Cooperative Institute for Marine and Atmospheric Studies

CIMAS

First Annual Report

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Benjamin Kirtman, Director
David Die, Associate Director

UNIVERSITY
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ROSENSTIEL
SCHOOL of MARINE &
ATMOSPHERIC SCIENCE

UNIVERSITY OF MIAMI
ROSENSTIEL SCHOOL OF MARINE AND ATMOSPHERIC SCIENCE

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I. EXECUTIVE SUMMARY

The Cooperative Institute for Marine and Atmospheric Studies (CIMAS) is a research institute hosted at the University of Miami (UM) in the Rosenstiel School of Marine and Atmospheric Science (RSMAS) and including at present nine additional Florida and Caribbean University Partners (FAU, FIT, 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 external funding (Tasks I, II, III and IV) during this reporting period was $27.2M. Task I which includes not only Administration but also Research Infrastructure (ship-time, computing resource access etc.) and Education and Outreach was ca. $2.4M. The University of Miami contributed an additional $.24 M towards Administration. Task II, which supports CIMAS employees conducting closely collaborative research off- campus was ca. $ 11.7M.

Individual research project funding (Tasks III and IV) totaled ca. $13.06M. The largest portions were the research projects within Themes 3 and 6 (Sustained Ocean and Coastal Observations & Ecosystem Management) which together account for 71%. The smallest portions were in Themes 1, 2, 4 and 5 (Climate Research and Impacts, Tropical Weather, Ocean Modeling and Ecosystem Modeling & Forecasting) which together account for only 27%. These percentages are somewhat misleading in that Theme assignments herein 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 the CA initiated October 2010. They do not include continuing expenditures during these same time period under prior agreements or awards.

During this reporting period a total of 135 individuals at UM were directly provided salary support through CIMAS. Of the 135 research employees who received NOAA support, 67 worked at AOML, 33 at the SEFSC, 2 at RSMAS, 2 at NHC, 4 at the University of Puerto Rico and 6 in other locations. The remaining 21 were comprised of administrative staff, graduate and undergraduate students. The employees in the Research Associate and Research Scientist ranks have a diverse demographic profile. The population is 42% female. Foreign born individuals make up 46% of the total. The largest foreign sub-groups are Hispanics (22%), Asian and

Pacific Islanders (14%). 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 40. The distribution is bimodal in that a number of NOAA FTE retirees are re-employed through CIMAS as required to complete projects or mentor successors.

During this last year there were 105 peer-reviewed publications and another 27 non-peer reviewed technical reports or other publications resulting from research projects conducted directly under our present Cooperative Agreement award number. 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 all the CIMAS projects can be found in the body of the Report within the set of individual project summaries sorted alphabetically by principal investigator provided for each of the seven individual CIMAS Research Themes (Section VI).

SOME RESEARCH HIGHLIGHTS

Goal 1: Healthy Oceans: Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems

Evaluation of Management Strategies for Fisheries Ecosystems
No-take marine reserves can be a useful tool for fisheries management, but they also make it more difficult to assess the sustainability of fisheries in the surrounding area. In order to effectively manage the fisheries around marine reserves, it is necessary to understand how the marine reserve influences the population dynamics. The project team combined an individual based movement model with fisheries stock assessment techniques to assess the status of Caribbean spiny lobster at Glover's Reef atoll, Belize, and found that, in part because of the reserve, the fishery was sustainable.

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.

Development of a Towed Camera System for Assessing Demersal Fish Stocks: C-BASS (Camera-Based Survey System)
Reef fish are notoriously difficult to assess because their habitats are not conducive to the use of traditional sampling gears such as trawls. This new technology has the potential to be transformational in providing such estimates in such habitats. Preliminary analyses show that the C-BASS did not significantly change the behavior of most species encountered. Ultimately such systems will significantly improve the precision, timeliness and credibility of NMFS fishery stock assessments.

Application and Automation of Underwater Image Mosaics for Sampling, Characterizing, and Classifying Corals as Protected Stocks and Habitat

The lack of marine remote sensing technologies that can directly sense benthic species or living from dead marine substrates is a critical knowledge gap impacting the management of both fish and coral stocks. Emerging underwater imagery tools can resolve individual coral colonies and other benthic organisms for identification by an analyst. Underwater images are easy to acquire, have high resolution for species delineation, and can cover increasingly large spatial scales (either with image mosaics or large quantities of images across many marine habitats). By combining large-area image acquisition technologies with current state-of-the-art automated classification techniques are improving the efficiency of benthic habitat characterization and assessment of protected coral stocks.

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

Data sets of conductivity, temperature, chlorophyll fluorescence, CDOM, backscatter fluorescence, and dissolved oxygen were collected throughout the upper 200m of the water column. Passive acoustic recordings were also collected. The project team demonstrated, for the first time (to our knowledge), the use of an ocean glider to perform an extended (month-long) survey in a western boundary current, including the ability (at times limited) to enter and exit the current to control glider location.

2014 National Coral Reef Monitoring Plan: Florida Benthic Sampling

A research team from the Oceanographic Center of Nova Southeastern University (NSU-OC) conducted surveys of coral reef benthic communities in southeastern Florida, from Broward County to the Dry Tortugas. Data analyses are ongoing and results will be presented in partnership with NOAA’s Coral Reef Conservation Program in the form of an annual monitoring report, as well as a periodic “Report Card” (still in development) that describes the condition of coral reefs under US jurisdiction.

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

NIDIS Apalachicola-Chattahoochee-Flint River Basin Drought Early Warning System

Seasonal hydrological and nutrient loading forecasts for watersheds for the Southeastern United States

The research team was able to show useful seasonal deterministic and probabilistic skill of streamflow and nutrient loading over several watersheds in the Southeastern United States (SEUS) for the winter and spring (December-May) seasons over a 20-year period (1982-2001). by forcing the three conceptual rainfall-runoff hydrological models with resampled historical rainfall observations derived by matching observed analogues of forecasted quartile rainfall anomalies from a seasonal climate forecast model. Skill in prediction of seasonal nutrient loading is nearly identical to the skill in predicting the seasonal streamflow.

Assessing the Impact of Global Hawk Dropsonde Observations on the Prediction of Tropical Storm Gabrielle (2013) by Utilizing the Hurricane Ensemble Data Assimilation System (HEDAS)

Experiments conducted using NOAA/AOML/HRD's HEDAS data assimilation system for Tropical Disturbance Gabrielle (2013) suggest that high-resolution manned and unmanned aircraft observations in and around the center of the system introduce a cascade of positive impacts as a function of the number and type of observation platforms are utilized. The addition of the Global Hawk UAS observations improved the intensity forecast with a tropical storm that reached peak intensity within 2-3 days much like the observed scenario.

Developments in the High-Impact Weather Prediction Project

Significant advancements were towards creating a global, nested-grid framework in NMMB, demonstrating 'proof-of-concept' of a 3 km resolution global tropical cyclone model with multiple moveable nests located anywhere in the world, towards developing a robust shell-script based system capable of performing automated forecasts of the NMMB model and updating plots to the AOML/HRD website for 'real-time' public dissemination and the idealized storm capability in NMMB was completed, allowing for analysis and evaluation of code modifications in a well-controlled environment.

Sustained and Targeted Ocean Observations for Improving Atlantic Tropical Cyclone Intensity and Hurricane Seasonal Forecasts

During the first glider missions upper-ocean observations under hurricane wind conditions were collected during the passage of Tropical Storm Bertha (2014), and of Hurricane Gonzalo (2014). Observations were transmitted in real-time and assimilated in numerical models used in the forecast; they are now being re-analyzed to improve our understanding of the upper-ocean response to TC wind conditions.

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 with multiple international satellite sensors requires a common calibration point, maintained at the highest accuracy possible. The MOBY calibration site provides that single reference point used to tie these measurements together. This allows the ocean color record to be maintained over generations of satellite instruments which is essential to studies of climate change and climate impacts.

Goal 3: Climate Adaptation and Mitigation: An informed society anticipating and responding to climate and its impacts

Southwest Atlantic Meridional Overturning Circulation ("SAM") Project

Monthly climatologies of temperature and salinity from observations and numerical models were used to estimate the Meridional Overturning Circulation (MOC) in the South Atlantic at 34°S. Observational estimates suggest that the geostrophic transport plays an equal role to the Ekman transport in the MOC seasonal variations, whereas in the models, the Ekman transport controls the MOC 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 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.

High-Frequency Variability of Near-Surface Oceanic Velocity from Surface Drifters
Understanding the cascade of energy in the ocean from large-scale forcing by winds and tides to small-scale high-frequency currents and associated mixing processes remains one of the outstanding issues in physical oceanography. A new quality-controlled global database of surface drifter positions and velocities at an unprecedented level of temporal (*hourly*) and spatial resolution is being made publically available through this project.

The South Atlantic Overturning Circulation and Extreme Weather
Multi-decadal variability of the South Atlantic Ocean plays a key role in modulating atmospheric circulation via interhemispheric redistributions of momentum, heat, and fresh water, forcing a thermally direct anomalous Hadley circulation in the atmosphere. This has implications on weather extremes. For example, weaker SAMHT leads to increase warm temperature extreme and an increase in the number of heat wave days over the Western United States.

PIRATA Northeast Extension (PNE)
CIMAS scientists participating in the PIRATA Northeast Extension (PNE) project quantified the seasonal cycle and interannual variability the northward transport of near-surface freshwater, from its origins under the ITCZ to the southern edge of the subtropical salinity maximum at 20N. and 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.

Developing the Operational Calibration/Validation Components for VIIRS SST Retrievals
Using a large data base of coincident measurements from VIIRS and in situ temperatures from buoys, we have continued to refine the atmospheric correction algorithm to provide more accurate SSTs measurements across the entire VIIRS swath. The application of our results will provide significantly more accurate SST measurements from VIIRS for many applications, and lay the foundations for the next series of NOAA weather satellites that will also carry VIIRS.

South Atlantic Meridional Overturning Circulation: Pathways and Modes of Variability
The pathways of North Atlantic Deep Water (NADW) in the South Atlantic are revealed through analysis of new observations including hydrographic sections, Argo data and chlorofluorocarbon measurements, and a global ocean-only numerical model. The joint analysis provided for the first time evidence of the two main passages of the recently ventilated NADW in the South Atlantic. It was concluded that the NADW follows two different pathways south of 5°S. The main pathway (~71%) is southward in the DWBC flowing along the coast of South America. A smaller portion (~22%) flows eastward towards the interior of the basin.

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

Florida Area Coastal Environment (FACE) Program

The FACE program seeks to understand the natural and anthropogenic contributors to coastal water quality and resulting ecosystem health, to elucidate the factors that can be controlled by society (i.e., wastewater plant managers and water management districts). The research team members are addressing the question of the impact of land-based sources of pollution on coral reefs of the southeast Florida reef tract, via the acquisition of high-quality chemical and physical oceanographic data. These data are fundamental to the question of the role of ocean outfalls in the maintenance of coastal ecosystem health.

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 nine additional Florida and Caribbean University Partners (Florida Atlantic University (FAU), Florida Institute of Technology (FIT), 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.*
- *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.*
- *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, among others, NWS/NHC, NOS/NMFS/FKNMS, Florida Sea Grant, SECART, GOMART);

- By broadening the participation of the regional academic community beyond UM by incorporating; complementary capabilities from other Florida and U.S. Caribbean research universities (specifically FAU, FIT, 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 putting in place new graduate and undergraduate educational programs to train the NOAA workforce of the future.
- By establishing collaborative relationships with other regional Cooperative Institutes (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 as well as responding to major events such as Hurricane Sandy and the Deepwater Horizon oil spill.

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 when CIMAS was established:

Goal 1: Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems*

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

Goal 3: Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts*

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 (even those funded by non-NOAA funds) 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. 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 by serving as a liaison between their university's faculty and CIMAS. 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 is 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. This is the only funding annually "guaranteed" to CIMAS. Task I also includes both Research Infrastructure and Education & Outreach on as "as needed" basis. Under Task II CIMAS supports research scientists or research associates who work within 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. All Task II employees are University of Miami employees. CIMAS "Scientists" (as distinct from Post-Doctoral Investigators or Research Associates) can also serve as Principal Investigators and, with the approval of the Director, submit proposals to NOAA through Task III and to other agencies (or private entities) through Task III non-NOAA, as described below.

Research in CIMAS under this CA was also carried out under Tasks III and Task III non-NOAA. These Tasks provided funding to both university faculty and CIMAS scientists to conduct project-based research consistent with CIMAS research themes. Task III encompasses research collaborations with NOAA scientists (typically but not necessarily located in Miami) and NOAA program offices (regardless of location). Support for individual Task III projects is based on proposals submitted to specific NOAA units or funding programs often but <u>not necessarily</u> in response to a competitive Announcement of Opportunity or Request for Proposals. Task III non-NOAA 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 CIMAS University Partners other than UM is through Task III as a subcontract from UM to those institutions.

III. PERSONNEL

Distribution of Personnel

CIMAS personnel participate in a wide range of NOAA-related activities. During the past twelve months a 135 research and 7 administrative persons were associated with CIMAS in various capacities. Of these, 114 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 114 who received over 50% NOAA support, 67 are located at AOML, 33 at the SEFSC, 2 at RSMAS, 2 at NHC. 6 work at distant NOAA facilities and 4 at UPR.

Table 1: CIMAS Research Personnel 2015 – 2016

Category	Number	BS	MS	Ph.D
Research Associate/Scientist	71	15	34	22
Part Time Research Associate/Scientist	6	1	2	3
Other Research Professional Category	3	1	1	
Postdoctoral Fellow	16			16
Research Support Staff	18			
Total (> 50% NOAA support)	**114**	**17**	**37**	**41**
Full Time Administrative Staff	5			
Task I Undergraduate Students	6			
Task I Graduate Students	10			
Visiting Scientist	7			
NOAA Association	67 - AOML 33 - SEFSC 2 - RSMAS 12 - (2) NHC, (4) UPR, (6) Other			
Obtained NOAA employment within the last year	3			

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 16 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 research support employee (e.g. computer program or engineer). At present there are three such employees but we expect this category 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 had the status of a "Department" within UM's Rosenstiel School it has no faculty. School faculty participate in CIMAS activities in many ways, but hold their primary appointment in one of the School academic departments (including both the CIMAS Director and CIMAS Associate Director). University faculty are not counted in the listing of CIMAS employees not even those who serve as CIMAS Fellows or serve as the Principal Investigators in conducting Task III research projects. All the graduate students who work on CIMAS Task I programs and are included above also have their primary affiliation with a RSMAS Academic Division which has the ultimate responsibility for overseeing their students' academic performance and the granting of degrees. The undergraduates listed are majors in the University of Miami Marine and Atmospheric Science undergraduate program which is administered and staffed by RSMAS faculty.

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 systematic 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 and not only hiring new employees within these limits but raising the salary of legacy employees so that all now fall within the appropriate pay bands;
3. Assisting personnel with respect to the markedly increasing difficulty of negotiating the escalating requirements of the Department of Homeland Security (many CIMAS Task II employees are not U.S. citizens) and U.S. Department of Labor; 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

At present there are 31 CIMAS Fellows. 6 CIMAS Fellows are from RSMAS, 8 from the local NOAA facilities and 17 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; Bonnie Ponwith, NMFS/SEFSC and R. Knabb, NWS/NHC), the Director of the NOAA CI Office: Candice Jongsma 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. Benjamin Kirtman, 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 thirtyeight former RSMAS undergraduate/graduate students and/or research employees funded through CIMAS 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 3 CIMAS employees transitioned to Federal position.

Demographics of CIMAS Employees

The CIMAS population is 58% male. Foreign-born individuals make up 54% of the personnel; of these Hispanics make up 22% of the ranks; Asian and Pacific Islanders, 14%. Only 2% are African-Americans despite our efforts to expand this group's participation. The population of CIMAS is relatively young with an average age of 40. The largest age decade is that between 30 and 40, for a total of 66. 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. It is somewhat bimodal in character in that NOAA FTE retirees are often rehired through CIMAS in order to complete projects and mentor successors.

