, and consequently, a vibrio risk model would need them to provide reliable estimates. The outputs of this model can be classified into 3 main groups: daily, cumulative and short term forecast. Operational and predicted risk datasets can be part of environmental planning initiatives, aimed to minimize the impact of vibriosis and perform more adequate health impact assessments.

The features of our online viewer (http://cwcgom.aoml.noaa.gov/cgom/OceanViewer/) have been expanded to incorporate additional basemaps, to allow the overlay of multiple layers and to provide animation capabilities. Consequently, users can create customized products selecting among multiple satellite fields and palettes (Figure 1).

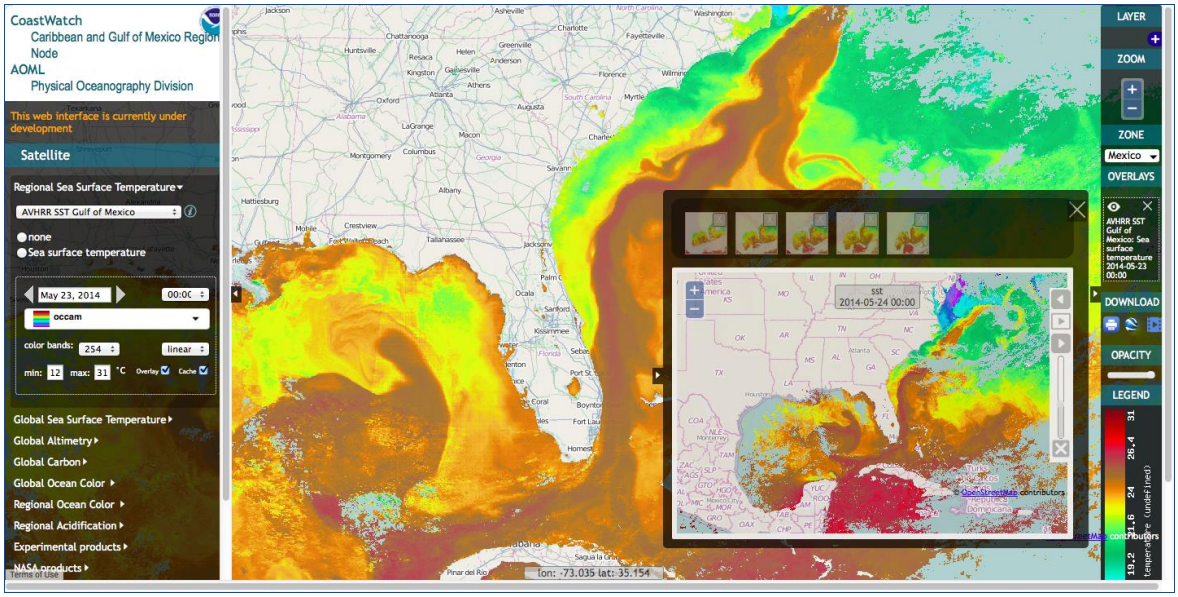

Figure 1: Viewer: AVHRR SST field for May 23rd, 2014. The animation widget is overlaid on the right half of the map.

During this period, and continuing with a task already performed in previous years, the following products in Climate&Forecast (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 surface current gradients. Resolution: 1/10th of degree.

2. Sea surface temperature
a) Daily Optimum Interpolated SST fields. Resolution: 1/4th of degree.

Research Performance Measure: All 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 and improved for visualization and data access. These solutions have been integrated within a SOA framework.

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Marine Optical Buoy (MOBY) Operations and Technology Refresh

Project Personnel: K. J. Voss (UM/Physics)
Other Collaborator: 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.

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: Paul DiGiacomo

Research Summary:
The goal of this project is to provide data for the on-orbit calibration of the international constellation of ocean color satellites, but in particular for the recently launched NOAA VIIRS instrument. We provide a time series of the most accurate measure of the water leaving radiance in a site with clear water and a clean maritime atmosphere (off of the island of Lanai in Hawaii). This time series began in 1997 and has been used as the primary calibration point by every national and international ocean color satellite instrument launched since 1997. This time series, with the highest quality data, allows multiple satellite missions to be tied together with a common calibration point, enabling an extended climate quality record of ocean color, spanning multiple satellite missions, to be produced.

The largest portion of this work is maintaining MOBY operations at the highest level of radiometric accuracy, which we do with our collaborators at the Moss Landing Marine Laboratory (SJSU) and NIST. This includes exchanging the MOBY instrument three times/year and replacing the main mooring for MOBY in alternate years. Each MOBY buoy system must be calibrated pre- and post-deployment, and diver calibrations/cleanings are performed monthly. All of these calibrations must be processed to maintain a real time data stream, along with a post-calibrated archive. The data is processed and then provided to users around the world through the NOAA CoastWatch site.

During this past year we have been able to begin work on a "Refresh" of the optical and electronic systems in the MOBY system. 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. Thus we are working towards implementing a newer optical design into the MOBY system. This system, once built, will be fully characterized and calibrated with SI traceability (through 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.

We have been maintaining current MOBY operations over this period, meeting our objectives of maintaining the accurate time-series for satellite vicarious calibration. Figure 1 shows results from the most recent deployment. In this figure the most current deployment, starting in May 2014 is shown as the data points. The overall annual variation is due to the seasonal variation of surface solar irradiance. On this graph the overall time series mean is shown as the black line (starting in 1997), with plus or minus one standard deviation indicated by the grey region. Bad data on this graph are predominately cloudy days, when the data would be invalid. Questionable data usually results from days for which the GOES imager may not show clouds, but the data is unstable over the measurement period, indicating the presence of small clouds. Good data is data that has passed all the quality control steps and is suitable for use in Satellite Vicarious calibration.

Figure 2 shows the MOBY data being used in action (courtesy of Menghua Wang, NOAA/NESDIS). This shows the MOBY data plotted with two versions of the VIIRS ocean color satellite retrieved water leaving radiance, since the launch of VIIRS. The discontinuity on February 6, 2012 was caused by the VIIRS operators putting in place the first true, post-launch, calibration table. One can see the improvement at that time, and since the current VIIRS processing is operational mode without re-processing any data, the effect of this calibration data does not propagate backwards in time. For the data from this date forward, MOBY becomes the critical calibration point to improve the satellite data quality.

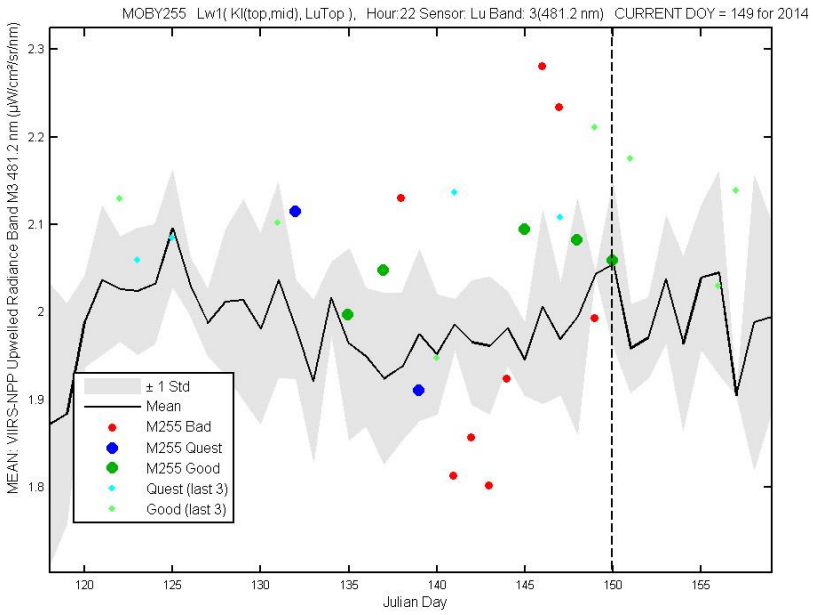


Figure 1: The MOBY time series, started in 1997, with the data from the most recent deployment. This deployment, M255, will be in the field until approximately September, when this MOBY instrument will be exchanged in the field for another instrument.

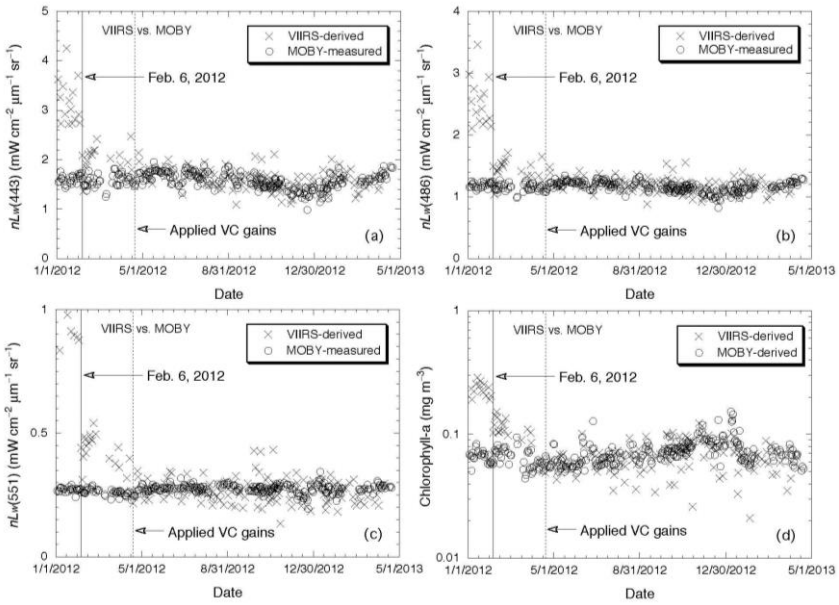
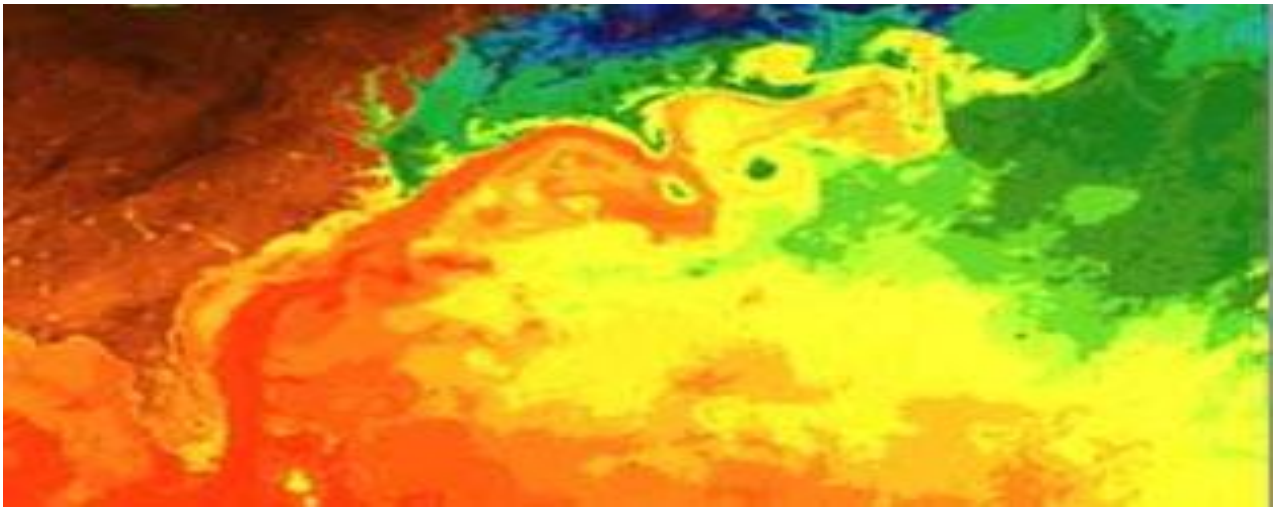


Figure 2: An illustration of the MOBY data being used for vicarious calibration of the VIIRS ocean color satellite, and two processing systems. The VIIRS IDPS-EDR is the current operational data processing system, while the NOAA-MSL I2 is the processing done by a group at NOAA/NESDIS. This figure is courtesy of Dr. Menghua Wang, NOAA/NESDIS.

Research Performance Measure: We are currently on schedule with our development of the MOBY-Refresh system.



VI. RESEARCH REPORTS

THEME 4: Ocean Modeling

South Atlantic Meridional Overturning Circulation: Pathways and Modes of Variability

Project Personnel: R.C. Perez, and S.L. Garzoli (UM/CIMAS)
Other Collaborators: R.P. Matano, and V. Combes (OSU/CEOAS); R. Msadek (UCAR, NOAA/GFDL)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To improve our understanding of the pathways of the upper and lower limbs of the Meridional Overturning Circulation (MOC) in the South Atlantic (SA).
***Strategy*:** 1) To characterize the pathways of the upper and lower limb of the MOC in the SA and identify the dynamical mechanisms that control these pathways; 2) to identify the natural modes of variability in the SA and their impact on the MOC; and 3) to determine the response of the SA pathways to predicted climate change scenarios and assess the impact of this response on the MOC.

CIMAS Research Theme:
***Theme 4*:** Ocean Modeling (*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/CPO
NOAA Technical Contact: James Todd

Research Summary:
Previous observational and modeling efforts on the meridional overturning circulation (MOC) have been focused on the North Atlantic and the Southern Oceans, the preferential sites for deep-water formation. To understand the feedbacks between the North Atlantic and the Southern Oceans we need to improve our understanding of the pathways of the upper and lower limbs of the MOC in the South Atlantic (SA) Ocean, which are the most important links between these sites. The SA is not just a passive conduit for the transit of remotely formed water masses, but actively influences them through air–sea interactions, mixing, subduction, and advection.

In this project we are: 1) characterizing the pathways of the upper and lower limb of the MOC in the SA and identify the dynamical mechanisms that control these pathways; 2) identifying the natural modes of variability in the SA and their impact on the MOC; and, 3) determining the response of the SA pathways to predicted climate change scenarios and assess the impact of this response on the MOC. Our research is focused on the analysis of state-of-the-art eddy-permitting and eddy-resolving NOAA/GFDL climate model simulations (CM2.5 and CM2.6), non-eddying Coordinated Model Intercomparison Project and Intergovernmental Panel on Climate Change Fifth Assessment Report models including the NOAA/GFDL coarse resolution models (CM2.1, CM3) but also includes process-oriented numerical experiments using regional ocean models, and global in-situ and satellite observations.

Efforts this year have centered on examining the fate of the Deep Western Boundary Current (DWBC) in the SA using in situ observations (Figure 1) and output from a global ocean-only numerical model, and the variability of the MOC on intra-seasonal to seasonal timescales in the SA using data from the SAM array and output from the NOAA/GFDL coupled climate and ocean-only simulations (CM2.1, CM2.5, and CM2.5 forced with CORE winds) as well as other regional and global ocean models. With OSU collaborators regional ocean model simulations have been generated in which synthetic tracers are inserted at key locations to study the pathways of key water masses in the SA (i.e., the DWBC as it enters the SA from the North Atlantic). We are also collaborating with NOAA/GFDL with regard to additional coupled climate simulations supportive of this research.

Research Performance Measure: Despite the project starting less than a year ago, much progress has been made on all major objectives. Preliminary results from this project were presented at the U.S. AMOC Meeting in Baltimore, MD in July 2013; a major paper was published in the Journal of Geophysical Research using data from the two pilot arrays along 34.5°S to estimate the strength of the MOC and on a short article about the expansion of these arrays was published in Eos, Transactions, American Geophysical Union. Moreover a manuscript is under review at Deep Sea Research on the fate of the DWBC in the SA.

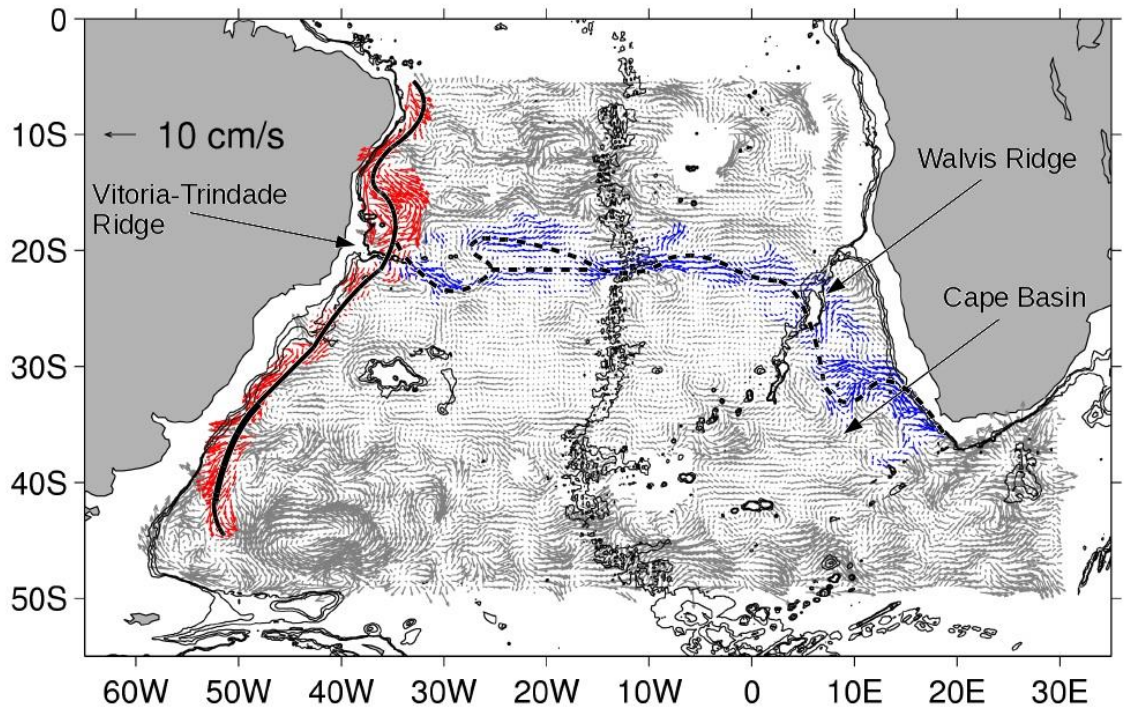


Figure 1: Velocity field at 2000 dbar derived from Argo data. Red highlights the strong southward flow along the western boundary; blue indicates the eastward velocity originating near the Vitória-Trindade ridge. Black lines: 2000, 2500 and 3000 m isobaths. Solid curves highlight the pathways of the DWBC along the South American coast. Dashed lines indicate regions where the pathway is less well developed as it moves to the interior of the basin.

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

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

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To improve the predictability of Atlantic Warm Pool (AWP) climate impacts.
***Strategy*:** To diagnose the mechanisms and climate impacts of the AWP within Coupled General Circulation Models and to develop an experimental forecasting system using NCAR's CESM1.

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

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

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

Research Summary:
In the process of evaluating the performances of Coupled General Circulation Models in simulating the AWP variability and its climate impact, we found that at inter-annual time scales the warming of the Atlantic Warm Pool (AWP) is associated with a tripole SST pattern in the North Atlantic and leads to more rainfall in the central and eastern US. On decadal to multi-decadal time scales, the AWP warming corresponds to basin-wide warming and results in less precipitation in the central and eastern US. See Figure 1. The difference in the relationship between AWP warming and US rainfall on different time scales is largely due to the sign of mid-latitude SST anomaly. The negative mid-latitude SST anomaly associated with the tripole pattern seems to enhance low sea level pressure over the northeastern North American continent and the barotropic response therein of the AWP-induced baro-tropic Rossby wave. This strengthened low pressure system, which does not occur when AWP warming is basin-wide, results in very different moisture transport and alters the rainfall pattern over the U.S.

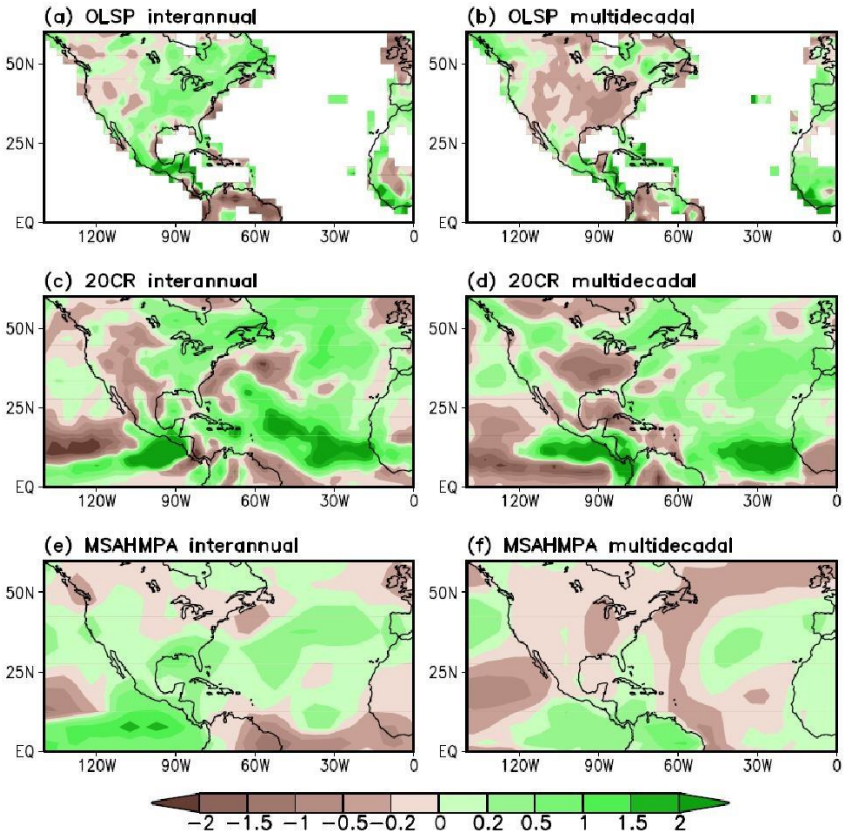


Figure 1: (left) Regression of the precipitation data from (a) OLSP, (c) 20CR and (e) MSAHMPA onto interannual band AWP index. (right) Regression of the precipitation data from (b) OLSP, (d) 20CR and (f) MSAHMPA onto AWP index of decadal-to-multidecadal band.

Research Performance Measure: Our primary research objective was met in that we were able to link specific AWP variability with changes in regional climate impacts.

Simulation of the Argo Observing System

Project Personnel: I. Kamenkovich, and A. Haza (UM/RSMAS)
NOAA Collaborator: C. Schmid (NOAA AOML)
Other Collabortors: 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: OAR/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.

For these OSSEs, we employ one of the most comprehensive numerical models of the World Ocean: the high-resolution ($1/12^{o}$) global Hybrid-Coordinate Ocean Model (HYCOM), which has been used extensively at the National Research Laboratory. The simulations without Argo floats have already been carried out, and all the fields needed for OSSEs have been archived. The simulated stratification closely resembles observations, and the eddy field is sufficiently realistic. In our OSSEs, Argo floats move with the oceanic currents, and take profiles in ways similar to the actual array. The deployment sites and times also 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 float trajectories exhibit strong signature of the mesoscale variability, particularly in such eddy-rich regions as the vicinity of the western boundary currents and the Southern Ocean. Movement of floats plays an important role in determining spatial coverage. Identification of regions corresponding to strong eddy dispersion is important, since these will require continuing redeployment of the floats.

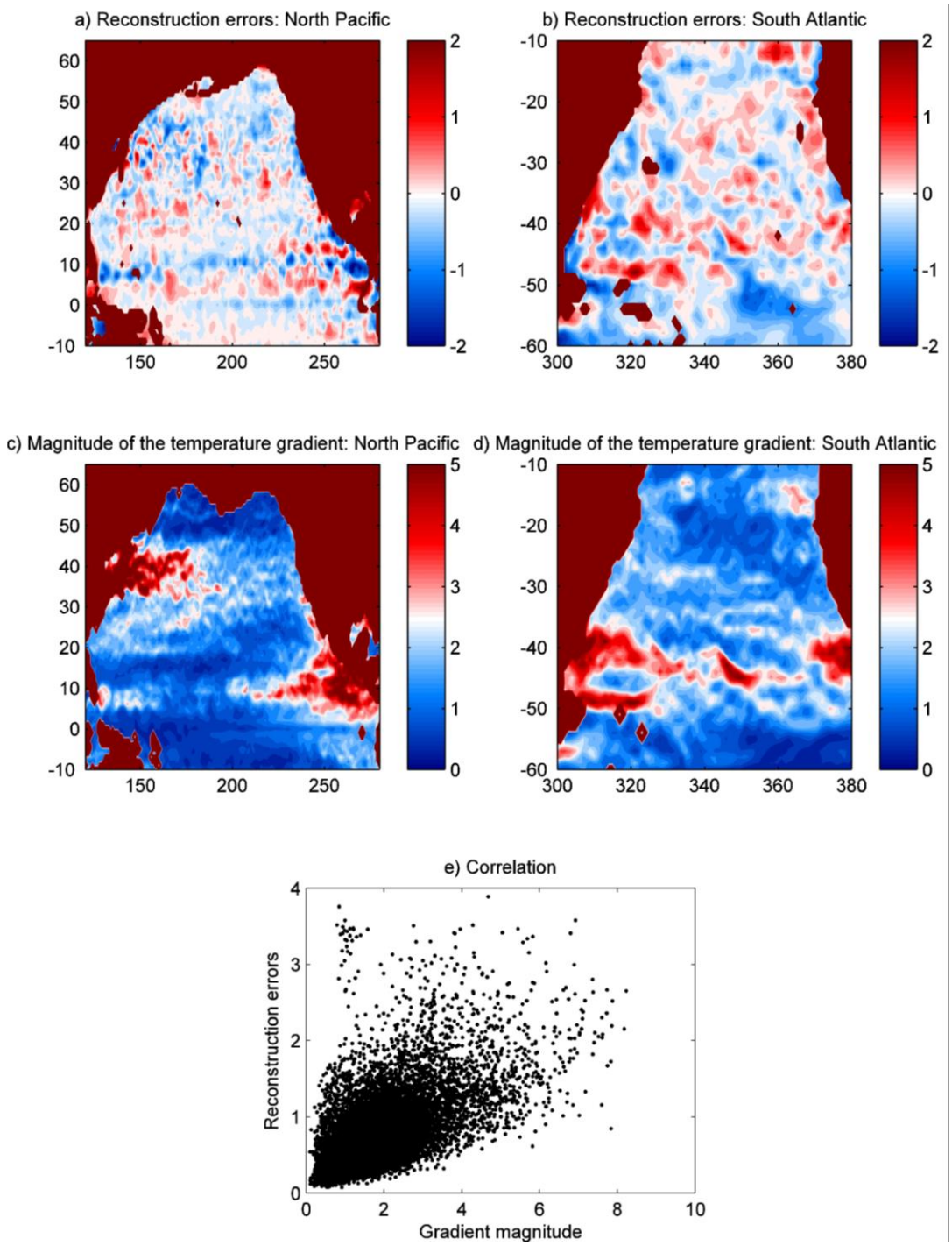


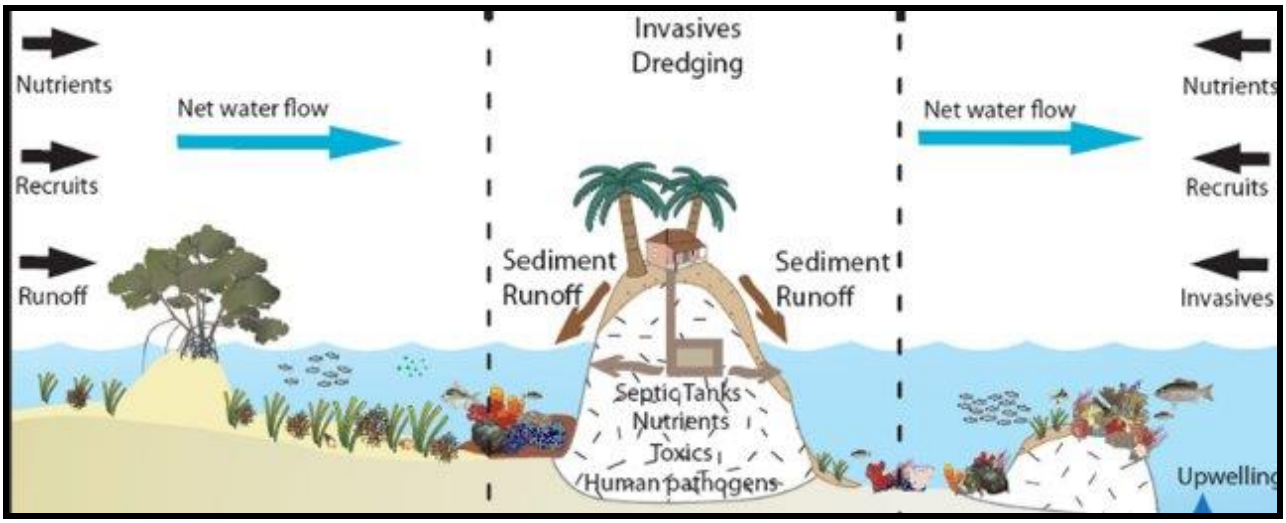
Figure 1: Reconstruction errors and their causes. The reconstruction errors (top row) and the magnitudes of the gradient (middle row) are shown here for the annual-mean temperature at 50m depth, for the North Pacific (left column) and South Atlantic (right column). The largest errors are found in the regions with the sharpest gradients. The correlation between the reconstruction errors and the magnitude of the gradient is shown in panel "e" for all levels and months. The correlation is 0.78.

We use the **reconstruction errors** – the differences between the reconstructed (gridded) and actual model-simulated fields – as a convenient metric for the evaluation and development of the analysis techniques, as well as for the optimization of the observing system. In particular, these errors assist in interpretation of such important deliverables of observing systems as the upper-ocean temperature, heat content and heat transport. The reconstruction errors exhibit a complex spatial pattern (Fig.1a-b), with maxima corresponding to regions with strong spatial and temporal variability in sampled fields (Fig.1c-d).

We examined the relationship between the magnitude of the reconstruction errors and other factors, and find the magnitude of the reconstruction errors to be most strongly correlated with the strength of variability in the sampled fields (correlation of 0.78; Fig.1e). The density of the spatial sampling coverage, in contrast, was found to be significantly less important.

The results emphasize the need for denser sampling coverage in the regions with sharp gradients and fronts. Such regions are also characterized by powerful oceanic currents, which strongly influence the reconstruction from the data obtained by moving profiling floats. The results suggest that the most efficient design of any observing system should not aim at obtaining uniform spatial coverage, but rather focus on regions with the highest variability and strongest advection. A set of carefully designed OSSEs can be particularly helpful in this regard.

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



VI. RESEARCH REPORTS

THEME 5: Ecosystem Modeling and Forecasting

Evaluation of Management Strategies for Fisheries Ecosystems

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 and to improve fishery assessment methodology.
***Strategy*:** To develop ecosystem models based on both individual-based modeling (IBM) and the Atlantis whole-ecosystem modeling framework, and to develop statistical methods for using tagging data.

CIMAS Research Theme:
***Theme 5*:** Ecosystem Modeling and Forecasting (*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: NMFS/SEFSC
NOAA Technical Contact: Theo Brainerd

Research Summary:
The UM ecosystem modeling component of this project has been collaborating with Cameron Ainsworth of U.S.F., and Michael Schirripa and others at NOAA/SEFSC to develop an ecosystem model for the Gulf of Mexico, using the Atlantis modeling framework. The model is now capable of producing a dynamic representation of the Gulf ecosystem in either 1980 or 2010, and Dr. Ainsworth's team are tuning the model to be consistent with the fisheries catches over the last thirty years. UM Ph.D. students Holly Perryman and Matt Nuttall contributed data analyses to inform the parameterization of the model, including an analysis deep sea benthic organism abundance and distribution and an analysis of the catch data from the U.S., Mexico and Cuba.

UM Ph.D. student Bill Harford, defended his dissertation, entitled *Integrated monitoring and stock assessment of spatially heterogeneous reef fisheries*, in December of 2013. He used a spatially explicit individual-based model (IBM) to evaluate how precision of spatially-stratified surveys influenced fisheries stock assessment and fisheries management for a black grouper (*Mycteroperca bonaci*) fishery within the Florida Keys reef tract. The IBM simulations were used to find ways to reduce the negative impacts of bias and imprecision in survey sampling on fishery assessment and management.The simulation framework was also used to evaluate whether a spatially explicit mark-recovery approach could accurately estimate exploitation status of a spiny lobster (*Panulirus argus*) fishery in Belize that occurs near a no-take marine reserve.

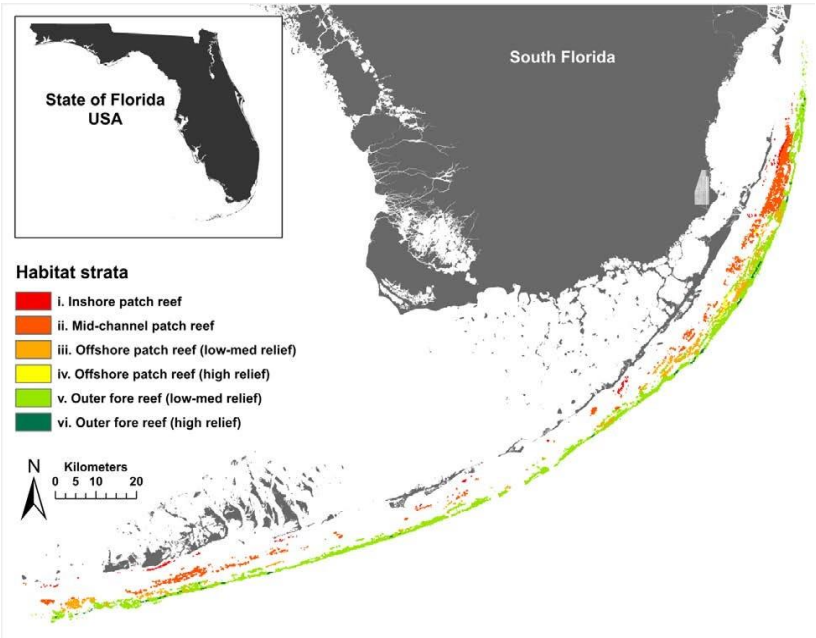


Figure 1: An improved statistical methodology for analyzing visual survey data found that pre-exploitation size black grouper have different distributions across depth in different habitat types in the Florida Reef Tract. This information informed a simulation test of management strategies for black groupers. (From the dissertation of William Harford, December, 2013)

VIMS student Lisa Ailloud conducted a simulation study of the effects of errors from cohort slicing (a method of estimating fish age from length) on estimates of fishing mortality from catch curve analysis (Ailloud et al. in press). This study used Swordfish as a case study. The study will be expanded to see how errors from cohort slicing affect the assessment of Bluefin tuna. Dr. Hoenig's lab also published a study of gear selectivity as estimated from tagging data (Myers et al. 2014;

Smith et al. 2014). A study design for evaluating mixed stock assemblages using pop-up satellite tags was conducted. Another study evaluated how much tagging data would be needed to obtain estimates of survival for Bluefin tuna. The study of Bluefin tuna growth based on tag returns is now being incorporated into an integrated model to estimate growth parameters from all available data. A fishery independent survey for blacktip sharks in western Florida is under development for use as an abundance index in the stock assessment.

Research Performance Measure: All of the objectives of this proposal were met or are in progress:

1. *Develop methodology to characterize trade-offs reef fish management objectives for spatial management strategies under uncertainty about the spatial dynamics of marine populations.* Dr. Bill Harford completed this objective with his dissertation, defended in December, 2013. He is in the process of submitting the chapters to the peer-reviewed literature.
2. *Develop an ecosystem model for the Gulf of Mexico using the Atlantis modeling framework*. This work is ongoing. The model is currently running for two snapshots in time, and the team is working on getting it to run across the time series. We expect the model to be fully operational for management strategy evaluation by the end of the study period.
3. *Evaluate tagging models for stock assessment*. Dr. Hoenig's lab conducted several studies on tagging models, as well as age-slicing models. This work is ongoing.
4. *Hold workshops on fisheries quantitative methods*. In November of 2013, Dr. Babcock taught a short course on Bayesian Statistical methods at the Southeast Fishery Science Center.

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Targeted Products for Improving Ecosystem-Based Fishery Management in the Gulf of Mexico

Project Personnel: D. Die (UM/RSMAS)
NOAA Collaborators: M. Karnauskas, X. Zhang, C. Porch, and M.l Schirripa (NOAA/SEFSC)
Other Collaborators: J. Simons (Center for Coastal Studies, Texas A&M); H. Liu (Department of Marine Biology, Texas A&M)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** 1) Explore the utility of nonlinear time series (NLTS) models for forecasting stock abundance of fish populations in the Gulf of Mexico. 2)Support the development of a publically-available trophic database for the Gulf of Mexico

***Strategy*:** 1) Conduct NLTS analysis on catch, size, and age composition data for East and West Gulf red snapper; to understand whether East and West stocks are dynamically coherent; to compare forecasts produced from NLTS models and the conventional stock assessment methods; to examine possible associations between the stock trends of Gulf red snapper and other relevant species and environmental variables. 2) Extract, compile, edit, and serve diet data for fishes in the Gulf of Mexico that are priority species for ecosystem-based fisheries models in the Gulf; edit and test all extracted data that is loaded into the GoMexSI database; and continue to refine and enhance the GoMexSI database and webpage interface.

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:
The TAMU-G portion of the project involved intensive collaboration with NMFS/SEFSC Personnel. TAMU-G employee Dr. Hui Liu is responsible for overseeing and carrying out the NLTS analyses for this project. During the report period, we have progressed on the work planned for this project. Through the NOAA/SEFSC collaborators Dr. Liu familiarized himself with a suite of abundance time series (Fig 1) currently incorporated in stock assessment of red snapper in the Gulf of Mexico (GOM). Dr. Liu is currently working on running analyses with 1) a set of abundance time series (landings, survey biomass and discards etc) to characterize the dynamics of Gulf red snapper, 2) comparing the dynamics of abundance time series separated as east and west GOM, 3) potential associations between the stock trends of red snapper and relevant environmental variables in the GOM. We have found differences in dynamics of red snapper populations separated as east and west GOM (Fig 2). Additionally, each of them has different patterns in response to the environmental indicators. These analyses are helpful to identify the potential ecosystem components affecting the dynamics of red snapper, which can be further considered to be included in assessments. There has been a debate about population structure of red snapper in GOM (i.e., single stock or two separate stocks) based on evidences from research of genetics and otolith microchemistry. Our analyses illustrate some evidences for the idea of two stocks from a new perspective of thinking about population dynamics of marine fishes in relation to environmental conditions. Further analyses are currently underway.

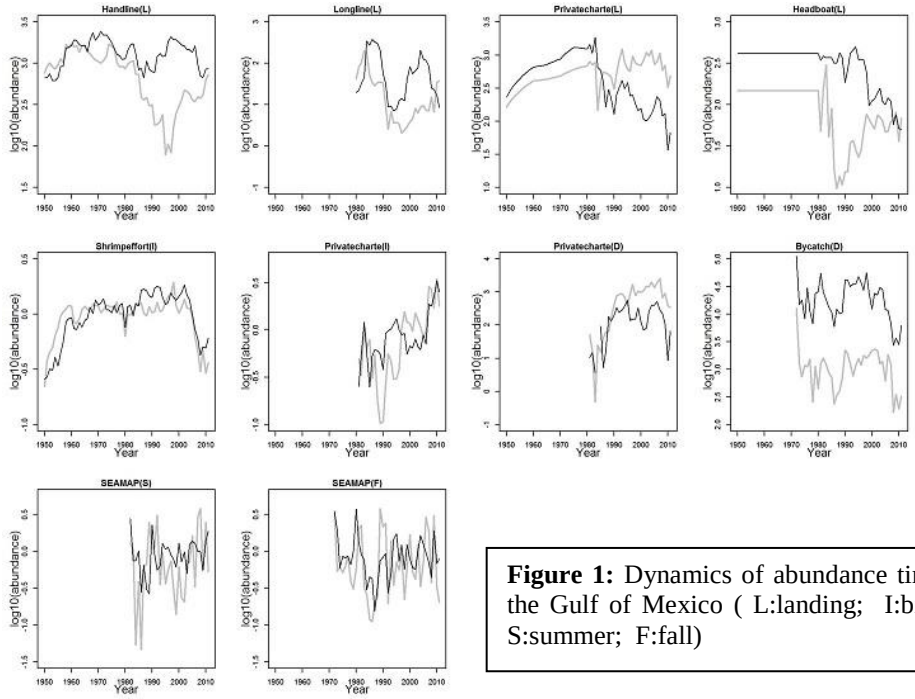

Figure 1: Dynamics of abundance time series of red snapper in the Gulf of Mexico (L:landing; I:biomass indices; D:discards; S:summer; F:fall)

The TAMU-CC portion of the CIMAS project funded through TAMUG was finalized on March 12, 2014. The primary activity had been the recruiting and hiring of a three quarter-time biological database technician. Three candidates were interviewed, all of whom had BS degrees in biology/marine biology. Theresa Mitchell was hired with an effective start date of May 1, 2014; she has been working on the GoMexSI database for almost two years through other grants. She will primarily be engaged in getting more data into the GoMexSI database. Since being hired she has been editing and preparing about 6000 lines of data for upload into the database. These are data that had been entered through another grant for GoMexSI data entry, but had not been fully edited for upload. She has also helped to prepare species lists for future consideration for collection of specimens for gut content analysis for the database. Three people were also trained to use Wordpress software to edit, update and enhance the GoMexSI webpage, through which the GoMexSI data is served. Near future activities include a small purchase order for some software work to enhance the functionality and data serving capability of the GoMexSI database/website.

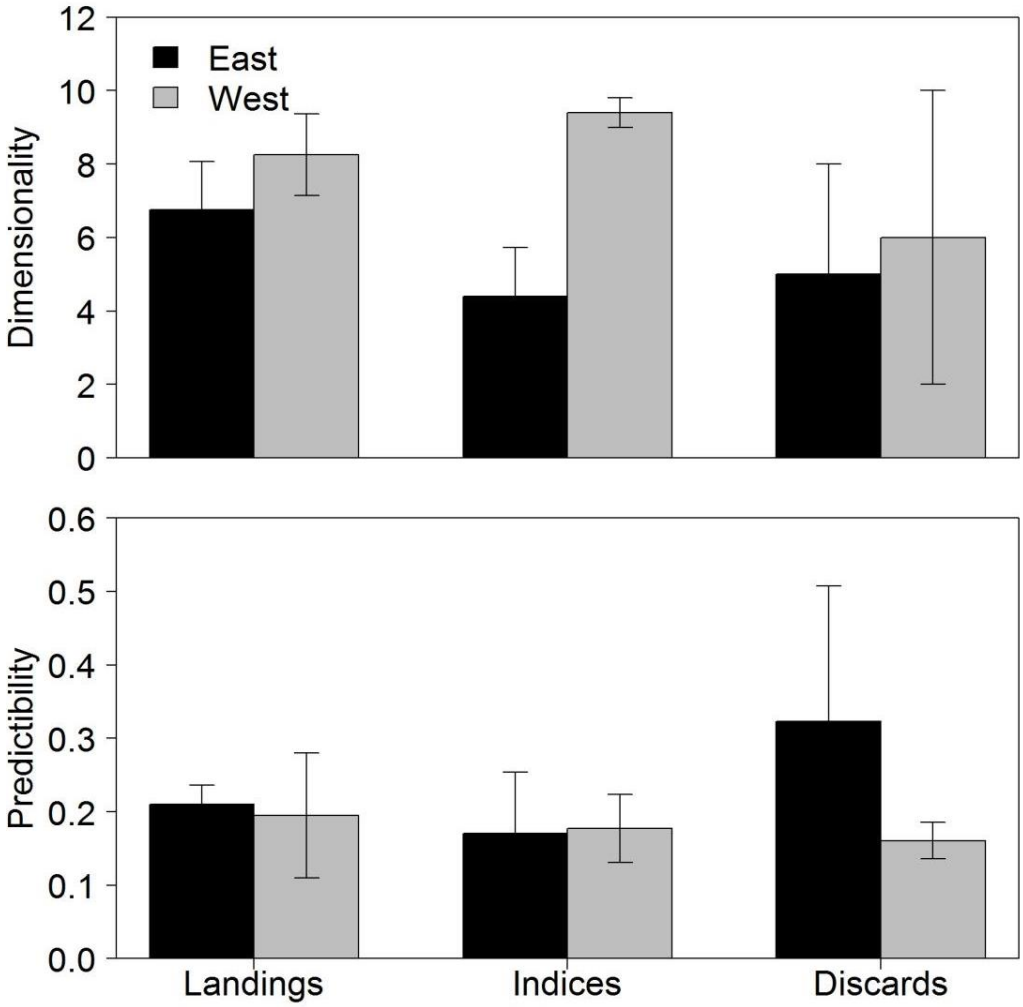

Figure 2: Comparison of dynamical characteristics of red snapper separated as east and west Gulf (Error bar: S.D).

Research Performance Measure: The project is attaining all its goals on schedule.

Using Generalized Linear Models and Generalized Additive Models to Produce Distribution Maps for NOAA's Integrated Ecosystem Assessment Program

Project Personnel: A. Grüss and S.R. Sagarese (UM/CIMAS)
NOAA collaborator: J. Walter III, M. Karnauskas, M.J. Schirripa, and M. Campbell (NOAA/SEFSC)
Other collaborators: M. Drexler, and C.H. Ainsworth (USF)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To develop habitat models (generalized linear models – GLMs – and generalized additive models - GAMs) to produce maps of abundance and egg production to be used in studies conducted under the auspices of NOAA's Integrated Ecosystem Assessment program.
***Strategy*:** To benefit from the experience of habitat modelers and from long-term survey data collected by NOAA/NMFS to develop reliable habitat models for different life stages of species/groups of species inhabiting the Gulf of Mexico at different seasons.

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

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

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

Research Summary:
We have conducted two studies for the present project. The first study consisted in developing delta generalized additive models (GAMs) to produce distribution maps for the ecosystem models OSMOSE-WFS (OSMOSE model of the West Florida Shelf) and Atlantis-GOM (Atlantis model of the Gulf of Mexico) (Fig. 1). This first study is completed. The second study, which is still underway, consists in developing generalized linear models (GLMs) to map the abundance and egg production of two socio-economically important species of the northern Gulf of Mexico, red grouper (*Epinephelus morio*) and gag grouper (*Mycteroperca microlepis*). This second study will be useful to: (1) improve some of the distribution maps produced for the ecosystem model OSMOSE-WFS; (2) obtain maps of egg production for red grouper and gag grouper so as to simulate the larval dispersal of these species with the Connectivity Modelling System; and (3) obtain distribution maps for red grouper and gag grouper so as to evaluate the degree of spatial overlap between these species and red tide events in the northern Gulf of Mexico over the recent years.

Our delta GAM approach predicts the spatial distribution of different life stages of the multiple functional groups represented in OSMOSE-WFS ('life-stage groups') at different seasons, over the entire Gulf of Mexico (GOM) shelf including areas where abundance estimates do not exist, using different research survey datasets and regional environmental and habitat features. Our delta GAM approach consists of fitting two independent models, a binomial GAM and a quasi-Poisson GAM, whose predictions are then combined using a delta method to yield spatial abundance estimates

(Fig. 2). Research survey datasets used to fit delta GAMs include the SEAMAP groundfish/trawl, NMFS bottom longline and SEAMAP reef fish video datasets. Predictor variables included in the binomial and quasi-Poisson GAMs are temperature, sediment type, depth, chlorophyll a and dissolved oxygen.

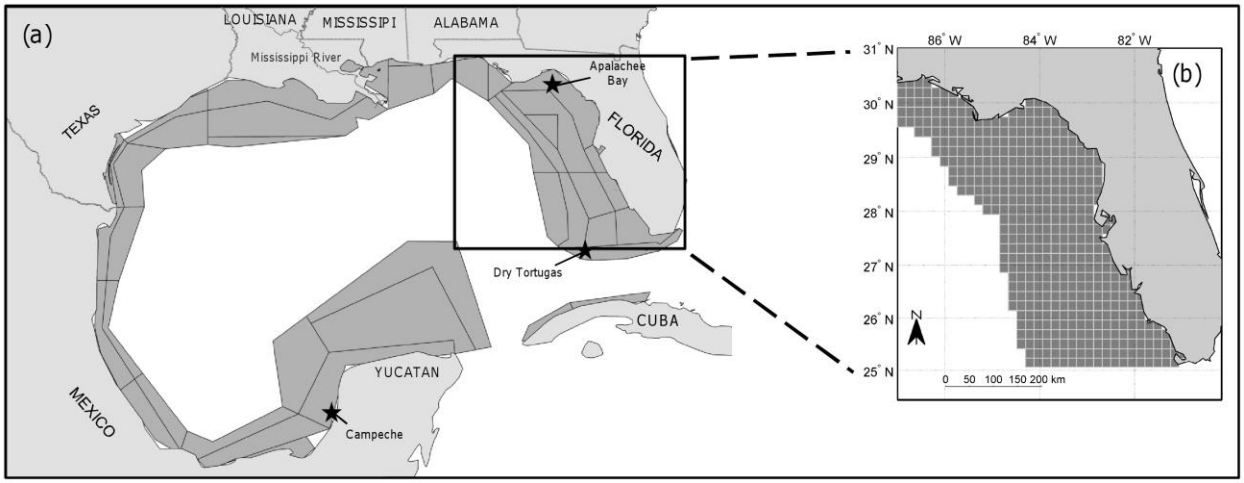

Figure 1: Study areas. **(a)** Map of the Gulf of Mexico showing the spatial polygons of the Atlantis-GOM ecosystem model (filled in dark grey). Black stars indicate the location of the Dry Tortugas, Apalachee Bay and Campeche. **(b)** Map of the West Florida Shelf in the Gulf of Mexico showing the spatial cells of the OSMOSE-WFS ecosystem model (filled in dark grey).

To validate our delta GAMs, bootstraps were used and Spearman's correlation coefficients (Spearman's ρ's) between predicted and observed abundance values were estimated and tested to be significantly different from zero. We used pink shrimp (*Farfantepenaeus duorarum*) to demonstrate our delta GAM approach by predicting the summer distribution of this species over the GOM shelf and the West Florida Shelf.

Predictions of the delta GAM reflected existing empirical research related to pink shrimp habitat preferences and predictions of a negative binomial GAM previously designed for the GOM. We found that using a delta rather than a negative binomial GAM saves significant computation time at the expense of a slight reduction in GAM performance. A positive and highly significant Spearman's ρ between observed and predicted abundance values indicated that our delta GAM can reliably be used to predict pink shrimp spatial distribution.

Spearman's ρ was also positive and highly significant in every life-stage group represented in OSMOSE-WFS and season, though often low. Therefore, delta GAMs fitted for the different life-stage groups and seasons correctly predict qualitative differences between low- and high-abundance areas and were deemed appropriate for generating distribution maps for OSMOSE-WFS. The delta GAM approach we developed is a simple, convenient method to create distribution maps to be fed into spatially-explicit ecosystem models, where wide spatial and taxonomic coverage is desired while benefits of high precision estimates are lost at run-time.

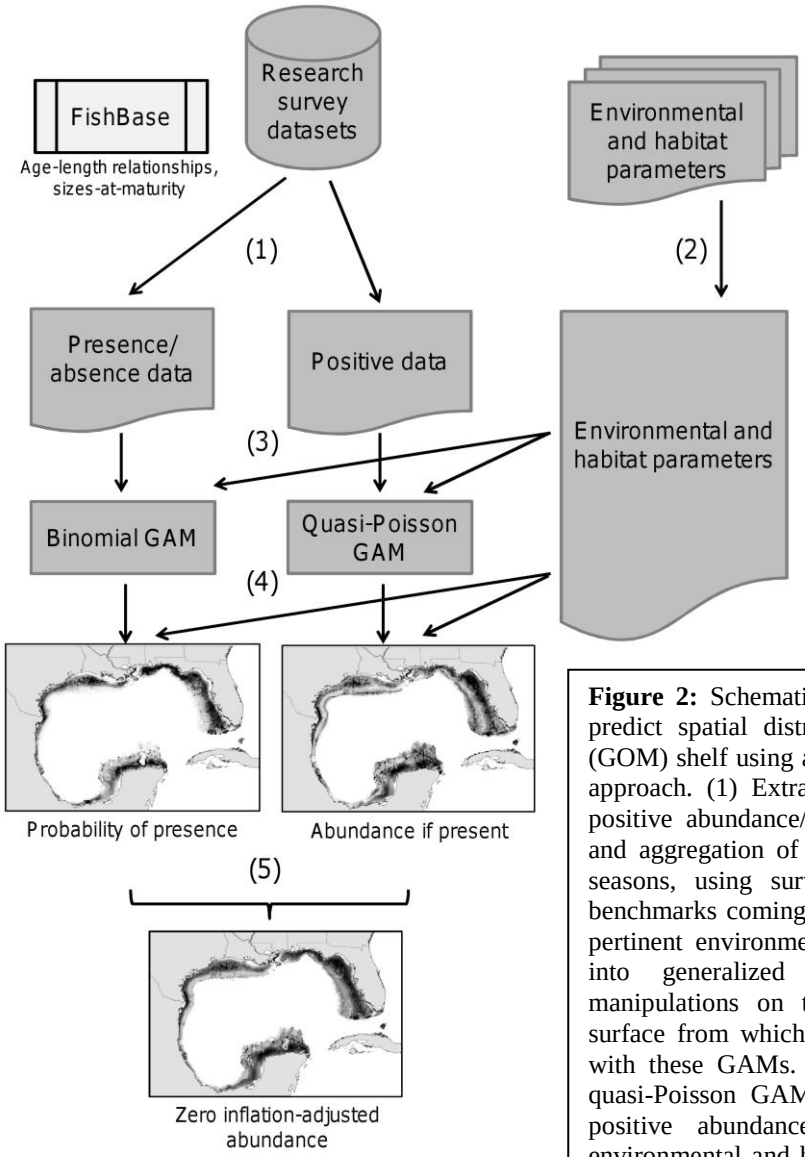

Figure 2: Schematic of the different steps followed to predict spatial distributions over the Gulf of Mexico (GOM) shelf using a delta generalized additive modeling approach. (1) Extraction of presence/absence data and positive abundance/biomass data from survey datasets, and aggregation of these data by life-stage groups and seasons, using survey body size estimates and size benchmarks coming from FishBase. (2) Identification of pertinent environmental and habitat parameters to feed into generalized additive models (GAMs) and manipulations on these data to obtain a contiguous surface from which to fit GAMs and make predictions with these GAMs. (3) Fitting of binomial GAMs and quasi-Poisson GAMs using presence/absence data and positive abundance/biomass data, respectively; and environmental and habitat parameters. (4) Predictions of probabilities of a non-zero event and abundances/ biomasses given a non-zero event over the GOM shelf using binomial GAMs and quasi-Poisson GAMs, respectively; and environmental and habitat parameters. (5) Predictions of spatial distributions over the GOM shelf through the combination of binomial and quasi-Poisson GAMs according to the delta method.

Research Performance Measure: Our objectives for the first study (i.e., the GAM study) were to: (1) have a fully operational framework ready before October 2013 so as to run simulations with the ecosystem model OSMOSE-WFS before the end of 2013; and (2) submit a manuscript on the study to the peer-reviewed journal *Fisheries Research* by the end of 2013. Our only objective for the second study (i.e., the GLM study) was to get started before the end of the fiscal year. All our objectives have been fully met and the manuscript that we submitted to *Fisheries Research* was recently accepted.

Evaluation of the Trophic Structure of the West Florida Shelf in the 2000s Using the Ecosystem Model OSMOSE-WFS

Project Personnel: A. Grüss (UM/CIMAS)
NOAA collaborator: M.J. Schirripa, and M. Karnauskas (NOAA/NMFS/SEFSC)
Other collaborators: D. Chagaris (Fish and Wildlife Research Institute, St. Petersburg); M. Drexler, and C.H. Ainsworth (USF); J. Simons (Texas A&M); Y.-J. Shin, P. Verley, and R. Oliveros-Ramos (IRD, France)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To develop an ecosystem model (OSMOSE-WFS) to provide stock assessments (SEDAR) with parameter estimates and ecosystem considerations each year; to explore the trophic structure of the West Florida Shelf ecosystem in the 2000s; and to estimate size-specific natural mortality rates for a socio-economically important species, gag grouper (*Mycteroperca microlepis*), which was evaluated under the auspices of SEDAR in 2013 (SEDAR 33).

***Strategy*:** To set up collaborations with different American and French research institutes, so as to access the best available information and knowledge to construct, parameterize, calibrate and validate the OSMOSE-WFS model; and to simulate the dynamics of both individual species and large species groups to be able to both deliver information to single-species stock assessments and offer a comprehensive snapshot of the trophic structure and functioning of the West Florida Shelf ecosystem in the 2000s.

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 applied the individual-based, multi-species OSMOSE modeling approach to the West Florida Shelf ecosystem, with the intent to inform ecosystem-based management (EBM) in this region (Fig. 1). Our model, referred to as 'OSMOSE-WFS', explicitly considers both pelagic-demersal and benthic high trophic level (HTL) groups of fish and invertebrate species, and is forced by the biomass of low trophic level groups of species (plankton and benthos). OSMOSE-WFS is currently a steady-state model describing trophic interactions in the West Florida Shelf in the 2000s.

OSMOSE-WFS was calibrated using a recently developed evolutionary algorithm that allowed simulated biomasses of HTL groups to match observed biomasses over the period 2005-2009 (Figs. 2 and 3). The validity of OSMOSE-WFS was then evaluated by comparing simulated diets to observed ones, and the simulated trophic levels to those in an Ecopath model of the West Florida Shelf (WFS Reef fish Ecopath). Finally, OSMOSE-WFS was used to explore the trophic structure of the West Florida Shelf in the 2000s and estimate size-specific natural mortality rates for a socio-economically important species, gag grouper (*Mycteroperca microlepis*).

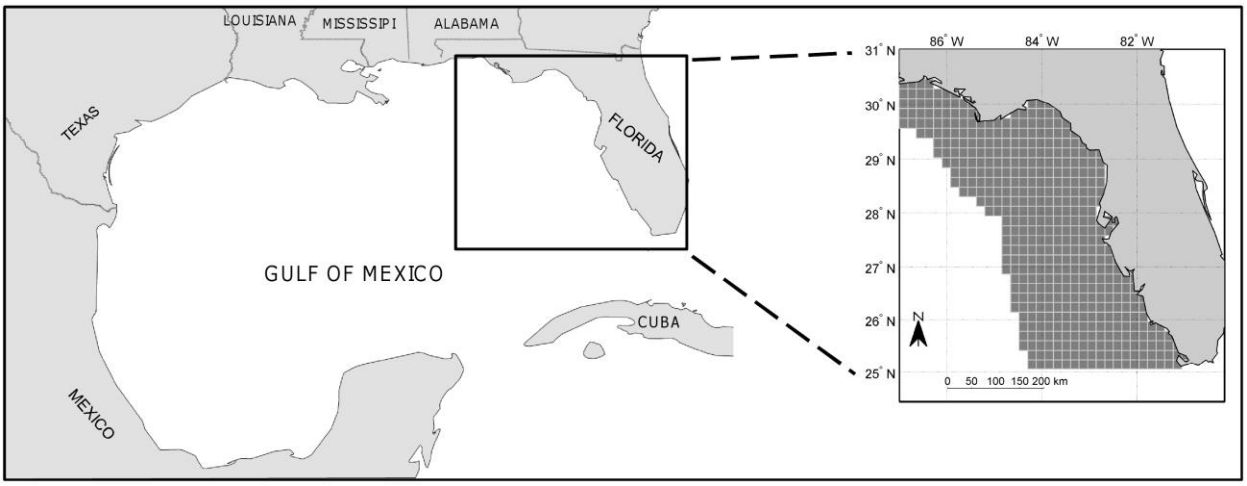

Figure 1: Map of the West Florida Shelf in the Gulf of Mexico showing the spatial cells of OSMOSE-WFS (filled in dark grey).

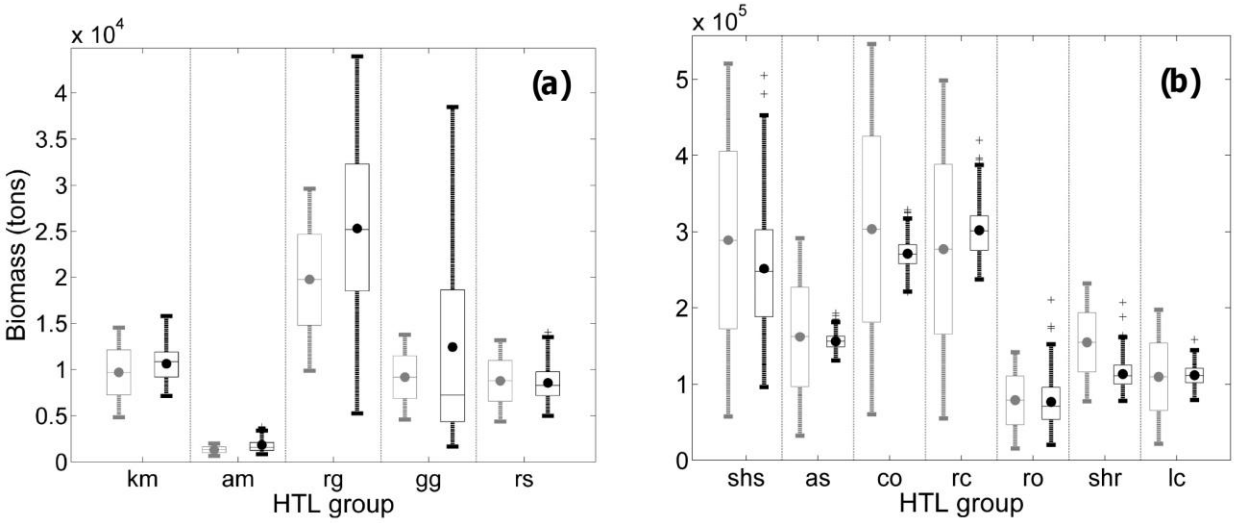

Figure 2: Biomasses observed over the period 2005-2009 (gray boxplots) and predicted by OSMOSE-WFS (black boxplots) for the 12 high trophic level (HTL) groups explicitly considered in OSMOSE-WFS. Mean observed biomasses (gray dots) are associated with valid intervals, i.e., minimum and maximum possible values, accounting for variability and uncertainty of mean biomass estimates over the period 2005-2009. Biomasses simulated with OSMOSE-WFS correspond to mean biomasses (black dots) +/- standard deviations for 10 replicates after 115 to 134 years of simulation. Note the change of scale of the y-axis between the left and right panels. (a) km: king mackerel – am: amberjacks – rg: red grouper – gg: gag grouper – rs: red snapper; (b) shsc: sardine-herring-scad complex – as: anchovies and silversides – co: coastal omnivores – rc: reef carnivores – ro: reef omnivores – shr: shrimps – lc: large crabs.

OSMOSE-WFS outputs are in full agreement with observations as to the body size and ecological niche of prey of the different HTL groups, and to a lesser extent in agreement with the observed species composition of the diet of HTL groups. OSMOSE-WFS and WFS Reef fish Ecopath concur on the magnitude of the instantaneous natural mortality of the different life stages of gag grouper over the period 2005-2009, but not always on the main causes of natural mortality (Fig. 4).

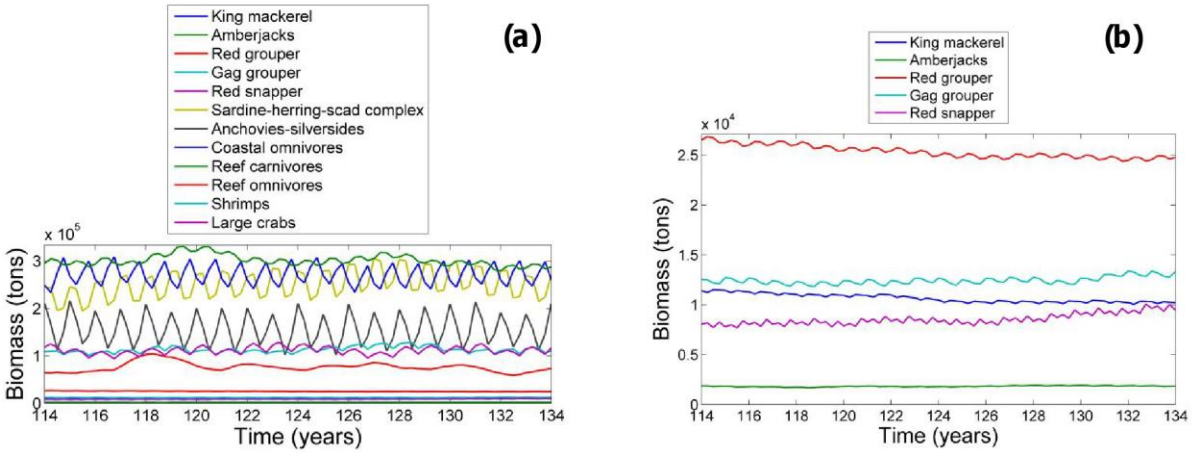

Figure 3: Mean trajectories of biomasses in OSMOSE-WFS (a) after 114 to 134 years of simulation for all HTL groups; and (b) after 114 to 134 years of simulation for king mackerel, amberjacks, red grouper, gag grouper and red snapper. 10 simulation replicates were run to produce these plots.

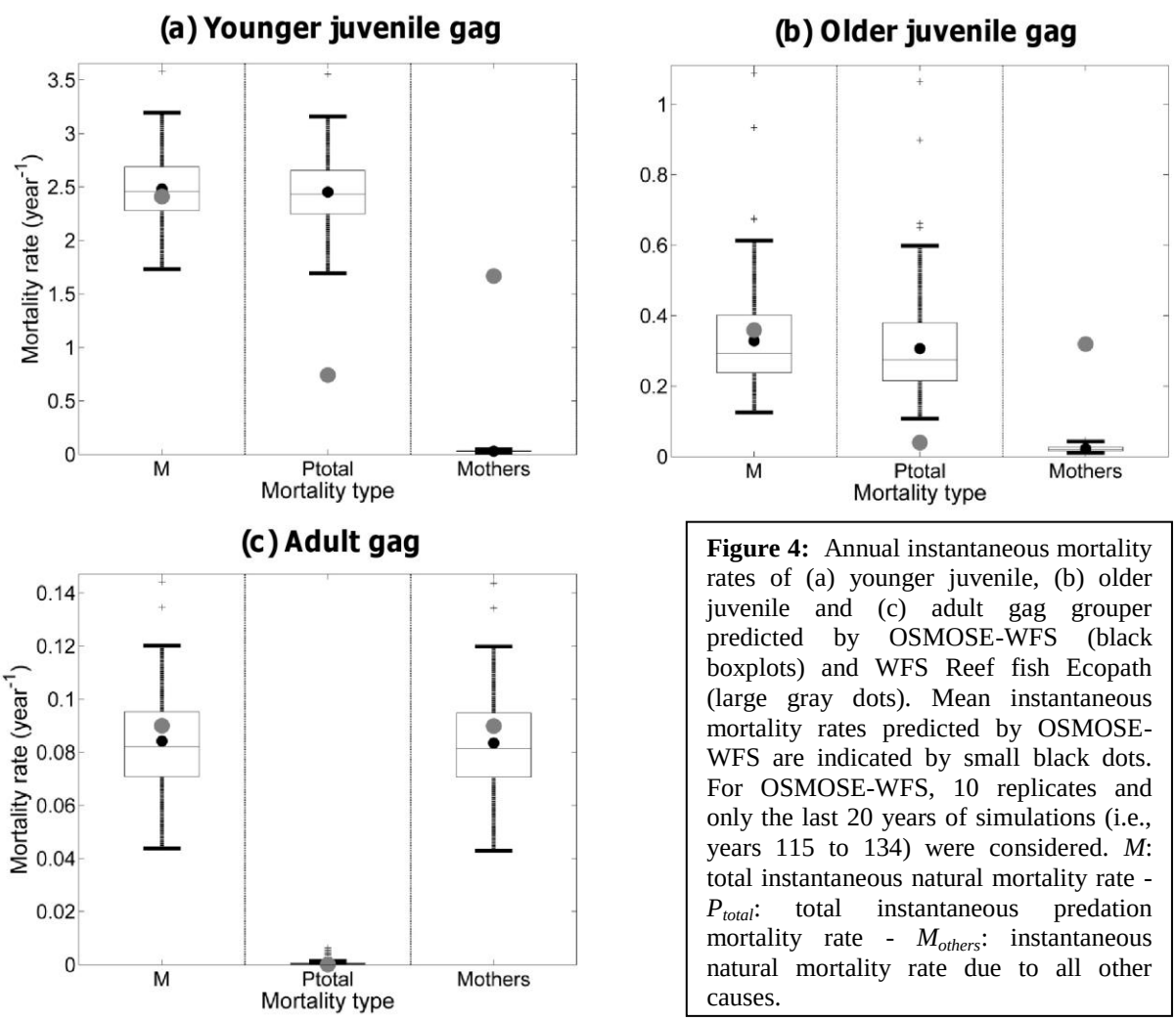

Figure 4: Annual instantaneous mortality rates of (a) younger juvenile, (b) older juvenile and (c) adult gag grouper predicted by OSMOSE-WFS (black boxplots) and WFS Reef fish Ecopath (large gray dots). Mean instantaneous mortality rates predicted by OSMOSE-WFS are indicated by small black dots. For OSMOSE-WFS, 10 replicates and only the last 20 years of simulations (i.e., years 115 to 134) were considered. *M*: total instantaneous natural mortality rate - P_{total}: total instantaneous predation mortality rate - M_{others}: instantaneous natural mortality rate due to all other causes.

The model evaluations we have conducted provides a strong basis for ongoing work exploring fishing and environmental scenarios so as to inform EBM. From simple size-based predation rules, we were indeed able to capture the complexity of trophic interactions in the West Florida Shelf, and to identify the predators, prey and competitors of socio-economically important species as well as pivotal prey species of the ecosystem.

Research Performance Measure: Our objectives were to: (1) have a fully operational steady-state OSMOSE-WFS model before the end of the year 2013; (2) use this model to inform fisheries stock assessments in 2013; and (3) submit a manuscript on the present project to the peer-reviewed journal, *Journal of Marine Systems*, by the end of the fiscal year. All these objectives have been fully met.

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Exploring Nonlinear Time Series Models for Forecasting Stock Abundances in the Gulf of Mexico

Project Personnel: W.J. Harford (UM/CIMAS)
NOAA Collaborators: M. Karnauskas, C. Porch, and X. Zhang (NOAA/SEFSC); B. Linton (NOAA/NEFSC)
Other Collaborators: H. Liu (Texas A&M)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To compare forecasts produced from nonlinear models to those produced from conventional assessment models;
To examine possible associations between stocks, in terms of population dynamics trends to elucidate relationships between the study species and other components of the ecosystem.
***Strategy*:** To achieve these objectives, nonparametric (and nonlinear) time series models were used to describing non-linear stock dynamics without requiring assumptions about underlying mechanistic relationships that are associated with traditional stock assessment modeling.

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* (*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:
We explore the utility of nonlinear time series models in producing short-term forecasts of fish stock abundances in the Gulf of Mexico. These nonlinear models allow for considerable flexibility in representing ecological processes in the ocean, and therefore, serve as useful complements to

traditional stock assessment methods. Nonlinear models are currently incorporated into assessments of stock inhabiting U.S. waters, and we extend their application to the Gulf of Mexico ecosystem.

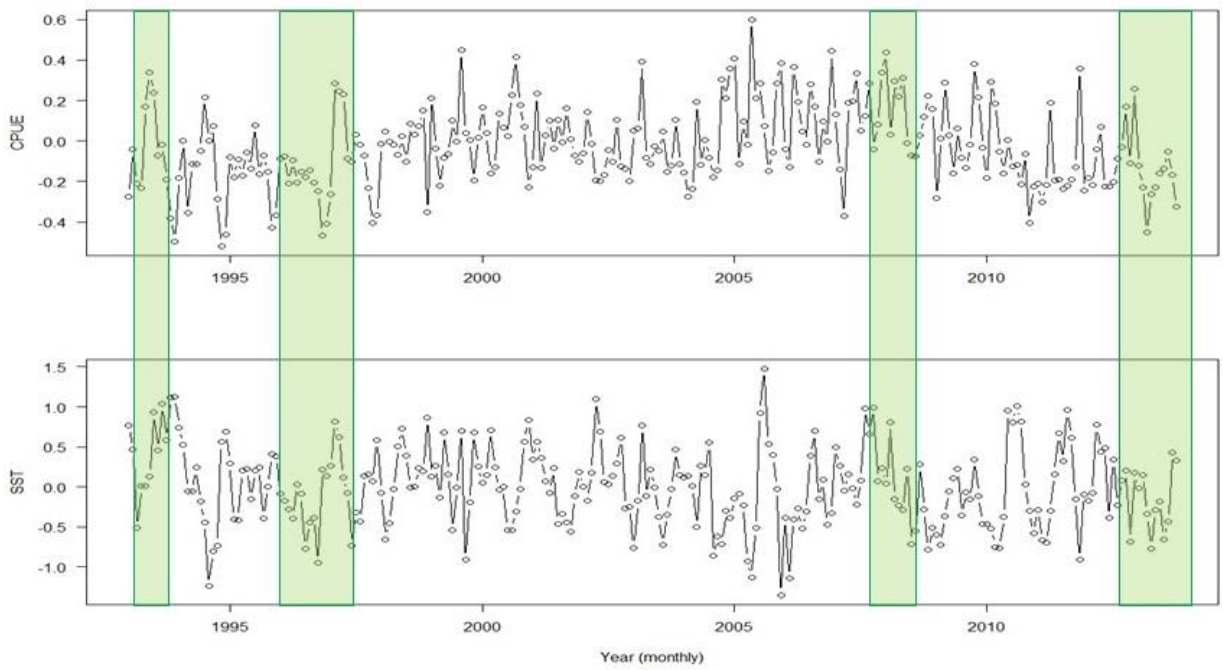

Figure 1: Nonlinear forecasting techniques can be used to detect whether time series share common dynamic histories. Regions of catch-per-unit effort (CPUE) time series that appear to be correspond to trends in sea surface temperature (SST) are shown.

Research Performance Measure: This project has been active for 4 months of the 2014 FY (Feb through May 2014). During period, we have developed a toolbox of the statistical methods necessary to achieve our objectives. Further, these methods were used as part of an integrated ecosystem assessment (IEA) for king mackerel in the South Atlantic, which enabled relationships with ecological drivers of abundance to be explored.

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Caribbean Sea and Gulf of Mexico Bluefin Tuna Research

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

Long Term Research Objectives and Strategy to Achieve Them:
Objectives: To define and investigate bluefin tuna spawning grounds in the western central Atlantic, including the Gulf of Mexico, Caribbean Sea and adjacent regions
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:
The western stock of Atlantic bluefin tuna (*Thunnus thynnus*) is only known to spawn in the Gulf of Mexico and adjacent areas, during spring (April to June). Previous and ongoing collaborations with scientists from UM/CIMAS, NOAA and other domestic and international institutions have confirmed that spawning activity exists throughout the Gulf of Mexico, as well as in the western Caribbean Sea, and north of the Bahamas. However, the northern Gulf of Mexico appears to constitute the main spawning ground.

Our recent research has therefore focused on environmental conditions in the northern Gulf of Mexico, and links to larval ecology and survival. To this end, the 2014 research cruise completed intensive sampling throughout this region, collecting and preserving larvae for studies of growth, condition and feeding patterns. The spatiotemporal extent of sampling was designed to complement the NOAA-led annual spring survey, which was completed on the NOAA ship Oregon II (Figure 1). Scientists from UM/CIMAS, NOAA-SEFSC, NASA, IEO (Instituto Español Oceanográfico, Spain), El Colegio de la Frontera Sur - ECOSUR (México) and Woods Hole Oceanographic Institution participated. The University of Miami research vessel *R/V F.G. Walton Smith* was used for the 28 days of sampling completing 76 stations.

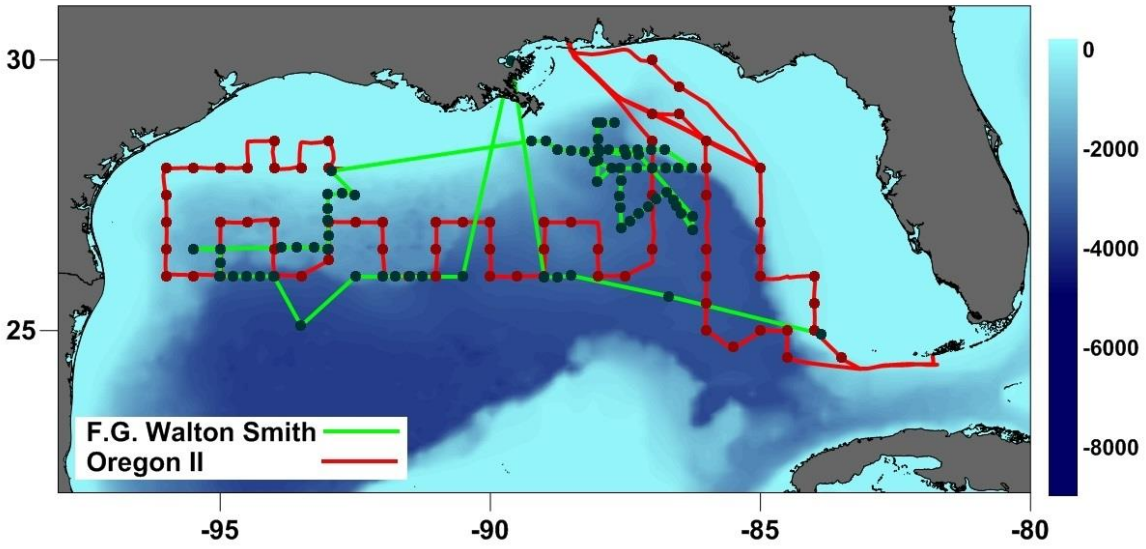

Figure 1: Cruise tracks and sampled stations with the R/V F.G. Walton Smith (University of Miami vessel), and the Oregon II (NOAA vessel). Colored contours show water depth (m).

Similarly to cruises completed in previous years (2009-2013), physical data from CTD casts, and biological data from plankton net tows were collected. Plankton samples were sorted at sea, and preliminary abundances of larval tunas were recorded. A subset of larvae, focusing on bluefin tuna, was then frozen separately in liquid nitrogen, and will be used for tissue stable isotope analyses. Collaborations with the Instituto Español Oceanográfico in Spain will allow us to compare results between the two known spawning grounds of Atlantic Bluefin tuna: the Gulf of Mexico and the Mediterranean Sea.

Preliminary results show two regions of high abundance for larval bluefin tuna (Figure 2). Several larvae were collected in the north-west Gulf of Mexico in early-mid May, and higher abundances were recorded north of the Loop Current, in the central-eastern Gulf.