CIMAS Student Employees

There are currently 10 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 the full list). In addition, 6 undergraduates are currently supported. A number of high school students have been employed as temporary hires (under the category "Research Support Staff"). Most of these were enrolled in the Miami-Dade MAST Academy, a magnet school in the county (see VII. Education and Outreach section) which is co-located on the Virginia Key Marine Campus adjacent to AOML and across the street from the Rosensteil School where CIMAS is located.

IV. FUNDING

General Funding:

This reporting period, funding from all sources totaled ca. $27.0M 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 III-Linked	Task IV	TOTAL
Year 1	2,409,244	11,790,648	9,558,989	2,477,798	1,032,644	27,269,323
TOTALS	**2,409,244**	**11,790,648**	**9,558,989**	**2,477,798**	**1,032,644**	**27,269,323**

The sources of that funding are shown in Table 2. The major source of NOAA funding continues to be OAR which provided 57% of the total. NMFS, NESDIS, NOS contributed at 19%, 14%, and 6% respectively. “Other” accounts for 3%, the source of funding includes awards from NASA, NSF and private industry as well as sub-contractual awards from Florida International University, Purdu, SUNY to CIMAS investigators.

Table 2: Funding by Source

1 July 2015 - 30 June 2016		
Source	**Funding $M**	**% Total**
NESDIS	3.81	14%
NMFS	5.13	19%
NOS	1.59	6%
NWS	0.19	1%
OAR	2.94	11%
OAR/AOML	11.84	43%
OAR/CPO	.85	3%
Other	.91	3%
GRAND TOTAL	**27.26**	**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, meeting costs, software subscription 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 Department within the School moreover UM charges no Indirect Costs (IDC) whatsoever on Task I expenditures.**

- **Task II** provides support for off campus 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 CIMAS postdoctoral research associates is also included under Task II. **UM charges only 26% IDC on Task II.**

- **Task III (including linked and non-NOAA)** 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 III non-NOAA 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 Task III non-NOAA proposals. Their subjects must be consistent with CIMAS research themes and contribute to NOAA strategic goals. **The UM indirect cost rate for Task III was 40.5 and for Task III non-NOAA either the federally negotiated UM rate (currently 55%) or whatever rate is specified in the relevant RFP or FAO.** The reduced rate accorded 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. Task III awards to Partner Universities through CIMAS are allocated as subcontracts. Total UM IDC on these (regardless of the number of individual projects or total amount awarded by NOAA) is only $10K per Partner University (40% of the first $25K) over the lifetime of the Cooperative Agreement. Partner Universities are encouraged (but not required) to also offer NOAA an IDC rate below the federally negotiated rate. In most cases this has not been possible.

The total of Task I Funding this project period was $ 2.41M, of which $0.71M was for the Administration component (that sum included a 0.25M UM contribution) and the bulk of the remainder for Research Infrastructure. The distribution of NOAA Task 1 expenditures is shown in Figure 1. The category “Administration” 15% covers a portion of the salary of CIMAS staff including its Director and Associate Director. The category "Other" 7% 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 13% of the total. Temporary Staff accounts for 29% which covers persons hired on a temporary basis to support specific research projects. Other research infrastructure access (e.g. supercomputing access, capital equipment) accounts for 26% and student stipends another 6%.

Task I: General

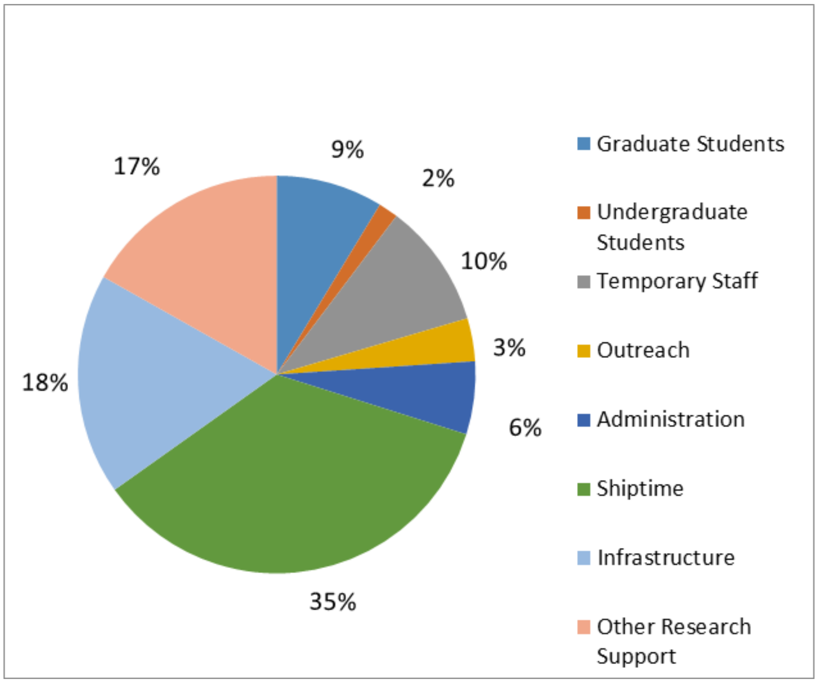

Figure 1: Distribution of Task1Funding

The funding provided for Task II employees totaled $8.2M over the past twelve months. The distribution of these funds by employee category is depicted in Figure 2.

Task II: Employees by Category

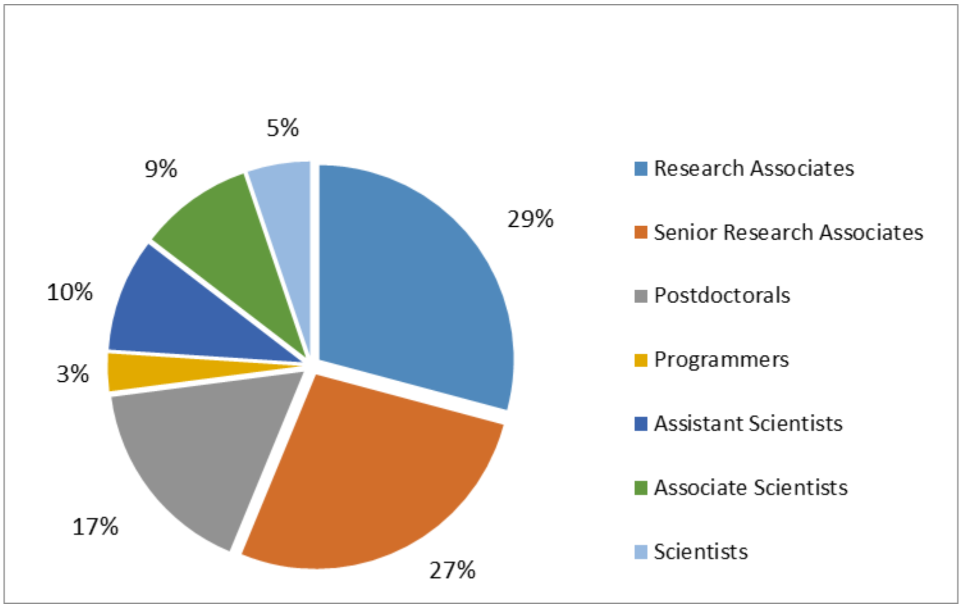

Figure 2: Distribution of Task 2: Funds by Employee Category

Funding by Theme

Project-specific research funding (Tasks III and Task III non-NOAA) under the new CA totaled ca. $12.8M as shown above in Table 1. Figure 3 shows the percentage of Task III and Task III linked to CIMAS 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 47%. The smallest portion of funding was in Theme 7: Ecosystem Modeling and Protection and Restoration of Resources – 2%.

The distribution of project specific funding by Theme as shown in Figure 3 is based upon somewhat arbitrary assessments of the major focus of specific projects. In truth nearly all CIMAS projects are highly interdisciplinary and could reasonably be assigned to more than one Theme. To better reflect this complexity projects are given not only *primary* but also *secondary* (and sometimes *tertiary*) theme assignments. Moreover, this figure only shows the distribution of funding under Tasks III and Task III non-NOAA; 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.

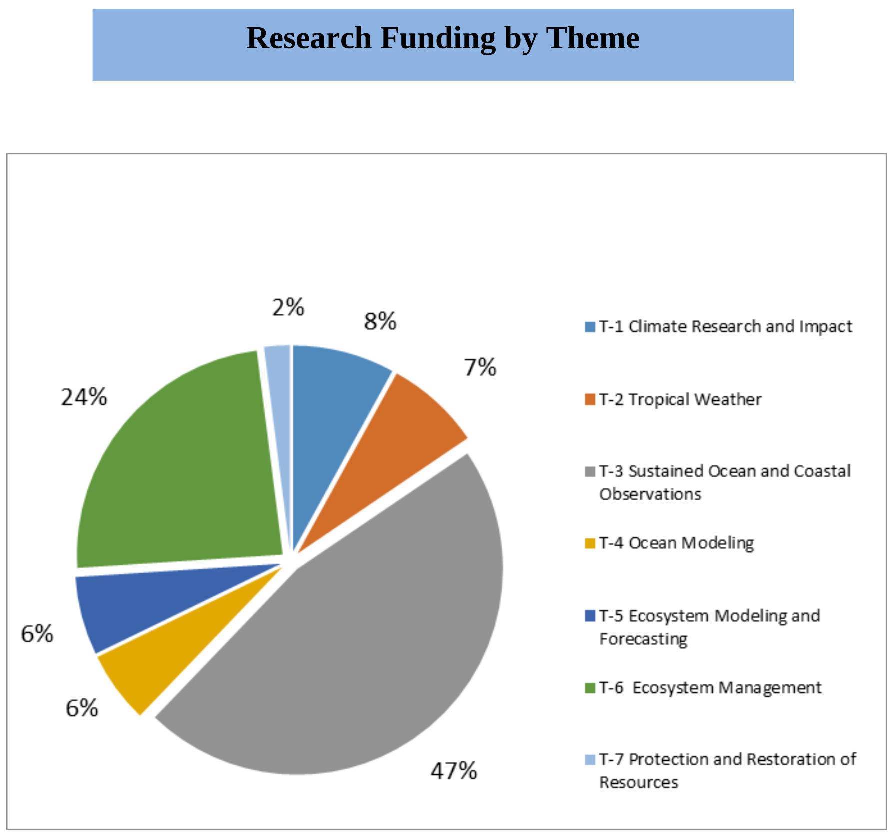

Figure 3: Percentage of Task 3 and Task 4 (Individual Research Project) funding per Theme

Table 3 below tabulates NOAA funding linked to CIMAS under the present Cooperative Agreement (CA). Marked with asterisk we indicate the 7 awards we received under the Disaster Relief Appropriation Act of 2013 related to Hurricane Sandy resulting in total for DRA funding of 6.8M. There are two ongoing projects.

Table 3: NOAA Projects with Individual Award Numbers

NOAA Award Number	Principal Investigator	Award Period	Project Title	Total Funds
NA15NOS4510233	Babcock, E	09/01/15 - 08/31/17	Ecosystem modeling efforts in the Gulf of Mexico: current status and future needs to address management and restoration activities	$ 164,698
NA11OAR4310077	Chen, S	09/01/11 - 08/31/15	Convective Structure and Environmental Conditions in the MJO Initiation over the Indian Ocean	$ 307,600
NA12OAR4310105	Criales, M	08/01/12 - 07/31/15	Integrated MODels for Evaluating Climate change, population growth, & water management (i.e. CERP) effects on south Florida coastal marine and estuarine ecosystems (iMODEC)	$ 264,858
NA14OAR4830172*	Dunion, J	08/01/14 - 07/31/17	Using NOAA UAS Assets and OSSE/DA Capabilities to Improve Sampling Strategies and Numerical Prediction of Tropical Cyclone Track, Intensity and Structure	$ 1,249,008
NA15OAR4590201	Dunion, J	09/01/15 - 08/31/17	Improvement to the Tropical Cyclone Genesis Index (TCGI)	$ 27,251
NA12OAR4310083	Goes, M	08/01/12 - 07/31/16	Toward developing in a seasonal outlook for the Occurance of Major US tornado outbreaks	$ 225,000
NA12OAR4310073	Kamenkovich, I	08/01/12 - 07/31/16	Mesoscale Variability in the Gulf of Mexico and its importance in climate extremes over North America	$ 408,500
NA14OAR4310193	Kirtman, B	08/01/14 - 07/31/17	Developing decision support tools for understanding, communicating and adapting to the impacts of climate on the sustainability of coastal ecosystem services	$ 178,788
NA14OAR4830127*	Kirtman, B	07/01/14 - 05/31/15	Severe Weather in the NMME	$ 69,990
NA12OAR4310089	Kirtman, B	08/01/12 - 07/31/15	A U.S national multi-model ensemble ISI prediction system	$ 259,626
NA130OAR4830224*	Kourafalou, V	10/01/13 - 09/30/15	Extending the Gulf of Mexico to the North Atlantic in support of Development & Demostration of a Relocatable Ocean OSSE System	$ 1,301,395
NA14OAR4830103*	Lee, S	02/01/14 - 01/31/16	CIMAS Contributions to OAR disaster Recovery Act Project	$ 1,983,254
NA15NOS4510226	Lehenaff, M	09/01/15 - 08/31/17	Evaluation of Gulf of Mexico oceanographic observation networks, impact assessment on ecosystem management and recommendation	$ 199,126
NA15OAR4590203	Nolan, D	09/01/15 - 08/31/07	Guidance on observational Understanding over the tropical Cyclone lifecycle	$ 37,292
NA11NOS4780045	Ortner, P	09/01/11 - 08/31/17	2011 REPP-Understanding Coral Ecosystem Connectivity in the Gulf of Mexico-Pulley Ridge to the Florida Key	$ 4,518,662
NA13OAR4310131	Pere, R	09/01/13 - 08/31/17	South Atlantic Meridional Overturning Circulation: Pathways and Modes of Variability	$ 222,723
NA130OAR4830217*	Shay, N	10/01/13 - 09/30/15	Evolving Data Fields for Use in OSSE Modeling	$ 105,935
NA10OAR4310120	Soden, B	05/01/10 - 07/31/15	Development of a long-term Homogenized upper tropospheric water vapor data set from satellite microwave radiances	$ 457,924
NA14NWS4680028	Zhang, Jun	08/01/14 - 07/31/16	Addressing deficiencies in forecasting tropical cyclone rapid intensification in HWRF	$ 389,332
NA13OAR4830232*	Zhang, X	10/01/13 - 09/30/15	Services to Support the Hurricane Forecast Improvement Proje	$ 1,027,950
NA14OAR4830119*	Zhang, X	04/01/14 - 03/31/17	CIMAS Contributions to OAR disaster Recovery Act Projects	$ 1,035,877

*** Awards under the Disaster Relief Appropriation Act of 2013.**

Funding distributed through CIMAS to the Partner Universities during the present reporting period was $3.1M or 33% of Task III. As discussed above, Partner Universities other than UM are eligible through CIMAS only for Task III funding.

Task III awards linked 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 Table 3.

Task III non-NOAA projects encompass project-specific research funding at CIMAS under the direction of CIMAS researchers. These projects supported by other funding sources including a NOAA project not linked to CIMAS are listed in Table 4.