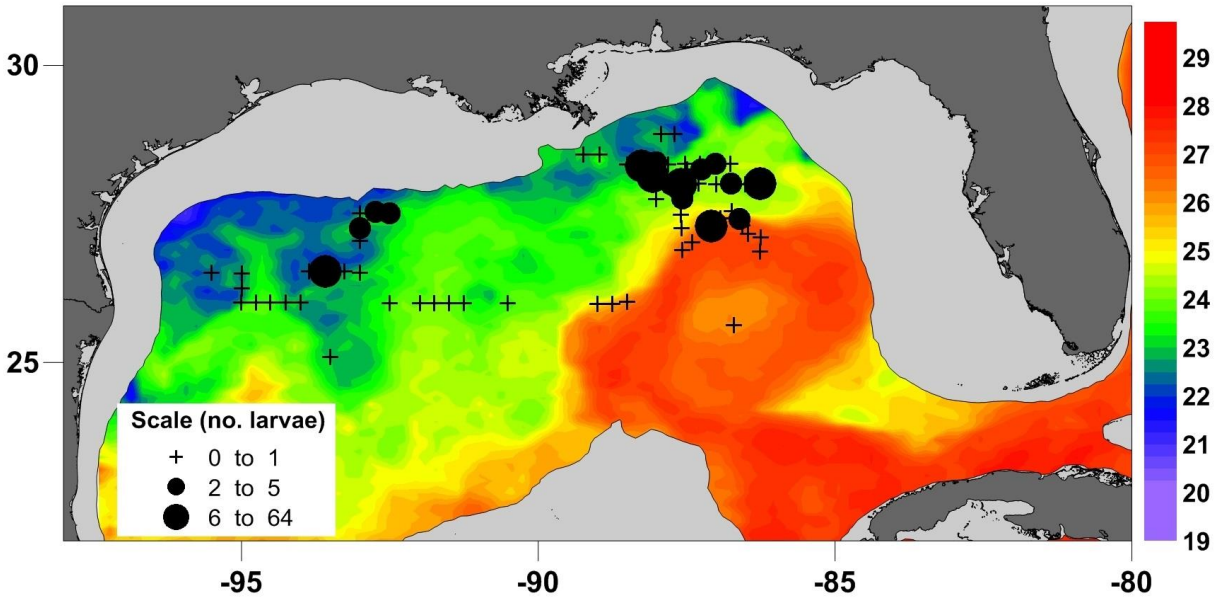

Figure 2: Preliminary abundances of larval bluefin tuna from the 2014 cruise. Colored contours show sea surface temperature from mid-May (°C).

Research Performance Measure: The research program is on schedule. This year's cruise was successfully completed on May 28, 2014; sample processing has started and sorting will begin shortly.

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

Project Personnel: E. Malca, and 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.J. González (MARfund)

Long Term Research Objectives and Strategy to Achieve Them:
Objectives: To establish research priorities in the Meso-American 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 enhance international capacity for 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: SEFSC
NOAA Technical Contact: Theo Brainerd

Research Summary:
Connectivity research has become an ambitious focus through the study of physical and meteorological processes in the ocean that strongly impact biological and ecological populations and communities living in marine and coastal habitats. We utilized existing regional capacity-building collaborations (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 in the Mesoamerican Reef System. Five activities have been carried out (workshop 1: May 17-19, 2010 Chetumal; workshop 2 March 3-4, 2012 in Chetumal with field components in Xcalak National Park, Mexico; Field workshop 1 September 1-8, 2013 and Field workshop 2: February 27-March 6, 2014). Participants in the two field workshops were multifaceted and included university students, park rangers in each country, boaters with unique knowledge in each MPA, taxonomists, conservation biologists, oceanographers, fisheries biologists, as well as volunteers and NGO staff. The total number of people involved was 67 between the two years.

Research Performance Measure: The program has been proceeding as a result of multiple contributions by all partners. Funding, weather and time limitations have reduced the duration of the experiments; however both field workshops were carried out with much effort from all partners. A total of 603 post-larvae and early juvenile fish were captured during the two simultaneous experiments belonging to 20 families, 27 genera and 34 species. Most fish collected were post-larval stages of reef fish although there were also early juveniles.

In addition, the protocols were updated to include both languages (English and Spanish) and were distributed to all participants via e-mail and posted on the project websites. A sixth workshop is scheduled for August 2014 pending participation and funding from our various partners. A multi-lingual larval fish catalog is being generated by ECOSUR-NOAA to be utilized as a field guide to the juvenile fishes of the Mesoamerican Barrier Reef System.

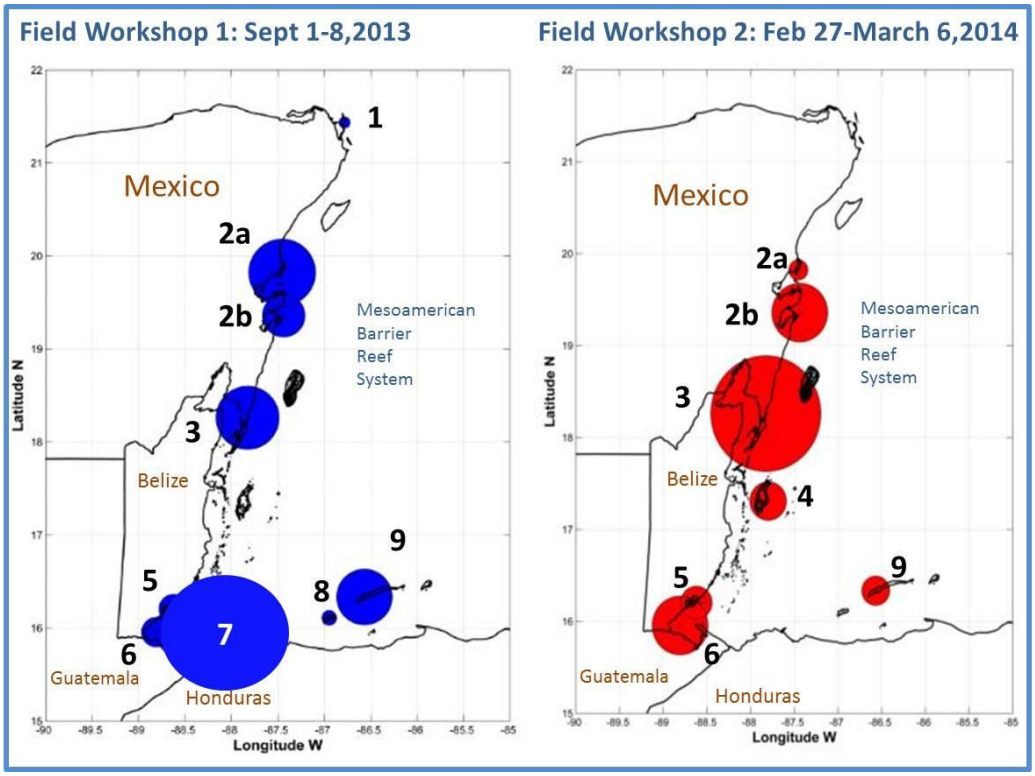

Figure 1: Total fish abundances from simultaneous field exercises in eleven Marine Protected Areas comprising four countries in the Mesoamerican Barrier Reef System carried out in September 2013 and March 2014. MPAs listed in the figure: Mexico: 1) Contoy National Park, 2) Sian Ka'an Biosphere Reserve: a) Bahía Ascensión 2b) Bahía Esp. Santo, 3) Xcalak National Park; Belize: 4) Turneffe Atoll, 5) Port Honduras Marine Reserve; Guatemala: 6) Rio Sarstun, 7) Punta Manabique Reserve; Honduras: 8) Turtle Harbor and Rocky Harbour, Utila 9) Sandy Bay West, Roatan.

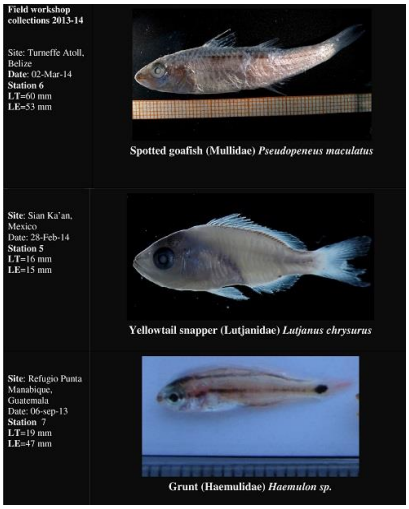

Figure 2: Excerpt from the Larval fish catalog to illustrate the juvenile fishes collected from the field exercise in the Mesoamerican Barrier Reef System.

Living on the (Shelf) Edge: Using Advanced Glider Technology to Assess Fishery Resources Along the South Atlantic Continental Shelf Break

Project Personnel: C. Lembke, A. Silverman, S. Butcher, M. Lindemuth, and S. Murawski (USF)
NOAA Collaborators: T. Kellison and C. Taylor (NOAA/SEFSC, Beaufort, NC Laboratory)
Other Collaborators: D. Mann, and C. Wall (Loggerhead Instruments Inc.); R. He (North Carolina State University)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** (1) Conduct the deployment of a Slocum underwater glider along the southeastern coast from Cape Canaveral, FL to Cape Fear, NC. (2) Use the Southeast Atlantic Bight Gulf of Mexico (SABGOM) nowcast / forecast model to navigate the glider inshore and within the Gulf Stream. (3) Analyze sensor data collected by the glider, with particular focus on passive acoustic recordings of soniferous organisms with intent to: (a) Provide context for relative spatial distributions of multiple species, focusing on red grouper but including others as data permit; (b) location of acoustically detected single- or multi-species "hotspots"; (c) potential locations of winter spawning aggregations for aggregating species.
***Strategy*:** USF's glider, equipped with a suite of biological, physical, chemical, and acoustic sensors was deployed on March 3 and recovered after traversing 900km on April 1, 2014. During the deployment, bi-weekly conference calls were conducted to discuss the glider's progress and forecasted conditions. During the deployment, some glider data was shared near real-time with the broader community through USF's COT Remote Observations Website (http://ooma.marine.usf.edu/CROW/), as well as updates to the Southeast Coastal Ocean Observing Regional Association (SECOORA). Upon retrieval, all data has been downloaded and is being processed.

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

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

NOAA Funding Unit: NMFS ASTWG (via SEFSC)
NOAA Technical Contact: Todd Kellison

Research Summary:
Due to the scope and range of this planned glider deployment, enhanced mission planning was needed to ensure success. Climatology for the water column within the planned trajectory and nearby regions was provided by Dr. He. This included full water column densities and currents for the same time period of 2013. This information was crucial for ballasting the glider properly for a deployment targeted for both cool shelf waters and warm Gulf Stream waters. Utilization of the knowledge of past currents allowed planning for a trajectory that used the Gulf Stream currents to

transit the glider from the mid-Atlantic Florida coast to the shelf break near the southern end of South Carolina, with a ultimate goal of having the glider within 40 to 80m isobaths of the Edisto or North Charleston Marine Protected Areas prior to the full moon of March 16. Lastly, prior to deployment, coordination between USF and NCSU resulted in an enhanced glider tracking page that overlaid SABGOM current prediction models onto the glider track presented on the USF tracking page (link above) to give quick visual information of the glider's current progress and predicted environment (Fig. 1).

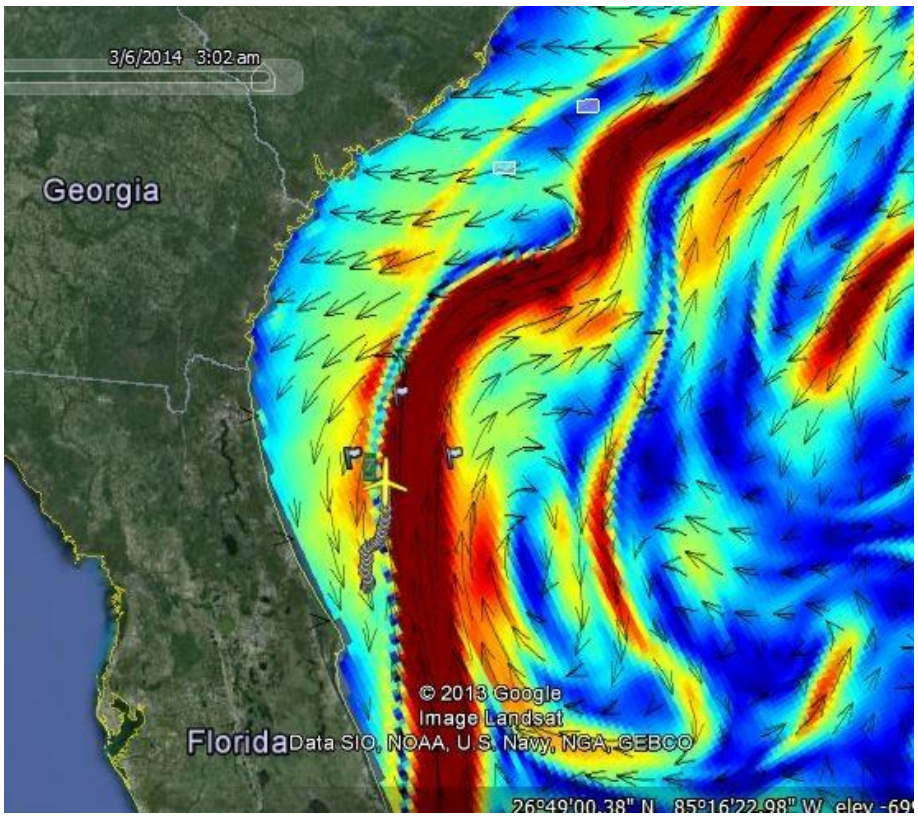

Figure 1: USF's CROW glider tracking Website with integrated NCSU's SABGOM current predictions for March 6, 2014

USF's glider Bass was deployed 160 km ESE of Ponce de Leon Inlet just north of Cape Canaveral, at the 30m isobath on March 3, 2014, from the charter FV Sea Lover by Dr. Kellison, Dr. Taylor, and Mr. Butcher. By March 5 the glider left the shelf region and began entering the Gulf Stream, achieving a maximum estimated speed of 1.7 m/s, compared to an average speed of 0.23 m/s. The glider progressed up the coast until reaching the North Charleston MPA mid-day March 16. For the next two weeks the glider loitered in the region, spending over 90% of the time within the desired depth ranges. A return to the south toward the Edisto MPA was attempted, but prevailing northerly currents prevented timely progress. Throughout the deployment, regular conference calls between the pilots at USF, the modelers at NCSU, and the biologists at SEFSC were conducted to monitor progress and plan coming days to keep the glider in the zones of scientific interest despite the currents. The glider was recovered on April 1, 75km S of Cape Fear by C. Lembke and T. Kellison (Fig. 2).

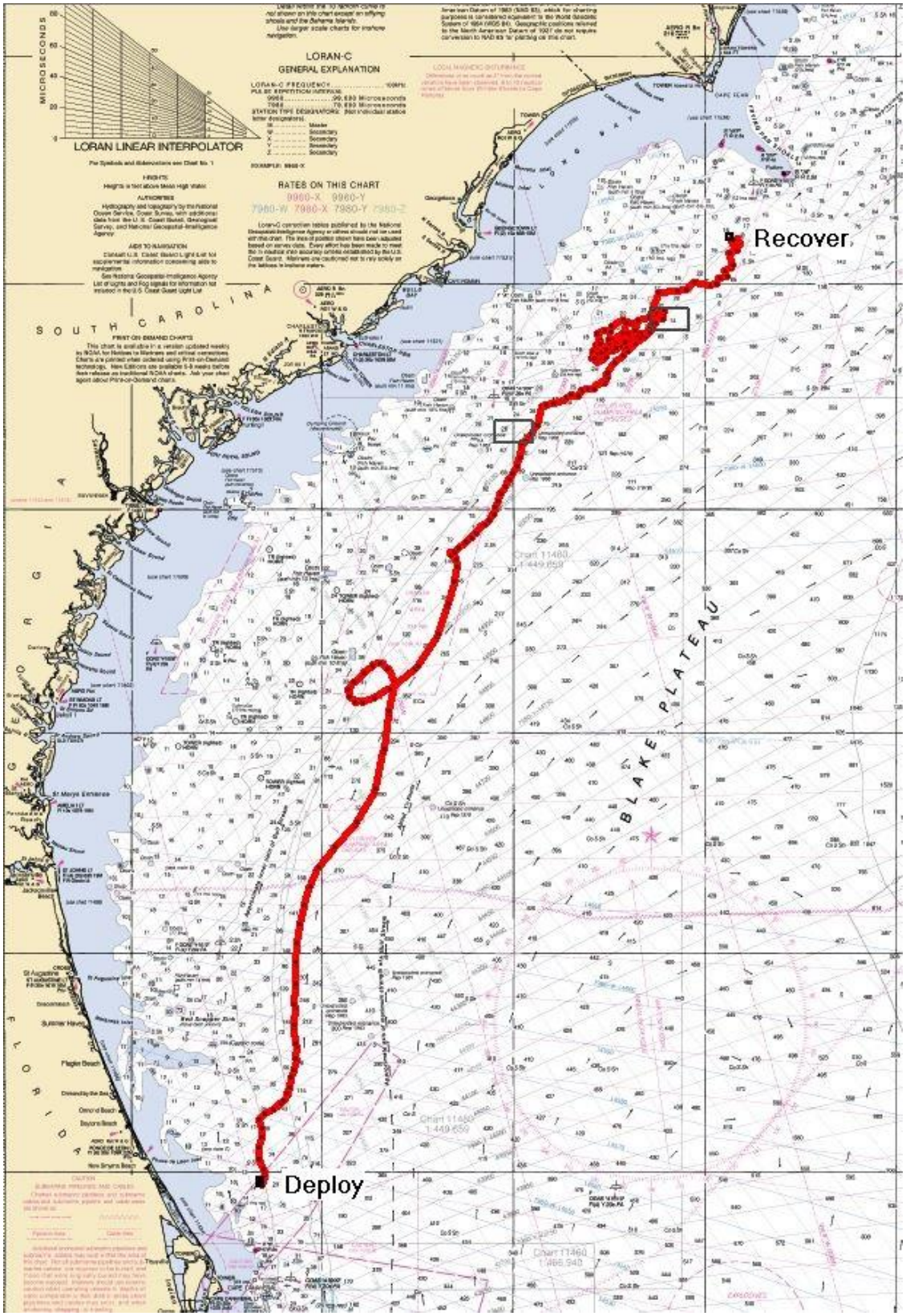

Figure 2: USF glider Bass trajectory from March 3 – April 1, 2014.

The onboard sensor suite for this deployment included the following:

- Seabird SBE-19Plus CTD
- WETLabs Triple Puck (Chlorophyll, CDOM, bb650)
- Aanderraa Dissolved Oxygen Optode 3835
- Loggerhead Instruments DSG Passive Acoustic Recorder
- Vemco VMT-35 Mobile Tag Transceiver (loaned from the Ocean Tracking Network)

A full data set from each sensor was collected and is currently being processed. USF has conducted QA of the CTD, Fluorometer, and Dissolved Oxygen sensors. A plot of the temperature readings recorded throughout the deployment is shown in Figure 3. Loggerhead Instruments (C. Wall) is currently manually processing all recorded acoustic files for known biological sounds. NCSU (R. He) is currently analyzing all physical data and comparing it to model results. The Vemco receiver data has been processed resulting in one tag detected off the coast of South Carolina, a scalloped hammerhead released from Cape Canaveral in June of 2013. Lastly, near real time data was transmitted not only to the research team involved in this project, but to the community at large through SECOORA and the deployment was used as a test case for attempting to transmit data to the IOOS National Glider DAC. While this last effort was not successful by the completion of the mission, valuable information was learned by both USF and the IOOS data managers which has led to enhancements to the uploading procedures and formats.

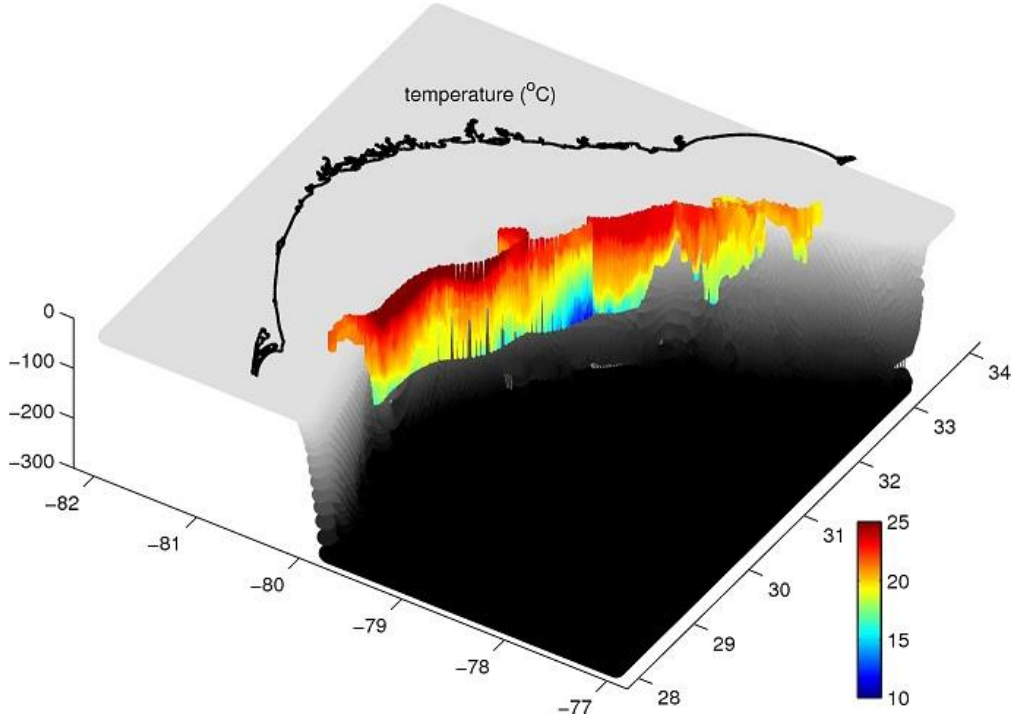

Figure 3: Water column temperature along the glider transect plotted along the South Atlantic Bight.

Research Performance Measures: Objectives 1 and 2 (as described above) were accomplished. Proper planning and preparation utilizing past, current, and forecasted data allowed the glider to navigate the coastal shelf waters and the Gulf Stream within the desired regions. Objective 3 is still in process. We anticipate no problems with any of the data collected. We are hopeful that the resulting data sets will be utilized in publications.

How Precise and/or Accurate do Forecasts of FATE Ecosystem Indicators Need to be to be Useful to Stock Assessments?

Project Personnel: E. Peebles (USF-CMS); M. Murphy (USF-CMS and Florida Fish and Wildlife Commission)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** Our goal is to quantify the level of environmental forecast precision needed to significantly improvement stock assessment projections. This should allow stock assessment scientists to determine if the available climate forecasts instill a meaningful amount of information into stock assessments.

***Strategy*:** We are incorporating an important ecosystem indicator into a typical, single-species population dynamics model and evaluate how stock assessment projections for these populations are affected at various levels of indicator variability. Specifically, we will investigate how various levels of uncertainty in forecasting the winter North Atlantic Oscillation/Gulf Stream North Wall (NAO/GSNW) indexes affect our ability to model and project future swordfish (*Xiphias gladius*) recruitment and stock dynamics.

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:

The population simulator FSIM (Goodyear 2005, philgoodyear@cox.net) has been successfully integrated into the overall analysis so that varying levels of precision for the index linked to recruitment deviations can be explored. Difficulties that have been overcome include: 1) resolving how the spawner-recruit formulation could be translated into the Stock Synthesis (Methot 2013, NOAA Fisheries Seattle, WA) stock assessment program's configuration, 2) accounting for the median-to-mean bias correction in the environmentally-linked, lognormal recruitment deviations, and 3) using the simulator to derive the initial-year conditions for the analyses.

Input for the stock assessment analyses were, for the most part, derived directly from the population simulator though some features of Stock Synthesis required additional information. The assessment program allows for time-specific phasing in the median-to-mean bias correction for recruitment deviation (Methot and Taylor 2011, *Can. J. Fish. Aquat. Sci*. 68:1744-1760), depending on the perceived information content in the data. Because the information content from the simulator was absolute, this "phasing-in" feature was not used as it would be in actual assessment runs. Also, when the simulator was run with very low levels of random variability on catch, index values, and age/length composition sampling, the low coefficients of variation (or large sample sizes) resulted in excessive emphasis on their likelihood components in the assessment model objective function.

These measures of uncertainty used in FSIM were tempered somewhat in the derived Stock Synthesis inputs.

Running the Stock Synthesis model using the simulated data gave estimates of recruitment, stock biomass, landings, and survey indices that closely match the simulation inputs, except when attempts were made to estimate natural mortality or the inherent variability in recruitment. Additional work needs to be done to understand why the Stock Synthesis model does not always return the exact values used to parameterize the simulator. The strategy used to investigate the forecast accuracy accrued by including a recruit-correlated environmental feature in the forecast period was conducted as follows: 1) run a complete scenario with the simulated data, 2) then run a complete-year scenario including only catch (excluding all survey indices, length/age comps, environmental signal) for the final 10-year 'forecast' period, and 3) run a complete-year scenario including only catch and the recruit-correlated environmental signal (excluding the other survey indices, length/age comps) for the final 10 years. The rate of change in the environmental signal (amplitude increase with constant periodicity) and the uncertainty of the environmental index were systematically changed to simulate different levels of environmental variability and forecasting abilities. Very preliminary findings for a simplified, recovering (increasing in abundance and age structure) fish population indicated a general improvement in the accuracy of the mean projected stock biomass as the uncertainty of the environment-based recruitment index decreased from a CV of 0.9 to 0.1 of only about 5-13%. The response of stock biomass to recruitment fluctuations is, of course, dependent on the relative proportion of the stock made up of new or recent recruits. The preliminary analysis was for a recovering long-lived (60 years) fish, so the potential biomass changes were dampened somewhat by the amount of biomass in older age groups.

Another feature of Stock Synthesis, the forecast module, is currently being investigated for similar capabilities to be used in testing the effects of including environment-linked recruitment deviations on stock projections. To gain experience with the performance of this module, I am using it to help evaluate the potential recovery of hogfish, *Lachnolaimus maximus*, in South Florida as part of a Southeast Data, Assessment, and Review (SEDAR 37) being conducted at the Florida Fish and Wildlife Conservation Commission's Fish and Wildlife Research Institute (FWRI).

As the refinements to the simulation programming continues, it is clear that to test the benefits of including environmental forecasts in stock projections it will be important to mimic 'real-world' assessment choices. These often include fixing hard-to-estimate parameters, e.g., natural mortality and initial fishing mortality, and a large degree of uncertainty in all data collected in earlier years.

This work continues to be discussed among colleagues involved in conducting several stock assessments at FWRI, including those for mutton snapper *Lutjanus analis*, hogfish, striped mullet *Mugil cephalus*, black drum *Pogoinas cromis*, and spotted seatrout *Cynoscion nebulosus*. The population simulator, the Stock Synthesis assessment model, and simplified Stock Synthesis - only catch (Cope 2012, *Fisheries Research* 142:3-14) are being used within the FWRI stock assessment group but because this current project is still incomplete there has been no direct application of any results yet. Additionally, analytical tools for retrieving and manipulating satellite-based remotely sensed oceanographic features that may be linked to recruit survival were developed while taking a course on "Remote Sensing in Oceanography" taught by Frank Muller-Karger, College of Marine Science, University of South Florida.

Research Performance Measure: This project is on schedule and is meeting its objectives.

Atlantic Marine Assessment Program for Protected Species in the US Atlantic Ocean: habitat modelling

Project Personnel: J. Ortega-Ortiz (UM/CIMAS)
NOAA Collaborators: L. Garrison (NOAA/SEFSC); D. Palka (NOAA/NEFSC)

Long Term Research Objectives and Strategy to Achieve Them:
Objectives: To develop models and associated tools to translate survey data into seasonal, spatially-explicit density estimates incorporating habitat characteristics for cetaceans and marine turtles.
Strategy: To compile data from aerial and shipboard surveys collected over the last four years, ensuring quality and compatibility between datasets. To import data into a geographic information system (GIS) and format datasets for input into statistical software for habitat modelling.

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

Link to NOAA Strategic Science 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 Atlantic Marine Assessment Program for Protected Species (AMAPPS) is a comprehensive effort to estimate abundance and develop seasonally specific, localized density estimates for marine mammals, marine turtles, and seabirds in the US Atlantic Ocean, from Maine to the Florida Keys. AMAPPS addresses existing data gaps and supports conservation initiatives mandated under the National Environmental Policy Act (NEPA), Marine Mammal Protection Act (MMPA), Migratory Bird Treaty Act (MBTA), and Endangered Species Act (ESA).

The AMAPPS work plan includes seasonal vessel and aerial surveys for marine mammals, sea turtles, and sea birds to quantify abundance and spatial distribution and to produce spatially explicit density distribution maps. The AMMAPS team conducted coordinated shipboard surveys with one vessel in the northeast (NE) and another vessel in the southeast (SE) during the summers of 2011 and 2013. NE and SE coordinated aerial surveys also took place in the summers of 2010 and 2011, winter 2011, spring 2012 and fall 2012. Additionally, aerial surveys were conducted in the SE in winter 2013 and spring 2014. To develop habitat model for cetaceans and marine turtles, we compiled, reviewed and standardized data from all these surveys and formatted it for input into statistical software. We use a 10x10 km grid of the study area to summarize survey effort and sightings in each grid cell. For this purpose, I imported survey data into a GIS and overlaid effort track lines and sightings on the grid. We are also assigning environmental data consisting of static (bottom depth, bottom slope, distance to shore) and dynamic (sea surface temperature, chlorophyll concentration, sea surface height) variables to the grid cells and dates in which effort occurred. Finally, we are developing general additive models and a Bayesian hierarchical framework to characterize the habitat of cetaceans and marine turtles.

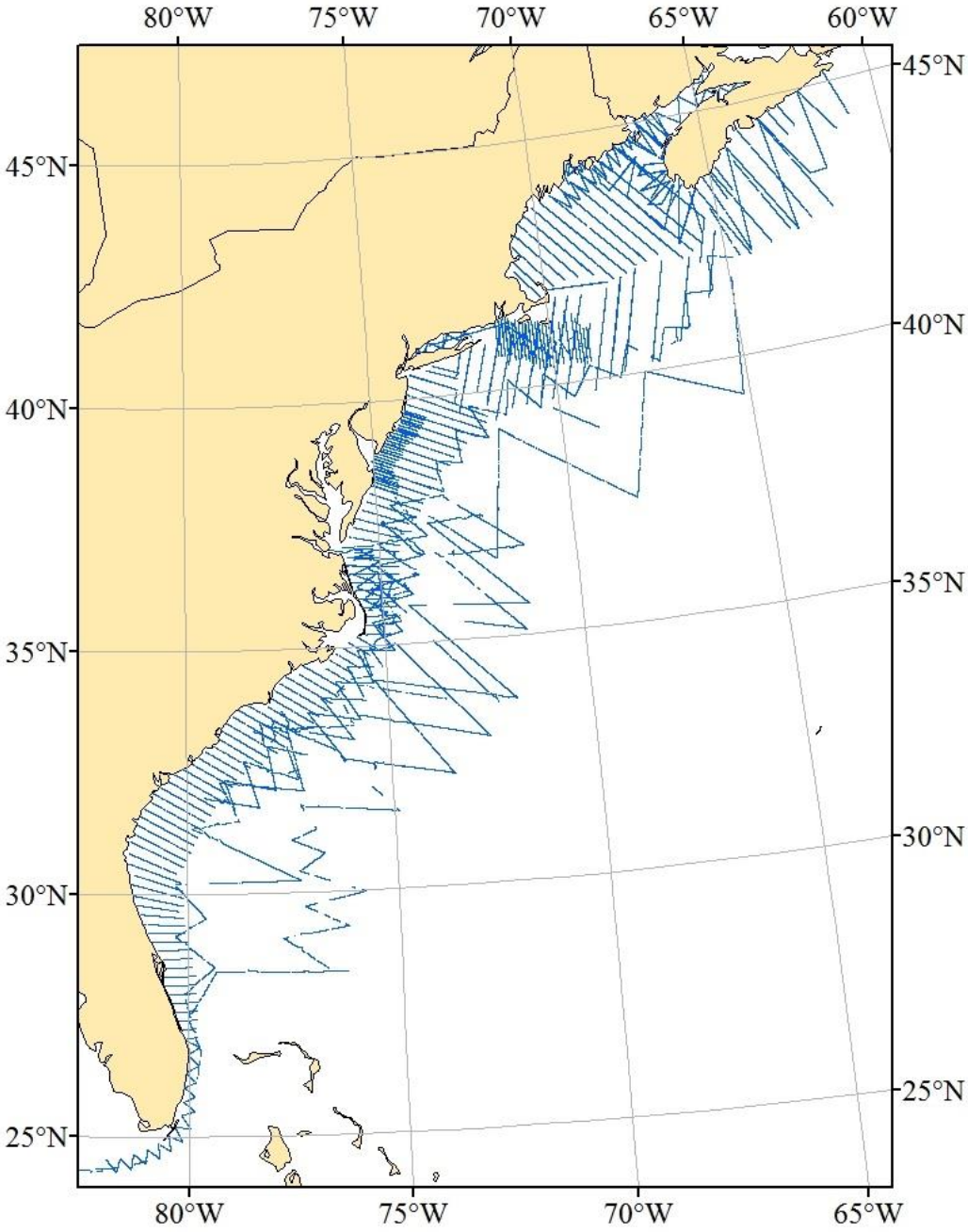

Figure 1: Tracklines of surveys conducted as part of the Atlantic Marine Assessment Program for Protected Species in the US Atlantic Ocean.

Research Performance Measure: All research objectives are being met on schedule. Survey data were imported into GIS, effort and sighting data were assigned to sampling units for analysis, datasets were formatted for input into statistical software and habitat modelling will start by the end of the reporting period.

Courtesy of Daniel Benetti

VI. RESEARCH REPORTS

THEME 6: Ecosystem Management

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

Project Personnel: J. Blondeau (UM/CIMAS)
NOAA Collaborator: J. Bohnsack (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 sampling sites, stretching from Miami to the Dry Tortugas. This year, 354 sites were completed between Miami/Dade and Martin Counties by additional 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.

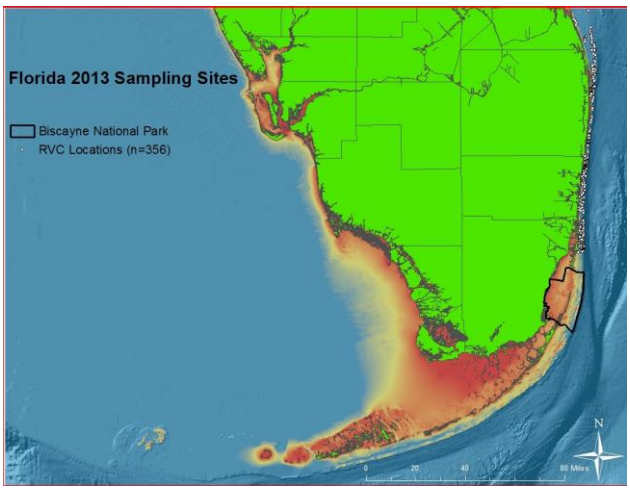

Figure 1: Sampling site locations for 2013 in the Florida domain.

In response the growing number of supporting agencies and geographical spread of sampling domain, an improved data entry system was developed. A centralized, online, data entry and management system was developed from scratch and deployed on the NOAA servers. This system greatly increases the efficiency of the data workflow, specifically, entering, editing, proofing and exporting of data into our existing QAQC workflow.

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 354 sampling sites were completed in the SEFCRI region (Miami/Dade County to Martin County) mainly by NOVA and their partners. The SEFSC supported four field trips in the SEFCRI regions with a total of 90 sites completed. All field related and QAQC milestones were met and objectives completed. Additionally, and new online data entry system was built, tested and successfully deployed to facilitate and streamline the data workflow.

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Coastal Fisheries Logbook Program

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

Long Term Research Objectives and Strategy to Achieve Theme:
***Objectives*:** To determine the fishing effort of federally-permitted commercial fishers in the South Atlantic and Gulf of Mexico.
***Strategy*:** To collect fishery 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.

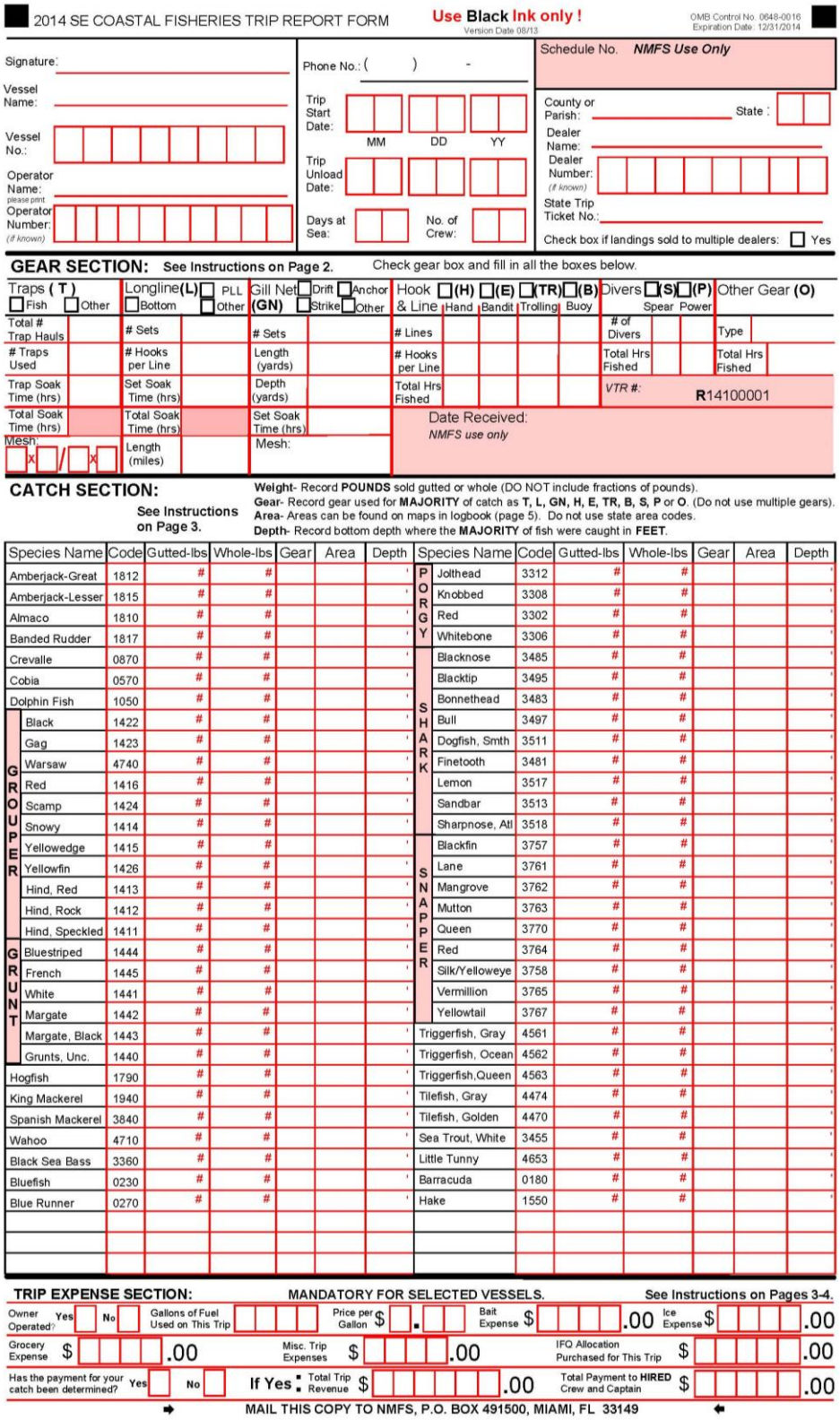
CIMAS Research Theme:
***Theme 6*:** Ecosystem Management

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 Coastal Fisheries Logbook Program is an ongoing fishery-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 23 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 collects landings and fishing effort data. Data collected is used for fisher permit compliance. Data is also used in conjunction with other fishery-dependent, and independent, data sets for stock assessments and fisheries management decisions. A recent stock assessment of Gulf of Mexico red grouper utilized indices of abundance created from logbook data.

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



2014 SE COASTAL FISHERIES TRIP REPORT FORM

Use Black Ink only !

Version Date 08/13

OMB Control No. 0648-0016
Expiration Date: 12/31/2014

Signature:

Vessel Name:

Vessel No.:

Operator Name: please print

Operator Number: (if known)

Phone No.: ( ) -

Trip Start Date: MM DD YY

Trip Unload Date:

Days at Sea:

No. of Crew:

Schedule No. NMFS Use Only

County or Parish:

State :

Dealer Name:

Dealer Number: (if known)

State Trip Ticket No.:

Check box if landings sold to multiple dealers: Yes

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

Traps (T) Fish Other	Longline (L) Bottom PLL Other	Gill Net (GN) Drift Anchor Strike Other	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 #: R14100001	
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	#	#			'	Knobbed	3308	#	#			'
Almaco	1810	#	#			'	Red	3302	#	#			'
Banded Rudder	1817	#	#			'	Whitebone	3306	#	#			'
Crevalle	0870	#	#			'	SHARK: Blacknose	3485	#	#			'
Cobia	0570	#	#			'	Blacktip	3495	#	#			'
Dolphin Fish	1050	#	#			'	Bonnethead	3483	#	#			'
GROUPER: Black	1422	#	#			'	Bull	3497	#	#			'
Gag	1423	#	#			'	Dogfish, Smth	3511	#	#			'
Warsaw	4740	#	#			'	Finetooth	3481	#	#			'
Red	1416	#	#			'	Lemon	3517	#	#			'
Scamp	1424	#	#			'	Sandbar	3513	#	#			'
Snowy	1414	#	#			'	Sharpnose, Atl	3518	#	#			'
Yellowedge	1415	#	#			'	SNAPPER: Blackfin	3757	#	#			'
Yellowfin	1426	#	#			'	Lane	3761	#	#			'
Hind, Red	1413	#	#			'	Mangrove	3762	#	#			'
Hind, Rock	1412	#	#			'	Mutton	3763	#	#			'
Hind, Speckled	1411	#	#			'	Queen	3770	#	#			'
GRUNT: Bluestriped	1444	#	#			'	Red	3764	#	#			'
French	1445	#	#			'	Silk/Yelloweye	3758	#	#			'
White	1441	#	#			'	Vermillion	3765	#	#			'
Margate	1442	#	#			'	Yellowtail	3767	#	#			'
Margate, Black	1443	#	#			'	Triggerfish, Gray	4561	#	#			'
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 SECTION: MANDATORY FOR SELECTED VESSELS. See Instructions on Pages 3-4.

Owner Operated? Yes No Gallons of Fuel Used on This Trip Price per Gallon $. Bait Expense $ .00 Ice Expense $ .00

Grocery Expense $ .00 Misc. Trip Expenses $ .00 IFQ Allocation Purchased for This Trip $ .00

Has the payment for your catch been determined? Yes No If Yes: Total Trip Revenue $ .00 Total Payment to HIRED Crew and Captain $ .00

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

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

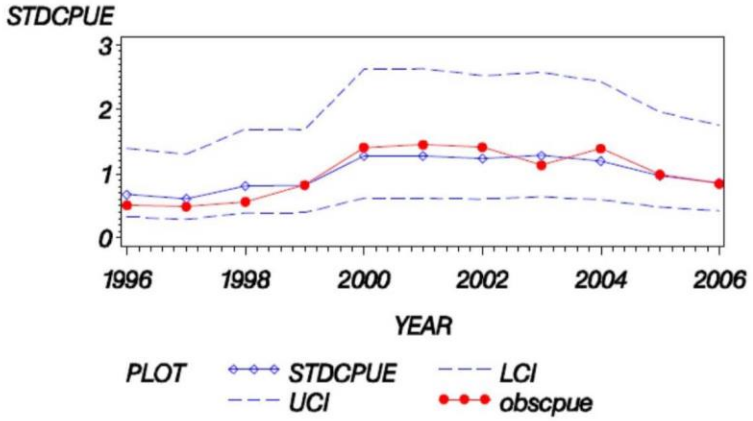


Figure 2. Red snapper (1996-2006) nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dashed lines) for commercial vessels fishing vertical line gear in the eastern Gulf of Mexico.

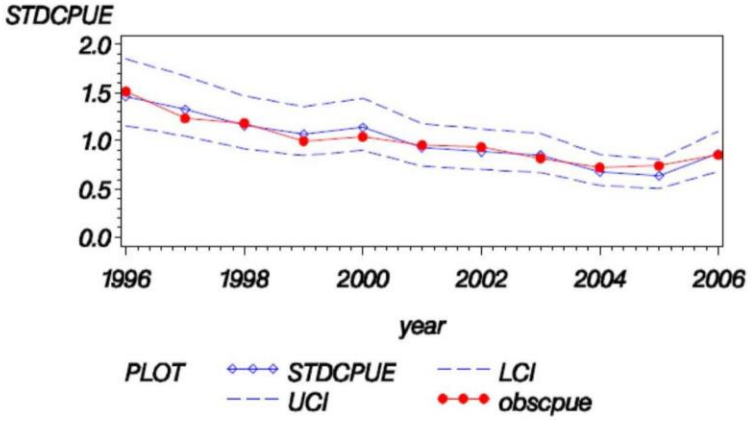


Figure 3. Red snapper (1996-2006) nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dashed lines) for commercial vessels fishing vertical line gear in the western Gulf of Mexico.

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Incorporating Ecosystem Considerations into Single-Species Stock Assessments: A Case Study for Gulf of Mexico Gag Grouper (Mycteroperca microlepis)

Project Personnel: S.R. Sagarese (UM/CIMAS)
NOAA collaborator: J.F. Walter III (NOAA/NMFS/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** Serve as a liaison between stock assessment analysts and the Integrated Ecosystem Assessment program to incorporate ecosystem considerations (e.g., red tide mortality) developed by the Gulf of Mexico Integrated Ecosystem Assessment program into stock assessment models constructed at the Southeast Fisheries Science Center for Southeast Data, Assessment and Review (SEDAR).

***Strategy*:** To provide additional manpower tasked with testing different methods and multiple environmental indices for incorporation into the Stock Synthesis integrated assessment framework, thereby ensuring consideration and integration of environmental indices into single-species stock assessments conducted at the SEFSC.

CIMAS Research Theme:
***Theme 6*:** Ecosystem Management (*Primary*)
***Theme 5*:** Ecosystem Modeling and Forecasting (*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:
Significant progress has been made within the Gulf of Mexico (GOM) in terms of identifying and incorporating ecosystem products into single-species stock assessments. For GOM gag grouper (*Mycteroperca microlepis*), Integrated Ecosystem Assessment products were tested within the Stock Synthesis integrated assessment framework, including indices of red tide and recruitment anomalies. Specific objectives of the present study were to: (1) assess whether the inclusion of environmental indices increased the plausibility of the 2012 stock assessment model for GOM gag grouper; and (2) evaluate different methods for incorporating environmental indices into the model.

Contemporary fisheries management mandates the consideration of environmental effects and other ecosystem processes when modeling stock dynamics. Within the Gulf of Mexico, red tide events caused by the dinoflagellate *Karenia brevis* are a key ecosystem stressor. While impacts are generally described for coastal areas, harmful algae blooms (HABs) often start offshore at depth, suggesting that offshore marine fauna may also experience higher natural mortality during these events. A significant HAB impact has been hypothesized for many large, GOM groupers because much of their habitat coincides with areas susceptible to HABs and mortality has already been documented for some large grouper species: red (*Epinephelus morio*), goliath (*E. itajara*) and warsaw (*E. nigritus*).

Given the aforementioned biological justification, four red tide indices were tested within the 2012 base stock assessment model for GOM gag grouper, configured by SEFSC analysts J. Tetzlaff and M. Bryan. Natural mortality (*M*) of large adults was linked to red tide indices. Available indices included statistical models of red tide severity produced by J.F. Walter III and an index of natural mortality derived from Ecopath with Ecosim developed by A. Gray and C. Ainsworth at the University of South Florida. Five scenarios based on candidate red tide indices and methods for inclusion were devised and compared. Regression analysis provided strong evidence for a relationship between deviations in *M* and evaluated environmental indices for both base models. Environmental consideration of red tide generally improved model fit in comparison to base models with no red tide (Figure 1). While this study does not provide direct evidence of red tide mortality on adult gag grouper, nor is the mode of mortality known, the results suggest that red tide causes mortality on adults.

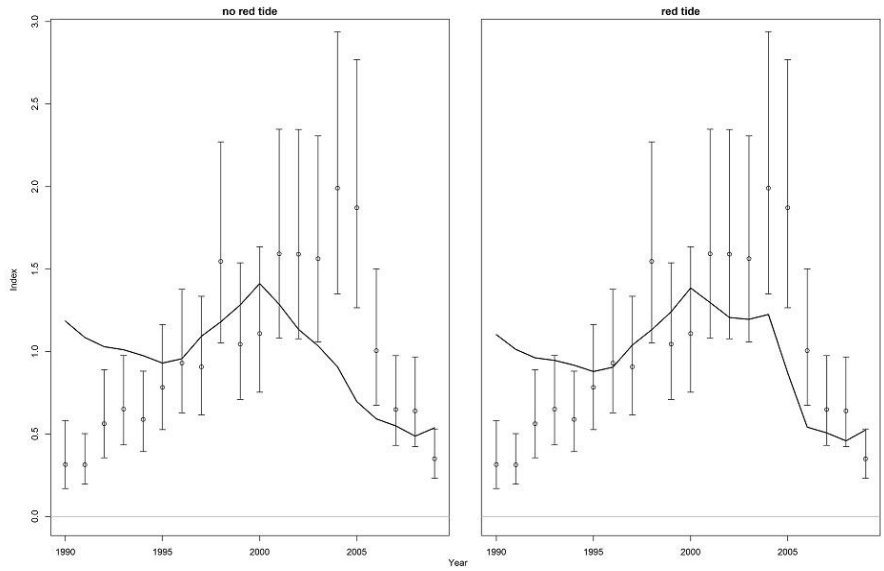

Figure 1: Model fits to indices of abundance for the commercial hand line both without (left) and with red tide (right). Black line reflects expected index, dots reflect observed values, and vertical lines reflect lower and upper bounds for each annual index observation. A significant improvement in model fit with red tide is evidenced by the fitted line (black) more closely matching the observed index (dots).

An index of recruitment anomalies (2003-2013) was produced by M. Karnauskas of the SEFSC using the Connectivity Modeling System, a biophysical model which simulated the transport and survival of spawned eggs and larvae. This index was also tested within the Stock Synthesis model as an environmental effect on recruitment deviations. Recruitment anomalies explained about one-third of the variation in the estimated stock-recruitment deviates and informed recent years of the assessment where cohort strength is poorly estimated.

For the upcoming SEDAR 42 assessment for GOM red grouper, a similar modeling approach for incorporating ecosystem considerations will be undertaken.

Research Performance Measure: The objectives for GOM gag grouper have been met. SEDAR33 is one of the first stock assessments conducted by the SEFSC where ecosystem considerations were comprehensively analyzed. The base model recommended by the Assessment Panel for management accounted for red tide mortality. A manuscript will be submitted to a peer-reviewed journal in the near future.

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

Project Personnel: D. Burkepile, and T. Adam (FIU)
Other 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:
Herbivorous fish can benefit reef-building corals by controlling algae that compete with corals for space. On many reefs, parrotfishes appear to be particularly important for controlling algae and creating favorable habitat for coral recruitment. However, evidence that herbivores in general and parrotfish in particular can promote coral recovery on Caribbean reefs has been inconsistent, and it is now clear that the impact of herbivores on the maintenance and recovery of coral-dominated reefs will be highly context-dependent.

During the research year (2013/2014) we completed a thorough synthesis of the existing literature examining the relationships between parrotfish and different measures of the status of coral populations and communities. This synthesis indicates that impacts of herbivores on coral populations will be modulated by physical characteristics of reefs such as depth and wave exposure, local anthropogenic impacts such as nutrification and sedimentation, recent ecological history, and predicted impacts of global climate change. The synthesis also revealed that different species and size classes of parrotfish are likely to have diverse impacts on algae and corals. A major knowledge gap we identified that is currently limiting our ability to predict when herbivores are most likely to promote coral recovery and/or persistence is a lack of information on the basic feeding ecology of many species of Caribbean parrotfishes. Thus, we initiated a field study to quantify the basic feeding ecology (including feeding preferences, grazing rates, and foraging ranges) of nine of the most common parrotfish species in the Florida Keys National Marine Sanctuary.

Our field observations revealed two distinct and complementary functional groups of Caribbean parrotfishes, those that can prevent the establishment of macroalgae by intensively grazing on algal turfs while scraping or excavating the calcium carbonate reef framework, and those that primarily feed on fleshy brown macroalgae that can overgrow corals (Figure 1). This research also revealed that species with similar diets were dissimilar in other attributes, including habitat selection and the substrates they target while foraging (Figure 2). In particular, some species were more likely to exert their impacts in places that are favorable for corals (e.g., high-relief reefs with low levels of macroalgae and sediments), while others predominantly exerted their impacts in places that are poor or marginal habitats for corals (e.g., unconsolidated coral rubble and low-relief hardbottom).

Together these observations greatly increase knowledge of the functional roles of different species of Caribbean parrotfishes. We are also conducting ongoing observational and experimental work to elucidate the mechanisms driving differences in foraging behavior, and to quantify the amount of algae removed by different size classes and species of parrotfishes.

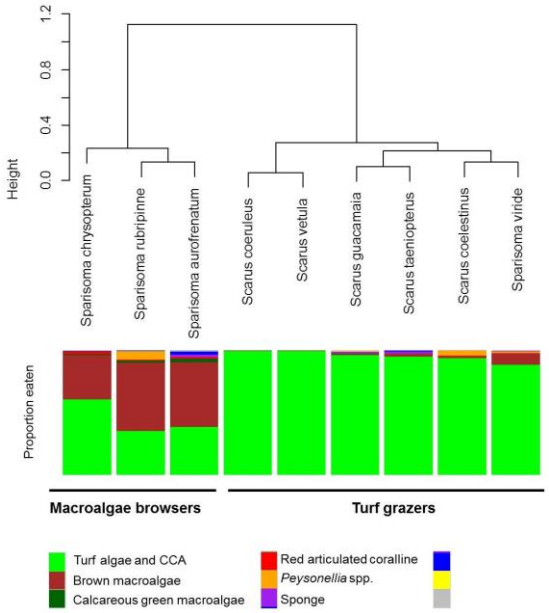

Figure 1: Species-averaged dendogram with proportion of different food items eaten by nine species of Caribbean parrotfishes showing that parrotfish cluster into two groups based on their diets. *Sp. chrysopterum*, *Sp. rubripinne*, and *Sp. aurofrenatum* feed largely on macroalgae (mainly *Dictyota* spp.), while fishes in the genus *Scarus* and *Sp. viride* feed primarily on microscopic turfs, endolithic algae, and CCA.

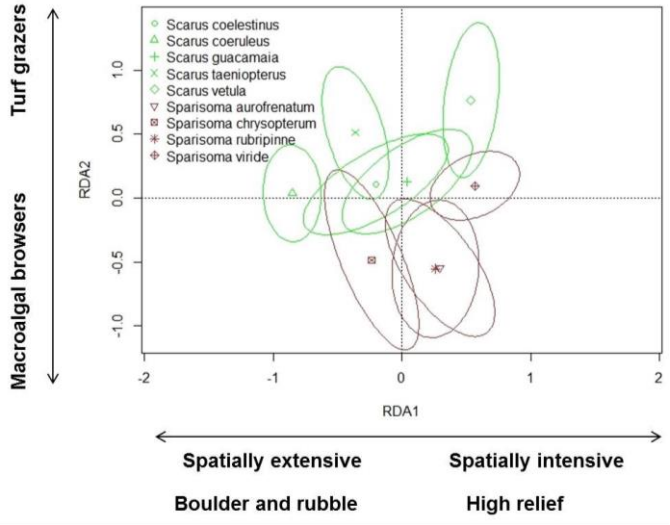

Figure 2: Ordination plot from redundancy analysis (RDA) of foraging traits of nine species of Caribbean parrotfishes. Centroids for each species are plotted with dispersion ellipses using 0.9 confidence limits of the standard deviation of species scores. Note that species with similar diets (i.e., similar values of RDA 2) tended to prefer different habitats where they fed on different substrates (i.e., they had different values of RDA 1).

Research Performance Measure: The synthesis has been completed and we are in the final stages of manuscript preparation and anticipate submitting the manuscript in June 2014. We also have a draft of a manuscript summarizing the most critical aspects of our field research, and we anticipate submitting this manuscript by September 2014. Information from both the synthesis and field work have been presented at multiple meetings and used to advise a court-ordered revision of the ITS statement for the Biological Opinion for the Reef Fish Fishery Management Plan of Puerto Rico and the U.S. Virgin Islands.

Gulf of Mexico Integrated Ecosystem Assessment

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

Long Term Research Objectives and Strategy to Achieve Them:
Objectives: To develop scientific products and analytical tools required for integrated ecosystem assessments within the Gulf of Mexico large marine ecosystem.
Strategy: To accomplish these objectives we are conducting integrated ecosystem-level risk assessments, developing network-based methods for exploring trade-offs in complex multi-sector systems, and informing resource management decision-making to minimize risk to ecosystem services provisioning while bettering the resilience and sustainability 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 (*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/AOML
NOAA Technical Contact: Alan Leonardi

Research Summary:
The marine environment provides a broad spectrum of benefits to people including the provisioning of seafood, recreational and commercial opportunities, oil and gas production, protection from storms, and buffers to pollution. These benefits, often described as ecosystem services, are one of the reasons that coastal communities are some of the fastest growing population centers in the nation, and the world. However, this beneficial relationship has the unintended consequence of placing increased pressure on the natural components of the coastal ecosystem, ironically threatening the long-term economic sustainability, health, and resilience of coastal communities. To protect human communities in coastal regions will require an understanding of how these complex human-natural systems interact with one another, and multi-sector ecosystem-based management approaches that both protect and sustain marine ecosystems and the services they provide.

The Gulf of Mexico (GoM) is vital to the economic health of our nation. More than 8 million jobs exist in the coastal counties of the GoM, contributing between $5-6 billion annually to the US Treasury. From a biological standpoint this region also plays a critical role. There are over 15,000 species inhabiting the GoM, generating more than 1 billion pounds of commercial seafood, 44% of the US marine recreational catch, and comprising half of the nations coastal wetlands. However the footprint of the GoM extends well beyond the coastal waters of Texas, Louisiana, Mississippi, Alabama, and Florida. Through its upstream linkages it impacts and is impacted by 31 of the 50

states comprising the greater 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. Due to the vast area encompassing the broader GoM we have leveraged existing partnerships within South Florida to conduct pilot projects to develop the ecosystem-based management tools necessary to study the various sectors comprising the broader Gulf of Mexico. For example, we have developed a suite of indicators for beach ecosystems in south Florida (Marshall et al., *in press*). This project builds upon the Marine and Estuarine Goal Setting for South Florida (MARES) project, and provides a management tool for evaluating and characterizing the various pressures threatening beach ecosystems and their continued provisioning of ecosystem services (Table 1).

Table 1: Indicators for developed to highly developed beaches in Southeast Florida (adapted from Marshall, Banks and Cook, *in press*).

	Indicator								
Condition	**Presence of built environment**	**Dune condition**	**Berm**	**Sea turtle nests**	**Value for low-cost shore protection**	**Access**	**Human health issues**	**Level of passive and active recreational use**	**Beach-related jobs**
Good (impacted, substantial public benefit from use)	**built environment near beachfront is single family or low-rise multi-family with development restrictions; no shorefront protection**	**dune system present in reduced form or has been restored**	**wide berm**	**sea turtle nests can be left in situ with limited need for protection from lighting and predators**	**low probability of shore protection needed in near future**	**good, safe access for general public with clean restrooms**	**never**	**good passive and active recreational opportunities available**	**jobs are available related to on- and off-beach activities**
Fair (moderately impacted), some public benefit from use)	**seawalls present back from beachfront; no groins, jetties, or shorefront protection**	**restored dune system in need of re-furbishment**	**narrow berm but wide enough for sunbathing and limited recreation**	**sea turtle nests can be left in situ with active protection from lighting and predators**	**probability good that active shore protection needed now or in near future**	**poor access for general public, limited parking, restrooms available, limited crime issues**	**occasional**	**limited passive recreational opportunities available**	**limited number of jobs are available related to on- and off-beach activities, construction of shore protection measures**
Poor (severely impacted, little public benefit from use	**bulkhead, jetty, groin, seawall, or shorefront protection present near high tide water**	**no dune system**	**no berm**	**sea turtle nests cannot be left in situ**	**human intervention needed to provide shore protection from erosion**	**limited or no access and/or no bathrooms, crime issues documented**	**frequent**	**no passive or active recreational opportunities**	**only jobs available are related to nourishing or construction of shore protection**

Similarly we were able to leverage results from the MARES project to develop matrix-based approaches for understanding and ranking the various pressures impacting the south Florida coastal ecosystem (Figure 1). In this project we quantified the relative risk posed by various pressures to component ecosystems (e.g. coral reefs, seagrasses, mangroves), and identified and ranked the relative risk of individual pressures to the continued provisioning of ecosystem services in coastal south Florida. The greatest relative threat to coastal ecosystem services in south Florida is the quality, quantity, timing and duration of freshwater delivery to downstream estuaries; recreational fishing activities poses the least pervasive threat to the suite of ecosystem services provided by south Florida coastal ecosystem (Figure 2).

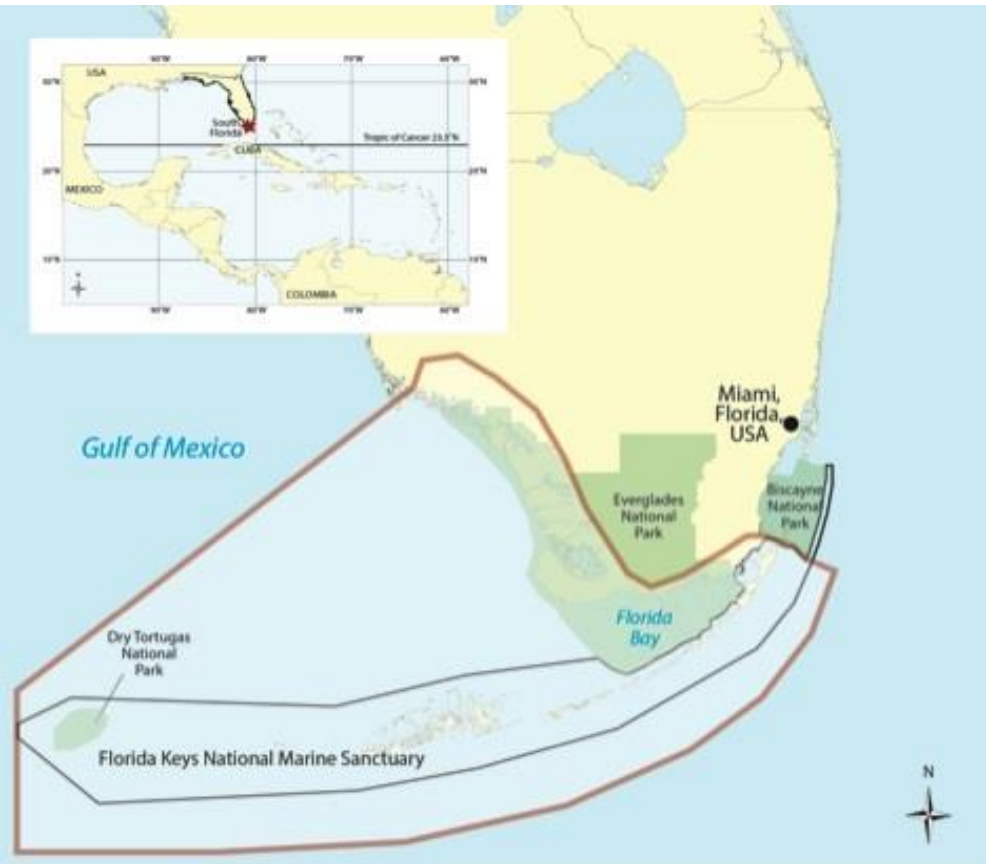

Figure 1: Map of South Florida coastal ecosystem. Outlined in brown is the region taken into consideration when experts quantified *Pressures*, *States*, and *Ecosystem Services*. Inset map shows study region (red star) within Florida and the wider Caribbean.

Through these pilot projects we developed complementary frameworks for exploring and characterizing the various pressures threatening the sustainability of ecosystem services in coastal south Florida. The results from these studies can be used to highlight the trade-offs inherent in various management decisions, and provide strategic guidance for managers wanting to target different components of these complex human-natural systems. In the upcoming year we plan to examine the transferability of these methods from local to regional spatial scales, use network-based approaches to highlight the critical ecosystem linkages hidden within these complex coastal systems, and show how these techniques can be used as decision-making tools to identify and implement management strategies with the greatest probability of success in mitigating threats to coastal ecosystem services.

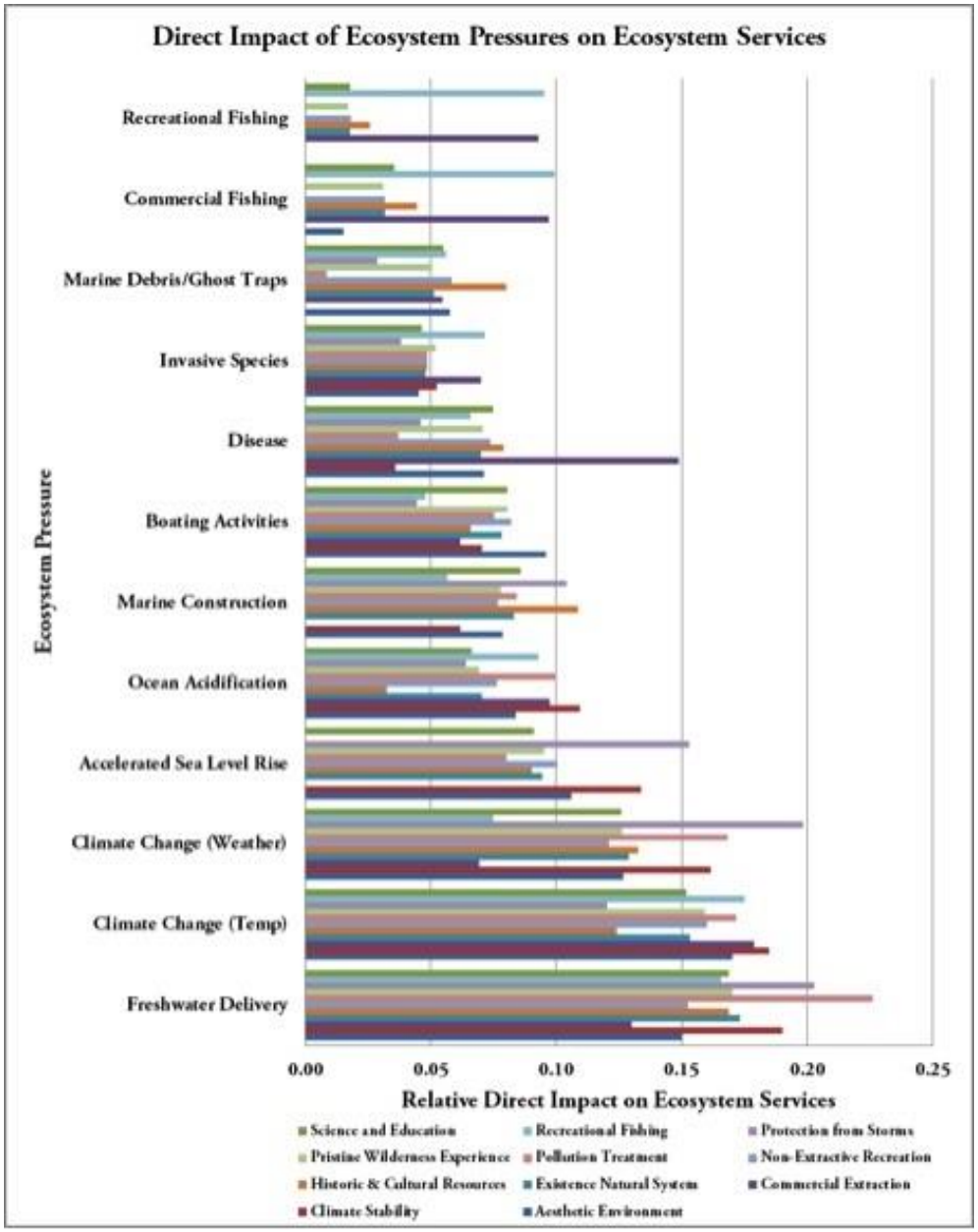

Figure 2: Relative direct impact of ecosystem *Pressures* broken down by individual *Ecosystem Services*. Values represent the proportional contribution of individual *Pressures* to individual *Ecosystem Services*; summing across all 12 *Pressures*, each *Ecosystem Service* sums to 1.

Research Performance Measure: All major research objectives are being met and are on schedule. By leveraging the intellectual products created through the MARES process we have created a framework for identifying and characterizing indicators for assessing the health of beach ecosystems, developed matrix-based tools for identifying the most at-risk ecosystem states in coastal ecosystems (e.g. mangroves, coral reefs), and ranked the relative threat of individual pressures to the provisioning of ecosystem services. Currently we are building upon these studies and applying these tools in concert with network-based approaches to better understand sources of risk within the broader Gulf of Mexico large marine ecosystem.

Evaluating the Impact of Individual Fishing Quotas (IFQs) on the Technical Efficiency and Composition of the US Gulf of Mexico Red Snapper Commercial Fishing Fleet

Project Personnel: D. Solis (UM/MBF)
NOAA Collaborator: J. Agar (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To determine the impact of individual fishing quotas (IFQs) on the technical efficiency (TE) and composition of the Gulf of Mexico red snapper commercial fishing fleet.

***Strategy*:** Employ a parametric stochastic distance frontier framework to see if IFQs improved the TE of the vertical line and bottom longline fleets, document changes in output and input distance elasticities and in returns to scale following the introduction of IFQs and investigate both the impact of regulations and weather on productivity and the effect of crowding on TE.

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:

While there is no agreement on the best governance structure, economists have favored the use of property rights because they promote resource stewardship and improve economic performance. One of the most well-known management failures has been the Gulf of Mexico red snapper fishery. Decades of regulation, which included quotas, access controls, trip limits and restricted fishing seasons, not only failed to protect and rebuild the declining stock, but also led to overcapacity and derby fishing conditions that resulted in market gluts, depressed prices, higher harvesting costs, and unsafe fishing practices. In response to these past failures the Gulf of Mexico Fishery Management Council (hereafter Council) established an individual fishing quota (IFQ) program for the commercial red snapper fishery on January 1, 2007.

The goal of this study was to analyze the impact of that IFQ program on the TE and composition of the Gulf of Mexico red snapper commercial fleet. Drawing on a stochastic distance frontier (SDF) model, which accounts for the multiproduct nature of commercial fish production, we find that IFQs enhanced the TE of the commercial fleet for both vertical and longline fleets (see Figure 1). Specifically, the analysis shows that these efficiency gains are mainly driven by the retirement of less efficient vessels in the fleet, and to a lesser extent, by efficiency gains of the remaining vessels. Changes in output and input distance elasticities and in returns to scale following the introduction of IFQs were also found.

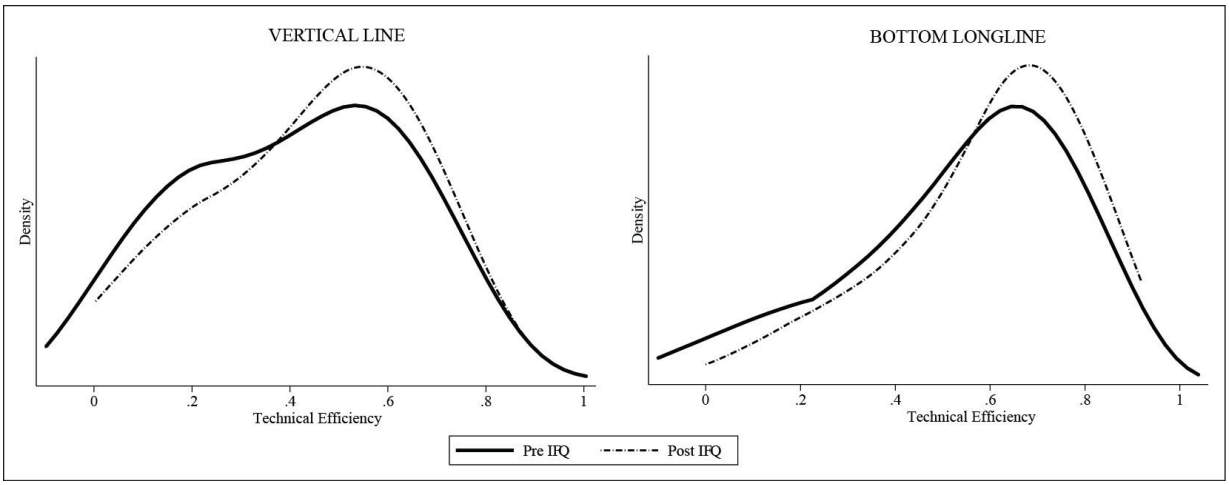

Figure 1: Kernel distributions of TE estimates for the vertical line and longline red snapper commercial fleets.

Research Performance Measure: Relevancy of analytical results to NMFS management needs in the Gulf of Mexico.

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Pelagic Fisheries Logbook Program

Project Personnel: A. Shideler (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 via logbooks 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). This program requires collaboration with individuals within the Sustainable Fisheries Division at NOAA Southeast Fisheries Science Center (SEFSC).

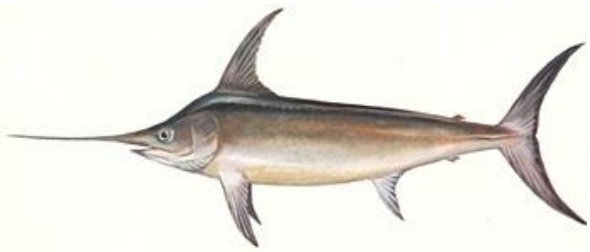


Figure 1: *Xiphias gladius*, the swordfish (www.safmc.net).

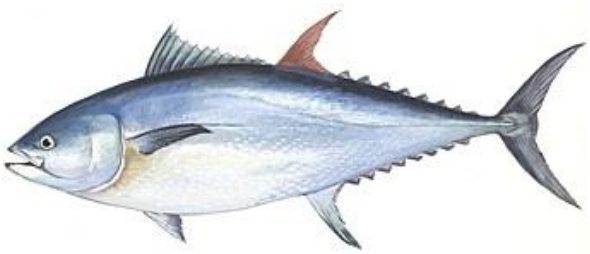
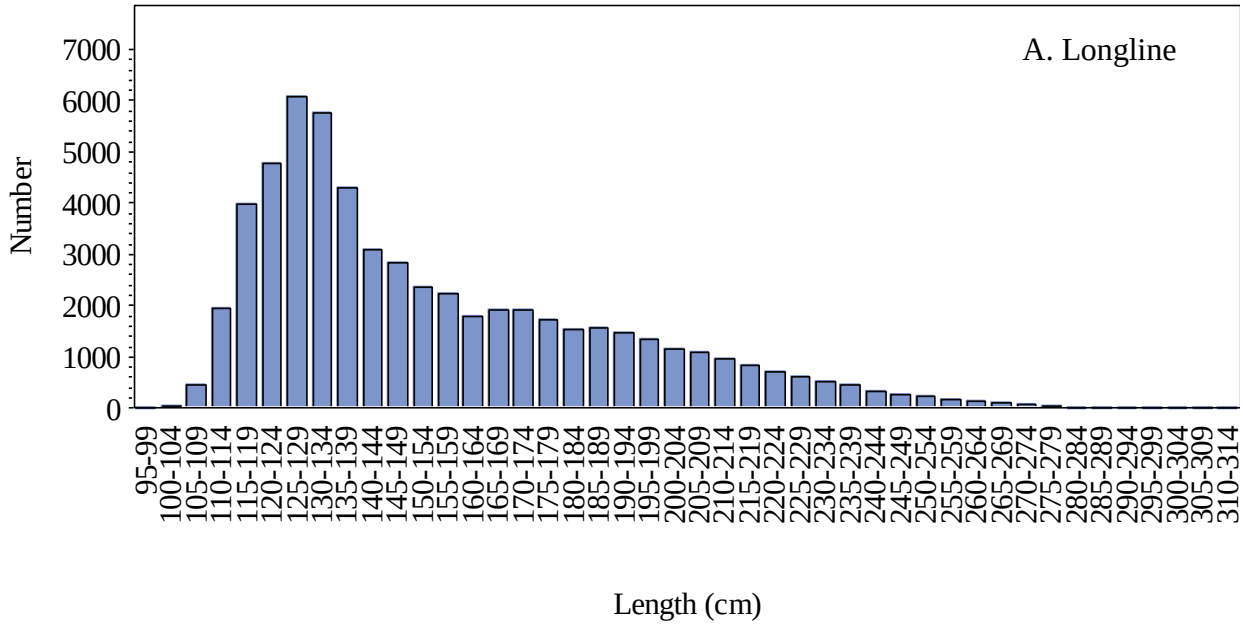


Figure 2: *Thunnus thynnus*, the Atlantic bluefin tuna (www.safmc.net).

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. To this end, a compliance audit which reconciles logbook data with dealer reported data was developed to identify delinquent or missing logbook reports.



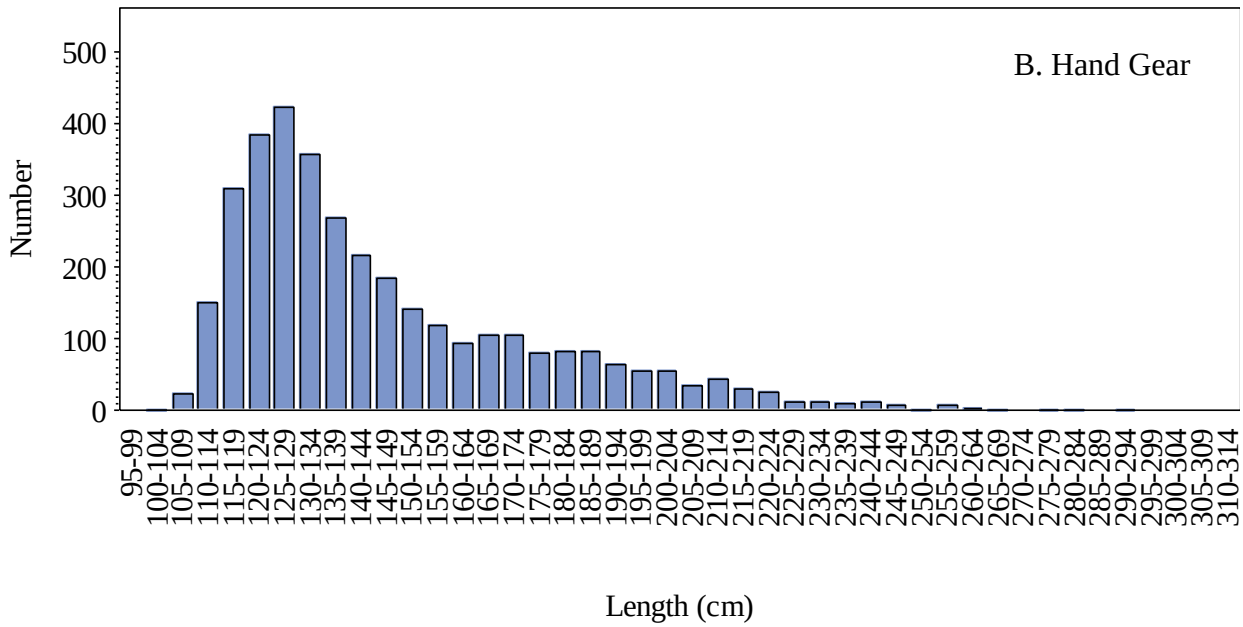


Figure 3: Length frequency (lower jaw fork length, in cm) of swordfish caught in commercial (A) longline and (B) hand gear fisheries obtained from catch as size (CAS) data reported to the Pelagic Longline program for 2012.