Table 4: Other Funded Projects

PI	Start/end date	Funding Source	Project Description
Annane, B	04/14/14 - 06/30/14	FIU	FPHL Model Operation & Maintenance & Model Upgrades
Annane, B	04/14/14 - 06/30/14	FIU	FPHLM Storm Surge & Flood Component Project
Annane, B	12/31/15 -12/30/19	Purdue	Assimilation of GNSS-R Delay-Doppler MAPS into Hurricane models
Dong, S	04/01/10 - 03/31/14	NSF	Dynamics of Eighteen Degree Water from CLIMOSDE Observations and its Climate Implications
Dunion, J	01/01/14 - 12/31/15	U of Wisconsir	An Observational and Numerical Investigation of Energy
Dunion, J	07/01/12 - 06/30/15	NASA	Utilizing NASA Reconnaissance Assets to Investigate Hurricane Upper-level Warm Core Evolution, Inner Core Pulsing, and Near-Environment Moisture Interactions
Goes, M	09/15/15 - 08/31/18	NSF	The Interannual Variability of the Brazil Current
Ortner	02/01/11 - 07/31/14	NSF	Development of a Submersible Ammonium Fluorescence Analyzer for In-Situ and Underwater Application with a View Towards Application on an Autonomous Underwater Vehicle (AUV)
Perez, R	10/01/14 - 09/30/17	NSF	Global Impacts of Eddies on Inertial Oscillation of the Mixed Layer
Perez, R	04/18/14 - 04/17/17	NASA	Variability of the South Atlantic Subtropical Gyre
Shultzitski, K	09/01/15 - 08/31/17	NOAA	Measuring larval bluefin tuna growth to improve a fishery-independent index, and help resolve uncertainty with the stock-recruitment relationship
Volkov, D	08/05/13 - 08/04/17	NASA	The Mediterranean & Black Sea: Analysis of Large Sea level and.
Volkov, D	09/10/13 - 09/09/15	NASA	Investigaring the Variability of Sea Level in the Sub--Artic Sea
Williams, D	01/15/15 - 12/31/15	NSF	Surviving Climate Change
Zhang, J	07/03/14 - 07/02/18	U of Washingto	Calculating tropical Cyclone Inflow and Boundary Layer Proce
Zhang, J	12/01/15 - 07/31/16	FIU-NOAA	Understanding the Impcat of Sub-Grid Scale Physics in HWRF
Zhang, J	03/15/15 - 03/14/16	SUNY-NSF	Mechanism of Intensity Change in Sheared Tropical Cyclone

Conclusion

In our funding summary we report only expenditures during the nine-month project period under the new Cooperative Agreement or associated with it under the new CI Policy. Awards that either just missed the deadline (or represented out-year funding under pre-existing awards – see examples in Table 3) were not included herein.

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

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

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: Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems*
Theme 3 activities contribute to NOAA Mission Goal 2: Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts*
Theme 3 activities contribute to NOAA Mission Goal 3: Weather-Ready Nation - *Society is prepared for and responds to weather-related events*

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: Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems*
Theme 4 activities contribute to NOAA Mission Goal 2: Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts*
Theme 4 activities contribute to NOAA Mission Goal 3: Weather-Ready Nation - *Society is prepared for and responds to weather-related events*

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

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

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

In Section VI following, Task II and III research activities under the Cooperative Agreement award number are briefly described and the participating university and NOAA personnel enumerated. Considerably 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. For NOAA funded Task III projects linked to CIMAS that have their own project numbers see Table 3. For Task III non-NOAA projects and NOAA funded projects not linked to CIMAS see Table 4. To avoid unnecessarily burdening the responsible principal investigators of such Task III and all Task III non-NOAA and non-CIMAS linked projects we did not require submission of a CIMAS specific report such as those included in Section VI.

VI. RESEARCH REPORTS

THEME 1: Climate Research and Impact

Western Boundary Time Series Project

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

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

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

Link to NOAA Strategic Science Goals:
***Goal 3*:** Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts*

NOAA Funding Unit: OAR/AOML and OAR/CPO
NOAA Technical Contact: Molly Baringer

Research Summary:

Variations in the transport of the Meridional Overturning Cell (MOC) in the Atlantic Ocean have been shown in numerical climate models to have significant impacts on the climate over a wide range of locations around the globe. In the Atlantic, near 27˚N, the warm upper-limb of the MOC is principally carried by the Florida Current between the eastern Florida coast and the Bahamas, although the Antilles Current east of the Bahamas also carries some of the warm northward flow. The southward deep flow of the MOC is contained primarily within the Deep Western Boundary Current east of Abaco Island in the Bahamas, although some fraction is also thought to transit near the Mid Atlantic Ridge. Long-term observations of the Florida Current, Antilles Current and Deep Western Boundary Current are required in order to quantify the natural time scales of variability for these currents.

This project maintains NOAA's well-established and climatically significant Florida Current volume transport time series. More than 30 years of daily mean voltage-derived transports have been obtained for the Florida Current using out-of-use and in-use telephone cables spanning the Straits of Florida. The cable voltages are converted to physically meaningful volume transport estimates, i.e. intensity of the flow, using electromagnetic induction theory and data from calibration sections on research vessels. Regular 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 as well as on small boat charters. During the past year, the monitoring and data distribution systems for the Florida Current cable program have continued, providing Florida Current volume transports in near real time via the web page http://www.aoml.noaa.gov/phod/floridacurrent (See Figure 1).

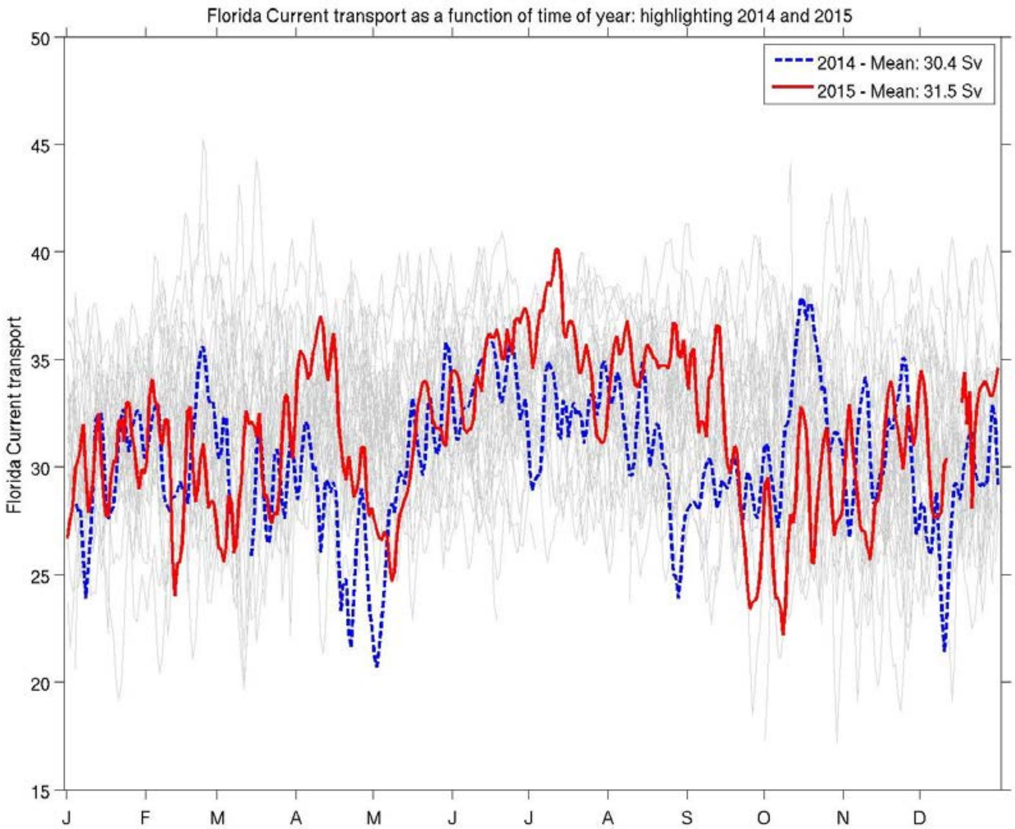

Figure 1: Volume transport of the Florida Current at 27ºN. The two most recent years are highlighted in color.

This project also maintains moored instruments and repeated hydrographic sampling east of Abaco Island that has established a high-temporal-resolution record of water mass properties in the Deep Western Boundary Current. Events such as the intense convection period in the Labrador Sea and the renewal of classical Labrador Sea Water in the 1980s are clearly reflected in the cooling and freshening of the Deep Western Boundary Current waters off Abaco, and the arrival of a strong pulse of Labrador Sea Water approximately 10 years later. Through a collaboration with the National Science Foundation-funded Meridional Overturning Circulation Heat-flux Array experiment and the United Kingdom Natural Environmental Research Council funded RAPID-Meridional Overturning Circulation program, this program executes hydrographic cruises each year to monitor water mass changes along 26.5ºN east of Abaco Island in the Bahamas. These cruises usually involve collaborations with scientists from RSMAS/University of Miami and from the National Oceanographic Centre, Southampton (NOCS), United Kingdom.

Research Performance Measure: Most research goals were met during this last year. The scientific and support personnel continue to achieve the main project objectives – to maintain the continuity of this long-term data set and to continually improve the calibration of the data obtained. Several data reports with hydrographic data collected during cruises in the WBTS region were completed during this period.

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Construction of an Agulhas Leakage Indicator

Project Personnel: F. Beron-Vera (UM/RSMAS); M. Goes (UM/CIMAS)
NOAA Collaborators: G. Goni and S. Dong (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To construct an Agulhas leakage indicator
***Strategy*:** To focus on Agulhas rings transport

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

Link to NOAA Strategic Goals:
***Goal 3*:** Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts*

NOAA Funding Unit: OAR/AOML
NOAA Technical Contact: Molly Baringer

Research Summary:
A signal of coherent water transported across the South Atlantic has been extracted from the altimetry record (Wang et al., 2015). The methodology employed, known as geodesic eddy detection, enables detection of Agulhas rings with material boundaries that preserve coherence for many months. Such rings can trap water and effectively carry it within across the South Atlantic basin. Yearly, 1 to 4 coherent rings are detected with diameters 40-280 km. A total of 23 ring cores of about 50 km in diameter and with at least 30% of their contents traceable into the Indian Ocean were found to travel across the subtropical gyre with minor filamentation. Only 1 ring core was found to pour its contents on the North Brazil Current. With this information and information on the vertical structure of the rings based on available observations and models, a coherent water transport time series was constructed (Fig. 1). Gray-shaded bar portions correspond to Indian Ocean water transport. The maximum annual transport produced by 1-year

coherent material rings is about 0.3 Sv. The maximum annual transport of Indian Ocean water trapped inside these rings does not exceed 0.2 Sv. Closer inspection of one particular ring has revealed the development of successive short-term coherent material loops that shield the rings' interior from mixing with the ambient fluid (Wang et al., 2016). These loops enclose a larger volume of water than that enclosed by 1-year coherent material rings. If applicable to all rings in the altimetry dataset, which awaits confirmation, this discovery would lead to an order of magnitude increase of the annual transport estimates in Fig. 1, thereby emphasizing the role of rings in carrying Agulhas leakage. Furthermore, such coherent Lagrangian Agulhas rings tend to form in Cape Cauldron, likely as a result of as a dual cascade of energy to larger scales and enstrophy to smaller scales.

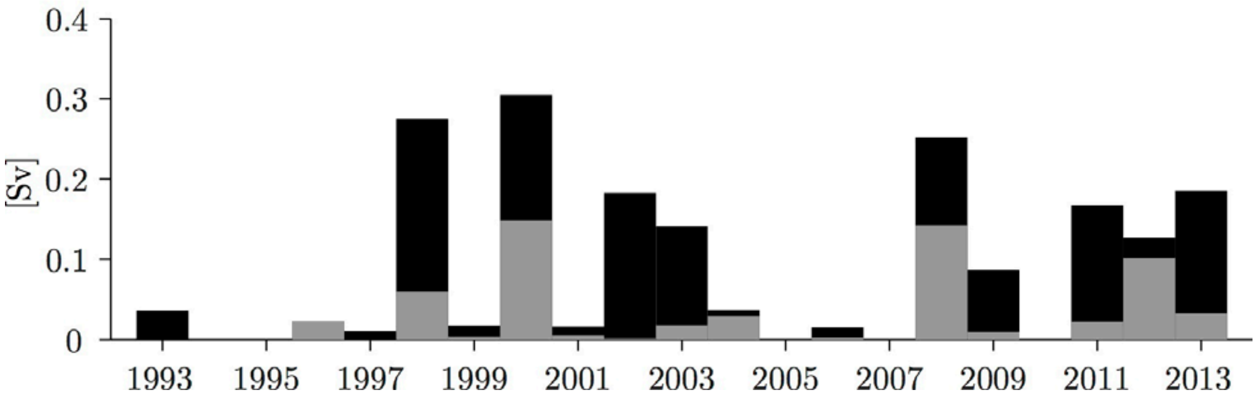

Figure 1: Annual average time series of transport across the South Atlantic produced by coherent material rings. Gray-shaded bar portions correspond to transport of Indian Ocean water trapped inside the rings.

Figure 2: Short-term coherent material loops (red) that provide shielding to the fluid in their interior as this evolves under the altimetry-derived flow. The green curve is a material loop that is assessed to be coherent only up to 31 May 1999 using geodesic eddy detection on 31 March 1999. Beyond 31 May 1999, however, this material loop experiences mostly tangential filamentation. This is guaranteed by the red material loop that encloses it over a long period of time. Eventually the green loop experiments strong nontangential filamentation. This happens after 18 Februrary 2001. Beyond that date the short-term shielding boundaries of the material Agulhas ring begin to shrink until no one can be detected. That happens past 19 May 2001, date by which the ring may be declared dead.

Research Performance Measure: A critical discovery for the purpose of this project has been that coherent Agulhas rings do not form as a consequence of an occlusion of, and subsequent pinch off from, the Agulhas retroflection, but rather emerge from turbulence in Cape Cauldron. This suggests that the kinetic energy in that region is the relevant variable to be monitored for the construction of an Agulhas leakage indicator that focuses on Agulhas rings transport.

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Hurricane Risk to U.S. Offshore Renewable Energy Facilities

Project Personnel: S. Cocke, D.-W. Shin, (FSU); M. Powell (formerly NOAA, FSU)
NOAA Collaborators: S. Murillo (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To assess risk of wind threat to offshore wind turbines due to hurricanes
***Strategy*:** To analyze vertical profile of hurricane wind near the hub height of turbines using GPS dropsondes and other sources of observational data; To use a catastrophe modeling approach to determine return periods of high hurricane winds.

CIMAS Research Theme:

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

Link to NOAA Strategic Goals:

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

Research Summary:

One of the primary aims of this project is to determine the vertical profile of winds in the lower hurricane boundary layer so that the risk of hurricane winds to offshore turbines can be estimated. Previous methods for estimating the vertical profile of winds, such as the IEC 61400-3 or the API RP 2A-WSD have known limitations and have not been validated against much of the recent GPS sonde data that has been collected by NOAA-AOML-HRD. We have been collecting and analyzing the HRD GPS dropsonde data sets. Presently we have access to the 1997-2005 dropsonde data, and HRD is currently processing the post-2005 data. Until the new data becomes available, we have done some preliminary analysis of the data which we currently have. The preliminary analysis is based on GPS sonde groups that were identified as shallow water sondes in the 2007 Joint Hurricane Testbed study. It is important to note that study was focused on surface layer properties and did not apply the resulting wind profiles to wind turbine rotor zones. In this study we apply the surface layer log-profile results to the full rotor zone and compare the observed hurricane profiles to those specified in various design condition standards documents.

We first analyze the GPS dropsonde data using the same profile method used in prior research (Powell et al., 2003; hereafter P2003), but focus on using sonde data that is over shallow water (less than 50 m depth) as this is more relevant to offshore turbines. As in P2003, the sonde data is binned in height (10 m intervals from 20 to 300 m, 20 m intervals from 300 to 500 m) and grouped in Mean Boundary Layer

(MBL) wind speeds (10 m/s intervals). The MBL wind is defined to be the mean of the vertical profile of the wind in the lowest 500 m of the boundary layer. The approach of P2003 is to assume the wind follows a logarithmic profile in the vertical, and depends on roughness (drag coefficient). The dependence on roughness is important, as the roughness could change depending on sea state or upstream fetch. P2003 found that roughness appears to decrease with increasing winds above 33 m/s for open ocean. It is not known whether that will be the case for shallow water conditions.

The profile method of P2003 assumes that the surface layer (below 200 m) can be described by the bulk aerodynamic method. The friction velocity and surface roughness are found using a least squares linear regression for each MBL group (bin). The regression was done for the 20 to 160 m surface layer. The intercept is just the log of the roughness length, and the slope determines the friction velocity. Figure 1 shows the fitted profiles of the wind for each MBL group. We have further subdivided the data according to whether the flow was offshore, onshore and along shore. As expected, the roughness for offshore flow was higher than onshore flow, indicating the importance of fetch. The dependence of the drag coefficient on wind speed is not clear, as the data sample is rather small. We will reanalyze the data when more GPS sondes are processed, so that the results will be more robust.

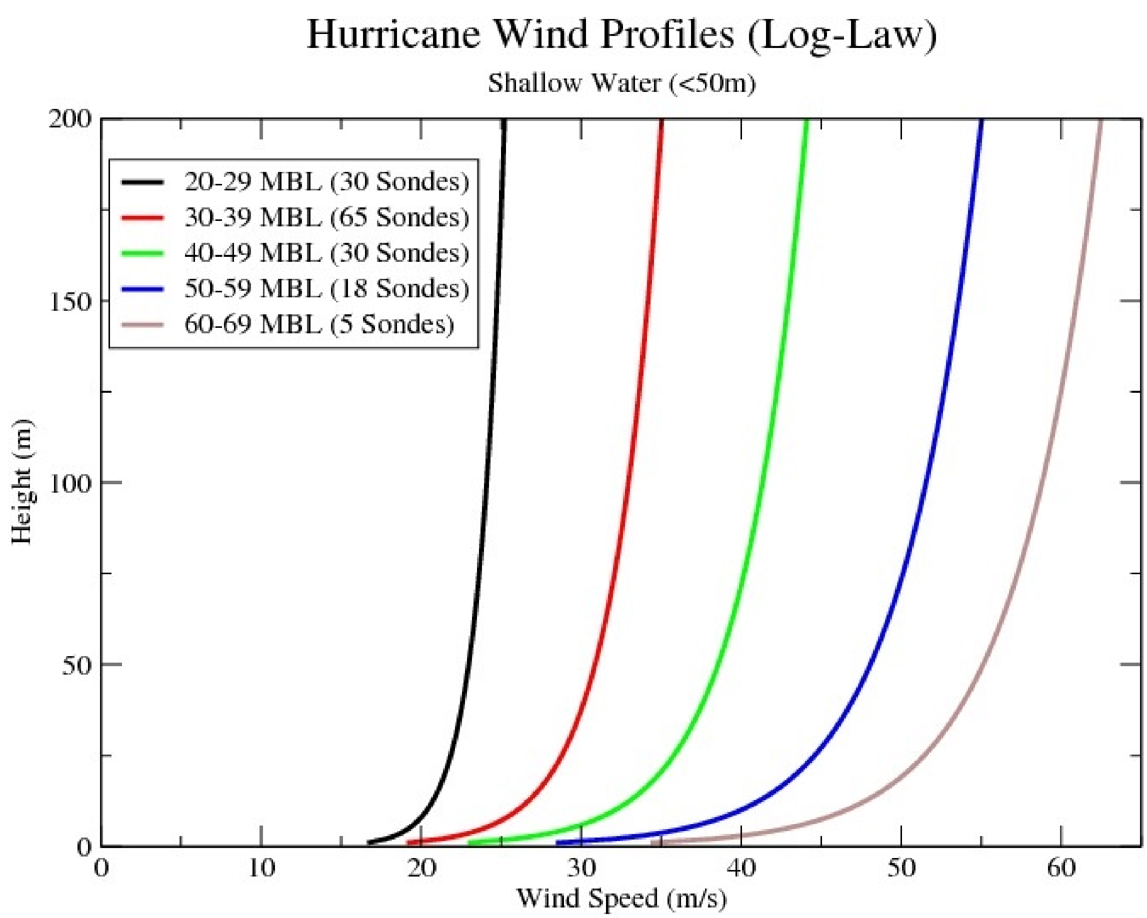

Figure 1: Fitted log-wind profiles for each MBL group.

Research Performance Measure: Significant progress has been made in analyzing some of the GPS dropsonde data. However, there has been a long delay in funds for the remaining fiscal year, and the project is temporarily stalled. We are eager to start moving forward again when the funding arrives.

Developing Decision Support Tools for Understanding, Communicating, and Adapting to the Impacts of Climate on the Sustainability of Coastal Ecosystem Services

Project Personnel: G.S. Cook, K.A. Kearney, P.B. Ortner and C. Quenée (UM/CIMAS)
NOAA Collaborators: C.R. Kelble (NOAA/AOML)
Other Collaborators: C. Carollo and D. Yoskowitz (Texas A&M – Corpus Christi); P. Fletcher (NOAA/Florida Sea Grant); D. Rudnick (US National Park Service)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives**:* To develop tools for understanding how pressures related to urbanization and climate change interact to impact ecosystem states, and how changes in these ecosystem states impact the production of ecosystem services and their economic value in coastal south Florida.

***Strategy**:* To accomplish these objectives we are using expert-opinion and matrix-based approaches to understand and rank predominant pressures, ecosystem states/habitat types, and ecosystem services in coastal south Florida. In a complementary analysis, we are coupling hydrodynamic-habitat suitability modeling with ecosystem services valuation (using meta-regression analyses) to predict how future changes in habitat areal abundance impact the future value of coastal ecosystem services.

CIMAS Research Theme:

Theme 1: Climate Research and Impact (*Primary*)
***Theme 6**:* Ecosystem Management (*Secondary*)
Theme 5: Ecosystem Modeling and Forecasting (*Secondary*)
Theme 7: Protection and Restoration of Resources (*Secondary*)

Link to NOAA Strategic Goals:

***Goal 3*:** Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts (Primary)*

***Goal 1*:** Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems (Secondary)*

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

NOAA Funding Unit: OAR/CPO – Coastal Ocean and Climate Application
NOAA Technical Contact: Adrienne Antoine

Research Summary:

The primary objective of this research project is to develop decision support tools to explore the effect of urbanization on the resilience of ecosystem services under future climate change scenarios in coastal south Florida. Specifically, we are taking a two-pronged approach to develop multiple lines of evidence for informing ecosystem-based management decisions. Over the past year, and continuing through 2015, we are using expert opinion analysis to develop cause & effect networks linking climate and human-development pressures (e.g. sea level rise, marine construction), to local ecosystem states (i.e. habitat types such as seagrasses, mangroves, etc.), and their associated ecosystem services (e.g. recreational opportunities, pollution attenuation, hazard moderation) throughout south Florida. A parallel examination is using habitat suitability models to estimate current and future changes in areal cover, abundance, and quality of those same habitat types throughout south Florida. Currently meta-regression valuation methods are being used to estimate the economic value of ecosystem services in the study region (please see below). Both network and habitat-suitability analyses are being applied in three distinct urbanization zones in south Florida: 1) the heavily urbanized southeast coast (i.e. Biscayne Bay), 2) the moderately

developed southwest coast (i.e. southern Charlotte Harbor, Sanibel-Captiva, Estero Bay, and 3) the relatively pristine undeveloped central coast spanning from Rookery Bay in the north west through Florida Bay and Everglades National Park to the south and east.

To facilitate the development of integrated conceptual ecosystem models (ICEMs) for our three urbanization sub-regions spanning south Florida, we identified a list of key natural resource managers within each sub-region. From this larger list we identified 3-4 "key" natural resource managers and decision makers representing local, state, and federal agencies. We held various formal and informal informational meetings with these individuals to identify which managers had a pending management decision and/or a need for the type of products we are developing through this COCA project. Using expert-opinion polling we introduced local experts to our COCA project, explained our methods and goals, and then had the local experts identify predominant Climate- and Urbanization-related Pressures within their management jurisdiction (e.g. Sea Level Rise on Sanibel-Captiva). They also identified the relevant ecosystem states (e.g. Estero Bay does not have Beach habitat), and the suite of ecosystem services derived from these ecosystem states (e.g. Mangroves in Florida Bay provide the Ecosystem Service Hazard Moderation). This information feeds directly into the habitat suitability models and the ecosystem service valuation work being completed by our Texas A&M University-Corpus Christi project partners (please see below). These data were then used to develop sub-region specific ICEMs and currently are being used to develop Pressure-State-Ecosystem Service semi-quantitative network models that will be used to simulate how various Climate Scenarios are predicted to impact the provisioning of ecosystem services in the second year of our study (Figure 1).

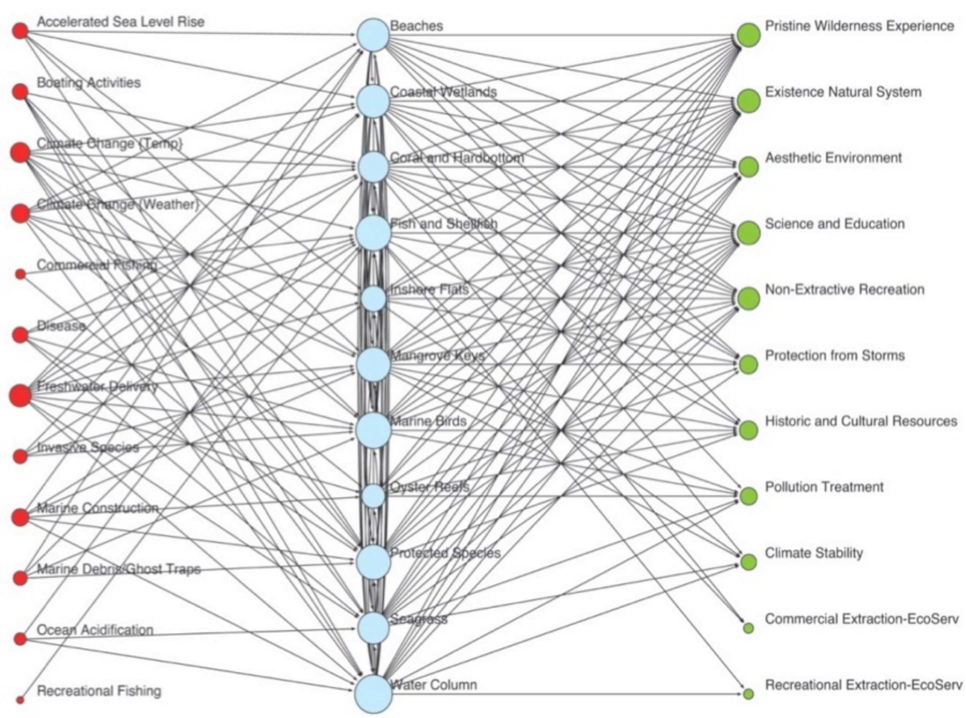

Figure 1: Ecosystem Pressure-State-Ecosystem Service network model for relatively pristine central study region (i.e. coastal Everglades National Park and Florida Bay). This model was constructed using regional expert opinion, and links various pressures, ecosystem states/habitat types, to a suite of ecosystem services. This network (and similar models developed for our other sub-regions) will form the baseline for our ecosystem services risk assessment to be completed during year two of this study.

Our original postdoc on this project (Kearney) left the University of Miami to accept a project scientist position at the University of Washington shortly after COCA funds became available. However, we have hired a replacement scientist who is taking over the hydrodynamic-habitat suitability empirical modeling component for our project. Before leaving Dr. Kearney developed statistical habitat suitability models linking hydrodynamic properties of the water column with target habitat types and the provisioning of sportfish within our central study region (Figure 2). These statistical models link various physical parameters (e.g. temperature, salinity, etc) associated with the suite of climate-related Pressures identified in our management engagement activities, with the distribution of key habitat types (e.g. spatial abundance of seagrass), and the generation of associated ecosystem services (e.g. recreational opportunities). The habitat suitability models enable us to quantify changes in seagrass cover, sportfish, and the prey base, which can be used to estimate changes in ecosystem services such as recreational opportunities, nutrient and pollution regulation attenuation under different climate and urbanization scenarios.

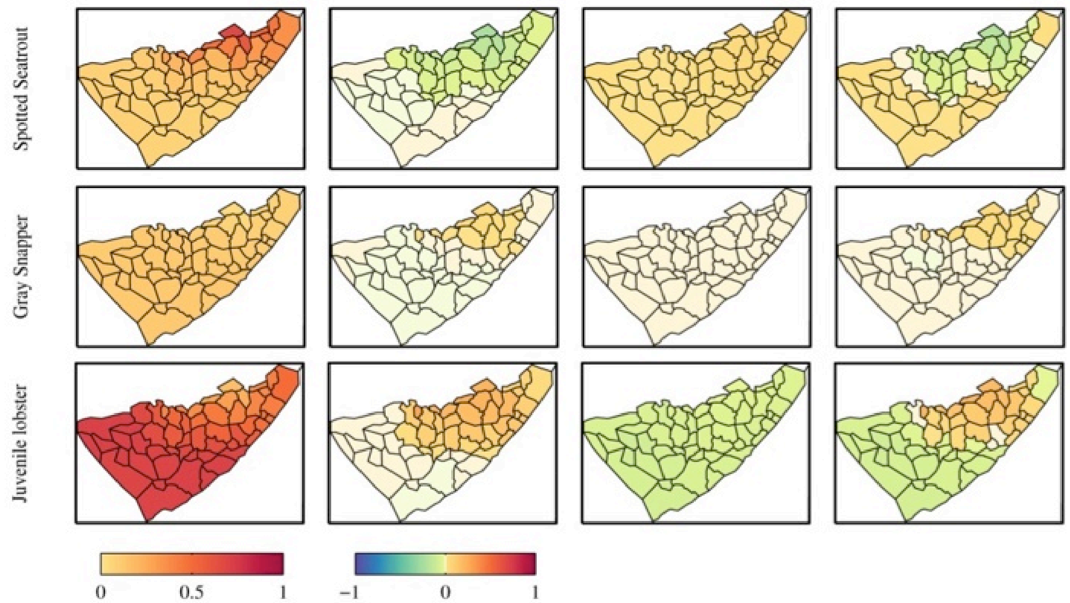

Figure 2: Habitat suitability models for spotted seatrout (*Cynoscion nebulosus*), gray snapper (*Lutjanus griseus*), and juvenile spiny lobster (*Panulirus argus*) in our relatively pristine central study sub-region. Figure panels depict (from left to right) habitat suitability for Flux Accounting and Tidal Hydrology at the Ocean Margin (FATHOM) model basins in Florida Bay for baseline (i.e. current) condition, and predicted changes in habitat suitability with increase in Sea Level Rise, increase in water Temperature, and combined effects of Sea Level Rise and water Temperature. Warmer colors indicate a relative increase in suitability; cooler colors indicate a relative decrease in suitability (adapted from Kearney et al 2015).

Members of the project team located at Texas A&M University-Corpus Christi have conducted a gap analysis and synthesized the primary studies and data necessary to conduct ecosystem services meta-regression analysis for Miami-Dade, Monroe, Collier, Lee, and Charlotte Counties (i.e. counties encompassing our focal study sites). From these analyses and based on the results from our focal study site manager interactions the quantification of ecosystem services for several of the key habitat types found within our study region was initiated. The focus of this year was on the development and testing of the meta-regression model.

The meta-regression analysis was tested on counties in our study areas (Table 1). According to our results, disturbance regulation has a higher value in all the counties considered for the testing of the model. The county with the highest value for both ecosystem services was Monroe, followed by Collier. It is possible the differences in values in this exercise are driven by a combination of the areal extent of coastal marshes and population density.

Table 1: Value of ecosystem services provided by coastal marshes calculated using a meta-regression analysis*

Counties	Disturbance Regulation US$ 2012 /ha/year	Disturbance Regulation US$ 2012 /year	Recreation US$ 2012 /ha/year	Recreation US$ 2012 /year	Total US$ 2012 /year
Miami-Dade	$6,430	$15,176,199	$222	$524,989	$15,701,188
Monroe	$1,450	$28,352,749	$50	$980,805	$29,333,554
Collier	$2,258	$20,192,662	$78	$698,524	$20,891,186
Lee	$5,557	$9,493,366	$192	$328,404	$9,821,770
Total	$15,694	$73,214,976	$543	$2,532,722	

* Model variables: area represents the areal extent of marshes in each county; person per square mile is population density in each county; region code is set to 1 to represent North America; coastal type is also set to 1 to represent coastal marshes; WTP and replacement cost are given the weight of how frequent they were used in the dataset (16.7% and 14.6%, respectively).