Research Performance Measure: All major objectives are being met.

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

Project Personnel: S. Murawski, C. Lembke, A. Silverman, S. Butcher, S. Grasty, J. Brizzolara, E. Hughes, and Katie Davis (USF/CMS)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** (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 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*

NOAA Funding Unit: NMFS/ST
NOAA Technical Contact: Theo Brainerd

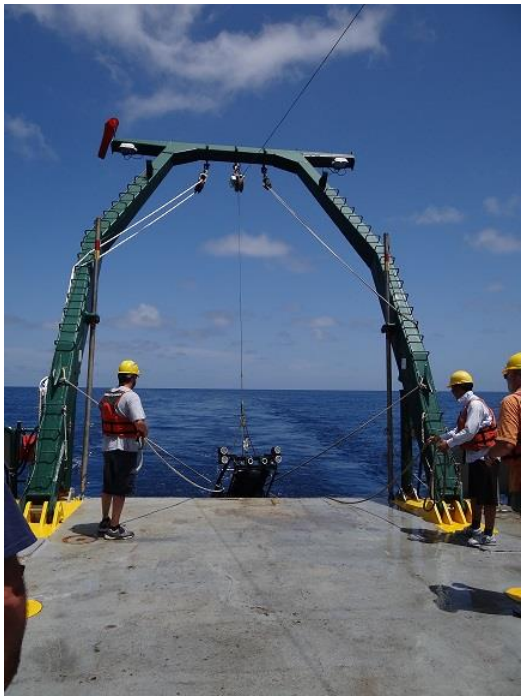


Figure 1: The C-BASS tow vehicle being launched from the stern of the research vessel. Note lateral stability and control. The vehicle can be safely launched and retrieved in up to 2 meter wave seas.

Research Summary:
During the project period we implemented several technical enhancements to the C-BASS tow vehicle (Figure 1), including (1) the addition of a second high-resolution camera (2 total) and two more low resolution analog cameras to increase our field of view (4 total), an upgrade to our analog video encoder which doubles our low resolution video, the fabrication and installation of a disaster recovery module, inclusion of twin green laser measurement system, fabrication and installation of more robust bottom skids made of hard plastic, to minimize damage from scraping bottom, and the installation of a Vemco acoustic receiver to detect the presence of fish that have been fitted with acoustic pingers as a part of other studies in the region. Additionally, work has commenced on integrating forward-looking DIDSON sonar to increase our observation range. In the past year, we conducted three additional survey cruises to the Florida Middle Grounds (FMG), the Madison-Swanson fishery closed area (M-S), and the Steamboat Lumps (SBL) fishery closed area (Figures 2 and 3). The three cruises were conducted to evaluate system performance with the additional capabilities implemented in the vehicle, and to demonstrate improved performance of the sensors onboard. In particular, the C-BASS team has continued to improve the resolution and operating performance of the high resolution video cameras onboard, and the software system for managing data during and post-cruise. With respect to the science objectives of the program, we have demonstrated that useful density estimates for target species can be obtained. One of the overarching concerns is the fish behavior in relation to the vehicle. In this regard, S. Grasty (M.S. student) has developed a fish behavioral classification scheme and is applying it to better understand which species and under what circumstances fish either are attracted to or avoid the vehicle, or if their reactions are neutral to vehicle presence. Additionally, because C-BASS is "flown" with a calibrated

Figure 2: The C-BASS (Camera-Based Survey Sampling System) tow vehicle, prototype 2. In the front there are 6 cameras (2 digital and 4 analog), four LED light sources, and a Didson forward-looking sonar.

hydroacoustic system (EK-60), we can produce simultaneous integrated echo estimates of fish abundance. The fish abundance estimates from both sensors are now being synchronized. The third cruise in the performance period (May, 2014) will be used in conjunction with cruises in 2013 to produce species abundance and species composition estimates for the MPAs.

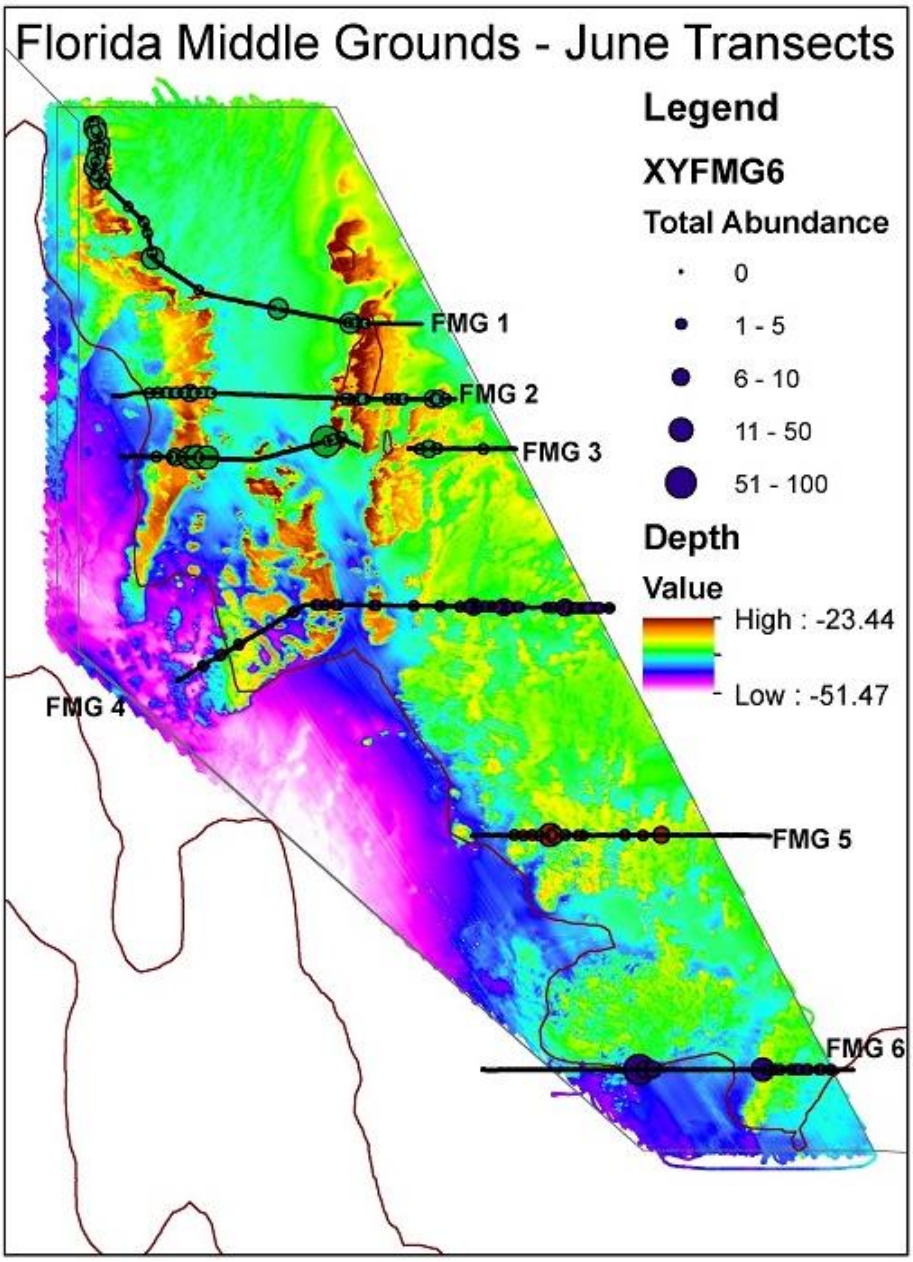


Figure 3: Fish abundance (numbers) along six video transects with C-BASS in the Florida Middle Grounds Habitat Area of particular Concern (HAPC), June, 2013. Numbers are per one minute video segment (approximately 100 m of tow track). The high-resolution multibeam bathymetry is given as the colored background.

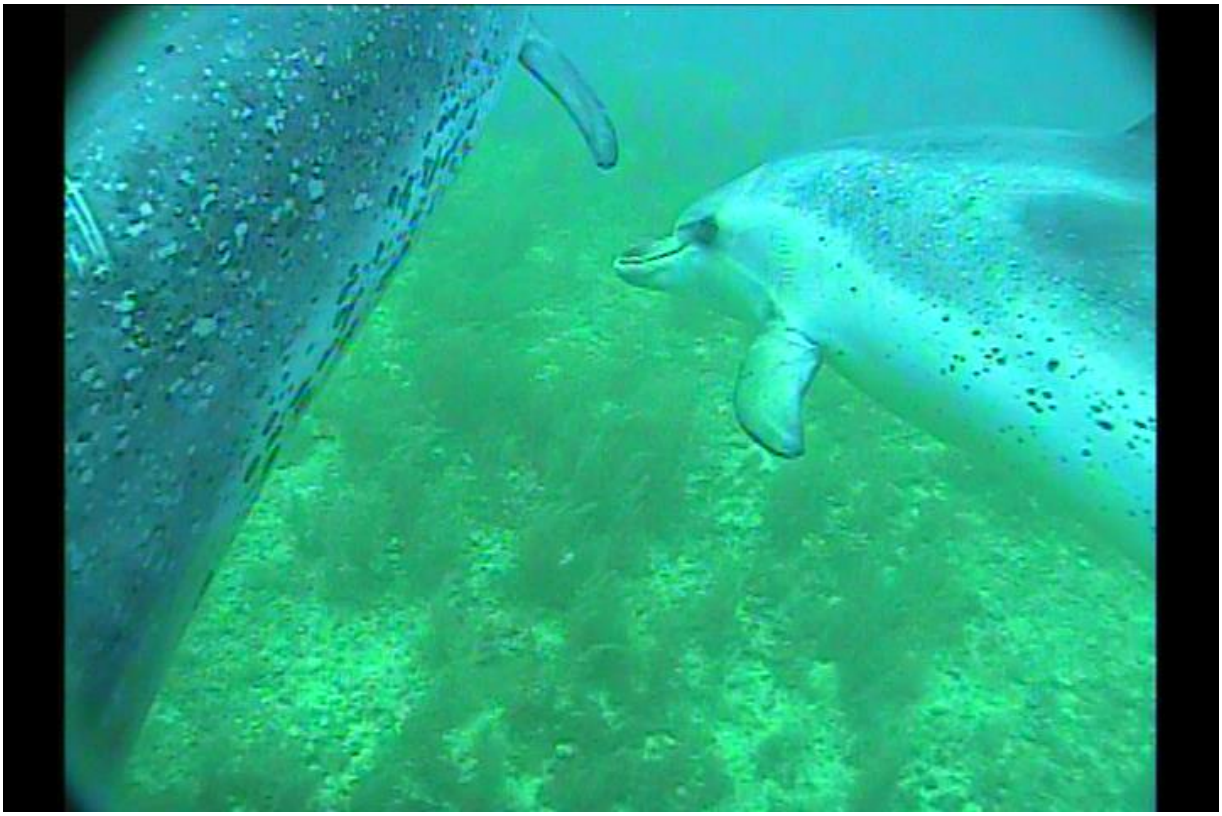


Figure 4: Image tropical spotted dolphins as seen from CBASS.

Research Performance Measures: Objectives 1, 2, and 3 (as described above) were accomplished; Cruises were completed in June 2013, November, 2013, and May 2014. In all three MPAs, density estimates for fishes were developed (Figure 3), which were number counts divided by the area sampled by the video cameras. The C-BASS vehicle performance has been significantly upgraded, and now is poised to transition from a research tool to an operational fish survey tool. Ongoing research with the imagery obtained from the three cruises conducted in the progress period includes: (1) density and species composition for observed fishes in the three MPAs, (2) classification of density estimates by habitat type as observed in the videos, (3) use of the EK-60 backscatter data to correlate with observed habitat types to develop an algorithm for classifying habitats using only acoustic data, (4) correlation of video species identity and density with EK-60 acoustic imagery, (5) development of algorithms for understanding the spatial geography of fishes and habitats (species associations) using video imagery, and (6) assessment of the species composition and density of benthic invertebrates (corals, gorgonians, sponges) associated with sampled habitats (new graduate student project) to assess reef health.

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. The National Academy of Sciences held a workshop in May, 2014, which aimed to assess the status of such projects and the feasibility of auto-recognition. The C-BASS team contributed significantly to this effort.

Evaluation of ESA listed Acropora spp. Status and Actions for Management and Recovery

Project Personnel: D.E. Williams, A.J. Bright, C.M. Cameron, and L. Richter (UM/CIMAS)
NOAA Collaborator: M.W. Miller (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives: (1) To document and identify demographic variables (recruitment, mortality etc.) in the Florida Keys *Acropora* spp. population. (2) 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'. (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 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*

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

Research Summary:

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. This is an on-going monitoring project entering its tenth year of thrice yearly surveys in the upper Florida Keys and eighth year of annual surveys in Curaçao. Study units are 150 m^2 plots in which all attached *Acropora palmata* colonies are mapped and surveyed each year. In Florida, individually tagged *A. palmata* colonies are surveyed more frequently to document their condition. Based on these observations, we can estimate basic population parameters including recruitment, growth and mortality, along with the causes of recent tissue 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.

The Florida Keys population suffered a 50% decline in live tissue area (Figure 1) resulting from the 2005 hurricane season, after which a very slow trend towards recovery has been observed. In 2010, a notable drop in live tissue area attributable to Hurricane Isaac occurred and the population has remained stable since then. Recovery from these disturbances has been slowed by continual losses from disease and predation. *A. palmata* in Curaçao suffered similar losses (~50%) due to Hurricane Omar in 2008 and to date has shown slow recovery trends similar to those observed in Florida.

Additionally, our data indicate that in the Florida Keys population, the most common source of tissue loss on *A. 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. Surveys of snail abundance following the removal indicate that it will take 4-5 years for snails to return to their original abundances, suggesting that predator removal by divers can aid in effectively conserving *A. palmata* colonies in targeted areas.

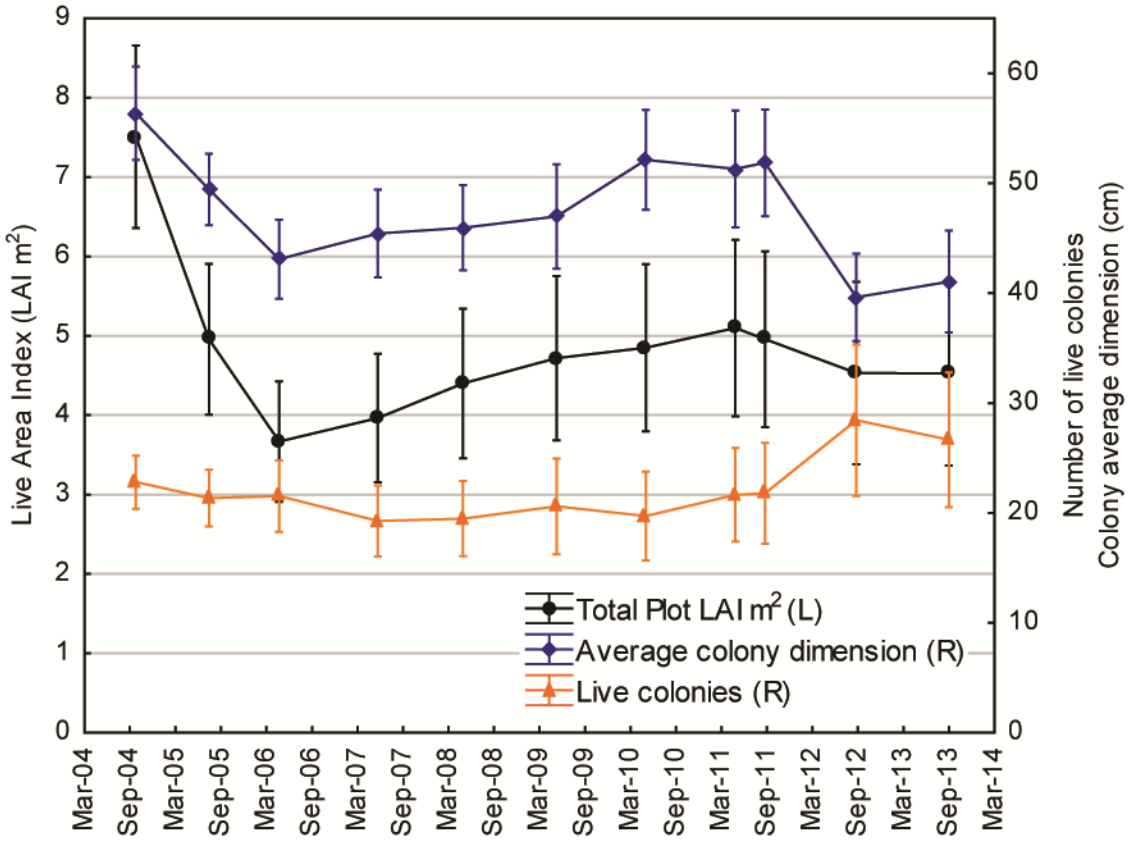


Figure 1: Florida Keys *Acropora palmata* population metrics over the ten year monitoring study. Tissue abundance as measured by a 'live area index' (left axis), the total number of colonies in the 150 m^2 study plot (right axis), and the average dimension of each colony (right axis) averaged for all 15 study plots (± standard error). Hurricane impacts can be discerned in 2005 and 2011 as decreased tissue abundance. Following Hurricane Isaac (2011), the colonies fragmented into greater numbers of smaller colonies.

Research Performance Measure: All planned surveys of the Florida Keys sites and the Curaçao sites were conducted as scheduled. The two year predator removal experiment was completed in September 2013 and one peer-reviewed manuscript is near submission.

Support for the Marine Resource Assessment Program at the University of South Florida College of Marine Science

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

Long Term Research Objectives and Strategy to Achieve Them:

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

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

CIMAS Research Theme:

***Theme 6*:** Ecosystem Management

Link to NOAA Strategic Goals:

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

NOAA Funding Unit: NMFS/SEFSC

NOAA Technical Contact: Theo Brainerd

Research Summary:

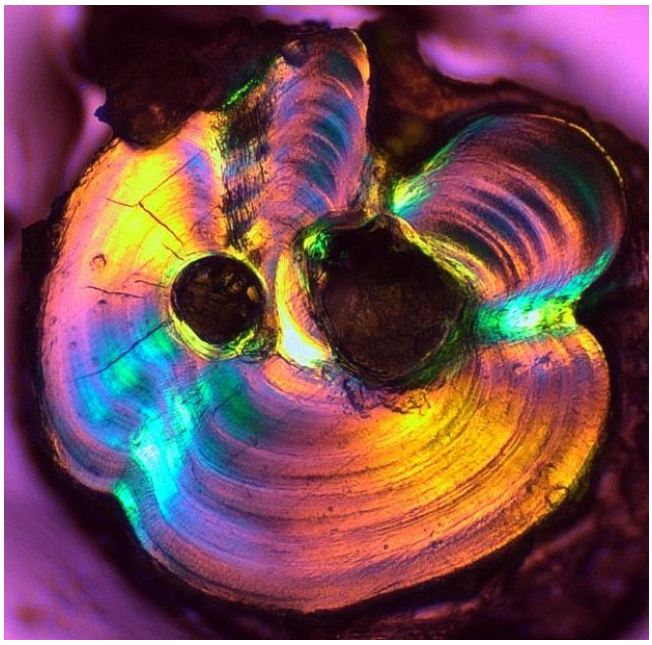
The schedule of course offerings remains once every two years for each of the courses listed below under the "MRA Core Courses" heading (see VII. Education and Outreach). The MRA program has succeeded in involving NOAA instructors in the design and execution of key coursework, specifically the *Fish Population Dynamics* course, which was team-taught by highly experienced NOAA personnel upon execution of the present agreement in August 2010 and has been taught since then by Dr. Cameron Ainsworth, a former NOAA fisheries biologist and modeler (contracted by NMFS NWFSC, Seattle). Dr. Ainsworth recently offered an *Ecosystem Modeling* course that was remotely attended by 18 fisheries professionals from ten different NMFS labs on the east and west coasts of the US. Dr. Christopher Stallings, who is another faculty member recruited to USF under the NOAA-sponsored MRA program, continues as the lead instructor for *Fish Biology*.

Dr. Ernst Peebles of USF continues to serve as Principal Investigator and Chair of the ad-hoc MRA committee at USF-CMS, a position that leads the coordination of future MRA program development under the guidance of appropriate USF Marine Science faculty. Dr. William Hogarth served as the

original Principal Investigator for this award. As a result of Dr. Hogarth's transition from Dean of USF-CMS to Director of the Florida Institute of Oceanography, Dr. Peebles assumed the role of Principal Investigator on the present award during 2011.

There are currently 30 fulltime USF-CMS students participating in the MRA program, with 14 being Master's students and 16 being doctoral students. The present award provides fellowships for 5 of the 30 students; all 5 are doctoral students. The remaining 25 MRA students work as Graduate Assistants on research grants and compete for internal and external graduate fellowships (see *2013-14 Awards & Honors*).

MRA student and NOAA Fellowship recipient Amy Wallace preparing to remove eye lenses and otoliths from a red snapper aboard the R/V Weatherbird II in the northern Gulf of Mexico (*Steve Murawski photo*).



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

Research Performance Measure: The MRA-related coursework supported by the present agreement has been successful at attracting career-minded students in the area of MRA. Participation in the MRA Area of Concentration is a popular request among prospective students; hundreds of qualified prospective students have applied to the program, but the number that is accepted has become limited by available resources (Fig. 1). MRA students currently represent ~32% of the student body at USF-CMS, which is comparable to the proportion concentrating in Biological Oceanography and is larger than the proportions concentrating in Chemical, Geological, and Physical Oceanography.

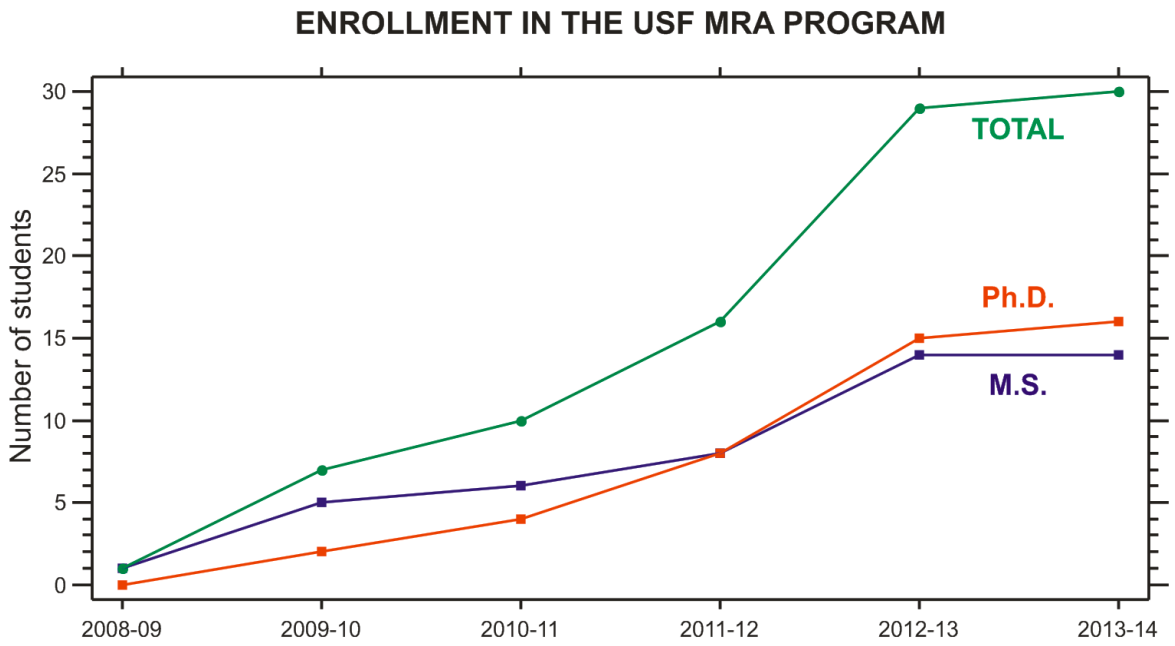


Figure 1: Enrollment in the USF-CMS Marine Resource Assessment (MRA) program by type of student and academic year. State and federal students are employed full-time by resource management agencies and take courses at USF as non-degree-seeking students. Some of these later obtain degree-seeking status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

Enrollment by professional fisheries scientists in MRA courses has exceeded expectations, with 31% of average class composition being employees of state and federal resource management agencies (range: 11-66%, n = 13 course offerings). Agency students have been associated with the following labs:

- Florida FWC: Fish and Wildlife Research Institute, St. Petersburg, FL
- NOAA Fisheries: Labs at Beaufort, NC; Sandy Hook, NJ; Miami, FL; Stamford, CT; Pascagoula, MS; Galveston, TX; Panama City, FL; Woods Hole, MS; La Jolla, CA; St. Petersburg, FL

As intended, most MRA graduates (88%) are employed by resource management agencies after graduation (75%) or pursue a doctoral degree (13%; see *MRA Graduates* under Education and Outreach).

VI. RESEARCH REPORTS

THEME 7: Protection and Restoration of Resources

Using SEDAR-Assessed Stocks to Validate the Accuracy of Data-Poor Methods

Project Personnel: R. Ahrens (UF)
NOAA Collaborators: J. Berkson (NOAA/SESFC)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To ascertain which data-poor stock assessment methods provide management recommendations similar to that recommended for SEDAR-assessed species.
***Strategy*:** To compare the catch recommendations from a suite of data-poor stock assessment methods for SEDAR-assessed species against the catch.

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/CIPO
NOAA Technical Contact: Elizabeth Perez

Research Summary:
Many fish stocks in the Southeast do not have sufficient data to allow for traditional stock assessments. These 'data-poor' stocks lack or have unreliable information concerning catch time-series, stock size, or life history parameters. Such data are the primary information sources for traditional stock assessments. Without this information it is difficult to conduct stock assessments and determine annual catch limits (ACLs) and other reference points legally required for every fished

stock by the Magnuson-Stevens Act. While data-poor stocks are present around the United States, 75% of stocks and stock complexes assessed for ACLs in the Southeast are stocks that have only catch history data. Alternative data-poor methods to calculate ACLs in such cases exist, but their effectiveness is still subject to question. Two of the more common data-poor methods, DCAC and DB-SRA, have been applied to data-rich stocks on the West Coast and found to be relatively accurate at estimating Maximum Sustainable Yield in comparison to the more traditional stock synthesis assessment method. Accuracy ranged from 70% to 85% for DCAC and 80% to 155% for DB-SRA for the west coast studies, but no similar work has been done on stocks in the Southeast. This study compares ACLs and biological reference point outputs from the Southeast Data, Assessment, and Review (SEDAR) stock assessments to those of data-poor methods (Figure 1) for the same stocks in order to determine the accuracy of the data-poor estimates when compared to the SEDAR estimates for fisheries in the Southeast. It will determine which, if any, simplified assessment methods are appropriate for use on a per-species basis and reveal which methods are best suited to set ACLs for data-poor fish stocks in the Southeast.

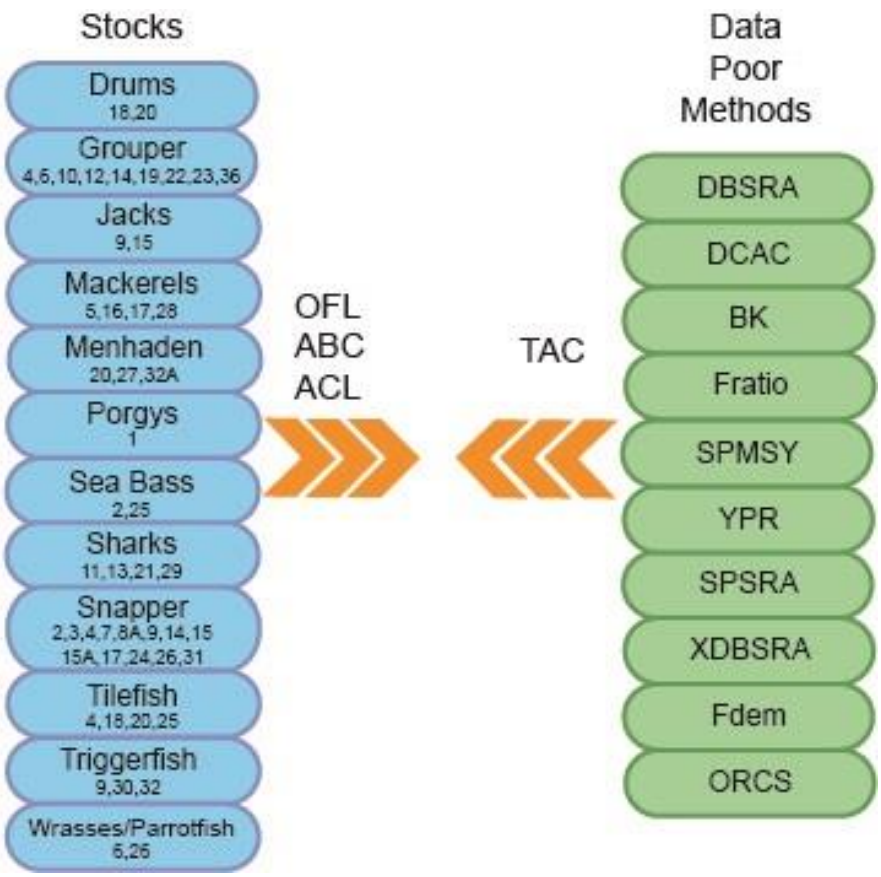


Figure 1: Schematic depicting species grouping and the associated SEDAR number from which annual catch limits (ACL), allowable biological catch (ABC), and overfishing limit (OFL) will be compared to total allowable catch (TAC) from data poor methods.

Research Performance Measure: Currently this project is in its infancy with the supported graduate student having completed their Masters thesis proposal related to the project. The final performance measures for this product will be a completed Masters thesis and a peer-reviewed publication.

Marine Mammal Research and Stranding Response

Project Personnel: L. Aichinger Dias (UM/CIMAS)
NOAA Collaborator: L. Garrison (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** (1) To assist the Southeast Fisheries Science Center (SEFSC)'s Protected Resources and Biodiversity Division in management and conservation of protected species under the Marine Mammal Protection Act (MMPA). (2) To support the Marine Mammal Health and Stranding Response Program (MMHSRP) in stranding responses in the US Southeast Region (SER), from NC to TX, and ensure data quality in compliance with the Data Quality Act. (3) To support the investigation of the Northern Gulf of Mexico Marine Mammal Unusual Mortality Event (UME) in data management and sample tracking under Chain of Custody (COC) procedures. (4) To assist during Natural Resource Damage Assessment (NRDA) studies associated with the Deepwater Horizon (DWH) Oil Spill in the Gulf of Mexico.

***Strategy*:** (1) To assist in project planning, data and sample management, and support field work during NOAA research cruises and small boat operations. (2) To respond and coordinate response actions during cetacean strandings dead or alive in the SER. (3) To validate historical stranding data working with the SEFSC staff and stranding network members to implement effective data auditing and correction. (4) To perform data management, auditing and image evidence handling in response to the investigation of the Marine Mammal UME in the northern Gulf of Mexico. (5) To assist in the collection, analysis and management of data gathered during NRDA studies associated with the DWH 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 developed and supported at the SEFSC's Marine Mammal Program relate to two main divisions of investigation: 1- Population Assessments and 2- Health and Stranding Response. Marine mammal population surveys were conducted in both offshore and near-shore waters of the Atlantic Ocean and Gulf of Mexico. During the summer of 2013, we participated as a marine mammal observer in the Southeast Atlantic Marine Mammal Assessment Survey cruise to assess the status of several marine mammal stocks under US jurisdiction. In the past year, we also assisted in the long-term monitoring of bottlenose dolphins (*Tursiops truncatus*), providing photographic services during the SEFSC Photo-identification (photo-ID) Project in Biscayne Bay, FL. That project monitors this wild dolphin population since the 90's and has a catalog of more than 200 resident animals. In addition to field efforts, and technical reports, permit renewals and Natural Resource Damage Assessment (NRDA) injury assessments related to the Deepwater Horizon oil spill in the Gulf of Mexico were prepared and submitted as required.

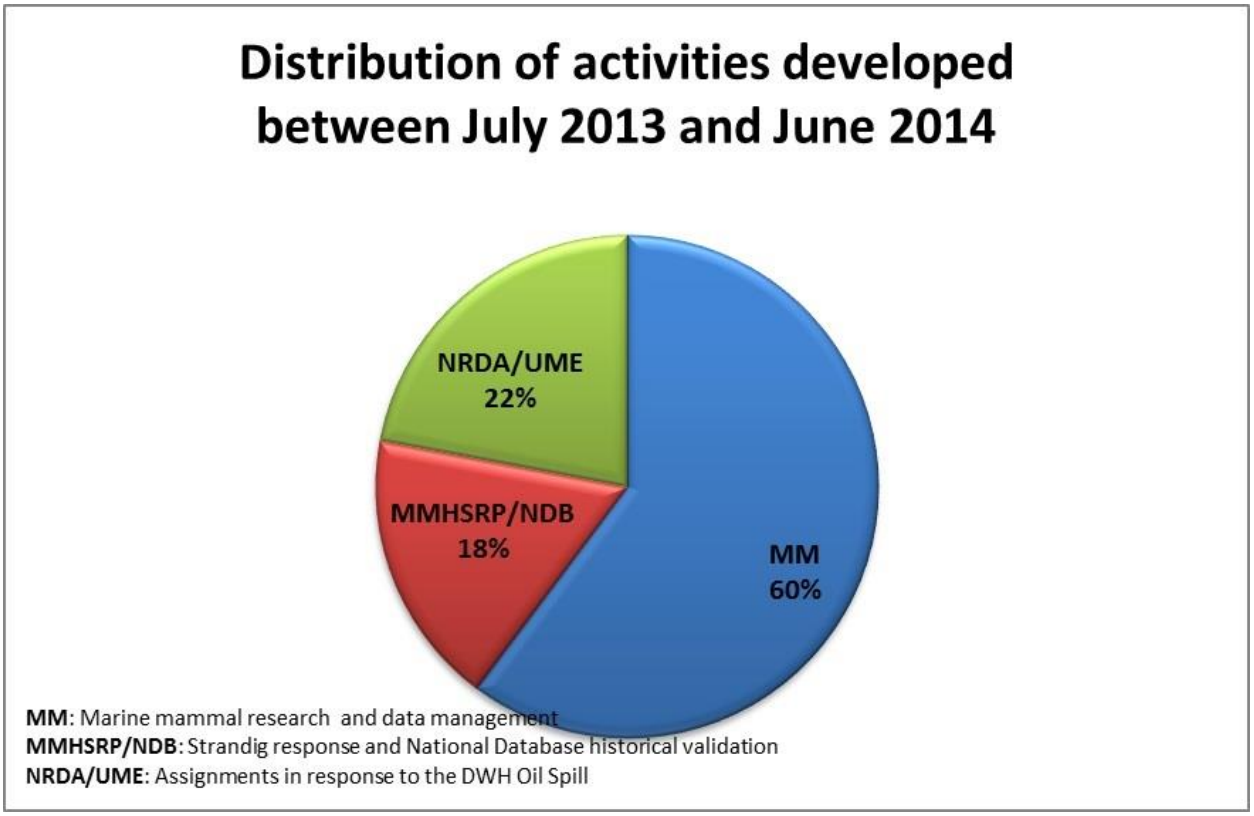


Figure 1: Distribution of activities developed between July 2013 and June 2014.

During the course of stranding actions, we responded to marine mammal strandings in the FL coasts, including a live sperm whale (*Physeter macrocephalus*) stranding in St. Petersburg and mass stranding events of pilot whales (*Globicephala macrorhynchus*) along the west coast of FL.

Concomitant to the SEFSC Marine Mammal Program's mission, the investigation of the Deepwater Horizon Oil Spill continues to be highly active. In the past year, we have managed data coming from the Gulf of Mexico in response to the oil spill such as marine mammal photographic evidence and COC records for samples collected during NRDA studies. In addition, we assisted in preparing and providing data in response to legal proceedings related to the DWH oil spill. Likewise, as part of the NRDA studies, we assisted in data analysis and in the writing of scientific reports to assess potential injury to offshore marine mammals associated with the DWH oil spill.

Recently, we were also involved in the response effort for the Galveston Bay oil spill, where we assisted in field response and necropsies of dolphin carcasses.

Figure 2: Risso's dolphins (Grampus griseus) seen approximately 90 nautical-miles off the South Carolina coast.

Research Performance Measure: All objectives were completed on time.

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Developing a Decision-Support Tool for the Management of Clam Farms on the FL Gulf Coast

Project Personnel: S. Baker, L. Sturmer, and P. Suprenand (UF)
NOAA Collaborator: J. Berkson (NOAA/SEFSC

Long Term Research Objectives and Strategy to Achieve Them:
***Objective*:** To develop a practical tool for understanding and predicting the risk of crop loss for use by Florida clam culturists in decision-making and farm management. Information from the Cedar Key area on the Gulf Coast of Florida will be used to develop a tool for this regain, and provide a proof of concept for a more general model.
***Strategy*:** To: 1) Identify and format available environment, clam mortality, health, physiology, and productivity data; 2) Synthesize data and develop a predictive model of crop loss risk, and 3) Provide a preliminary decision tool to growers.

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: Fisheries, Office of Aquaculture
NOAA Technical Contact: Mike Rust

Research Summary:
Hard clam culture research and monitoring activities have amassed a large quantity of data related to the environment, clam mortality, health, physiology, and productivity in Florida. Other than casual use by growers and researchers, and use in documenting qualifying perils, the environmental data sets have not been systematically examined and remain underutilized. In conjunction with the clam breeding research, field data sets on clam growth and mortality in different years and at different lease sites exist, as do laboratory data on upper thermal limits and survival time in multi-stressor challenges. Despite a great amount of work and data, no immediate and practical tool has been developed to help farmers reduce crop loss. To maintain and grow the economic impact of the hard clam aquaculture industry of Florida, to meet the increasing national and global demand for aquaculture products, and to respond to global climate change, the industry needs a practical tool for understanding and predicting the risk of crop loss for use in decision-making and farm management.

Funds are intended to support a Post-Doctoral Associate for one year; we have hired Dr. Paul Suprenand who will begin July 1, 2014. All project personnel (Berkson, Baker, Sturmer, Suprenand) have consulted together in Cedar Key and have begun an ongoing conversation concerning the project. To date, we have begun to identify data sets and consider appropriate formatting and archiving options. Water quality data sets (temperature, salinity, dissolved oxygen, turbidity, and water depth), spanning more than a decade, are available from monitoring platforms and *in situ* loggers. Clam productivity and mortality event documentation is being provided by Sturmer.