Research Performance Measure: All major research objectives are being met. We have had not had any major deviations from our proposed workplan, and we anticipate the same outcomes as predicted originally.

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High-Frequency Variability of Near-Surface Oceanic Velocity from Surface Drifters

Project Personnel: S. Elipot (UM/RSMAS); R. Perez (UM/CIMAS)
NOAA Collaborators: R. Lumpkin (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To characterize and quantify the high-frequency variability of the near-surface oceanic velocity field on a global scale; to improve our understanding on the distribution and characteristics of inertial motions, tides (diurnal and semidiurnal) and submesoscale motions.

***Strategy*:** To build a new quality-controlled global dataset of surface drifter positions and velocities at an unprecedented level of temporal (*hourly*) and spatial resolution, and implement analyses of the resulting dataset.

CIMAS Research Theme:

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

Link to NOAA Strategic Goals:

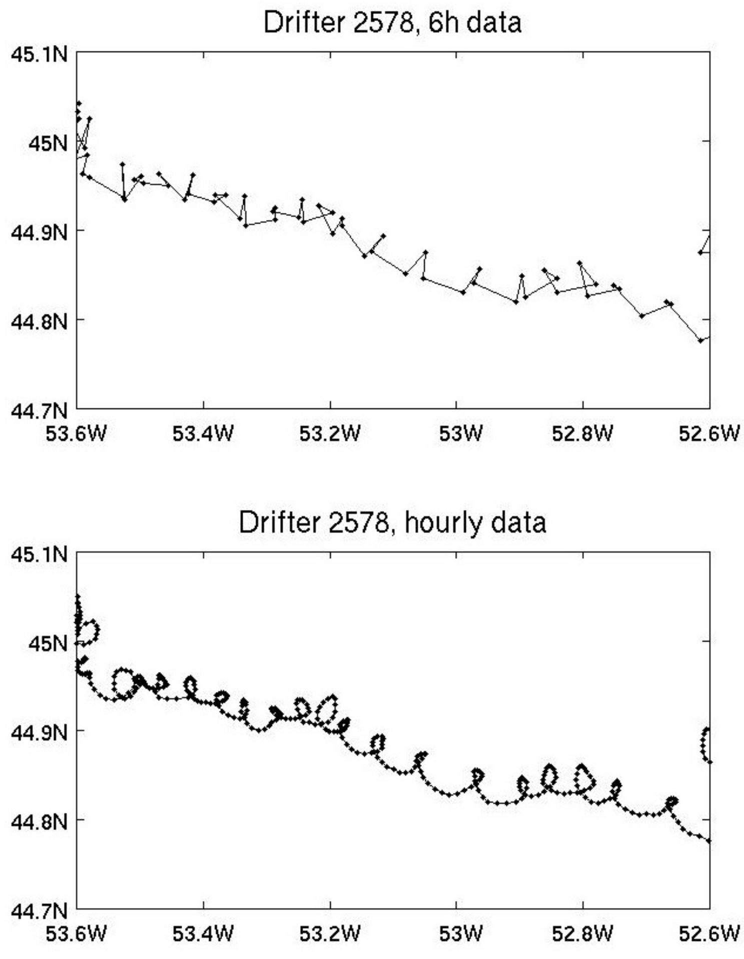
***Goal 3*:** Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts*

NOAA Funding Unit OAR/AOML
NOAA Technical Contact: Molly Baringer

Research Summary:

Understanding the cascade of energy in the ocean from large-scale forcing by winds and tides to small-scale high-frequency mixing remains one of the outstanding issues in physical oceanography. Many uncertainties remain regarding not only the rates, but also the mechanisms, by which the ocean's energy reservoir is supplied, distributed, and dissipated. This lack of knowledge affects our capability to understand and predict large-scale and regional oceanic circulations and global climate. To date, observations have been insufficient to shed light on the spatial structure of high-frequency kinetic energy sources and sinks. Although recent studies have made it clear that the distribution of these sources and sinks is not homogenous and varies with time.

NOAA's GDP maintains a 5° x 5° global array of ~1250 satellite-tracked surface drifters providing observations of near-surface oceanic currents. Drifters are predominantly tracked by the Argos positioning system, providing drifter locations with O(100 m) errors at nonuniform temporal intervals. In 2005 the number of satellites available for the Argos satellite tracking system reached six satellites, reducing the time interval between consecutive drifter position fixes to 1.2 h on average. As a result, the GDP dataset contains physically meaningful, high-frequency information about near-surface currents including sub-mesoscale, inertial and tidal signals, at all latitudes. However, the standard GDP product which is drifter positions and velocities with 6-hourly resolution obtained by a method called kriging, is insufficient to capture high-frequency and small-scale oceanic processes. In order to eventually study these processes, we have estimated *at hourly time intervals* positions and velocities of drifters (see a comparison between 6-h and 1-h product in Figure 1). In order to do so we have devised an interpolation methodology which was carefully informed by studying the distribution of Argos location errors, and modelling these with appropriate probability distribution functions.



A global spectral analysis of the velocity variance from the new hourly data set reveals a sharply defined ridge of energy closely following the inertial frequency as a function of latitude, distinct energy peaks near diurnal and semidiurnal frequencies, as well as higher-frequency peaks located near tidal harmonics as well as near replicates of the inertial frequency (Figure 2). Compared to the spectra that can be obtained using the standard 6-hourly GDP product, the new data set contains up to 100% more spectral energy at some latitudes.

Figure 1: Segment of trajectory of drifter with ID 2578 as estimated at 6-hourly intervals by the kriging method (top) and at 1-hourly interval by the new method described in Elipot et al. 2016 (bottom).

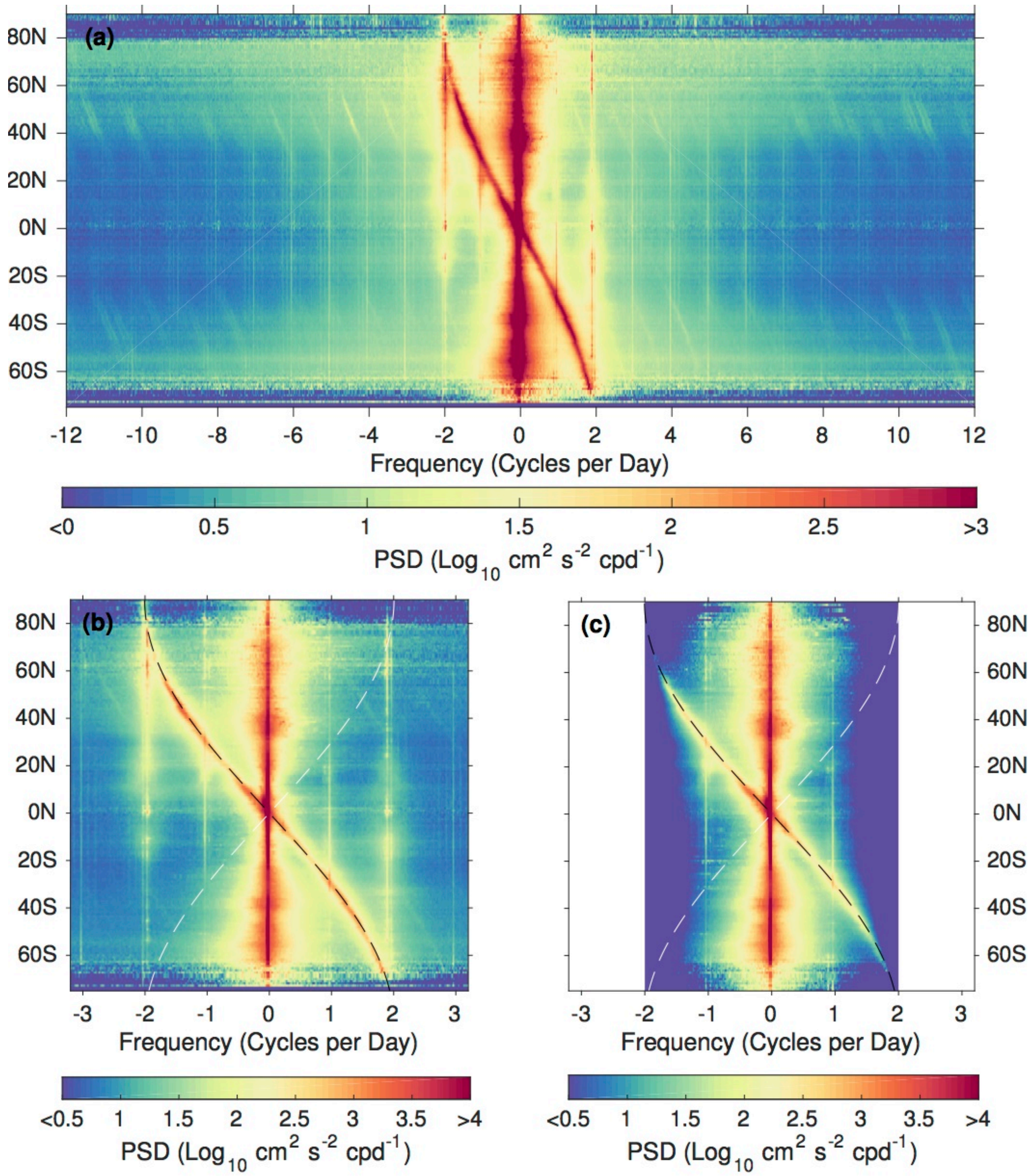


Figure 2: (a) Zonally averaged drifter rotary velocity spectra in 1degree latitude bins from 2048 h (85 days) trajectory segments at hourly resolution, overlapping by 50%, from the new global hourly product post-2005. (b) Same as in (a) but zoomed in for frequencies in the range ±3.2 cpd. The black dashed curve indicates the inertial frequency ($-f/2\pi$ cpd) and the white dashed curve the Coriolis frequency ($f/2\pi$ cpd). Note that the color scales indicate different ranges of values and are both saturated. (c) Same as (b) but calculated from the post-2005 6-hourly kriged global product for the same trajectories.

Research Performance Measure: The methodology to produce the new hourly dataset, as well as preliminary analyses of the global upper-ocean variability from this dataset, are presented in a paper published in May 2016 in the Journal of Geophysical Research – Oceans (doi: :10.1002/2016JC011716). The new dataset is freely available through the Data Assembly Center of the Global Drifter Program (http://www.aoml.noaa.gov/phod/dac/hourly_data.php).

Ocean OSSE System Development and Applications

Project Personnel: V. Kourafalou (UM/RSMAS), M. Mehari and M. Le Hénaff (UM/CIMAS**)**
NOAA Collaborators: G. Halliwell and R. Atlas (NOAA/AOML)

Long Term Research Objectives & Strategy to Achieve Them:

***Objectives*:** Perform Observing System Experiments (OSEs) and Observing System Simulation Experiments (OSSEs) to evaluate existing and new ocean observing systems. The OSSE system was expanded into an Atlantic Ocean domain to evaluate ocean observing systems with respect to improving ocean model initialization in coupled hurricane prediction systems. The system will eventually be expanded to global to address ocean climate applications

***Strategy*:** Perform ongoing development of the code base for Observing System Simulation Experiments (OSSEs) and Observing System Experiments (OSEs) at NOAA/AOML and UM/RSMAS, including the ocean data assimilation system and the toolbox to sample synthetic observations from the nature run. The OSSE system is designed to be relocatable so that regional observing system evaluations can be conducted upon request. Perform OSSEs in the new Atlantic Ocean domain (98ºW to 20ºW, 5ºS to 45ºN), initially for hurricane prediction applications and later for other applications.

CIMAS Research Themes:

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

***Goal 3*:** Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts*

NOAA Funding Unit: NOAA/QOSAP
NOAA Technical Contact: Molly Baringer

Research Summary:

This project is performed by the joint AOML/CIMAS/RSMAS Ocean Modeling and OSSE Center (OMOC). An ocean OSSE system has been developed following strict design criteria and rigorous evaluation procedures that enable a-priori determination of the expected realism of observing system impact assessments obtained from the system. This is the first ocean OSSE system to employ all of the techniques developed and long used to provide realistic assessments of atmospheric observing systems. Initial evaluation of the ocean system in the open Gulf of Mexico (Halliwell et al., 2014; 2015) demonstrated that it is capable of providing credible estimates of observing system impacts. Under previous support by a Sandy Supplemental project, the OSSE system was expanded into an Atlantic Ocean domain to focus on ocean observing system impacts with respect to improving ocean model initialization in coupled hurricane prediction systems. Over the past year, this Atlantic hurricane work has continued under support from the NOAA QOSAP program. Plans are now being made to expand the OSSE region, eventually to global, to evaluate ocean observing systems for other applications including climate monitoring and prediction applications.

The OSSE system has been successfully ported to and evaluated within a new Atlantic Ocean domain (98ºW to 20ºW, 5ºS to 45ºN). The system Nature Run has been validated for representing the “true” ocean based on realistic representation of ocean climatology and variability (Kourafalou et al., 2016, Androulidakis et al., 2016). The forecast model (FM) has been validated as being neither too similar nor too different from the NR model, a key design requirement of a credible OSSE system (Halliwell et al., 2016). OSE-OSSE comparison experiments identified a tendency of the OSSE system to overestimate observing system impacts by about 10%. OSSE system results are now calibrated to correct this tendency. Finally, the OMOC group contributed to a community paper on observing system impact assessments (Oke et al., 2015).

An example OSSE evaluating components of the operational ocean observing system is presented in Figure 1. The control experiment assimilated the operational ocean observing system, and the Brier skill score of 0.57 calculated for model output fields of Tropical Cyclone Heat Potential (TCHP) with respect to the 26ºC isotherm quantifies the resulting improvement over the unconstrained FM due to assimilation. The large skill score reduction when altimetry is denied demonstrates the large impact of this observing system on a field important for hurricane prediction. Smaller skill score reductions for Argo floats and SST systems (both satellite and in-situ) also demonstrate positive impact. Impact is not detected for the XBT system because only five XBT transects occurred across the Atlantic hurricane domain during the 2014 season. A second OSSE example illustrates the impact of conducting a two-day, rapid-response AXCTD airborne ocean profile survey ahead of Hurricane Gonzalo (2014). By adding profiles from this survey of synthetic profiles to the control experiment that assimilated the existing observing system, additional error reduction is realized in the resulting ocean analysis as demonstrated by the skill score of 0.50, which in this case measures improvement over the control experiment.

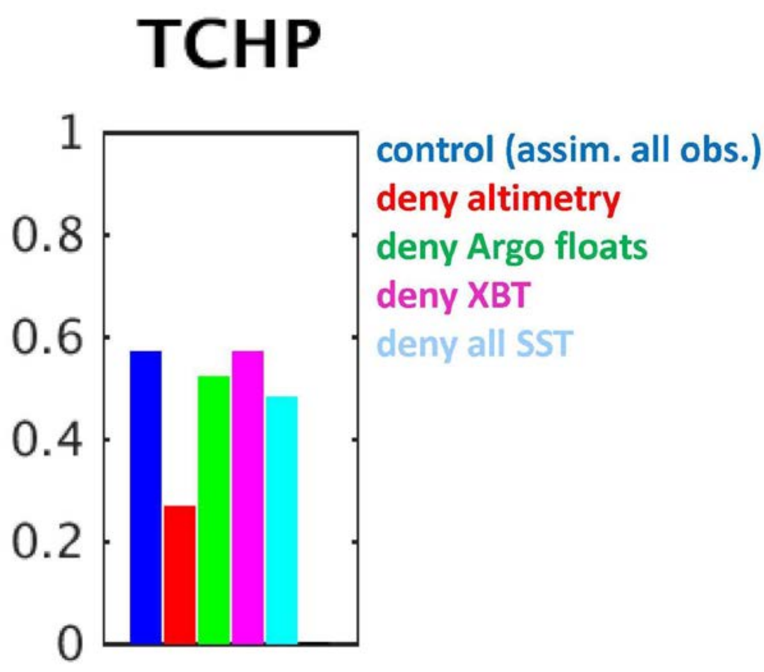


Figure 1: Brier skill score over the Atlantic Ocean hurricane domain (10ºN to 35ºN and east to 30ºW) measuring improvement over an unconstrained run of the OSSE system forecast model for several experiments listed in the legend during the 2014 hurricane season. The control experiment assimilates the existing ocean observing system while the other four experiments deny one component of this observing system. Reduction in skill score resulting from denial is a measure of the positive impact of that system.