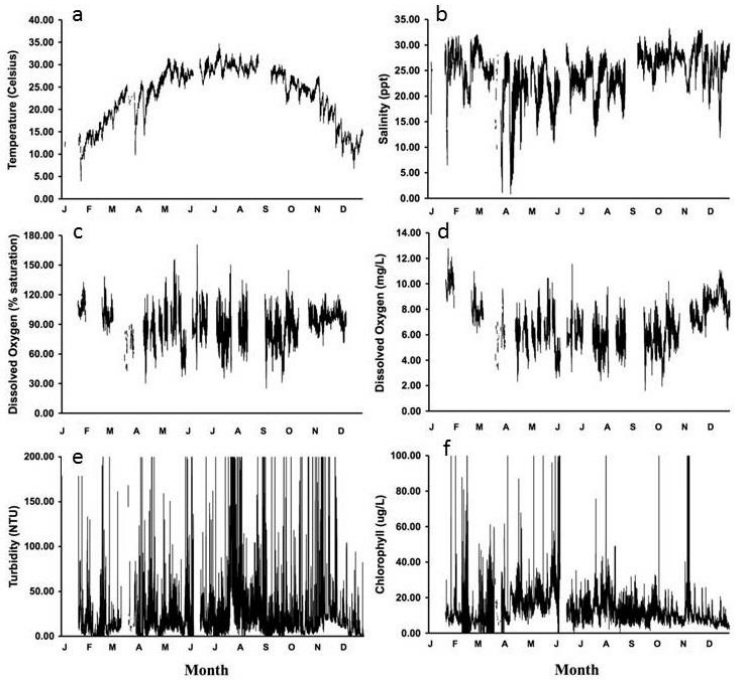

Figure 1: Data for **a** temperature, **b** salinity, **c** dissolved oxygen saturation, **d** dissolved oxygen concentration, **e** turbidity, and **f** chlorophyll measured at the Gulf Jackson shellfish aquaculture lease area, off of Cedar Key Florida, during 2003.

Research Performance Measure: Our progress towards the original objectives is consistent with the funding and hiring timeline. The budget was not released to the PI (Baker) until January 2014. Our first advertisement of the Post-Doctoral Associate position ended in a failed search, requiring that we re-advertise. We have now secured an accomplished collaborator (Suprenand) and progress toward our objectives should accelerate considerably.

Natural Resource Damage Assessment Plankton Processing

Project Personnel: S. Privoznik, A. Ender, P.E. Fortman, H. Krakoski, L. Rock, A. Jugovich, E. Keister, and T. Morrell (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 process relative the Deep Water Horizon BP oil spill incident.
***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 Deep Water Horizon (DWH) oil spill in 2010 has generated larger volumes of 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 sends plankton samples for analysis. The Early Life History laboratory at the NOAA/NMFS Southeast Fisheries Science Center, Miami Lab is assisting in the analysis of DWH plankton samples which are critical to ongoing DWH oil spill impact assessments and to advance understanding of plankton dynamics in the highly productive Gulf of Mexico.

Figure 1: (Clockwise from top left) Zooplankton samples arrive at Miami Lab. A. Ender processes sample following safety protocols under fume hood. Folsom splitter is used to divide a plankton sample into smaller aliquots. T. Gerard uses the Zooscan to capture an image of a plankton sample. E. Fortman sorts a plankton sample to remove ichthyoplankton. Juvenile fishes greater than 25 mm. Background image is a scan from the Zooscan of plankton after ichthyoplankton has been removed.

Table summary illustrating sample completion within all tiers received and completed by the Miami Lab as part of the DWH plankton processing project.

Research Vessel Name	Tier	Completion
Bunny Bordelon	1B	100%
Bunny Bordelon	2B	100%
Bunny Bordelon	3D	45%
McArthur II	1A	100%
McArthur II	2A	100%
McArthur II	3A	100%
Meg Skansi	1C	100%
Meg Skansi	2C	100%
Nick Skansi	3A	100%
Sarah Bordelon	1C	100%
Sarah Bordelon	2C	100%

Research Performance Measure: The large volume of samples generated in response to the DHW was divided into prioritized Tiers among the multiple institutions to facilitate processing and data acquisition. The SEFSC Miami Lab has processed a total of 1,250 samples. The first shipment included 1,100 zooplankton samples. To date, Tiers 1A, B and C and Tiers 2A, B, and C have been completed. This includes samples from five cruises carried out using the research vessels McArthur II, Bunny Bordelon, Sarah Bordelon, and Meg Skansi. Upon swift completion of the first shipment the Miami Lab received 692 additional zooplankton samples. Tier 3 is comprised Tier 3A & 3D: McArthur II 2, 4, and 5, Nick Skansi 9 & 10, and Bunny Bordelon 7. The Miami Lab processed 150 samples from Tier 3A. In addition, as part of the DWH protocols, all ichthyoplankton samples from Tier 1B have been scanned on a flatbed scanner. The ZooScan instrument is used to digitally record plankton samples at high-resolution. The contents of these images can later be identified and archived with specialized software. The Miami Lab also received a ZooScan instrument and completed scans of Tier 2A which contains 58 zooplankton samples.

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

Project Personnel: A. Gleason (UM/RSMAS)
NOAA Collaborators: G.T. Kellison, and C. Taylor (NOAA/Beaufort, NC Laboratory)
Other Collaborators: 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 and CRCP
NOAA Technical Contact: Theo Brainerd

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

Understanding the relationship between seabed habitat and spawning aggregations is important for the management of fish populations. One example is the design of marine protected area networks. In 1998 a large (~100 individuals) black grouper (*Mycteroperca bonaci*) aggregation was observed less than 100 m outside the Carysfort Sanctuary Preservation Area (SPA) within the Florida Keys National Marine Sanctuary (FKNMS). In 2003 this site was mapped with a single-beam acoustic seabed classification system and the site of the aggregation was observed to fall on the steep slope of the first Carysfort outlier reef, inshore of the deeper outliers. In 2007 four other sites of known historical FSAs in the upper Keys were mapped with the same acoustic system, all of which were found to also be associated with outlier reefs. In 2010 4 FSA sites in the lower Florida Keys were mapped with the same acoustic system. These results, along with those for the areas previously mapped in the upper Keys, were shared with NOAA and Florida Fish and Wildlife Conservation Commission (FWC) partners who used additional hydroacoustic surveys and diver observations to assess the current state of these aggregations.

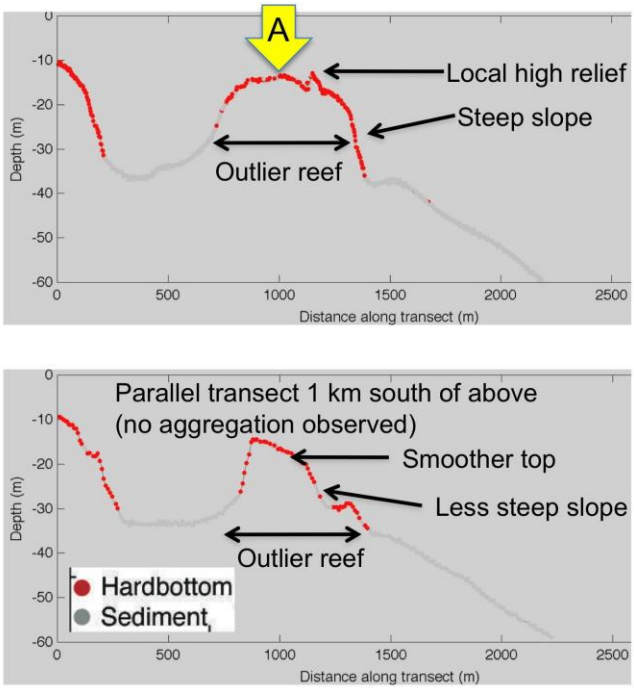

Figure 1: Two transects showing depth and substrate type near Western Dry Rocks in the FL Keys. Both transects run perpendicular to the arc of the reef tract from shallow water on the left side to deeper water on the right. The transect in the top panel ran directly over a site of regular grey snapper aggregations (located at the point of arrow "A"). The transect in the bottom panel is parallel to the one in the top panel, but located 1 km away. Note the differences in outlier reef morphology between these two nearby sites; the site where the aggregation was found has more small-scale relief and a steeper forereef slope than the site where the aggregation has not been found.

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.

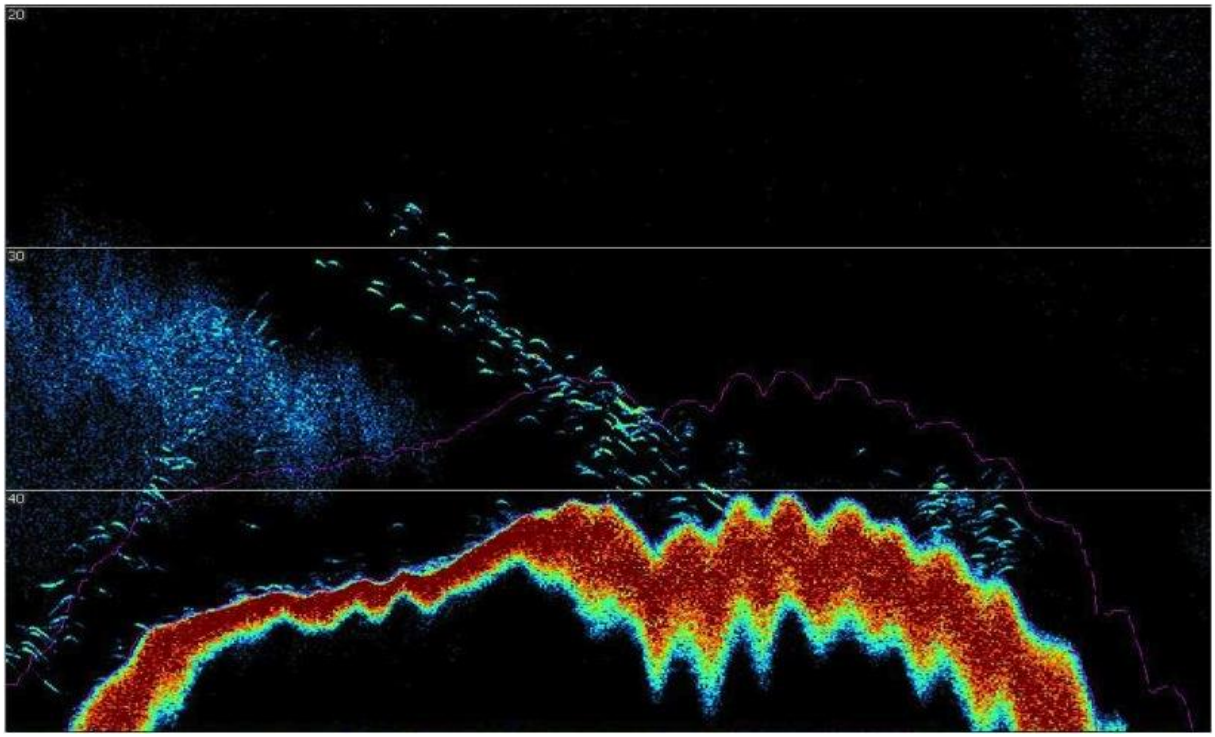

Figure 2: Acoustically-imaged fish (species not groundtruthed) over the Western Dry Rocks site; created from SIMRAD EK-60 backscatter data.

Research Performance Measure: Accomplishments were to (1) perform field surveys to assess the locations and status of reported reef fish spawning aggregations in the FL Keys, and (2) communicate our project results to relevant management agencies. For the field work component, we performed on-water (acoustic and diver) and aerial surveys across a broader range of months and predicted spawning moons than in previous years – made possible by increasing our sampling effort-to-cost ratio via increased sampling efficiencies. We performed on-water and aerial surveys on full moons in April (Key West and Key Largo), June (Key West), July (Key West and Key Largo) and August (Key West and Marathon), and on new moons in June (Key West) and July (Key West and Marathon). Planned surveys on the May full moon, targeting mutton snapper spawning aggregations, were necessarily canceled due to poor weather, which (in a good turn for the mutton snappers) apparently precluded a majority of fishers from targeting the full moon-associated spawning aggregations.

Mandatory Ship Reporting System

Project Personnel: R. Domingues (UM/CIMAS)
NOAA Collaborators: G. Goni, F. Bringas, J. Harris, and J. McKeever (NOAA/AOML)
Other Collaborators: P. Chinn (Consultant)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives: To reduce the number of whales killed or injured by ship strikes through the education of merchant mariners on the plight of the right by providing them with information about reducing the risk of ship strikes.

Strategy: The Mandatory Ship Reporting system requires all commercial vessels heavier than 300 gross tons to report to the Coast Guard upon entering two designated report areas (Figure 1). Reports are received through e-mail (RightWhale.MSR@noaa.gov) or Telex (236737831), processed and stored in a database, and a reply message is sent to the ships containing information about how to reduce the risk of ship strikes, including information about latest right whale sighting.

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/OPR and USCG
NOAA Technical Contact: Alan Leonardi

Research Summary:

The North Atlantic right whale has shown no significant signs of recovery over the past 60 years despite being a protected species. Ship strikes account for nearly one third of all known right whale mortality. In an effort to reduce the number of whales killed or injured by ship strikes, the United States proposed the creation of the Mandatory Ship Reporting System (MSR) to educate merchant mariners on the plight of the right whale, and to provide information about reducing the risk of ship strikes. The MSR was formally adopted in December, 1998, through the Resolution A.858(20), and commenced its operation on 1 July 1999. It requires all commercial vessels heavier than 300 gross tons to report to the Coast Guard upon entering two designated report areas (Figure 1).

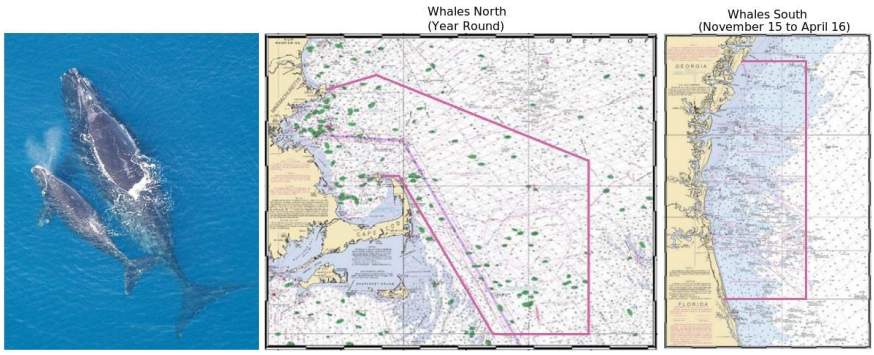

Figure 1: (left) North Atlantic right whale with calf. The (center) Whales North and (right) Whales South reporting areas along the east coast of United States within the Mandatory Ship Reporting system. The reporting requirements for each area are emphasized above the maps.

Nortel Governmental Solutions (previously known as PEC Solutions Inc.) designed and maintained the first version of the MSR under a contract to the USCG from 1999 to March 31st, 2014. In 2013, the USCG and NMFS opted to transition the system to an in-house government facility because of certain I/T security requirements. AOML/PhOD has been awarded with the development, management and housing of the new MSR, because of its previous experience with AMVER/SEAS, which is a program used for oceanographic and meteorological observations transmissions that involves systems very similar to the MSR.

The new MSR developed by AOML/PhOD is a LINUX-based system that includes a modern web interface (Figure 2), through which registered users can manage check the compliance with the MSR and manage the system. The information collected by the MSR database yields data on ship traffic volume, routes, and ports of call and assists in tailoring any necessary future ship strike mitigation measures. It also enables the generation of reports about the ship compliance with the U.S. MSR.

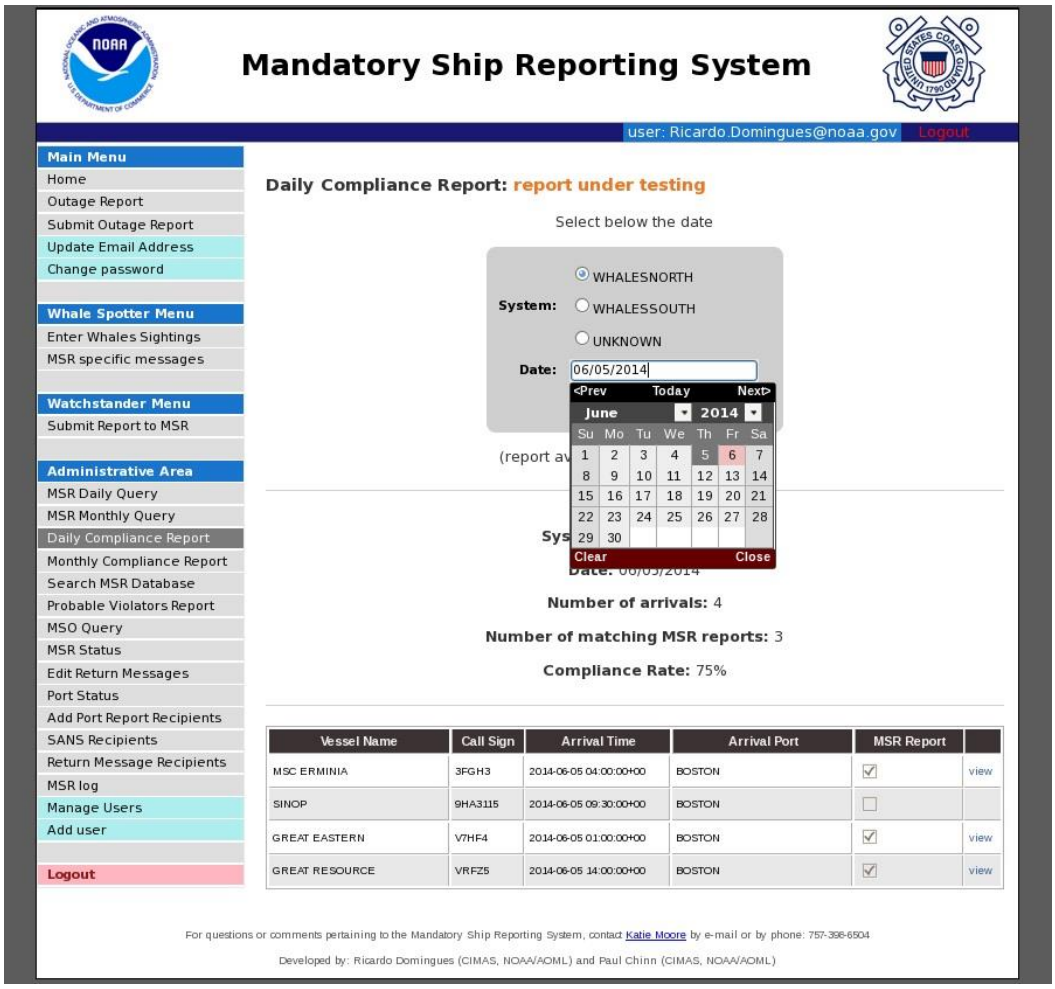

Figure 2: Screenshot of the new Mandatory Ship Reporting system web interface, which is available through the link for registered users: https://www.rightwhalesmsr.aoml.noaa.gov/.

Research Performance Measure: All planned goals were met during this year with respect to designing the new Mandatory Ship Reporting system, implementing it, and starting its official operation after April 1st, 2014.

Spatial Analysis of Pop-up Satellite Archival Tag data for Tuna and Istiophorid Billfishes incorporating Oceanographic Environmental Data and considering the Implications of Climate Change

Project Personnel: J. Luo, J. Ault, and N. Shay (UM/RSMAS); J. Hoolihan (UM/CIMAS)
NOAA Collaboraters: E. Prince (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To analyze pop-up satellite tag data to improve our understanding of the spatial/environmental habitat of tuna and billfishes, and to consider how environmental factors affect interactions with pelagic longline fishing gear.

***Strategy*:** To provide analytical support to the SEFSC Highly Migratory Species (HMS) Branch relative to analyses of data derived from electronic popup satellite archival tag data, and analysis of oceanographic features associated with the movement data derived from these electronic tags.

CIMAS Research Theme:

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

Link to NOAA Strategic Goals:

***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*

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

Research Summary:

Ocean heat content (OHC), a measurement of heat stored in a water column, has been used by oceanographers and hurricane researchers to study hurricane intensity over the past 4 decades. Expressed in joules per cm^2, OHC is estimated by integrating heat content from the depth of the 26 ^oC isotherm to the ocean surface. Currently, OHC is estimated by a Systematically Merged Atlantic Regional Temperature and Salinity (SMARTS) Climatology model that blends various data from satellite remote sensing (altimetry and SST) with ocean observing system data. In recent years, 100s of individual pelagic and coastal fishes have been tagged with pop-up satellite tags (PSATs) with temperature-depth-location sensors. Using a novel approach, we estimated the OHC from PSAT data and evaluated the accuracy and usefulness of this additional data source for the global OHC maps that are used for enhancing hurricane intensity forecasts. In pursuing this exercise, it became evident that dynamic OHC maps were potentially superior for revealing pelagic fish habitat than maps based on sea surface metrics (i.e., temperature or altimetry) alone. In this study we demonstrated how to use the OHC maps to refine movement tracks of large pelagic fishes, and to show how the fishes track the features of the ocean, such as fronts and eddies, using the OHC.

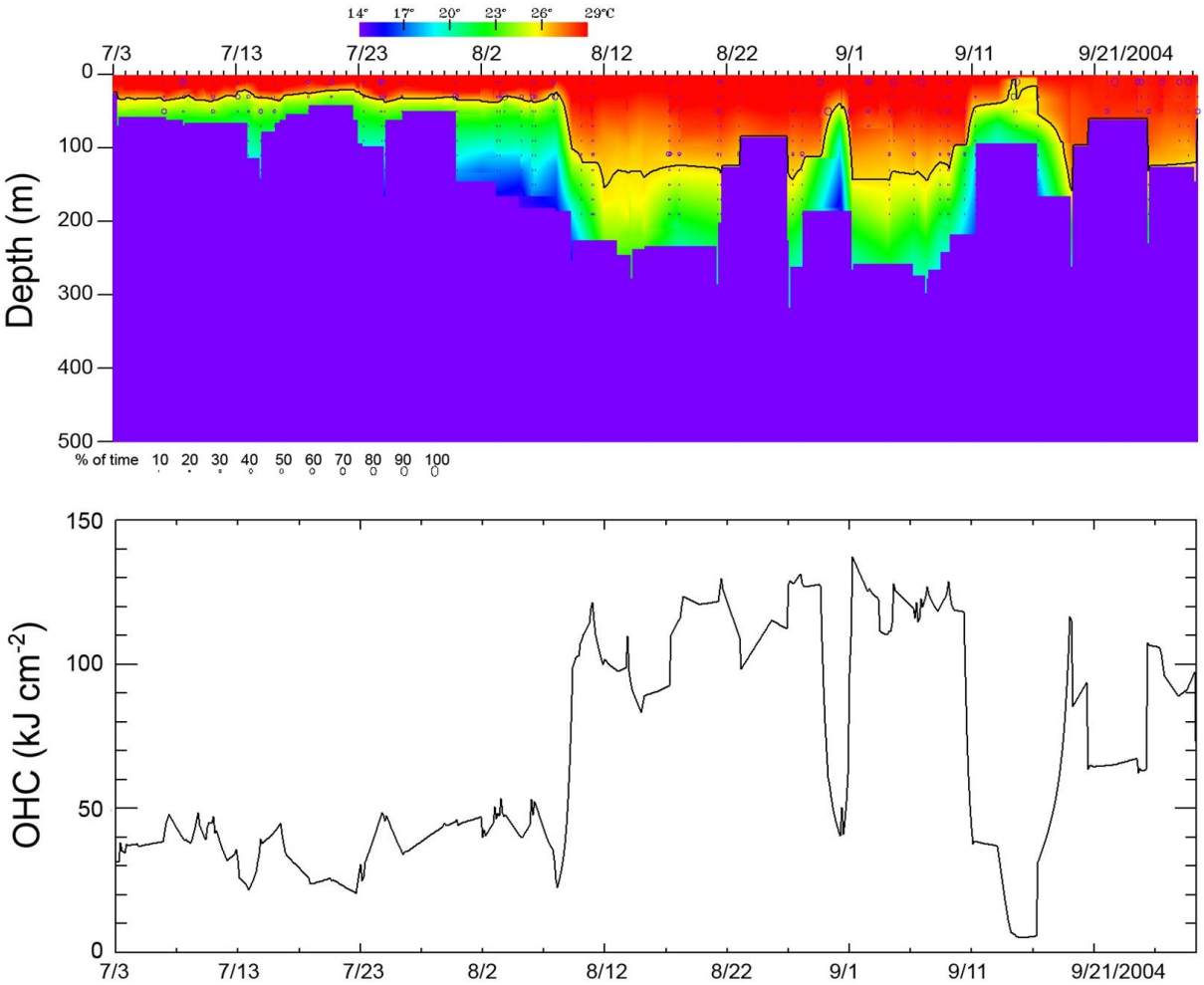

Figure 1: Depth and vertical temperature profile (top panel) from a PSAT tagged blue marlin in Gulf of Mexico, in 2004. Temperature is presented as color scale from 14 to 29 ^{o}C, and the black line indicates the depth of 26 ^{o}C isotherm. OHC estimates (bottom panel) from the depth and temperature profile.

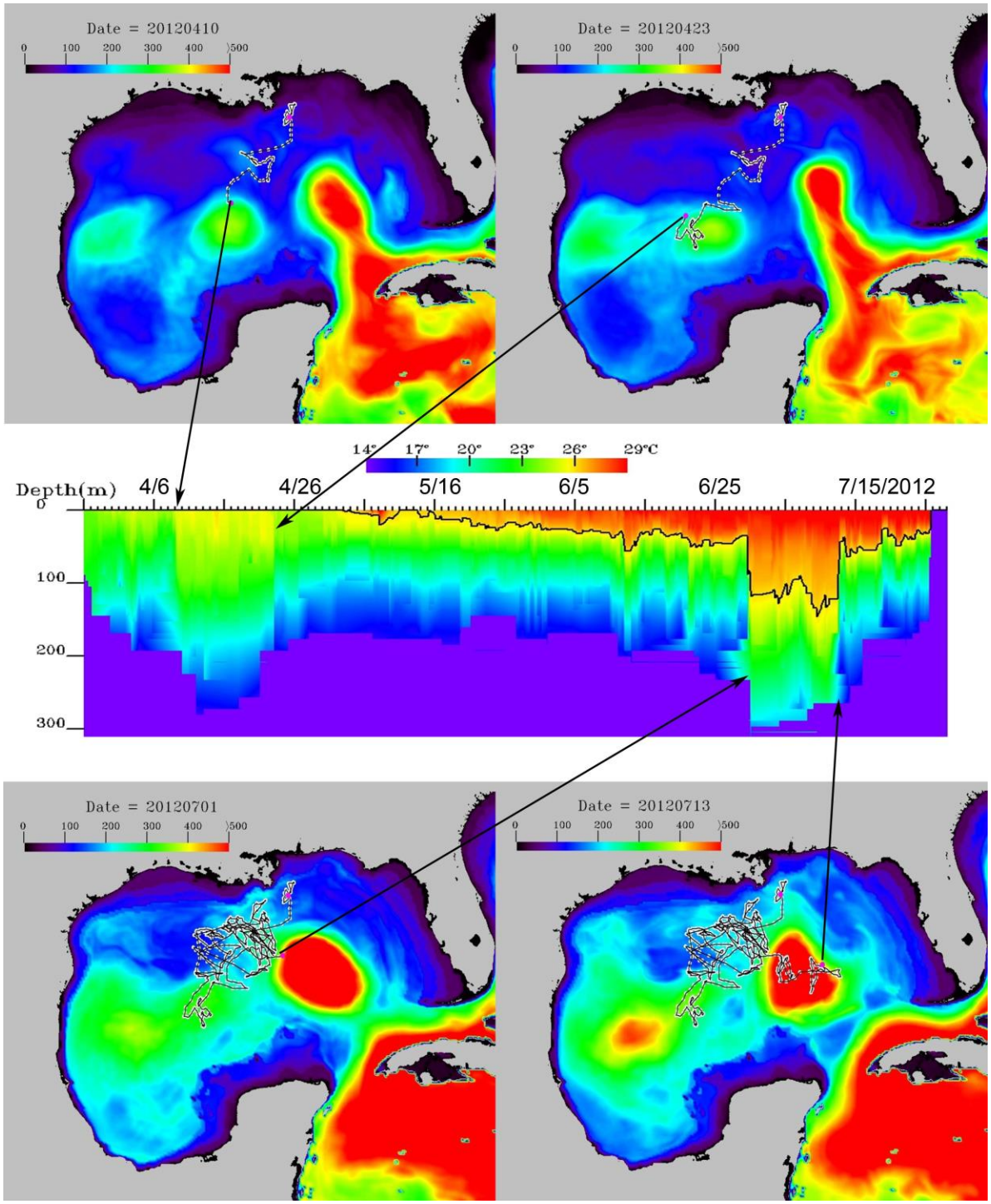

Figure 2: Eddies and frontal utilizations by a yellowfin tuna in Gulf of Mexico. (A) track position overlaid on the OHC map on April 10, 2012; (B) track position overlaid on the OHC map on April 23; (C) depth and temperature profile from the yellowfin tuna; (D)) track position overlaid on the OHC map on July 1; and (E)) track position overlaid on the OHC map on July 13.

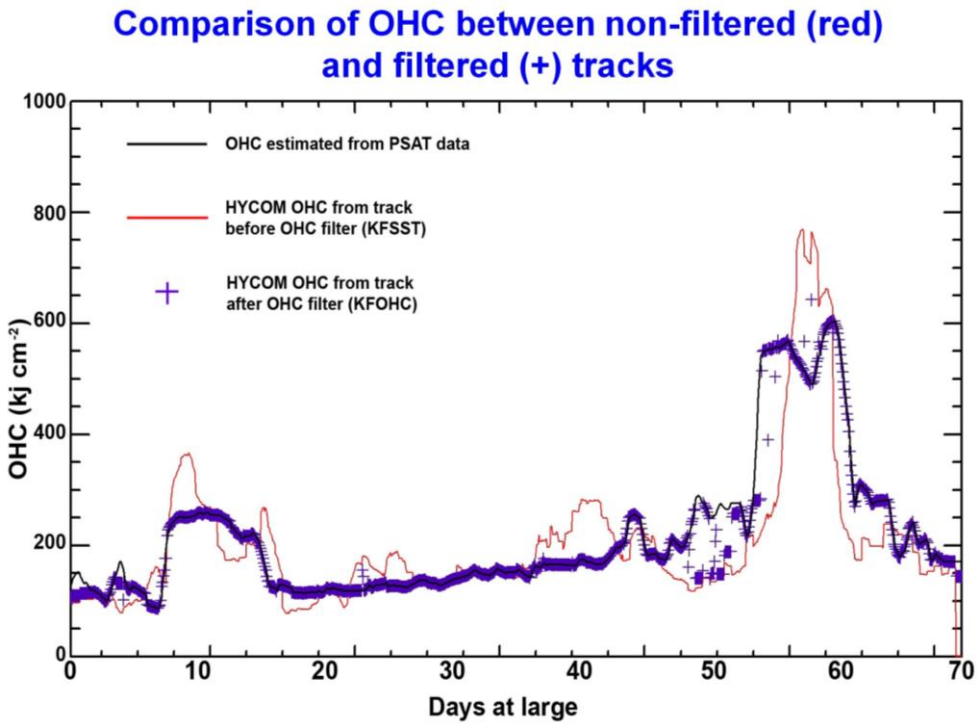

Figure 3: Comparison of OHC between SST filtered track and OHC filtered track. Black line is the OHC estimates from PSAT data; red line is HYCOM OHC values from SST filtered track; purple cross is the HYCOM OHC values from OHC filtered track.

Research Performance Measure: This project accomplished more than the original objectives.

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Dispersal, Habitat Use and Behavior of Neonate Sea Turtles

Project Personnel: K.L. Mansfield (FIU and UCF); M. Heithaus (FIU)
NOAA Collaborator: S. Epperly, and P. Richards (NOAA/NMFS/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** to integrate empirical (satellite telemetry) and theoretical (simulations of sea turtle dispersal in ocean circulation models) techniques to quantify the distribution of young sea turtles in the Gulf of Mexico; and to provide information to better evaluate the impacts of and guide restoration activities associated with the *MCS 252* oil spill. 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 released during three separate releases: November 2012 and 2013, February and April 2013, periods representing different current regimes offshore of the turtles' natal beaches. We have since been collecting and analyzing data and preparing a manuscript for publication.

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

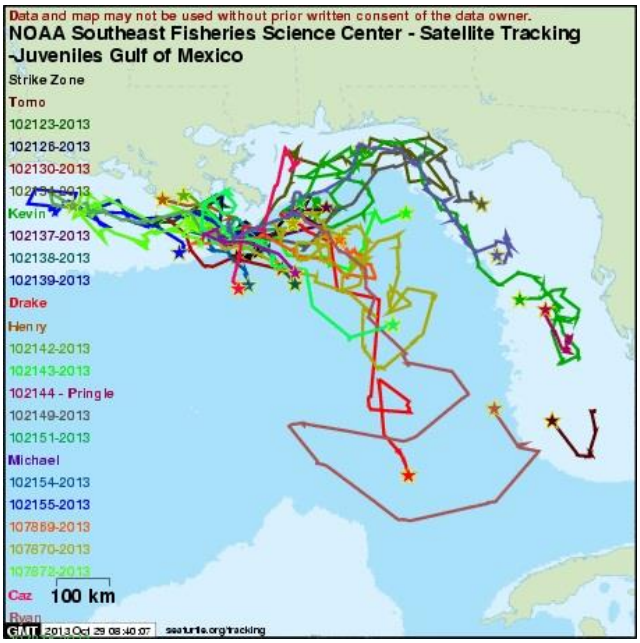
Link to NOAA Strategic Goals:
***Goal 3*:** Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems*

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

Research Summary:
Juvenile oceanic developmental and foraging habitats are not defined for any sea turtle species. As obligate air-breathers and relatively weak swimmers, the distribution of young, oceanic or pelagic stage juveniles is likely strongly constrained by surface currents. This leads to young turtles associating with flotsam and *Sargassum* found in small-scale downwelling zones that entrain passive or weakly swimming animals. Flotsam and *Sargassum* within these zones may also be actively sought by young turtles, as they provide refugia from predation and may concentrate turtles' prey items; however, they may also concentrate oil and other pollutants that are ingested by small turtles. Thus, young turtles may experience extended effects of oil exposure or habitat degradation.

Oceanic stage Kemp's ridley (*Lepidochelys kempii*) sea turtles were observed within oiled regions of the Gulf of Mexico in 2010. This size-range of turtle (typically <25 cm carapace length) is too small to be detected by aerial surveys. The greatest obstacle to recovery efforts and mitigating the impacts of the oil spill for sea turtles is the paucity of data regarding their oceanic stage distribution and habitat use in the Gulf. The immediate and ongoing impacts of the *MCS 252* spill is most difficult to quantify for post-hatchling, oceanic and transitioning neritic stage Kemp's ridleys. This species of sea turtle originates from nesting beaches located within the western Gulf of Mexico the majority spend their developmental oceanic years within Gulf waters.

Following methods by Mansfield *et al.* (2012), we are using solar-powered satellite transmitters to remotely track oceanic stage sea turtles captured in the Gulf of Mexico. Argos-derived and satellite imagery data, allows us to characterize fine-scale habitat selection, oceanographic conditions/features, and oiled areas encountered by the turtles. This is a multi-year project with field sampling occurring late summer 2011, spring-fall 2012-2014.



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 encountered by the turtles.

Figure 1: Movements of oceanic stage turtles tagged in the Gulf of Mexico (all species)

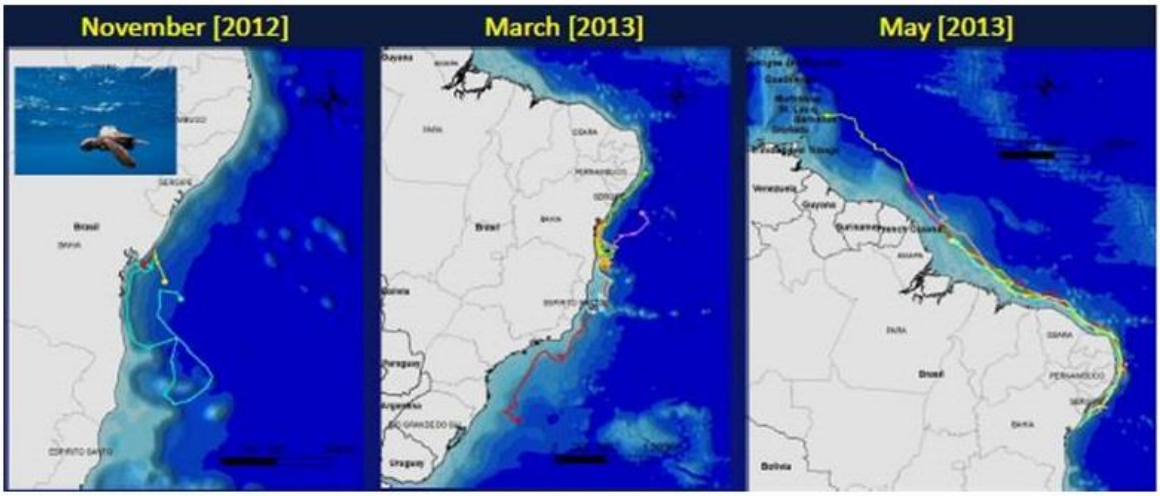


Figure 2: Movements of oceanic stage turtles tagged in the South Atlantic

Research Performance Measure: For our work in the Gulf of Mexico, to date, we have satellite tagged 48 oceanic stage and wild-caught sea turtles in the northern Gulf of Mexico. This includes the first wild-caught oceanic stage hawksbills (*Eretmochelys imbricate; n=2*). We also released 15 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 completed 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 has been published.

For our work in Brazil, we successfully released 19 tagged turtles during four different releases. We released 7 drifter pairs in conjunction with the turtle releases. We are currently analyzing data from the tagged animals and are on track to conclude this portion of the grant by the end of summer 2014.

Coral Restoration and Recovery

Project Personnel: B. Huntington, L. Richter, C. Cameron, D.E. Williams, and A.J. Bright (UM/CIMAS)
NOAA Collaborator: M.W. Miller (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To enhance scientific basis for implementing restoration and recovery of coral populations in south Florida and the Caribbean, 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 and potentially mitigating coral success, including cultured/restocked colonies.

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 ongoing project incorporates several components focused on supporting restoration and recovery of reef corals. The first component involves studies related to spawning, larval and post-settlement ecology of broadcast-spawning coral species. During the current project year, coral spawning in the Florida Keys was prolific and we completed several controlled crossing studies to test the compatibility of parental genotypes (ie., leading to successful fertilization), including those in active nursery culture for restoration. High variation in fertilization success (0-93%) was documented in these experiments mixing gametes from four haphazardly selected parents. This suggests either higher clonality in the parent population than anticipated (for *Orbicella faveolata*) or some degree of incompatibility in the parental genotypes (for *Acropora* spp. crosses in which parental genotypes were already known). Genetic analyses from these experiments are underway. Meanwhile, post-settlement survivorship also shows very high variation over multiple annual cohorts for both *A.palmata* and *O.faveolata* (0-50% over 6-9 weeks)

The second project component involves surveillance and mitigation studies to evaluate the performance of outplanted coral colonies (in comparison with local wild populations) and potential benefit of proposed mitigation actions to address disease and/or predation on outplanted colonies. This three-year study was completed in Nov. 2013 and has two related manuscripts under peer review. Overall, the prevalence of neither disease nor fireworm predation differed between outplanted and wild populations of staghorn coral in the upper Florida Keys. Simple interventions to mitigate severe disease impacts (i.e., epoxy band over the diseased-tissue line or excision of healthy branch tips from diseased colonies) on staghorn did not provide significant benefit whereas a simple intervention (snipping off of dead skeleton of preyed branch tips) reduced by more than half the rate of recovery of growing tips on staghorn branches preyed by fireworms.