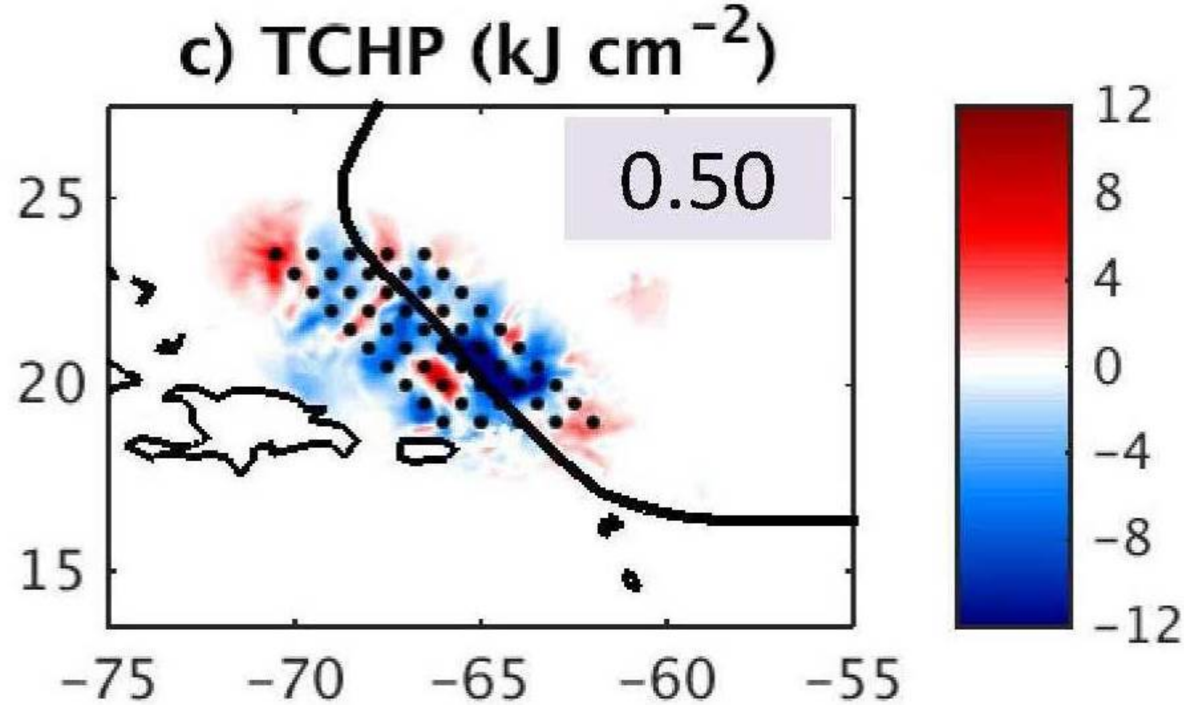


Figure 2: Summary of the impact of sampling synthetic ocean profiles of temperature and salinity ahead of Hurricane Gonzalo (track shown). Colors show the correction in TCHP resulting from a two-day synthetic AXCTD survey (surface to 1000 m) resulting from adding these profiles to the control experiment that assimilated the existing ocean observing system. Within the domain sampled by the synthetic profiles, the Brier skill score of 0.50 documents the positive impact of adding these synthetic profiles to the existing ocean observing system, which will reduce errors in the ocean model initialization of coupled hurricane prediction systems.

Research Performance Measure: We have met the fundamental objectives of this project during the previous year. The ocean OSSE system was successfully ported to and validated within the new Atlantic Ocean domain. OSSEs have been run to evaluate the impacts of several components of the operational ocean observing system toward reducing errors in ocean analysis products used to initialize the ocean component of coupled hurricane prediction systems. OSSEs have been run to evaluate different strategies of sea glider deployments during the 2014 hurricane to evaluate their impacts when added to the existing ocean observing system. OSSEs have been run to evaluate rapid-response instrument deployments ahead of storms, including WP-3D ocean profile surveys, to quantify further error reduction in ocean analysis products. Output from ocean OSE and OSSE experiments can now be used to initialize the HYCOM-HWRF coupled hurricane prediction system and is now being used to evaluate the impact of reducing ocean model initialization errors on coupled intensity forecasts. OSEs have been run to demonstrate that the operational ocean observing system exerts a significant influence on couple hurricane intensity forecasts of Hurricane Gonzalo (2014).

Coral Health and Monitoring Program (CHAMP)

Project Personnel: N. Amornthammarong, I.C. Enochs, R. van Hooidonk, P.R. Jones, X. Serrano, R. Carlton, M. Jankulak, G. Kolodziej and L. Valentino (UM/CIMAS); L.J. Gramer (UM/CIMAS, USF/FIO); K. Peebles (UM/RSMAS)

NOAA Collaborators: J. Hendee, D. Manzello, M. Shoemaker and J. Stamates (NOAA/AOML)

Other Collaborators: P. Fletcher (Florida Sea Grant); C. Hu and B. Barnes (USF); A. Soloviev (NSU)

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, 7) assess the synergistic effects of thermal stress and nutrient enrichment in the early life stages of two Caribbean coral species, and 8) apply ongoing research in shallow-ocean fluid dynamics to improved understanding and conservation of coral reef ecosystems.

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; and conduct controlled-laboratory experiments to assess the effects of climate change and land-based sources of pollution.

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

***Goal 1*:** Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems* (*Secondary*)

NOAA Funding Unit: OAR/AOML, NOS/CRCP, OAR/OAP
NOAA Technical Contact: Molly Baringer

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. In the past year, CHAMP's Coral Reef Early Warning System (CREWS) has continued its collaboration with the Caribbean Community Climate Change Centre (CCCCC) to deploy coral reef monitoring buoys and to collect, process, disseminate and archive their data. CIMAS personnel conducted a thorough analysis and reprogramming of a previously nonoperational buoy that is destined for deployment at Belize's Calabash Caye, and two new buoys were deployed off the north and south coasts of the Dominican Republic. Figure 1a shows the CWDR1 buoy being deployed at Catuan Wreck, near Boca Cheeca, D.R., and Figure 1b is a recent screencap of that buoy's data feed as accessed via the CHAMP Portal data query web site (http://www.coral.noaa.gov/champportal).

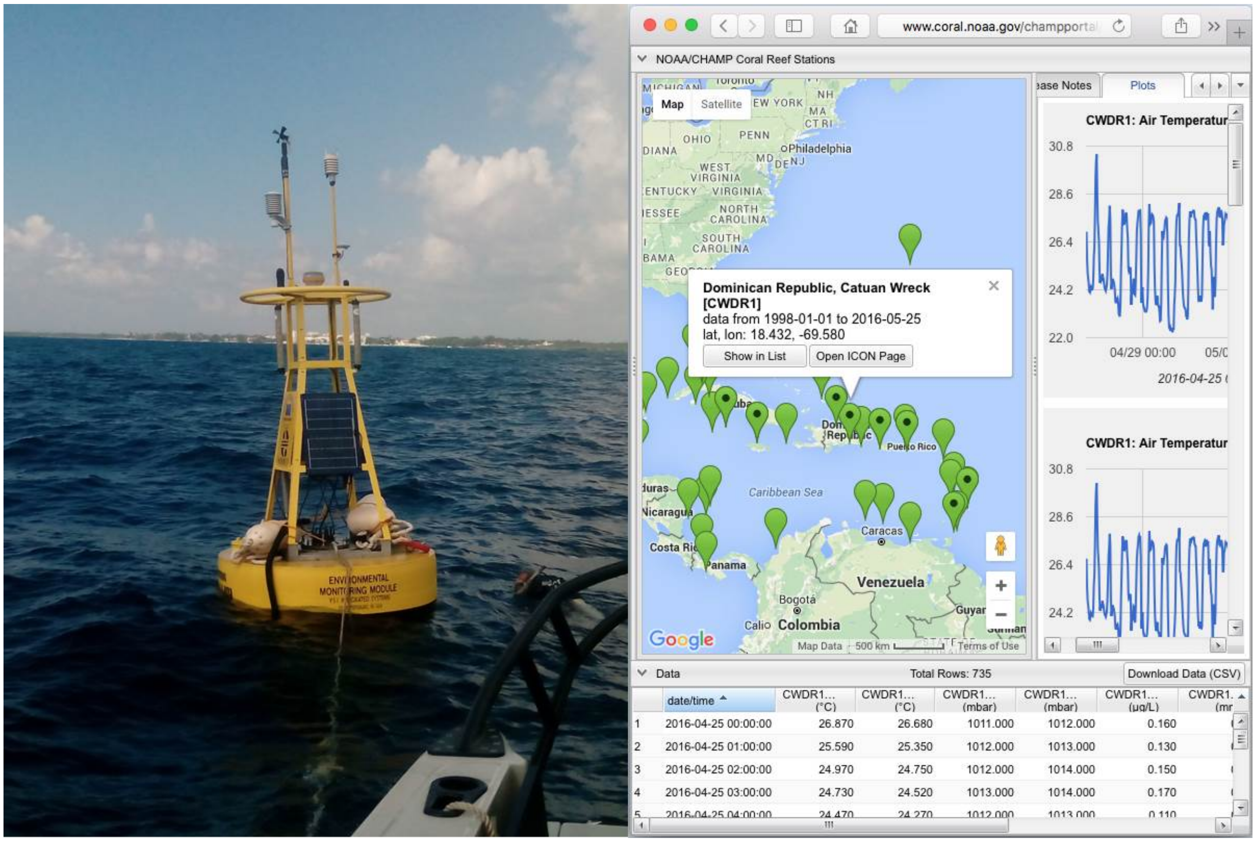


Figure 1: A) (left) shows the CWDR1 buoy being deployed at Catuan Wreck, near Boca Cheeca, D.R.; and B) (right) is a recent screencap of that buoy's data feed as accessed via the CHAMP Portal data query web site.

In addition to these new in situ data sources, this past year the CHAMP Portal also added a new source of remotely-sensed sea surface temperature (SST) data based on products produced by Remote Sensing Systems (www.remss.com). This newly-integrated SST data source allowed the CHAMP Portal to add 92 more 'virtual' stations, including several sites of interest in Cuban waters such as the Banco de San Antonio which serves as a sister sanctuary to NOAA's Flower Garden Banks and Florida Keys National Marine Sanctuary in the US.

The Acidification, Climate, and Coral Reef Ecosystems TEam (ACCRETE) lab is actively researching how climate change and ocean acidification will, and, already are, affecting the construction (coral growth, calcification) and breakdown (bioerosion, dissolution) of coral reef ecosystems, as well as the associated ramifications this has for ecosystem function (e.g., biodiversity). To this end, ACCRETE scientists utilize a unique interdisciplinary approach that incorporates aspects of biology, chemistry, and geology within an ecological framework. Through field, laboratory, and modeling studies, this laboratory is improving our understanding of the rate and magnitude of climate change and acidification on coral reefs, as well as the ecological impacts of these changes.

This year, ACCRETE/CIMAS personnel, Ian Enochs, Paul Jones, Renee Carlton, Graham Kolodziej, and Lauren Valentino continued implementation of the National Coral Reef Monitoring Plan (NCRMP), and climate/ocean acidification (OA) monitoring therein. NCRMP assets were deployed in the Flower Garden Banks and in the Dry Tortugas. These monitoring units included high-accuracy temperature loggers, as well as biodiversity, calcification, and bioerosion monitoring units. Bioerosion monitoring units constructed by CIMAS personnel were also deployed by collaborators in Panama as part of a collaboration with an NSF-funded study in the region.

ACCRETE'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). Ian Enochs, Paul Jones, Mike Jankulak, Renee Carlton, Lauren Valentino, and Graham Kolodziej continued support and monitoring activities at the AOAT. Activities included carbonate budget surveys, high-resolution photo-mosaics, fish surveys, quantification of coral growth using coral cores, monitoring coral symbiont communities, collection and processing of calibration/validation water samples, as well as electronics replacement and servicing of the MAPCO2 mooring.

ACCRETE personnel, along with collaborators from University of Miami, Mote Marine Laboratory, The Nature Conservancy, and NSU continued 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 was 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. This year, collaboration with NOAA PI Chris Kelble, and CIMAS scientist Lindsey Visser has led to periodic data collection throughout the Floriday Keys on board the RSMAS ship, the RV Walton Smith. This has provided valuable data and increased the spatial and temporal coverage of this project.

ACCRETE scientists completed coral reef monitoring associated with the Numeric Nutrient Criteria (NNC) study, involving monitoring three replicate reef sites at each of four reefs. Reef biometric data was generated using the EPA Stony Coral Rapid Bioassessment Protocol and the Periphyton Rapid Bioassessment Protocol to assess nuisance algal growth. Benthic surveys provide information on coral abundance and health using SCUBA-based in-situ measurements, as well as seasonal fluctuations in total benthic organismal abundance by analysis of photo-quadrats. The water sampling of the study is providing accurate measurements of nutrient levels (total Nitrogen and Phosphorous), phytoplankton abundance (chlorophyll-*a*) and other parameters (turbidity, temperature, salinity etc.), which will be used in conjunction with this data to assess nutrient criteria for reef development.

CIMAS researcher Xaymara Serrano, in collaboration with NOAA/NMFS scientist Margaret Miller and RSMAS professor Andrew Baker, completed a series of laboratory-controlled experiments with larvae and newly-settled coral recruits from the species *Porites astreoides* and *Orbicella faveolata*, with the goal of investigating the effects of nutrient enrichment and elevated sea surface temperatures on the early life stages of these two species. Effects in symbiont community (identity and abundance), larval oxygen

consumption, proportion settlement and larval survival of these two species were measured (Figure 2). A manuscript is currently being written summarizing the main findings from this study. Overall, results are expected to provide empirical evidence that might support the implementation of environmental policies aimed at improving water quality and maximizing reef resilience. Furthermore, because this research was undertaken using a species just listed as threatened under the ESA (*O. faveolata*), results are timely and relevant for the conservation and protection of this species.

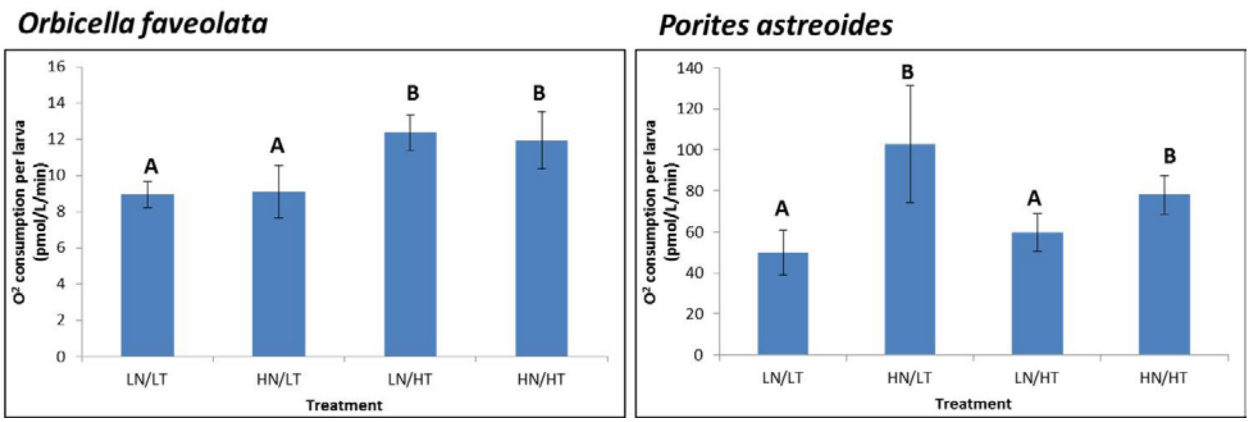


Figure 2: Respiration rates measured in *Orbicella faveolata* (left panel) and *Porites astreoides* (right panel) coral larvae after exposure to one of four experimental treatments: 27°C / 0.4 µM $NaNO_3$ (low nitrate and low temperature, denoted as LN/LT), 27°C / 14 µM $NaNO_3$ (high nitrate and low temperature, denoted as HN/LT), 31.5°C / 0.4 µM $NaNO_3$ (low nitrate and high temperature, denoted as LN/HT), and 31.5°C/ 14 µM $NaNO_3$ (high nitrate and high temperature, denoted as HN/HT). Different letters indicate significant differences among treatments.