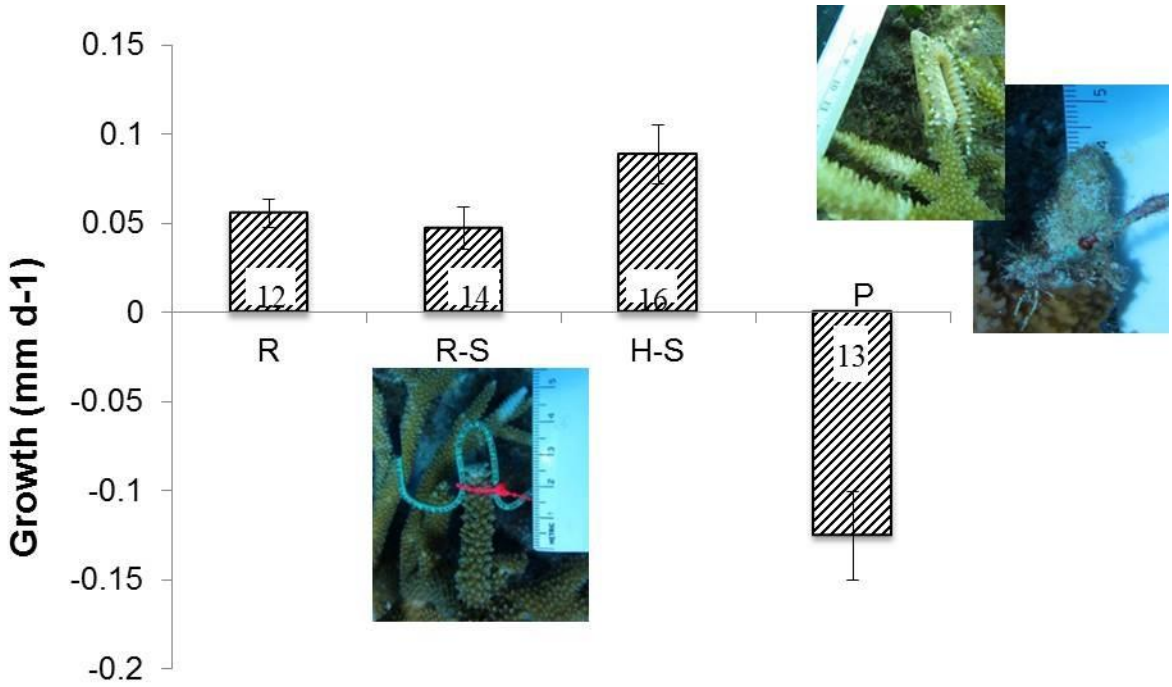


Figure 1: Fireworm Predation Mitigation: Growth (in mm d^{-1}) of branch tips from four treatments in the fireworm predation (pictured in upper inset) mitigation experiment. A significant one-way ANOVA on Ranks ($p<0.001$) indicated via Dunn's pairwise post-hoc comparisons that the preyed controls (P, pictured in upper inset) were significantly different from the three other treatments (R=dead skeleton removed; R-S= removed with shield, pictured in lower inset; H-S = Healthy tip control with shield), which did not differ from each other. N is given within each bar. Negative growth rate depicted for the P treatment indicates natural erosion of the dead skeletal tip (upper inset).

The third project component, initiated in 2012, involves observational and experimental studies to characterize naturally recovering staghorn populations in different regions (US Virgin Islands and Dry Tortugas during this project year). The primary objective of the research is to discern potential thresholds in staghorn coral density that affect associated fish communities and conspecific coral condition in order to aid design of staghorn coral outplants. Of the areas surveyed in 2013, the Pulaski Shoal region in the Dry Tortugas had the most dense, successfully recovering staghorn thickets that housed significantly greater fish species richness and small reef fish biomass compared to areas with sparser populations of staghorn coral. These dense thickets also showed improved coral condition (i.e., greater colony height, lesser predation and partial mortality) suggesting facilitation at high abundances. Furthermore, a growth experiment at Pulaski Shoal revealed that staghorn coral branch tips grew at a faster rate in dense thickets when compared to their counterparts in sparsely populated areas. The staghorn coral populations in the USVI, where 'high' staghorn coral abundance was much lower, did not show similar distinction in growth rates.

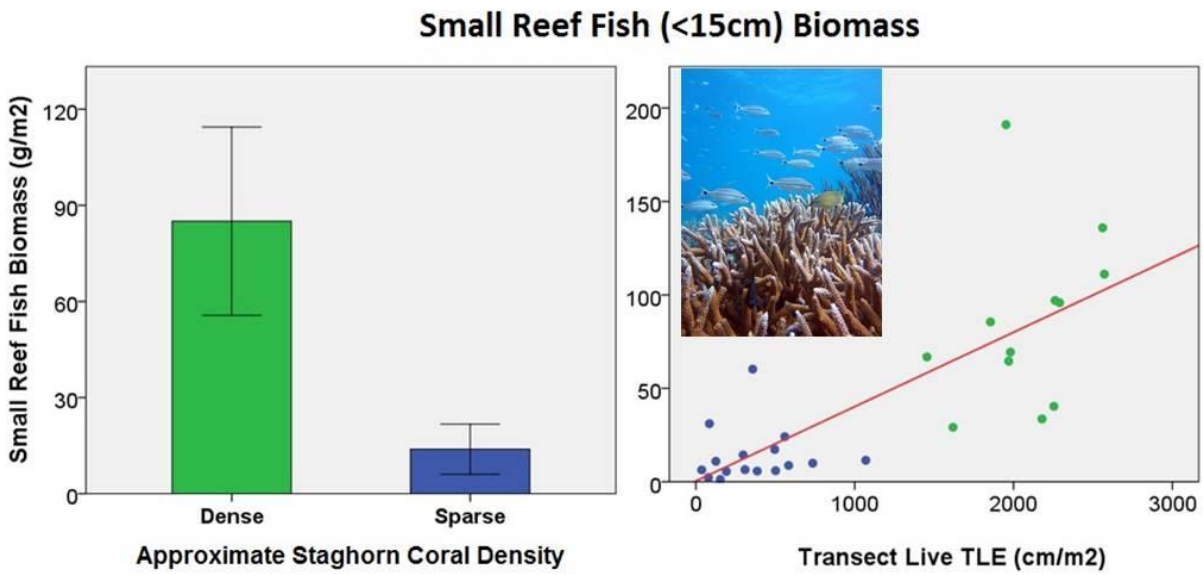


Figure 2: Small Reef Fish Biomass: The bar graph on the left shows that biomass of small reef fish (<15cm; illustrated in inset) is significantly greater (~6x) in reefs with dense assemblages of staghorn coral in the Dry Tortugas, when compared to more sparsely populated areas in the region. The scatter plot on the right mirrors this, displaying a significant positive regression between small reef fish biomass and total linear extension (TLE) of staghorn coral on each transect in the Dry Tortugas. TLE is a measure of abundance of staghorn coral (see Huntington and Miller 2014). The green and blue data points represent individual transects in the dense and sparse staghorn assemblages, respectively.

Research Performance Measure: Intensive field work is involved in each project component. This field schedule was accomplished, including multiple research trips, during the project year. The surveillance/mitigation component study has been completed and two resultant peer-reviewed publications are currently under review.

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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:
The common bottlenose dolphin (Figure 1) is a well known marine mammal that is common in the bays, sounds and estuaries (BSEs) of the northern Gulf of Mexico. The utilization of BSE environments, which are typically heavily impacted by anthropogenic activities, means that these dolphins are exposed to a wide variety of threats, such as pollution, fisheries, industrial activities, boat traffic, 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 etiology. Determining the impacts of all of these stressors on BSE dolphin stocks is currently difficult because little is known about the seasonal movement, gene flow, abundance and levels of mortality for the majority of the BSE stocks that have been delimited in the northern Gulf. Therefore, the aim of this research is to assess the population structure of bottlenose dolphins in selected bays, sounds and estuaries of the Gulf of Mexico using genetic methods.

Figure 1: Bottlenose dolphin, *Tursiops truncatus*.

In the summer of 2013, a total of 139 skin samples were collected from bottlenose dolphin for genetic analysis, 50 from Western Mississippi Sound in Mississippi and 89 from Texas (Figure 2). In Texas, the samples were collected from the Corpus Christi Bay and Aransas/Copano Bays area, the coastal waters adjacent to Corpus Christi Bay, San Antonio Bay, Matagorda Bay and the coastal waters adjacent to Matagorda Bay (Figure 2). Genomic DNA was extracted from all of these samples and we have genetically determined the sex of the sampled dolphins. Genetic data have been generated for these samples using two different molecular markers, mitochondrial DNA (control region) and microsatellite loci. To further expand the study across a broader geographic area, this year we have also generated genetic data from another 88 tissue samples previously collected from Tampa Bay, FL, Charlotte Harbor, FL and Sarasota Bay, FL. Additional sampling is planned to take place at the end of May through June 2014 to increase the number of samples in the coastal waters in Texas. The main goal in acquiring these additional samples is to be able to compare the dolphin stocks in Corpus Christi Bay, Copano/Aransas Bay and Matagorda Bay to the adjacent coastal stocks in each of these areas.

We have also developed a threat assessment priority scoring scheme that prioritizes the bottlenose dolphin stocks in the BSE's in the northern GoMx based on the number and severity of threats that dolphin stocks face and an evaluation of the quality of data available for performing a stock assessment. We have drafted a Technical Memorandum that fully describes the threat assessment process and explains the rationale behind the scoring used to produce a final assessment of the priority of a given stock (low, medium or high). We have also completed summaries of literature reviews performed for each of the seven BSE dolphin stocks in Texas and the final overall priority score for each of the seven Texas BSE stocks.

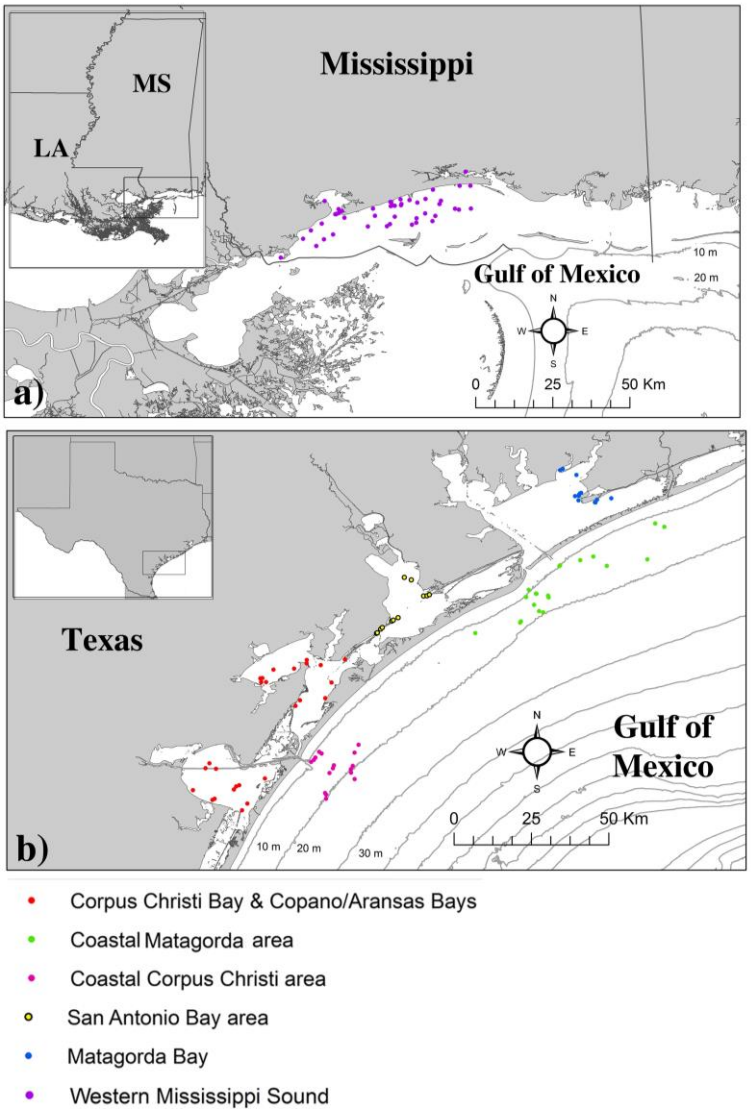

Figure 2: Sampling locations of bottlenose dolphins in: a) Mississippi and b) Texas in the summer 2013.

Research Performance Measure: All tissue samples collected in the second 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 of the literature reviews for the Texas BSE's dolphin stocks have been completed and the Technical Memorandum was drafted. All major objectives are being met.

Developing a Low-Cost, In-Water Stereo-Video Camera for Use in Fishery-Independent Surveys

Project Personnel: K. J. Voss and A. Gleason (UM/Physics)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To develop a low cost (<$10K) stereo camera system that can be mounted on a fish-trap and used during fishery-independent surveys.

***Strategy*:** To survey existing commercial stereo systems and individual cameras to find a suitable system that can be economically packaged in underwater housings; to build a prototype camera system using the selected camera components.

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: Todd Kellison

Research Summary:

Fishery-independent surveys, which are a central component of modern fishery stock assessments, often employ fish traps as a sampling method. However, there are concerns on selectivity of these traps, thus it would be desirable to have a camera system that could optically survey the volume around the trap to independently measure fish length for stock assessment. More accurate measurements would allow decreased uncertainty in the assessment and thereby improve fishery management decisions. Stereo-camera systems exist and have been used previously for fish census and sizing, but typical costs for such systems are >$15,000 which limits the number of units that can be deployed. Furthermore, since fish traps are often placed in oceanic areas with high current, there is a risk of equipment loss during deployment. Thus a relatively low cost (<$10K per unit) stereo system is desired from the perspective of both increasing sampling capability through the use of multiple systems and decreasing the impact of loss.

This effort was to survey the existing stereo camera systems and techniques to determine the most cost effective system and then build a prototype system.

Research Performance Measure: We have met the objectives of the project. We built a camera system, in an underwater housing rated to 100 m depth that cost less than $3,000. We have done some very preliminary testing of this prototype system. We currently have three cameras in the system at this time. Three cameras allow both more accuracy at longer distances (by using the two outside cameras with an effectively longer baseline) and decrease the distance in the near field for the first overlap region between two cameras. In the intermediate range it may help us determine the measurement uncertainty, as we will have 3 pairs of stereo camera images to work with. As we test the system we will be working to see if the gain in three cameras is worth the extra complexity (and size) of the system.

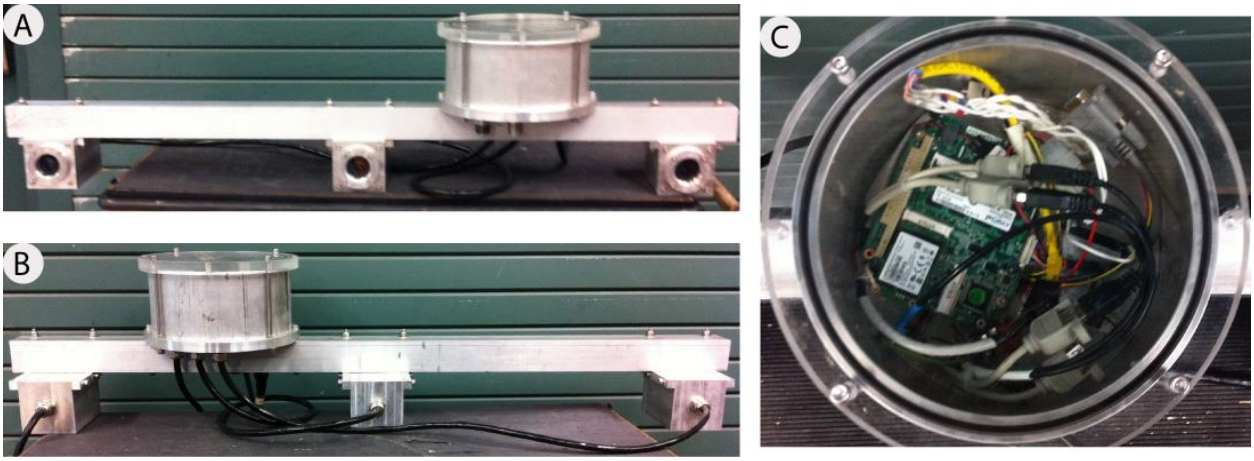

Figure 1: Pictures of the assembled camera system, which incorporates three synchronized cameras and a control computer. The windows on the front of the camera housings are visible in view (A), and the cables connecting the cameras to the computer housing are visible in view (B). Top view (C) shows the single-board control computer and wiring.

Figure 2: Sample synchronized images from the three cameras. Red arrows point to a computer monitor that was displaying a clock. By comparing the times on the clock, synchronization was verified to < 1 ms.

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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 Division through data collection and management within the Marine Mammal Program. (2)

Strategy: (1) To perform field work and data management during marine mammal sampling efforts in the Gulf of Mexico and Atlantic Ocean. (2) To lead surveys within the Southeast Atlantic Marine Mammal Assessment Program and collect data on the abundance, habitat, and spatial distribution of cetaceans within U.S. waters. (3) To support the Atlantic Marine Assessment Program for Protected Species (AMAPPS) by collecting biopsy samples, photographic data,

acoustic data and visual data. (4) To assist on the Biscayne Bay's bottlenose dolphin population long term 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 marine mammals in the southeastern United States waters. I have supported research projects in the Gulf of Mexico and Atlantic Ocean resulting in over 500 marine mammal sightings, 39 biopsy samples, and 5,475 (km) of visual survey effort. The summer 2013 AMAPPS large vessel survey assessed the abundance, habitat and spatial distribution of marine mammals, sea turtles and seabirds through visual and passive acoustic monitoring and biopsy sampling.

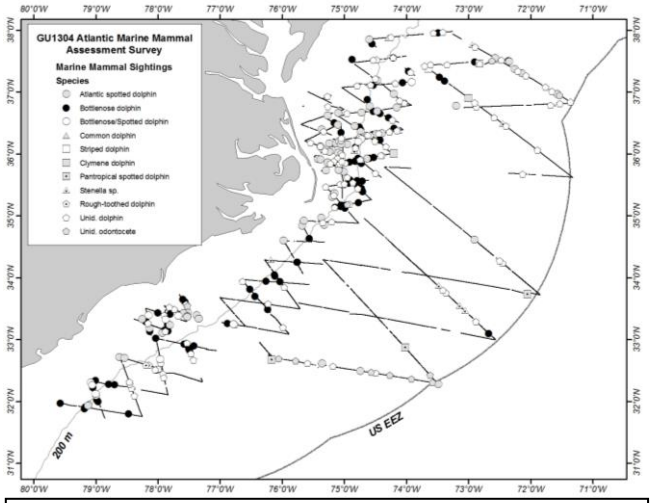

Figure 1: Dolphin Sightings.

Research Performance Measure: all objectives were completed on time.

- Conducted Pre and Post cruise planning and supported the development of procedures and protocols for marine mammal research cruises with a focus on passive acoustic and photographic data collection and management.
- Served as Field Party Chief and small boat coxswain onboard NOAA ship Gordon Gunter during the marine mammal large vessel survey during the summer of 2013.
- Assisted in the development of cruise plans and lead survey teams while in the field.
- Maintained and verified data quality, interacting with principal investigators to effectively execute scientific methodology during the cruises.
- Managed and updated the Biscayne Bay Photo ID Database and continued to import historical data into FinBase database
- Assist in NOAA small boat field work through SE United States.

NOAA Coral Reef Conservation Program (NOAA CRCP) National Coral Reef Monitoring Plan (NCRMP) Benthic Component Development

Project Personnel: S.L. Miller, M. Chiappone, and L.M. Rutten (NSU-OC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To assist NOAA's Coral Reef Conservation Program (CRCP) with protocol development and implementation to assess the status and trends of coral reef resources and process in U.S. territorial waters.

***Strategy*:** (1) Assist scientists from NOAA's Southeast Fisheries Science Center (NMFS/SEFSC) and NOAA's Biogeography Branch with the development of protocols for surveying reef benthos using standardized methodologies in the U.S. Atlantic (Florida, NW Gulf of Mexico, Puerto Rico and the U.S. Virgin Islands) to acquire information on the coverage of reef benthos and the density, size, and condition of corals. (2) To conduct on-the-water training to field test and refine benthic survey protocols prior to initial fieldwork in the U.S. Virgin Islands and NW Gulf of Mexico (Flower Gardens) during July-September 2013. (3) To assist NOAA and the National Park Service with benthic and reef fish surveys in the U.S. Virgin Islands (St. Thomas and St. John) during July 2013. (4) To take lead responsibility with the coordination of reef benthic surveys in southeast Florida with Federal, State, and Academia partners.

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/SEFSC
NOAA Technical Contact: Theo Brainerd

Research Summary:

NOAA's Coral Reef Conservation Program (CRCP) initiated the *National Coral Reef Monitoring Plan* (NCRMP) to provide a consistent flow of information to assess and report the status and trends of environmental conditions, living reef resources, and the people and processes that interact with coral reef ecosystems in Federal and U.S. territorial waters (NW Gulf of Mexico, Florida, U.S Virgin Islands, and Puerto Rico). The NCRMP builds upon a decade of CRCP-supported monitoring and reporting efforts in U.S. territorial waters. The scope of the NCRMP is necessarily large and when fully implemented over the course of several monitoring cycles, is intended to "take the pulse" of coral reef ecosystem conditions throughout U.S. States and Territories. It is also intended to provide a backdrop to help evaluate other more localized CRCP programs in coral reef ecosystem conservation and management.

The NCRMP aims to answer the following questions across four monitoring themes (benthic community condition, fish community structure, climate, and human dimensions):

- What is the status of coral reef ecosystem biota?
- Is community structure changing over time?
- What are the trends in temperature and acidification in waters surrounding coral reefs?

- What is the status of human knowledge, attitudes, and perceptions regarding coral reefs?
- How are human uses of, interactions with, and dependence on coral reefs changing over time?

These questions will be answered in all of the primary coral reef jurisdictions of the United States, in both the Atlantic and Pacific basins. In the Atlantic basin, benthic and fish monitoring will be conducted every other year, alternating between the U.S. Virgin Islands and NW Gulf of Mexico in one year with Florida and Puerto Rico the next. A requirement of the program is that the monitoring protocols must be relatively quick and efficient to conduct underwater and must be clear enough to train benthic divers effectively. Additionally, the protocols must be based on best scientific practices.

Research Performance Measure: From January to June 2013, a substantial effort was devoted to working with NMFS/SEFSC and NOAA Biogeography to develop benthic sampling protocols to capture information on the coverage of reef benthos, the depth/topography of reef and hard-bottom habitats, and the density, size, and condition of reef-building corals in four regions of the U.S. Atlantic targeted for sampling in 2014. By April 2013, these protocols, which were largely based upon a long-term monitoring program in the Florida Keys, were field tested during a three-day training mission during April 2013 with agency and academia partners (P.I. Steven L. Miller) at Broad Key, FL. Subsequent to this training event, the benthic survey protocols and underwater data forms were finalized in preparation for field sampling in the U.S. Virgin Islands (St. Thomas and St. John), which commenced on July 8, 2013. A team of scientists from Nova Southeastern University, University of the Virgin Islands, NOAA Biogeography, NMFS/SEFSC and the National Park Service conducted reef fish and benthic surveys, along with water sample collection, at over 400 sites during July 8-19 around St. Thomas and St. John. Hard-bottom and reef habitats were surveyed for: (1) the species/density/size of reef fishes, (2) benthic cover, (3) density/size/condition of reef corals, presence and absence of corals listed or proposed for listing under the U.S. Endangered Species Act, and the density of queen conch, spiny lobster, and *Diadema antillarum* urchins. Data forms were scanned and entered into a data entry system constructed by NOAA Biogeography (see Figures 2 and 3 for scanned versions of the data forms). Survey teams also compiled and organized digital photos of each site visited. Post-mission work included QA/QC of field data forms and further refinement of benthic survey protocols, which were used in the NW Gulf of Mexico (Flower Garden Banks) during September 2013. A significant effort was spent during January-May 2014 with coordination of planning of reef fish and benthic surveys in Florida to be conducted during June-October 2014. Because of our history sampling in Florida, we accepted responsibility for benthic survey design and implementation in three sub-regions: the Southeast Florida Coral Reef Initiative region from Martin County to

Figure 1: National Park Service biologist Rob Waara conducting a reef fish survey in St. John on 8 July 2013. Line transects were used to survey reef fishes and benthic organisms around the islands of St. Thomas and St. John at over 400 sites during July 2013.

NCRMP Line Point Intercept Datasheet

LPI Diver		Fish Diver		Demo Diver	
Site ID		Date		Time	
Habitat type	Bedrock Linear Patch Pavement Scattered Coral/Rock				
Categories: one tick every 20cm	Hardbottom		Soft	Rubble	Macroinvertebrates on 25x2 transect
Coral (to Genus)					Count
					Lobster
					Conch
					Diadema
					Presence(1)/Absence(0) on 25x2 transect
Bare					A. palmata
TURF-no sediment					A.cervicornis
TURF w/sediment					D. cylindrus
MACRO-*Dictyota*					M. ferox
MACRO-*Halimeda*					A. lamarcki
MACRO-*Lobophora*					M. annularis
MACRO-other fleshy					M. franksi
MACRO-other calcareous					M. faveolata
CCA					D. stokesii
Peysonnellia					
GORG upright					
GORG encrusting					
SPONGE other					
SPONGE *Cliona* spp					
CYANOBACT/DIATOM					
Millepora					
PALYTHOA					
SEAGRASS					
Other					
NOTES					

Figure 2: The NCRMP data form for surveying benthic cover, the presence-absence of ESA-listed or proposed corals, and the density of queen conch, spiny lobster, and *Diadema antillarum* urchins.

NCRMP Coral Demographic Datasheet

Demo diver		Site ID		Habitat type					
Fish diver		Date		Bed	SCR	Patch	Linear	Pave	Other
LPI Diver		Time		Transect completion (1-10 meter)					

Coral Dimensions				Old mort. (%)	Recent mort. (%)	Bleached-Total, Partial, None (T, P, N)	Disease-Present (P), Absent (A)	Coral Dimensions				Old mort. (%)	Recent mort. (%)	Bleached-Total, Partial, None (T, P, N)	Disease-Present (P), Absent (A)
Coral ID	Max Diam (cm)	Perp Diam (cm)	Height (cm)					Coral ID	Max Diam (cm)	Perp Diam (cm)	Height (cm)				

NOTES

Figure 3: The NCRMP data form for surveying the numbers, sizes, and condition of scleractinian reef corals. This data form was used in the U.S. Virgin Islands during July 2013 and in the NW Gulf of Mexico during September 2013.

northern Dade County, the Florida Keys from northern Biscayne National Park to the Marquesas region, and the Marquesas/Dry Tortugas area. Survey protocols and data forms were slightly modified based upon the NCRMP protocols used in 2013 for use in Florida during 2014. At the time of this writing, we have coordinated field sampling equipment, addendums to the NCRMP benthic survey protocols, and delivery of field data forms for the first of two research cruises to the Dry Tortugas region. Our research group will be conducting surveys at approximately 400 hard-bottom and coral reef sites in the Florida Keys beginning June 1, 2014. This effort will sample NCRMP variables, but also a larger suite of variables (species richness of gorgonians and sponges, other invertebrates, marine debris). We will also help coordinate surveys in the SEFCRI area in conjunction with reef fish surveys planned by Nova Southeastern University.

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Synthesis of Information on Octocoral Biology, Ecology, and Fisheries in the U.S. South Atlantic in Support of Effective Management

Project Personnel: S.L. Miller, M. Chiappone, and P. Espitia (NSU-OC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To synthesize known life history and quantitative information for the prominent octocoral species being collected for the marine life aquarium trade in the U.S. South Atlantic (especially Florida), and to describe the octocoral fishery in this region.

***Strategy*:** (1) To conduct a thorough literature review of the most commonly targeted taxa in the U.S. South Atlantic octocoral fishery (as identified in the Scope of Work and per communications with collectors) and synthesize a life history table based on this review. Additional quantitative data from several years of benthic monitoring as part of a Florida Keys-wide monitoring project directed by Dr. S.L. Miller are being analyzed and mapped to describe octocoral species abundance and distribution at multiple spatial scales over time. (2) To review landings data collected by the Florida Fish and Wildlife Conservation Commission and interact (through conversations and observations) with octocoral collectors to validate the octocoral species being collected, the collection locations, collection and shipping techniques, and collectors' perceptions of the sustainability of the fishery. (3) To assess data gaps to determine research and management needs for the octocoral fishery and to develop a species identification guide to better standardize reporting by collectors to State and Federal management entities in the U.S. South Atlantic.

CIMAS Research Theme:

***Theme 7*:** Protection and Restoration of Resources (*Primary)*
***Theme 6*:** Ecosystem Management (*Secondary*)
***Theme 1*:** Climate Research and Impact (*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:
A three-tiered approach is being utilized to evaluate octocoral landings and fishery impacts for better management of the U.S. South Atlantic octocoral fishery. Current quotas and landings are based on a broad taxonomic classification (e.g. class and color) that group species with less vulnerable life histories with those with potentially vulnerable life histories such as slow growth and low recruitment rates. For example, no distinction in quotas or landings is currently made between shallow-water and deep-water octocoral species, despite the limited distribution and life history data available for deep-water species. Further confounding this issue is the popularity of deep-water species within the aquarium industry due to their vibrant red and orange coloration.

The first step in this study was to identify the targeted octocoral taxa within the fishery. Species/genera lists were supplied by octocoral collectors Jack Rudloe from Gulf Specimen Marine Lab (Wakulla County), Daniel Fenton (Hillsborough County), and Dr. Henry Feddern (Monroe County). A literature search of these species has resulted in over 300 references from which a life history table summarizing the range, depth, reproductive traits, growth and regeneration rates, etc. is being constructed. The distribution and abundance of shallow-water octocoral species are currently being analyzed and mapped, using data from several years of benthic monitoring as part of a Florida Keys-wide monitoring project directed by Dr. S.L. Miller. The next steps will be to determine collection sites and then compare these sites with the known distributions and abundance patterns of these species. This will provide information about whether or not collectors are removing octocorals from areas of relatively high or low colony densities. These data will also help to determine if additional benthic surveys are required to better understand the habitat characteristics of collection areas and the condition of octocorals.

The second part of this study involves sending written and electronic requests for information to the 64 octocoral collectors who reported TRIP tickets in 2013. Twenty interviews of presumably the more active octocoral collectors in the southeast and western Florida regions were conducted by phone and in person. The octocoral fishery is primarily an “on demand” fishery. While octocorals consistently comprise at least 20% of some businesses, others receive fewer than 50 requests for octocoral colonies per year. The majority of collectors are selecting small (< 30 cm colony height) specimens that comprise a variety of shallow-water species from the Florida Keys, the west coast of Florida, and Miami-Dade, Broward, and Palm Beach Counties. In addition to collecting entire colonies, some (n=5) collectors clip several 10-cm long sections from a few larger adult colonies. These types of clippings (or fragments) have been branded “Eco-Gorgs” and are perceived as an ecological alternative to removing an entire colony. As such, they are sold at a higher price point. One collector who has been identified specializes in collecting (both whole colonies and clippings) and selling deeper-water species such as *Swiftia exserta* and *Diodogorgia nodulifera*, mainly from Palm Beach County. The collector sources the colonies to wholesalers including other collectors. Many collectors listed did not respond to paper or electronic requests for interviews.

Members of the Florida Marine Aquarium Society (FMAS) have also been contacted. Following a presentation on octocoral biology and ecology given during an FMAS monthly meeting, several members were forthright in sharing their experiences with keeping octocorals in their home aquariums. Four octocoral hobbyists interviewed indicated that the demand for octocorals is growing as knowledge on octocoral care is spread via hobbyist list-servers and magazines. In addition, octocorals are perceived to be a sustainable and well-managed group of organisms, thus are considered an ideal candidate for home and public aquariums. The next steps are to work with collectors in the field from the Florida Keys, Miami-Dade, Broward, and Palm Beach Counties, and

the west coast of Florida, with the goal of better understanding which species are being collected and to document the collection techniques used. Specimen photographs will be used to create a waterproof identification guide that can be used by collectors, which will hopefully improve the effectiveness of future reporting and help refine identification of octocorals that are being sold.

Step three of this study is to determine if the level of data being collected at the State of Florida and Federal levels is sufficient to effectively manage the octocoral fishery. Initial review of the available literature indicate that there are notable information gaps in distribution, reproduction, growth, and regeneration data for deep-water octocoral species such as *Diodogorgia nodulifera* and *Swiftia exserta*. In addition, collectors uniformly agree that more specific reporting (genera and some species) practices are necessary. Collectors have expressed concern about reporting fragments versus entire small colonies. For example, how does one report five (5) fragments from a single colony? It appears that as more collectors begin to clip fragments rather than take whole colonies, these types of reporting issues will need to be addressed. An additional year of funding has been granted to this project (now a three-year study) to address some of the data gaps identified in the first step of this study. Potential areas of study include collecting distribution and abundance data for sites not captured in previous benthic surveys such as nearshore and deep-water sites, and determining growth, regeneration, and recruitment rates of deep-water species.

Figure 1: The deep-water octocoral *Diodogorgia nodulifera*, which is collected along the southeast Florida coast for the marine aquarium trade.

Research Performance Measure: All research objectives are being met and are progressing according to schedule. Initial delays in acquiring hardware and software approval (from NSU-OC) for data analyses have been resolved. Collector participation has been lower than expected; however, in speaking with the governing members of the Florida Marine Life Association (of which the majority of collectors are members), a 31% response rate (20/64) is considered successful.

Southeast Atlantic and Caribbean Coral Reef Ecosystem Monitoring and Assessment

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

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To develop and implement quantitative methods for robust evaluation of status and trends of coral reef fish populations and communities in the Florida Keys, South Atlantic and Caribbean coral reef ecosystems. To determine the efficacy of "no-take" marine reserves in 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) to sustain regional exploited reef fish populations. To transfer the methodological approaches developed here to other jurisdictions in the Southeast Atlantic and U.S. Caribbean.

***Strategy*:** Design and 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. Use strategic applications of probabilistic sampling design theory and acoustic telemetry methods 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 the Comprehensive Everglades Restoration Program.

CIMAS Research Themes:

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:

Commercial and recreational fisheries target hundreds of fish and shellfish species across the seascape of southern Florida including inshore coastal bays, the flats of barrier islands, coral reefs and offshore pelagic waters. The ecological dynamics and economic sustainability of these valuable fishery resources are key conservation concerns. Overfishing, habitat degradation and prey reduction are the principal threats to sustainability of coral reef and coastal fisheries in Florida. This research emphasizes assessing the effectiveness and impacts of no-take marine reserves and other resource management measures in Biscayne National Park, the FKNMS, and DTNP towards meeting their marine ecosystem management goals. No-take marine reserves (NTMRs) in the National Marine Sanctuary (FKNMS) and Dry Tortugas National Park of the Florida Keys are a joint fishery and ecosystem management effort between the NOAA National Marine Sanctuary Program, National Park Service (NPS), and the State of Florida. The FKNMS has implemented three types of no-take areas: (1) 16 small Sanctuary Preservation Areas (SPAs) totaling approximately 46 km^2 that protect the high-relief coral reef; (2) one large (30 km^2) ecological reserve (ER) that includes several

different habitats; and, (3) 4 special-use SPAs designed for research purposes. Two large Ecological Reserves, 206 and 312 km^2, are were added in 2001 west of the Tortugas, Florida. The NPS Service implemented a 100 km^2 Research Natural Area (RNA) in the western half of Dry Tortugas National Park in January 2007.

We continue to evaluate the performance of the SPAs and TERS in the FKNMS. During the past year we conducted spatially-synoptic sampling of reef fish and coral reef habitats in the Florida Keys, 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 highly collaborative team effort measures how the protected areas 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 (Ault et al. 2013, 2014). Such unprecedented collaboration allows completion of 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.

Results of community-level applications of fishing impacts on sustainability of reef-fishes are compared in a "community control rule" format for southern Florida (Fig. 1, Ault et al., 20014). In this case, "average length" in the exploited phase of the stock was the principal indicator variable used to estimate rates of fishing mortality for the reef fish community. Although these analyses were conducted one species at a time, plotting the results together on a control-rule graph provides a community perspective on sustainability status. It is evident that the majority of species analyzed have experienced unsustainably high rates of fishing mortality. The results also suggest that the severity of overfishing differed among species, even though nominal fishing effort in each area generally affects the reef-fish complex as a whole. This differential response to exploitation is linked to life history characteristics, with slower-growing, longer-lived species such as groupers being more susceptible to fishing impacts compared to faster-growing, shorter-lived species such as grunts.

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, for mutton snapper spatial data we found that the extent of occupancy markedly increased after implementation of the protected areas (between 1999-2000 and 2008-2010). There were significantly more (and larger) fish in the two protected areas, but not in the fished areas where the number of large animals continues to decrease, which has been observed for a broad range of intensively exploited reef fish species.

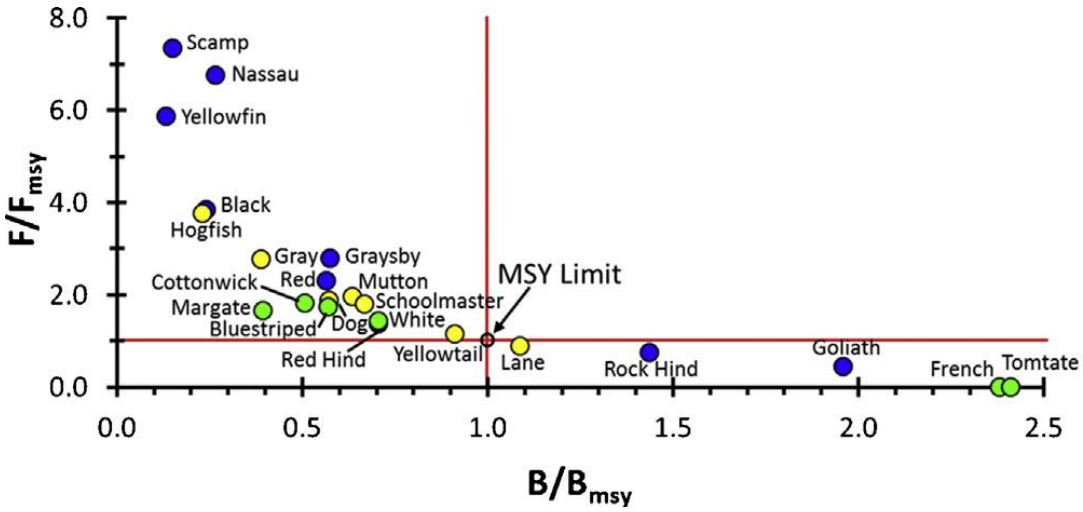

Figure 1: Limit control plots showing estimated levels of spawning stock biomass (x-axis) and fishing mortality rate (y-axis) with respect to MSY levels for exploited reef-fish communities in southern Florida (redrawn from Ault et al., 2005b; blue circles, groupers; yellow circles, snappers and wrasses; green circles, grunts).

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). 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.

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.