Serrano also collaborated with scientists from the Department of Environment in the Cayman Islands and RSMAS professor Andrew Baker to investigate the genetic connectivity of corals between the Cayman Islands and among depths (shallow vs. deep) at each island. The two target coral species in this project were the broadcaster spawner *Montastraea cavernosa* and the brooding coral *Porites astreoides*. Data from this project is currently being analyzed to include in a manuscript. Overall, findings will help collaborators ensure that Marine Protected Areas in the Cayman Islands adequately protect important sources of larval recruits, maximize reef recovery, and prevent further habitat loss and degradation.

Local-scale projections of coral reef futures and implications of the Paris Agreement.
In the past Ruben van Hooidonk produced climate model-resolution (~1x1°) projections of the timing of annual severe bleaching (ASB) under the Representative Concentration Pathway emissions scenarios for all coral reefs in 2013 and 2014. These projections have informed global policy (they are cited in IPCC AR5) but are too coarse to inform conservation planning. To meet the need for higher-resolution projections, van Hooidonk generated statistically downscaled projections (4-km resolution) for all coral reefs. This research highlights the spatial patterns of these projections and evaluates the implications of the COP21 Paris Agreement for the projected timing of the onset of ASB; a point at which reefs are certain to change and recovery will be limited. These downscaled projections reveal high local-scale variation in ASB under RCP8.5 (a ‘no climate policy’ scenario). Timing of ASB varies >10 years in 71 of the 87 countries and territories with $\geq$500km^2 of reef area and some countries have far more relative ‘climate winners’ than other countries (Figure 3). These results indicate the projections warrant consideration in conservation and management planning at all spatial scales. Emissions scenario RCP4.5 represents lower emissions mid-century than will eventuate if pledges made following the 2015 Paris Climate Change Conference (COP21) become reality. RCP4.5 adds ~15 years on average before ASB occurs when compared to RCP8.5; however, >75% of reefs still experience ASB before 2070 under

RCP4.5. Much greater emissions reductions are required than were pledged following COP21 to prevent the great majority of coral reefs from experiencing severe bleaching conditions annually this century.

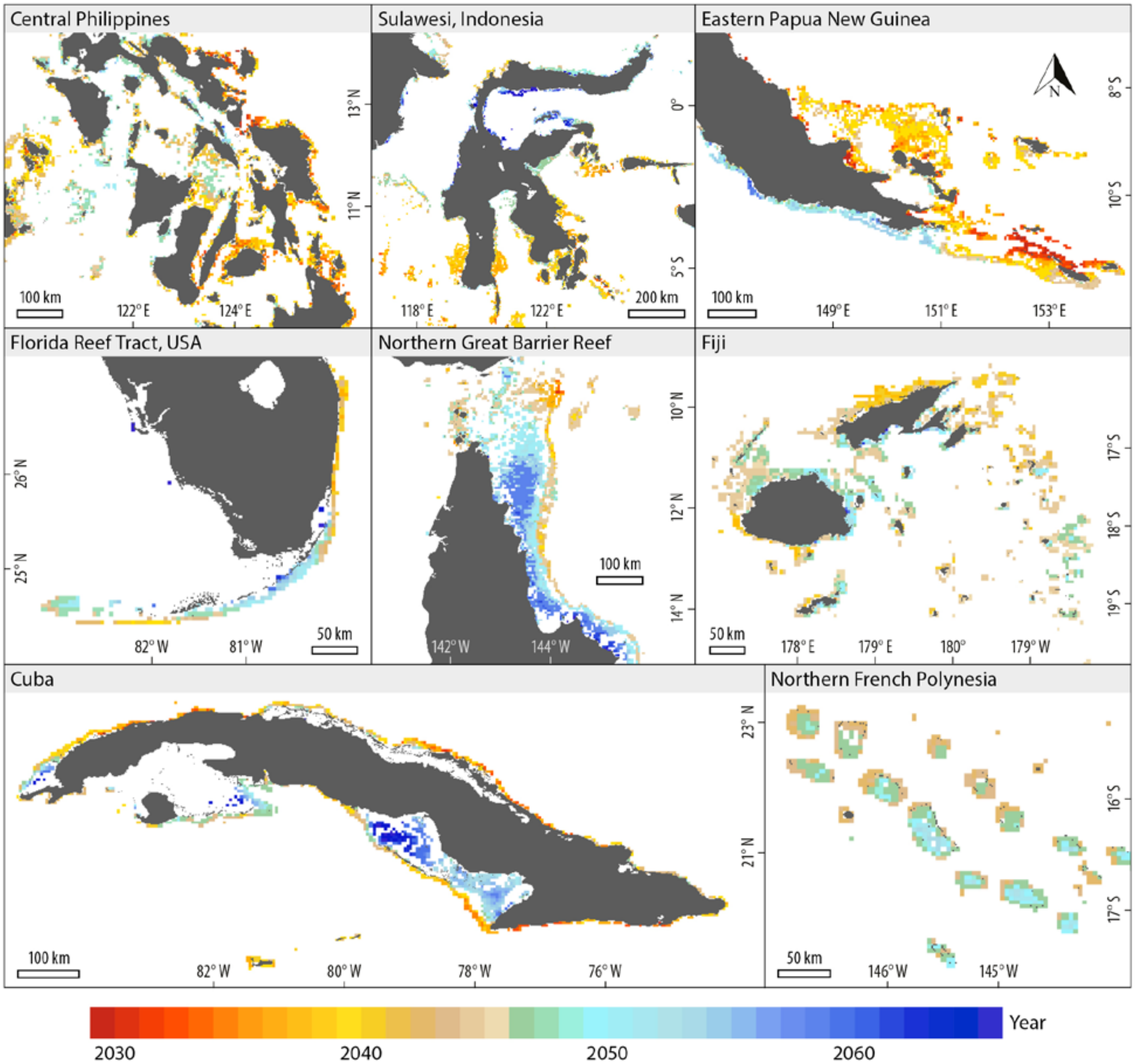


Figure 3: Statistically downscaled projections of the timing of the onset of annual severe bleaching (ASB) conditions under RCP8.5. These exemplify the high local-scale (10's of km) variation seen in projected ASB timing in most locations and, though atypical, the low variation seen in Northern French Polynesia.

This is a novel effort; these are the only downscaled projections produced to date for a marine ecosystem with a global distribution. The results will be shared as easy to use Google Earth files on NOAA's Coral Reef Watch website (http://coralreefwatch.noaa.gov/satellite/research/index.php) and the United Nations Environment Programme Live website (http://uneplive.unep.org/).

Since 2013, CIMAS researcher Lew Gramer has collaborated with Prof. Chuanmin Hu and Brian Barnes (University of South Florida) on final products from a NOAA CRCP-funded three-year project to monitor turbidity over shallow reef waters in southeast Florida, American Samoa, and the Commonwealth of the Northern Mariana Islands (CNMI). These partners developed an algorithm to produce a proxy (Color Index or "CI") for "relative" in-water turbidity within shallow (<= 5 m) generally clear waters, using

ocean color data from the MODIS and VIIRS instruments aboard polar-orbiting satellites. The algorithm was applied to twelve years of daily satellite overpasses in these three regions of particular interest for U.S. coral reef conservation. In prior years, customized ocean color data products were generated and analyzed for each of these three regions. These data are generated at 250m spatial resolution, with forward processing occurring in near-real time. This processing methodology has been applied to the entire MODIS Aqua dataset (2002 – present) for these regions in order to generate long-term time series of derived products. From this dataset, time series at individual locations were previously extracted, with the goal of identifying locations for sensor deployment with maximal quantity and quality of concurrent satellite data. These satellite ocean color products were analyzed to understand the impact of the port of Miami dredging on turbidity plumes, and their impact on coral reefs. A paper was submitted by USF partners to the journal Remote Sensing of Environment. In 2015-2016, Gramer processed and analyzed high-resolution wave model products for the three regions, and found linear relationships between relative turbidity and wave action seasonally in southeast Florida and a portion of the coastline of the major island of American Samoa, Tutuila. Wave action did not explain significant events of relative turbidity at multiple sites within these two regions, nor was such a relationship apparent for any pixels analyzed within the CNMI (Figure 4). This together with the spatial placement of periodic events within each coastal region suggest that the satellite products do in fact allow frequent monitoring of in-water turbidity over these three disparate shallow coral reef systems.

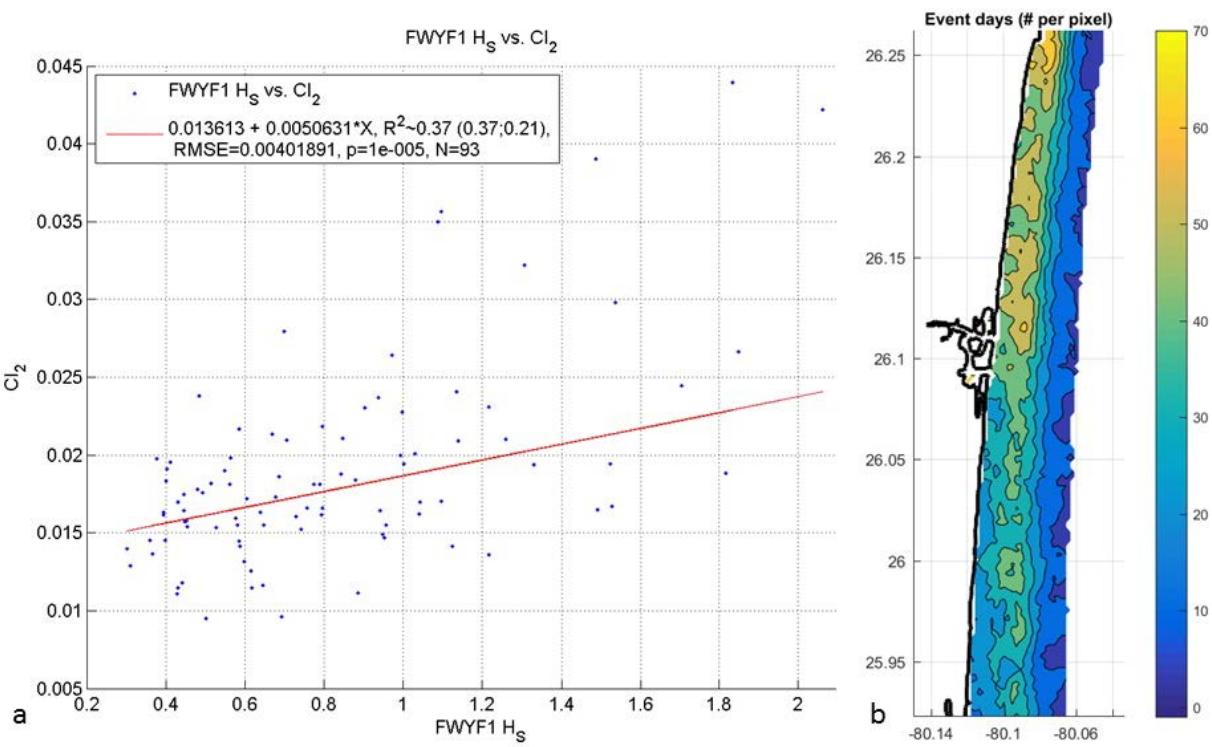


Figure 4: (a) Regression plot show robust linear relationship between Color Index (CI) at a pixel near Port of Miami and significant wave height (Hs) from the operational NOAA WaveWatch III model for the site. (b) Map showing incidence on southeast Florida shelf, of anomalously high relative turbidity (>93rd percentile CI pixel values) coincident with median or lower wave heights. Presence of anomalous, non-wave-related turbidity north of the Port Everglades channel suggests that sediments suspended in the water during Port dredging were advected northward on multiple occasions, and may have remained near the coast for 20 km or more as they moved.

Gramer also continued collaborations with Profs. Brian Walker and Alexander Soloviev (Nova Southeastern University), and Luke McEachron (Florida Fish and Wildlife Commission) to gather and analyze oceanographic data on upwelling in southeast Florida; the goal of this collaboration is to characterize the role of upwelling in the nutrient mass budget of the northern Florida reef tract. Approximately fourteen (14) years of acoustic Doppler current profiler (ADCP) ocean current profiles, and sea temperature data at multiple sites, were analyzed for the region, with continuous data covering all hurricanes and tropical storms that passed south Florida during the period. Analyses of summer periods between storms in prior years shows that upwelling driven by mechanisms other than wind consistently delivers cool water masses onto the shallow shelf of southeast Florida during each summer; temperature observations at multiple sites from Miami-Dade to Martin Counties confirm that such rapid cooling events occur along the entire approximately 100 km of the northern reef tract each summer. Gramer analyzed data from cross-shore profiling sections of SE Florida shelf at depths from 20 to 360 m, covering the entire seasonal cycle, in cruises between 2006 and 2014. He found consistent linear relationships between temperature (T) below 24C and each of the three macronutrients, nitrogen, phosphorous, and silicates (Figure 5). Zero-intercept in all cases was between 24 and 25C, slope of robust regressions (R-squared of 0.7 or greater, $p<0.001$) was approximately -0.8 to -1.5 micromole / K for NOx and Si, and -0.06 to -0.09 for P (consistent with the Redfield ratio). No such relationship could be observed for ammonia or nitrite. Sea temperature and currents data from the array of moorings at depths of 11 to 140 m in the central SE Florida shelf over two years, and thirteen years of such data from the mooring at 11 m, showed episodic upwelling of water at initial temperatures less than 24C each summer analyzed, and currents data show that this cooler, nutrient-rich water reaches the 11 m isobath at final temperatures ranging from 21 to 27C, multiple times during two successive summers. The signature of these upwelling events was then observed at 11 m during each of the other ten complete summer records available. Gramer also analyzed four years of sea temperature from partner moorings throughout the SE Florida shelf – from coastal waters of Miami-Dade north through Martin Counties, at a range of depths from 4 to 30 m. These data show cool temperature pulses (below 23 to as low as 10C) throughout the region during summer that cannot be explained by air-sea processes –indicative of upwelling events like those observed at the ocean current moorings in the central SE Florida shelf. These events are most intense and obvious in temperature records from the northern portion of SE Florida shelf (Palm Beach and Martin Counties), but are observed throughout the region every summer. Overall, this project has demonstrated that oceanic upwelling significantly cools the summer waters of SE Florida shelf every year, and appears to contribute of order 1000-3000 kg/m^3/year to total nitrogen and total silicates, 60-180 kg/m^3/year to total phosphorous. Distributed across the length of the SE Florida shelf, total volume of upwelled water at the 30 m isobath is of order 1 million m^3/year.

The timing of southeast Florida upwelling events, outside of those associated with tropical cyclones, is generally not consistent with wind forcing (coastal Ekman flux divergence). Timing of events appears to be dependent on near-surface stratification, consistent with observations that these events do not occur during months when near-surface vertical-ocean mixing is most energetic, generally December, January, February, or March. Coincidence of events with periods of enhanced summer stratification in the shelf water column is in fact consistent with their being related to the breaking on the sloping shelf topography, of either internal waves or of isotherms of the Florida Current. Frequency of summer upwelling appears to be similar everywhere. Intensity of upwelling, i.e., magnitude of cooling and nutrient influx, is dependent on local water depth and on geographic location: The higher end of the nutrient concentration ranges described above tends to be observed at the outermost reef line, and in the northernmost third of the SE Florida shelf; however, the lower end of these ranges encompasses the entire SE Florida shelf north of Biscayne Bay, to water depths as shallow as 5 m. This is a significant contribution to knowledge of the coastal environment in Florida, and will directly inform decisions related to the management of the reefs and potentially competing human uses in this region.