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 MRA program period is provided below to create a complete record of its curriculum and graduate-student activities. The following courses were developed for the MRA program as part of the present award's Statement of Work. Additional courses are currently under development. "Florida FWC" refers to employees of the Florida Fish and Wildlife Conservation Commission. Courses are listed by their course designations within the USF system.

MRA Core Courses

OCE6934.635F09: ***Fish Biology***, taught Spring 2009* by Ernst Peebles, David Mann and Joseph Torres of USF-CMS (19 students, including 4 agency employees - 21% agency).
USF students: Heather Broadbent, Aaron Brown, Christine Cass, Lindsey Flynn, Danielle Greenhow, Sennai Habtes, Mark Hartman, Lara Henry, Sheri Huelster, Eloy Martinez, Monica Mion, Erica Ombres, Kara Radabaugh, Holly Rolls, Carrie Wall
Florida FWC students: Kelley Kowal, Christy Stephenson, Laura Wiggins
NOAA students: Catherine (Bruger) Hayslip (NMFS SERO, St. Petersburg)

This course was taught for the second time during Spring 2012 by Christopher Stallings, Ernst Peebles, and Joseph Torres of USF-CMS. (14 students, including 6 agency employees – 43% agency)
USF students: Dinorah Chacin, Michael Drexler **(formerly FWC), Alisha Gray, Joshua Kilborn**, Orian Tzadik (formerly FWC)**, Amy Wallace**, Sky Williams (part-time FWC), Maria Vega-Rodriguez
Florida FWC students: Christopher Bradshaw, Michael Murphy, Beverly Sauls, Dustin Addis (audited)
US Coast Guard students: Aron Kaloostian (Marine Science Technician, USCG)
NOAA students: Mary Janine Vara (NMFS SERO, St. Petersburg)

This course was taught for the third time during Spring 2014 by Christopher Stallings and Ernst Peebles of USF-CMS. (28 students, including 3 agency employees – 11% agency)
USF students: Erik Anderson, Emily Chancellor, Marcy Cockrell**, Joseph Curtis, Kristina Deak, Lindsey Dornberger, Jenny Fenton, Ileana Freytes-Ortiz, Sarah Grasty, Elizabeth Herdter, Jacquelin Hipes, Brock Houston, Stephanie Lawlor, Timothy Lee, Kaitlyn Lizza, Michelle Masi, Leo Meirose, Garrett Miller, Morganne Morrison, Tiffany Nicholson, Michael Sipes, Susan Snyder, Lindsey Sorg, Kara Wall, Lena Wray
Florida FWC students: Oscar Ayala, Benjamin Kurth

NOAA students: Katie Davis (NMFS SERO, St. Petersburg)

OCE6934.635X10: ***Fish Population Dynamics***, taught August 2010 by Dr. Jim Berkson (USF Courtesy Associate Professor) with Co-Instructors Dr. Katie Andrews (NMFS, SEFSC, Panama City Lab), Dr. Brian Linton (NMFS, SEFSC, Miami Lab), Dr. Shannon Cass-Calay (NMFS, SEFSC, Miami Lab), Dr. Steve Cadrin (University of Massachusetts at Dartmouth), and Dr. Rick Hart (NMFS, SEFSC, Galveston Lab)(13 students, including 8 agency employees – 62% agency)
USF students: Claudia Baron-Aguilar, Sennai Habtes, Sheri Huelster, Elon Malkin, Kara Radabaugh
Florida FWC students: Christopher Bradshaw, Angela Collins, Claire Crowley, Anne Dowling, Michael Drexler, Michael Murphy, Holly Rolls, Beverly Sauls
NOAA students: none

This course was taught for the second time during Fall 2012 by Cameron Ainsworth of USF-CMS (24 students, including 3 agency employees - 13% agency)
USF students: Dinorah Chacin, Emily Chancellor, Marcy Cockrell**, Lindsey Dornberger, Jenny Fenton, Jennifer Granneman, Sarah Grasty, Alisha Gray, Elizabeth Herdter, Jacquelin Hipes, Brock Houston, Joshua Kilborn**, Lucy Sprung, Timothy Lee, Kaitlyn Lizza, Matthew McCarthy, Michelle Masi, Susan Snyder, Paul Suprenand, Orian Tzadik**, Amy Wallace**, Sky Williams
Florida FWC students: Beverly Sauls, Lucy Sprung
NOAA students: Mary Janine Vara

OCE6934.629S10: ***Applied Multivariate Statistics***, taught Spring 2010 by David Mann and David Jones of USF-CMS (13 students, including 4 agency employees - 31% agency)
USF students: Brian Barnes, Regina Easley, Lindsey Flynn, Adrienne George, Sennai Habtes, Mark Hartman, Sheri Heulster, Elon Malkin, Leslie Wade
Florida FWC students: David Chagaris, Claire Crowley, Holly Rolls
NOAA students: Catherine (Bruger) Hayslip (NMFS SERO, St. Petersburg)

This course was taught for the second time during Fall 2011 by David Jones and David Mann of USF-CMS (18 students, including 4 agency employees - 22% agency)
USF students: Dinorah Chacin, Michael Drexler (formerly FWC)**, Alisha Gray, Joshua Kilborn**, Natasha Mendez-Ferrer, Juan Millan, Kara Radabaugh, Benjamin Ross, Paul Suprenand, Orian Tzadik (formerly FWC)**, Maria Vega-Rodriguez, Amy Wallace**, Sky Williams, Bo Yang
Florida FWC students: Richard Knudsen, Michael Murphy, Beverly Sauls
NOAA students: Mary Janine Vara (NMFS SERO, St. Petersburg)

This course was taught for the third time during Fall 2013 by David Jones USF-CMS (22 students, including 3 agency employees - 14% agency)
USF students: Emily Chancellor, Marcy Cockrell**, Kristina Deak, Lindsey Dornberger, Nora Douglas, Jenny Fenton, Ileana Freytes-Ortiz, Jennifer Granneman, Sarah Grasty, Elizabeth Herdter, Jacquelin Hipes, Max Hopkins, Brock Houston, Selena Johnson, Kaitlyn Lizza, Michelle Masi, Matthew McCarthy, Benjamin Prueitt, Susan Snyder, Erin Symonds
Florida FWC students: Lucy Bartlett, Benjamin Kurth, Benjamin Prueitt

NOAA students: none

OCE6934.628S11: ***Dynamics of Marine Ecosystems***, taught Spring 2011 by Kendra Daly and Mark Luther of USF-CMS (9 students, including 4 agency employees - 44% agency)
USF students: Natasha Mendez-Ferrer, Benjamin Ross, Mark Squitieri, Tonu Toomepuu (audited), Sky Williams
Florida FWC students: Claire Crowley, Matthew Garrett, Richard Knudsen
NOAA students: Catherine (Bruger) Hayslip (NMFS SERO, St. Petersburg)

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)
USF students: Mary Abercrombie (audited), Lucy Bartlett, Jenny Fenton, Ileana Freytes-Ortiz, Jennifer Granneman, Jacquelin Hipes, Brock Houston, Eddie Hughes, Joshua Kilborn**, Tim Lee, Mathew McCarthy
Florida FWC students: Michael Murphy, Brittany Combs
NOAA students: none

MRA Elective Courses

OCE6934.640F11: ***Fishery Ecology Reading Group***, taught Fall 2011 by Chris Stallings, Cam Ainsworth, Ernst Peebles and Steve Murawski of USF-CMS (9 students, including 3 agency employees - 33% agency).
USF students: Dinorah Chacin, Michael Drexler (formerly FWC)**, Alisha Gray, Joshua Kilborn**, Orian Tzadik (formerly FWC)**, Amy Wallace**
Florida FWC students: Christopher Bradshaw, Beverly Sauls, Julie Vecchio
NOAA students: none

OCE6934.641.S13: ***Ecosystem Modeling***, taught Fall 2013 by Cam Ainsworth of USF-CMS (32 students, including 21 agency employees – 66% agency).
USF students: Emily Chancellor, Marcy Cockrell**, Lindsey Dornberger, Michael Drexler**, Kristen Emrich, Jennifer Granneman, Sarah Grasty, Elizabeth Herdter, Joshua Kilborn**, Timothy Lee
University of Miami student: Matt Nuttall
Florida FWC students: Wade Cooper, Claire Crowley, Michael Murphy
NOAA students (from 10 NMFS labs): Ariel Poholek, Derrick Alcott, Arnaud Gruss, Amy Uhrin, Jason Rumholz, Jennifer Samson, Joan Browder, Glenn Zapfe, Skyler Sagarese, Jennifer Leo, Kate Andrews (Seigfried), Mandy Karnauskas, Harmon Brown, Adam Schlenger, Emily Gardner, Matthew Campbell, Kevin Purcell, Kimberly Clements

Note: This course introduced NOAA, USF, UM and FWC students to a variety of approaches for quantitative modelling of marine ecosystems. Remote students participated in the course in real time via a two-way audio-visual connection using multi-party video conferencing. We offered an accredited certificate of completion signed by USF and the Ecopath with Ecosim consortium. 18 NOAA employees took the course, including participants from the following laboratories: Beaufort, NC; Sandy Hook, NJ; Miami, FL; Stamford, CT; Pascagoula, MS; Galveston, TX; Panama City, FL; Woods Hole, MS; La Jolla, CA; St. Petersburg, FL. Tuition was waived for all

NOAA FTEs and contractors. This was done above and beyond our contractual requirement to provide training to NOAA employees. Such an arrangement is not necessary with state institutes like FWC since their employees are entitled to enroll in 6 credit hours per term under the State of Florida Educational Assistance Program. Course material was particularly relevant to NOAA employees participating in the Integrated Ecosystem Assessment (IEA) program, Marine Spatial Planning (MSP) program, or various FATE programs. However, any NOAA employee engaged in stock assessment could benefit as ecosystem interactions can be considered in the stock assessment process: for example, as part of Tier 3 next-generation stock assessments, as part of ecosystem consideration chapters, or in ecosystem terms of reference.

*Course as taught prior to present award as part of the MRA program.
**USF graduate students supported by Fellowships under the present award (fellowships first became effective Fall 2011).

RSMAS Graduate Education

For many decades, the Rosenstiel School of Marine and Atmospheric Science has offered graduate instruction leading to the Doctor of Philosophy (Ph.D.) and Master of Science (MS) degrees. In 2014, RSMAS was restructured into a departmentalized school. New Ph.D. and MS degrees within the five new departments will be offered in Atmospheric Sciences, Marine Biology and Ecology, Marine Ecosystems and Society, Marine Geosciences, and Ocean Sciences. Interdisciplinary, cross-departmental programs such as Meteorology and Physical Oceanography will continue to remain a strength. Currently there are about 200 students enrolled in the RSMAS graduate programs, 80% of whom are in the Ph.D. programs.

Many Ph.D. and M.S. graduates from RSMAS 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 nation. This training pipeline for NOAA jobs was greatly facilitated by CIMAS activities such as 1) collaborative research teams of faculty, NOAA and CIMAS scientists and graduate students; 2) funding of graduate students with the support of NOAA fellowships and graduate research assistantships; and 3) participation of NOAA scientists in student mentoring and teaching. As the students were not necessarily CIMAS employees, we do not report these hirings in our annual report.

Since 2010, the University of Miami has run a Master of Professional Science (MPS) program 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 program offers internships in relevant government NGOs and businesses. The MPS tracks especially relevant to NOAA are those in Fisheries and Meteorology. This program now has an enrollment of about 90 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 or Meteorology and a Bachelor of Arts in Marine Affairs. In academic year 2013, more than 100 students enrolled in the program. The BSc students earn dual majors in Marine Science and, for example, Biology, Chemistry, Physics, Mathematics or Geology, and have among the highest GPA and SAT scores of all undergraduate programs 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 in 2007 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.

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

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

- Dong. S., 2013: "Seasonal Variations in the South Atlantic Meridional Overturning Circulation from Observations and Numerical Models". NASA OSTST meeting, Boulder, CO, October 2013.
- Dong. S., 2014: "Seasonal Variations in the South Atlantic Meridional Overturning Circulation from Observations and Numerical Models". 2014 Ocean Science Meeting, Honolulu, HI, February 2014.

Elucidating Net Ecosystem Prediction and Calcification at the Atlantic Ocean Acidification Testbed

- Project personnel run a Citizen Science Program with the Earthwatch organization. Results and activities in this coral reef monitoring program are incorporated into the training that is performed. This K-12 outreach; undergraduate student activities; public awareness; etc. Two day-long training sessions took place in October 28 and 30 (2013) and on May 15 (2014).

Global Drifter Program

- In an effort to better assess drogue presence, E. Valdes completed a reanalysis of 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 participated in numerous educational outreach programs, working with middle schools around the country to deploy and track drifting buoys.
- To maximize drifter data quality and increase drifter lifetimes, S. Dolk worked closely with R. Lumpkin to create a MATLAB program that evaluates drifters based the number of operational sensors, drogue presence, age, proximity to nearby drifters, and expected lifetimes (based on historical data from drifter deployments across the globe). Using this program, the GDP can better assess data quality and target future drifter deployments accordingly. Likewise, the GDP can utilize this information to highlight (and avoid) areas where drifters have historically lived short lifetimes.
- R. Perez participated in several K-12 outreach events at UM/RSMAS, NOAA/AOML, and local schools.
- R. Lumpkin collaborated with authors from NOAA's ClimateWatch Magazine to create an article about the Global Drifter Program (http://www.climate.gov/news-features/climate-tech/doing-their-part-drifter-buoys-provide-ground-truth-climate-data

Southwest Atlantic Meridional Overturning Circulation ("SAM") Project

- C. Meinen and R. Perez developed a brief video for NOAA/AOML/PhOD webpage (hosted on Youtube) explaining the SAM project.

Coral Health and Monitoring Program (CHAMP)

- The American Museum of Natural History in New York produces a data visualization and a youtube video/google hangout based on modeled reef futures by R. van Hooidonk.
  See: http://www.amnh.org/learn-teach/educators/data-visualization-google-hangouts/warm-forecast-for-coral-reefs-google-hangout.

Development of an Objective Scheme for Predicting Tropical Cyclone Genesis
J.P. Dunion (UM/CIMAS)

- Guest Speaker, Marlborough Elementary School Career Day, Marlborough, CT (June 2014)
- Guest Speaker, Marlborough Elementary School, Marlborough, CT (February 2014)
- Guest Speaker, Marlborough Elementary School, Marlborough, CT (January 2014)
- Guest Speaker, Marlborough Elementary School, Marlborough, CT (January 2013)

- Guest Speaker, University of Wisconsin-Madison/CIMSS (April 2013): *Development of a Probabilistic Tropical Cyclone Genesis Prediction Scheme*

Impact of Geostationary Hyperspectral Sounder on Prediction of Tropical Cyclones

- Marlins' Weather Day (22 May 2014): L. Bucci (UM/CIMAS) and E. Uhlhorn (NOAA/AOML/HRD) were invited to speak at Marlin's Weather Day - a day at Marlins' stadium where students from local schools come and learn about the weather. The event was organized and run by the local CBS station and their chief meteorologist, Craig Setzer. Different tables were set up on the field where local meteorologists and scientists were interviewed and taught something about their work to the kids. HRD's station was about flying into hurricanes and the how the data collected helps weather models make better track and intensity predictions.

Studies in Support of NOAA's NESDIS Operational Ocean Heat Content Product Suite

- Nick Shay gave a talk at the Vineland Elementary School on "Oceans, Hurricanes, and Oil Spills", 21 May 2014.
- Nick Shay presented an NHC Seminar "Oceanic Impacts on Hurricane Intensity", 27 May 2014.

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

- Delgado, S., 2013: Recent Revisions to HURDAT. Florida Commission on Hurricane Loss Projection Methodology, Tallahassee, FL (18 June 2013).
- Delgado, S., 2014: Reanalysis of the 1955-1964 Atlantic hurricane seasons, FIU Earth and Environment Graduate Symposium, Miami FL (Talk given 21 Feb. 2014).

Ship of Opportunity Program

- The XBT Science Team website was created to provide easy access to eXpendable BathyThermographs (XBTs) data, XBT-derived products, and other XBT-related scientific and operational information; and to also bring together scientists to highlight the uses of XBT data including upper ocean thermal structure and variability, and ocean current transport. The website is available through the link: http://www.aoml.noaa.gov/phod/goos/xbtscience/index.php
- A video from the XBT network has been included in AOML's Physical Oceanography Division website to provide additional information to the general public and to the science community about the project. The video is accessible through the link: http://www.aoml.noaa.gov/phod/videos/load.php?varid=xbt_network
- Dr. Silvia Garzoli participated in two general public panels on oceans and their role in climate that were open to the public:
  1. Lecture and panel member: Sea Level Rise: Separating Facts from Fiction. Greater Miami Chamber of Commerce, December 12, 2013.
  2. Lecture and panel member: Water is Life; the Future of Water in South Florida, Coral Gables Museum, March 13, 2014.

Calibration/Validation Support for NPP VIIRS Data Product Continuity

- Oct 19, 2013, the PI (C. Hu)'s group (Optical Oceanography Lab at USF CMS) attended the Science Festival in St. Petersburg, Florida. OOL co-hosted an exhibition booth to demonstrate various satellite observation technologies. The attendants of this festival were estimated to be > 20 thousands.

Global Impact of Eddies on Inertial Oscillations of the Mixed Layer

- R. Perez participated in several K-12 outreach events at UM/RSMAS, NOAA/AOML, and local schools. R. Lumpkin collaborated with authors from NOAA's ClimateWatch Magazine to create an article about the Global Drifter Program (http://www.climate.gov/news-features/climate-tech/doing-their-part-drifter-buoys-provide-ground-truth-climate-data.

Evaluation of Management Strategies for Fisheries Ecosystems

- Dr. Babcock teaches an undergraduate course to University of Miami Marine Science students. She is also a co-P.I. on a study, funded by Earthwatch, which takes volunteers, including high school students, to Glover's Reef Marine Reserve, Belize, to help with our shark research program.

Evaluation of the Trophic Structure of the West Florida Shelf in the 2000s Using the Ecosystem Model OSMOSE-WFS

- Grüss gave lectures on OSMOSE and OSMOSE-WFS for a course on marine ecosystem modeling at the College of Marine Science, University of South Florida, St. Petersburg in October 2013.
- Grüss gave seminars on the present project: (i) at the College of Marine Science, University of South Florida, St. Petersburg in October 2013; and (ii) at RSMAS, UM in March 2014.
- The present project was presented to fisheries scientists and decision-makers involved in the SEDAR process during the SEDAR 33 Assessment Workshop Webinar 9 held in September 2013.

Caribbean Sea and Gulf of Mexico Bluefin Tuna Research

- Undergraduate students from the University of Miami's RSMAS participated in the project in research cruises, sample and laboratory processing: K. Dale, K. Doering, J. Mastowy, J. Suca, G. Dehnert and A. Spera. Graduate student L. Denson participated as a member of the science party sponsored partly by a NOAA Internship.
- Websites with educational information regarding the project and research survey: http://www.nasa.gov/centers/marshall/news/earth-science-travelogue.html
  http://notyourtimzone.blogspot.com/2014/05/a-research-cruise-huh.html
  http://ws1405.tumblr.com/

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

- Undergraduate students from ECOSUR in Mexico, and Victor Gudiel Corona, University of San Carlos, Guatemala are utilizing samples to carry out their 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://ocean-ecosur.com/index.php/vinculacion/12-vinculacion/5-workshop-1

Living on the (Shelf) Edge: Using Advanced Glider Technology to Assess Fishery Resources Along the South Atlantic Continental Shelf Break

Multiple posts of deployment activity by NOAA's National Ocean Service, SouthEast Coastal Ocean Observing Regional Association, and the Ocean Tracking Network.

- Data sharing achieved via SECOORA, attempted via IOOS National Glider DAC.

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

- We have partnered with the Marine Lab (a program of the Marine Resources Development Foundation, a 501(c)3 organization in Key Largo) to help train students in basic techniques in marine behavioral ecology.

Gulf of Mexico Integrated Ecosystem Assessment

- 2014 Review Panel for NOAA Ernest F. Hollings and Educational Partnership Program Undergraduate Scholarship Programs.

Synthesis of Information on Octocoral Biology, Ecology, and Fisheries in the U.S. South Atlantic in Support of Effective Management

- Paola Espitia (NSU-OC) was the guest speaker at the Florida Marine Aquarium Society monthly meeting in Plantation, Florida, where she presented information about octocoral biology and ecology.
- P. Espitia was the co-organizer of the "Beneath the Waves Film Festival: Bridging the Gap", which was a free, public screening of several short documentaries highlighting local and international marine-related issues aimed to increase public awareness about marine conservation. This event was followed by a discussion panel of scientists from NSU-OC (including Dr. Steven L. Miller), the Florida Department of Environmental Protection, and the Florida Fish and Wildlife Conservation Commission.
- P. Espitia organized and participated in public outreach efforts to increase public awareness about the coral research being conducted at the NSU-OC, including the Friends of Nature Music Festival in Miami, Florida, and the Tortuga Music Festival in Ft. Lauderdale, Florida.

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

- Participated in the St. Petersburg Science Festival, October 18-19, 2013; showed visitors (25,000) the C-BASS vehicle and a tape of highlights from our cruises.

Natural Resource Damage Assessment Plankton Processing

- The NRDA plankton team provided an interactive, entertaining yet educational experience for children during this year's "Bring your child to work day." The modules included multiple puzzles & games; a creative plankton interactive activity; a Marine world magnified activity (microscope viewing activity); and scientific illustrations for the younger individuals (face painting of marine world).

Assessing the locations and status of reef fish spawning aggregations in the Florida Keys

- We communicated our project results to Florida Keys National Marine Sanctuary (FKNMS) managers via frequent verbal (including in-person meetings) and e-mail updates during and after our field season, through provision of data and related information to project leaders for the ongoing CRCP-funded Biogeographic Assessment for the FL Keys, and by provision of an invited presentation to the FKNMS Ecosystem Protection: Ecological Reserves/Preservation Areas and Wildlife Protection Working Group, which will make spatial management recommendations to the FKNMS Advisory Panel.
- We also participated in a radio interview (recorded for subsequent broadcast) discussing our project and implications for management for Captain Ted Lund's fishing program on Keys Radio 107.1FM, and provided interviews and video footage in support of the creation of a for-public-television "Waterways" episode.

Mandatory Ship Reporting System

- The Mandatory Ship Reporting system website: https://www.rightwhalesmsr.aoml.noaa.gov/
- One news item about the Mandatory Ship Reporting system has been published on AOML's Physical Oceanography Division website: http://www.aoml.noaa.gov/phod/news/load.php?pFullStory=20140416_20140515_MSR.html
- The Mandatory Ship Reporting system was also highlighted on AOML's Newsletter, issue of March-April 2014: http://www.aoml.noaa.gov/keynotes/PDF-Files/Mar-Apr14.pdf

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 Dispersal, Habitat Use and Behavior of Neonate Sea Turtles

- Mansfield, K.L., J. Wyneken, W.P. Porter, and J Luo. *New perspectives on the oceanic niche of neonate loggerhead sea turtles*. Oral presentation. 34th Annual International Symposium on Sea Turtle Biology and Conservation in New Orleans, FL (April 2014).
- Louisiana Department of Wildlife and Fisheries: *Habitat use, behavior, and foraging ecology of oceanic stage sea turtles in the Gulf of Mexico.* Invited scientific advisory service seminar. New Orleans, LA (April 2014).
- University of Florida, Archie Carr Center for Sea Turtle Research, monthly seminar series. New insights to the Sea Turtle Lost Years. Gainesville, FL (February 2014).
- Sea Turtle Preservation Society: *FOUND: the sea turtle lost years.* Public lecture series, Melbourne Beach, FL (January 2014).
- Florida State University Coastal and Marine Laboratory, Conservation Lecture Series: *Found: the sea turtle lost years!* St. Teresa, FL (October 2013).

Coral Restoration and Recovery

- L. Richter participated in Career day at Leonard J. Tyl Middle School, Montville CT on November 26, 2013.

Support for the Marine Resource Assessment Program at the University of South Florida College of Marine Science

- http://www.marine.usf.edu/graduate-programs/degree-requirements/marine-resource-assessment
- http://www.juvenile-grouper-project.com/index.php?subject=articles&page=7

Aquarius Reef Base Maintenance and Monitoring

October 12, 2012: Dr. Mark Patterson, *Aquarius 2013 and Beyond*, public lecture in the 2012-2013 Ocean Life Lecture Series, Key Largo

March 11, 2014: Aquarius program represented at Family Science Night at Key Largo School. Reached 128 k-12 students and their families with an interactive educational display about ocean exploration.

April 4, 2014: Aquarius program represented at Family Science Night at Plantation Key School. Reached 245 k-12 students and their families with an interactive educational display about ocean exploration.

May 23, 2014: Aquarius program represented at Family Science Night at Treasure Village Montessori School. Reached 105 k-12 students and their families with an interactive educational display about ocean exploration.

September 23-26, 2013: Meet the Scientist Lecture Series, Live link between Aquarius and students at Treasure Village Montessori School

October 15, 2013: Meet the Scientist Lecture Series, Live link between Aquarius and students at Coral Shores High School

November 22, 2013 and February 27, 2014: Meet the Scientist Lecture Series, Live link between Aquarius and students at The Academy at Ocean Reef

February 7, 2014: Aquarius program represented at the Marine Science Day Eco-Fair held at Plantation Key School. We reached 276 students in 6th through 8th grades with a message about the importance of STEM education and marine science and conservation.

November 17-23, 2013: During the FIU-led saturation diving mission, we led 21 "Virtual Field Trips" of Aquarius through live internet video links between aquanauts in the habitat and schools around the country. This program is designed to stress the importance of STEM training and excite students about ocean science and conservation. We connected to 13 different schools, including 1 university, 3 high schools, 4 K-8 centers 2, K-12 schools, two elementary schools, and one school for special needs students. These schools were located in the states of Florida, North Carolina, New York, Illinois, Missouri, California and Washington. We reached 755 students in these sessions.

January-May 2014: We continued the Virtual Field Trips and reached an additional 5 classrooms and 100+ elementary school and middle school students.

February 13-14, 2014: Sunshine State Scholar's Conference, Orlando, Fl. The Florida Education Foundation honored the 2014 Sunshine State Scholars at the Sunshine State Scholars Conference in Orlando, FL in February 2014. These students were the top 11th graders in science, technology, engineering, and mathematics (STEM) and represented every school district in Florida. On Feb 13 & 14, they were recognized for their academic achievements and recruited to pursue their postsecondary education and STEM-related careers in Florida. FIU SEAS was on hand to disseminate information about the University and degree programs. Aquarius was highlighted as part of the Discovery and Innovations portion of the conference. It is worthy of note that the conference organizers have requested FIU Aquarius be featured as part of one of the key note presentations for the Sunshine State Scholars Conference in 2015.

February 26, 2014: Public lecture about STEM education and the Aquarius Reef Program, Islamorada Chamber of Commerce.

May 8, 2014: International Woman's Day. In celebration of International Women's Day, Alyssa Engiles of the History of Diving Museum (HDM) presented a brief history of female

aquanauts via a live internet broadcast from FIU's Aquarius Reef Base Headquarters in Islamorada, Florida. This lecture was developed by the History of Diving Museum in Partnership with FIU SEAS MERI Aquarius program. The event featured women who have made great scientific contributions and/or lived and worked in underwater habitats, such as Sylvia Earle, Karen Kohanowich, Marie Knafelc, and Peggy Lucas Bond. The goal of this program was twofold: to educate and inspire a segment of the global community with an engaging history of women who have pioneered and excelled in this field, but also to raise awareness about both the importance of Aquarius Reef Base and the opportunities available for groups and institutions to make use of the facility for their own projects. This event was scheduled to coincide with International Women's Day

Media coverage of Aquarius Reef Base, 2013-2014:

Media Exposure to Date:

Major media exposure of the Medina Aquarius Program – including Mission 31, FIU Ecology of Fear Science Mission, and the NASA Extreme Environmental Operations project (2013-2014).

Live/taped television (including Skype from Aquarius) & print

- The Weather Channel (weekly live events) (US)
- CBS This Morning
- ABC Nightline
- NBC Today
- CNN
- CNN en Espanol (US and Latin America)
- Reuters TV (National/International)
- Associate Press
- BBC Radio (UK)
- Motherboard Magazine (UK)
- Globo TV (South America)
- Seven Network (Australia)
- Agency France
- CBC News Network (Canada)
- ABC Spain
- Bloomberg TV
- Japan Times
- Univision & Fusion
- CBS News
- Fox News
- Time Magazine
- Sky News (International)
- Wall Street Journal
- Town & Country Magazine
- CNET News
- Huffington Post
- National Public Radio
- National Geographic Explorer

VIII. CIMAS FELLOWS AND EXECUTIVE ADVISORY BOARD

The Fellows provide guidance to the Director on matters concerning the ongoing activities and fture direction of CIMAS. Fellows-related matters are now addressed and implemented by means of email exchanges and all meetings 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. James Hendee	NOAA/AOML/Ocean Chemistry Division
Dr. Richard J. Pasch	**NOAA/National Hurricane Center**
Dr. James Bohnsack	**NOAA/Southeast Fisheries Science Center**
Dr. Lance Garrison	NOAA/Southeast Fisheries Science Center
Dr. John Quinlan	NOAA/Southeast Fisheries Science Center
Dr. Joseph Serafy	NOAA/Southeast Fisheries Science Center
Dr. Mahmood Shivji	**NOVA Southeastern University**
Dr. Alex Soloviev	NOVA Southeastern University
Dr. Ellen E. Martin	**University of Florida**

Dr. Yeayi (Peter) Sheng	University of Florida
Dr. Jerald S. Ault	**University of Miami/RSMAS**
Dr. Rana Fine	University of Miami/RSMAS
Dr. Brian Haus	University of Miami/RSMAS
Dr. Ben Kirtman	University of Miami/RSMAS
Dr. David Letson	University of Miami/RSMAS
Dr. Sharan Majumdar	University of Miami/RSMAS
Dr. Richard Appeldoorn	**University of Puerto Rico**
Dr. Kent Fanning	**University of South Florida**
Dr. Frank Muller-Karger	University of South Florida
Dr. Rick Nemeth	**University of Virgin Islands**
Dr. Tyler Smith	University of Virgin Islands

Chair:
Dr. Peter B. Ortner, Director UM/CIMAS

***Ex Officio*:**
Dr. David Die, Associate Director UM/CIMAS

[1]No longer with FIU. Replacements to be selected by FIU.

EXECUTIVE ADVISORY BOARD

Institutional Representatives

Ms. Camille Coley	Florida Atlantic University
Dr. Andrés G. Gil	Florida International University
Dr. Gary Ostrander	Florida State University
Dr. Robert Atlas	NOAA/AOML, Director
Dr. Bonnie Ponwith	NOAA/Southeast Fisheries Science Center
Dr. Richard Knabb	NOAA/National Hurricane Center
Dr. Richard Dodge	NOVA Southeastern University
Dr. Winfred M. Phillips	University of Florida
Dr. Nilda E. Aponte	University of Puerto Rico
Dr. Jacqueline E. Dixon	University of South Florida
Dr. Naseer Idrisi	University of the Virgin Islands[1]
Dr. Roni Avissar	UM/RSMAS Dean

***Ex Officio* Members**

Dr. Philip Hoffman	NOAA CI Office
Dr. Peter Ortner	UM/CIMAS – *ex officio*
Dr. David Die	UM/CIMAS – *ex officio*

[1]No longer at UVI. Replacement to be selected by UVI.

IX. AWARDS AND HONORS

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

- December 2013, Hailong Liu received the Scientists and Engineers Expanding Diversity and Success (SEEDS) You Choose Leadership Award of University of Miami.

Western Boundary Time Series Project

- Chris Meinen was nominated to serve on the Executive Committee directing the U.S. AMOC Science Team

Southwest Atlantic Meridional Overturning Circulation ("SAM") Project

- The recently published Meinen et al. (2013) paper was selected by the Journal of Geophysical Research as an "Editors' Highlight" item and by EOS Transactions AGU as an "EOS Research Spotlight" item.

A Study on the Asymmetric Rapid Intensification of Hurricane Earl (2010) using the HWRF System

- Hua Chen, Lisa Bucci, Xuejin Zhang and other members of the Hurricane Research Division (HRD) Modeling Team at NOAA/AOML were recipients of South Florida Federal Executive Board's (SFFEB) Federal Employee of the Year Award (Team), May 2014.

Studies in Support of NOAA's NESDIS Operational Ocean Heat Content Product Suite

- In April 2014 it was announced that Lynn .K. Shay has been appointed Editor-In-Chief of Elsevier's Dynamics of Atmospheres and Oceans journal to be effective July 1, 2014.

Ship of Opportunity Program

- Dr. Silvia Garzoli (UM/CIMAS) received the NOAA FY13 Distinguished Career Service Award in recognition of her excellence in scientific research of Atlantic Ocean dynamics and extensive service to the oceanographic community. Dr. Garzoli has been a leader in the expendable bathythermograph (XBT) program and other observational networks at NOAA/AOML.

Support for the Marine Resource Assessment Program at the University of South Florida College of Marine Science

- Joseph Curtis – 2014 NSF Graduate Research Fellowship, 2013 Von Rosenstiel Fellowship
- Dinorah Chacin – 2013 NSF Graduate Research Fellowship
- Jennifer Granneman – 2014 William and Elsie Knight Fellowship
- Susan Snyder – 2014 Garrels Memorial Fellowship
- Benjamin Kurth – 2014 Paul Getting Memorial Fellowship
- Lindsey Dornberger – 2014 Jack and Katharine Ann Lake Fellowship, 2013 Wells Fargo Fellowship
- Jenny Fenton – 2014 William Hogarth Marine Mammal Fellowship
- Michelle Masi – 2014 Carl Riggs Fellowship, 2013Aylesworth Scholarship
- Michael Drexler – 2014 Gulf Oceanographic Charitable Trust Fellowship
- Alisha Gray – 2013 Sanibel Captiva/Bridell Memorial Fellowship

X. POSTDOCTORAL FELLOWS AND GRADUATE STUDENTS

CIMAS-Supported Postdoctoral Fellows and Graduate Students

CIMAS-Supported Postdoctoral Fellows and Graduate Students

Postdoctoral Fellows
Chen, Hua
Gruss, Arnaud
Harford, William
Kearney, Kelly
Liu, Yanyun
Lopez, Hosmay
Phillips, Nicole
Sagarese, Skylar
Song, Zhenya
van Hooidonk, Ruben

Graduate Students
Task I
Vaughan, Nathan
Johnston, Michelle
Yurek, Simeon
Hoenig, Daniel
Marmet, Christina
Ondrasik, Katherine
Sculley, Michelle
Fisch, Jay
Armentrout, Ashleigh
Hariharan, Sam
Toich, Matthew

Task III
McCaskill, Claire
Rudzin, Johna
Woosley, Ryan

Employees
Domingues, Ricardo
Gramer, Lewis J.
Jankulak, Michael
Malca, Estrella
Privoznik, Sarah
Seaton, Kyle

Other Participants in CIMAS Projects

Postdoctoral Fellows
Adam, Thomas
Barnes, Brian
Putman, Nathan

Graduate Students
Barton, Mark
Bhatti, Laura
Brizzolara, Jennifer
Chacin, Dinorah
Cossuth, Joshua
Davis, Katie
Delgado, Sandy
Drexler, M.
Fortman, Philip
Grasty, Sarah
Gray, Alisha
Hall, Brittany
Hayslip, Catherine (Bruger)
Hughes, Edward
Kotokowski, Rachel
Melnikova, Liubov
Oliveros-Ramos, R.
Olson, Emily
Qi, Lin
Rock, Laura
Saul, Beverly
Shantz, Andrew
Valla, Daniel
Vara, Mary Janine
Williams, Sky
Zenone, Adam
Zhao, Jian

XI. RESEARCH STAFF

Aguilar, Sandra	Senior Research Associate III
Aichinger Dias, Laura	Research Associate II
Aksoy, Altug	Associate Scientist
Amornthammarong, Natchanon	Assistant 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
Cascioli, Robin	Research Associate I
Chen, Hua	Post-Doctoral 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
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.	Senior Research Associate III
Gruss, Arnaud	Postdoctoral Associate
Halliwell, Vicki	Senior Research Associate III
Harford, William	Postdoctoral Associate
Helmle, Kevin	Assistant Scientist
Hoolihan, John	Associate Scientist
Hooper, James	Research Associate III
Jankulak, Michael L.	Systems Administrator
Johnson, Darlene R.	Senior Research Associate I
Lopez, Hosmay	Postdoctoral Associate
Kearney, Kelly	Postdoctoral Associate
Klotz, Bradley	Senior Research Associate I
Kolodziej, Graham	Research Associate I
Le Henaff, Matthieu	Assistant Scientist
Lee, Sang-Ki	Scientist
Liu, Hailong	Senior Research Associate II
Liu, Yanyun	Postdoctoral Associate
Lopez, Hosmay	Postdoctoral Associate
Malca, Estrella	Research Associate III
Manzello Derek	Associate Scientist
Melo, Nelson	Senior Research Associate II
Muhling, Barbara	Associate Scientist
Ortega-Ortiz, Joel	Associate Scientist
Otero, Sonia	Senior Research Associate II
Perez, Renellys	Associate Scientist
Phillips, Nicole	Postdoctoral Associate
Pierrot, Denis P.	Associate Scientist
Privoznik, Sarah	Research Associate II

Rawson, Grant T.	Research Associate III
Richter, Lee	Research Associate I
Roddy, Robert	Research Associate III (PT)
Sabina, Reyna	Research Associate III (PT)
Sagarese, Skylar	Postdoctoral Associate
Seaton, Kyle	Research Associate II
Sellwood, Kathryn J.	Research Associate III
Shideler, Allison	Senior Research Associate I
Song, Zhenya	Postdoctoral Asociate
St. Fleur, Russell	Programmer Intermediate
Sullivan, Kevin F.	Senior Research Associate III
Thacker, William C.	Scientist (PT)
Tonioli, Flavia	Senior Research Associate I
Valdes, Erik	Research Associate III
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)
Yao, Qi	Senior Research Associate I
Zhang, Jun	Associate Scientist
Zhang, Liping	Senior Research Associate I
Zhang, Xuejin	Associate Scientist

XII. VISITING SCIENTISTS

Dr. Nancy Maynard - 1 October, 2012 (to continue through 2015)
NASA Emeritus
NASA Goddard Space Flight Center
Greenbelt, MD

Dr. Phillip Arkin - 1 August, 2013 – 30 June, 2014
NOAA/OAR
Climate Program Office
1315 East-West Hwy
Silver Spring, MD 20910

Prof. U.C. Mohanty - 15 – 21 June, 2014
School of Earth Ocean and Climate Sciences
Indian institute of Technology Bhubaneswar
A2-708, Toshali Bhawan, Satya Nagar
Bhubaneswar-751007, Odisha, India

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	31	13	27
Non-Peer Reviewed	15	14	22

Refereed Journal Articles

Abraham, J.P., M. Baringer, N.L. Bindoff, T. Boyer, L.J. Cheng, J.A. Church, J.L. Conroy, C.M. Domingues, J.T. Fasullo, J. Gilson, G. Goni, S.A. Good, V. Gouretski, M. Ishii, G.C. Johnson, S. Kizu, J.M. Lyman, A.M. Macdonald, W.J. Minkowycz, S.E. Moffitt, M.D. Palmer, A.R. Piola, F. Reseghetti, K. Schuckmann, K.E. Trenberth, I. Veliconga and J.K. Willis (2013), A review of global ocean temperature observations: Implications for ocean heat content estimates and climate change, *Reviews of Geophysics*, 51, 450–483, doi:10.1002/rog.20022.

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