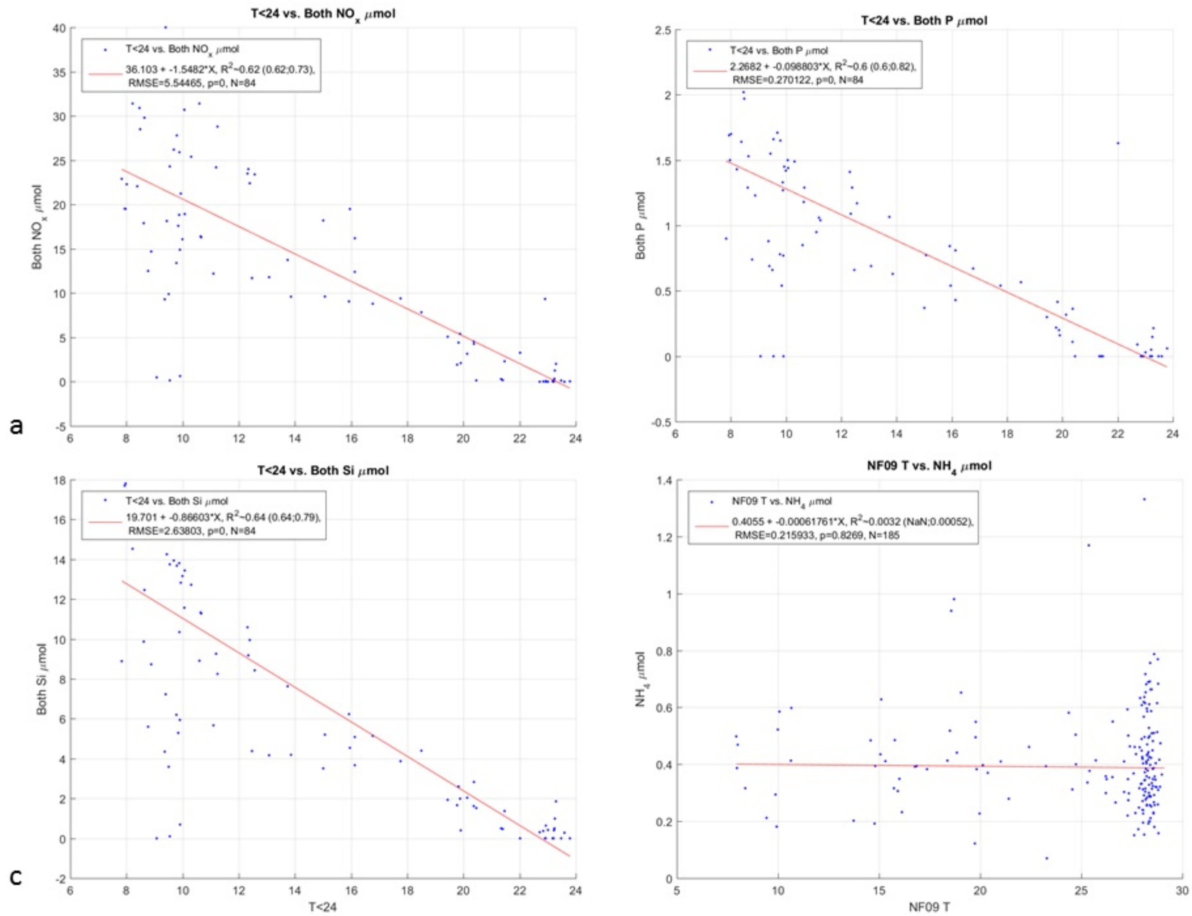


Figure 5: Scatter plots showing robust linear relationships between sea temperature below 24ºC and respectively, (a) nitrogen (NO_3^-), (b) phosphorous, and (c) silicates on the southeast Florida shelf. For comparison, (d) ammonia (NH_4) shows no relationship to sea temperature. Data gathered by cruises of the NOAA Florida Area Coastal Environment program, analyzed for the Gramer et al. upwelling study.

CIMAS scientist Dr. Natchanon Amornthammarong is developing novel instrumentation for in situ measurement of ocean properties: sea temperature, and dissolved nutrients in the nanomolar concentrations prevalent on coral reefs. For nutrients, Dr. Amornthammarong has developed a novel technology called the Autonomous Batch Analyzer (ABA). In situ sensors for ammonia measurement in natural waters have been built and field-tested using the ABA method. With its simple design, the system is robust, flexible, inexpensive, and requires minimal maintenance. Instrument packages are compact and have low power consumption (less than 7.5 W), allowing them to be moored at depth on reefs or other generally oligotrophic coastal habitats, for periods of one month or longer. Packages can thus log nutrient concentrations, together with other standard variables (temperature, salinity, dissolved oxygen) at high frequency, up to four times per hour; sampling may also be programmed in response to detection of other environmental triggers, e.g., sea temperature or salinity change. This can allow research and management partners to document episodic or high-frequency fluxes to reef environments in situ, from both natural processes (diurnal and monthly tide cycles, upwelling, sediment resuspension, ground-water discharge) and anthropogenic sources - even at low concentrations that may be associated with non-local or far-field sources. The limit of detection is of order 10 nanomole (nM) for ammonia, with reproducibility 0.6% (n=10) at an ammonium level of 200 nM. In addition, the system produces a calibration curve by autodilution from a single stock standard solution with the same accuracy as traditional manual calibration methods. Representative field data and comparisons with standard EPA methods confirm the

utility of the ABA for ammonia measurement. Instruments use low-cost components, allowing multiple packages to be built for projects that require resolving spatial as well as high-frequency temporal variability. Nitrate/nitrite and phosphate sensors are also under development based on the ABA method, and are expected to offer similarly low detection limits and high reproducibility for autonomous underwater deployments.

Dr. Amornthammarong is collaborating with Dr. Gramer on upwelling. It is considered critical to quantify uncertainty in the contribution of upwelling to nutrient dynamics on the southeast Florida shelf (see paragraphs above). Because of the episodic nature of upwelling on the shelf, directed boat observations of nutrient concentrations during multiple periods of upwelling during this project proved to be too logistically challenging. New technology developed at NOAA-OAR-AOML is being adapted to observe nanomolar in situ near-bottom nutrient concentrations at hourly frequency for deployments of one month or more at a time: this research has resulted in a viable sensor for the most volatile of the forms of available nitrogen, ammonia. Development and testing are ongoing to enable both nitrate and nitrite to be observed in this manner. This work is expected to result in deployment of sensors to simultaneously measure nitrate, nitrite, and ammonia during the upwelling season of 2016. Analysis of ocean currents and sea temperature data is also ongoing to distinguish upwelling mechanism between breaking of internal waves vs. onshore movement of Florida Current eddies and meanders; it will be important to distinguish between these two mechanisms, to make it possible to predict the potential impact of climate change scenarios on frequency and intensity of upwelling in this area.

Research Performance Measure: The CHAMP project addressed and met the defined objectives during 2015-2016 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. 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.

The North American Multi-Model Ensemble (NMME) Phase-2: Deployment, Operation and Seasonal Prediction Science

Project Personnel: B.P. Kirtman (UM/RSMAS/CIMAS)
NOAA Collaborators: H. van den Dool (NOAA/CPC); J, Huang (NOAA/CPO)
Other Collaborators: B, Denis (Environment Canada); W. Anderson (GFDL); J. Tribbia (NCAR); S. Pawson (NASA/GSFC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To deploy the NMME-Phase II Seasonal System into NCEP operations and of establishing the terms of operation following deployment to satisfy both service and research purposes for the operational phase.

***Strategy*:** To continue producing real-time CCSM4 forecasts on time all the time, lead the overall NMME science team in collaborative research and the investigate the skill and predictability of the NMME system with particular focus on CCSM4.

CIMAS Research Theme:

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

Link to NOAA Strategic Goals:

***Goal 3*:** Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts*

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

Research Summary:

The research is a continuation an existing National Multi-Model Ensemble (NMME) team producing operational seasonal to interannual (ISI) predictions. The project includes both basic and applied prediction research, and the production of real-time, on-time all the time operational prediction with CCSM4.

a) NMME Operational Activities

- NMME Partnership Agreement signed by all parties (May 2016).
- NMME team continues to meet monthly via telecom to address all science and data production issues
- CESM retrospective forecasts have been completed and evaluated and the system is being considered for the operational production suite
- All forecast providers (RSMAS/COLA/NCAR, GFDL, CMC, NASA) continue to submit real-time predictions on time all the time.
- IRI continues to upload and serve all real-time and retrospective data
- CPC continues to ingest data, produce graphical images of forecasts and skill assessments including probabilistic measures. CPC also developing evaluation of skill of real-time forecast.
- New monthly mean data are now routinely being provided to CPC: Winds for hurricane seasonal outlook, and sea-ice extent and thickness for skill assessment
- Phase-II high frequency and additional fields continue to accumulate at the NCAR data server (see table 1 for details).

TABLE 1: NMME Phase-II data published as of March 9, 2016.

NMME Phase-II Data Archive Overview: Mar 9, 2016

Archive Data by Variable and Model

	CCSM4		CESM1	CFSV2		CanCM3	CanCM4	FLORB	GEOS5
Variable	Daily	3hr	Daily	Daily	6hr	Daily	Daily	Daily	Daily
TAS	⦸	✔	EX	P	✔	✔	✔	✔	✔
TA	✔	⦸	EX	P	✔	✔	✔	⦸	✔
TASMIN	✔	⦸	EX	P	✔	✔	✔	✔	✔
TASMAX	✔	⦸	EX	P	✔	✔	✔	✔	✔
PR	⦸	✔	EX	EX	✔	✔	✔	✔	✔
PSL	✔	⦸	EX	EX	✔	✔	✔	⦸	✔
UA	✔	✔	EX	EX	✔	✔	✔	⦸	✔
VA	✔	✔	EX	EX	✔	✔	✔	⦸	✔
G	✔	⦸	EX	EX	✔	✔	✔	⦸	✔

✔ Complete
EX Expected (not yet published)
P In Progress
⦸ Not Expected

- CFSV2 daily complete Apr 30, 2016
- CESM1 daily complete May 31, 2016

b) Prediction and Predictability of Land and Atmosphere Initialized CCSM4 Climate Forecasts over North America

To understand the contribution of land and atmosphere initialization to seasonal forecasts we consider the atmospheric component of CCSM4 coupled to the land component (CAM4-CLM4) with prescribed data ocean/ice.

We compare 2 experiments, as follows:

1. No-Init: 30-year simulation where monthly climatological SST and sea ice coverage from observational estimates are prescribed.
2. LA-Init: Initialized hindcasts (1982-2009; 10-member ensembles) using observed atmospheric and land states (initialization strategy discussed below). Prescribed climatological SST and sea-ice as above.

Though we refer to experiment 2 as a "hindcast" as it uses initial data identical to fully coupled CCSM4 hindcasts, SST and sea ice are prescribed from 1982-2001 climatology using Hadley Centre Global Sea Ice and Sea Surface Temperature (HadISST) data. Thus, this experiment emphasizes atmosphere and land initialization in the absence of SST or sea-ice anomalies.

Our analysis (see Fig. 1) highlights the influence of land and atmosphere initialization on monthly deterministic prediction skill and predictability, isolating this influence from SSTA constructive or destructive interference by prescribing climatological SSTs. On monthly time-scales, there is a significant increase in precipitation skill over North America at lead 0 mainly due to atmospheric initialization (larger prediction skill is found in the first two weeks after initialization, not shown). 2-meter temperature monthly prediction skill is similarly increased at lead 0, with positive influence of land surface initialization on skill in the remaining 2 months in summer. These results are discussed in detail in Infanti and Kirtman (2016), and are part of Infanti's Ph. D. (May 2016).

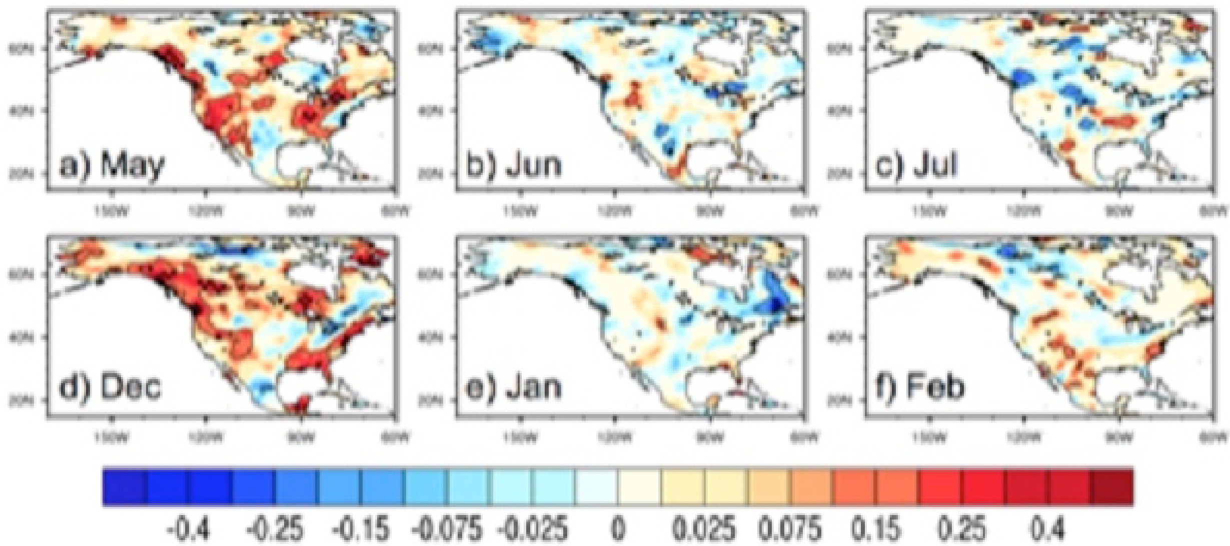


Figure 1: Difference in anomaly correlations for precipitation (anomaly correlation for LA-Init minus NoInit). Stippling (contours) indicate significance of difference at 99% (95%) confidence level based on Monte Carlo estimation of significance. (a) – (c) May initialized hindcasts verifying in May, Jun, Jul (or NoInit verifying in May, Jun, Jul). (d) – (e) Dec initialized hindcasts verifying in Dec, Jan, Feb (or NoInit verifying in Dec, Jan, Feb).

c. An alternate approach to ensemble ENSO forecast spread: Application to the 2014 forecast

Many dynamical forecast models predicted a 2014 El Niño event. Yet despite the moderate sea surface temperature (SST) warming that was observed, the 2014 forecast is often described as a "busted" forecast. The question that arises is of practical importance—was 2014 actually a bust or is the usual method of calculating ensemble spread (defined below) underestimating forecast uncertainty and by extension, affecting the retrospective evaluation of El Niño–Southern Oscillation (ENSO) predictions?

For example, Figs. 2c and 2d show the CCSM4 March initialized Niño-3.4 anomaly forecasts with 10 ensemble members (gold), ensemble mean (black solid), forecast spread (grey polygon), and the observed Niño-3.4 index from the National Center for Environmental Prediction Climate Prediction Center (CPC; black dashed). To be clear, "forecast spread" is computed from the actual CCSM4 initialized forecasts, whereas "expected spread" is the proposed supplemental spread discussed below. The 2015 observed Niño-3.4 evolution falls within the forecast spread is on track to verify, albeit the final amplitude may vary from that predicted by this particular model (2.33°C in December). On the other hand, observed 2014 Niño-3.4 sits well below the forecast spread and verifies at 0.78°C as compared to the ensemble

mean forecast of 1.67°C. So was 2014 a “bust” or does 0.78°C fall within the expected spread generated via noise-driven processes in CCSM4, despite the December forecast spread spanning only 1.16–2.17°C?

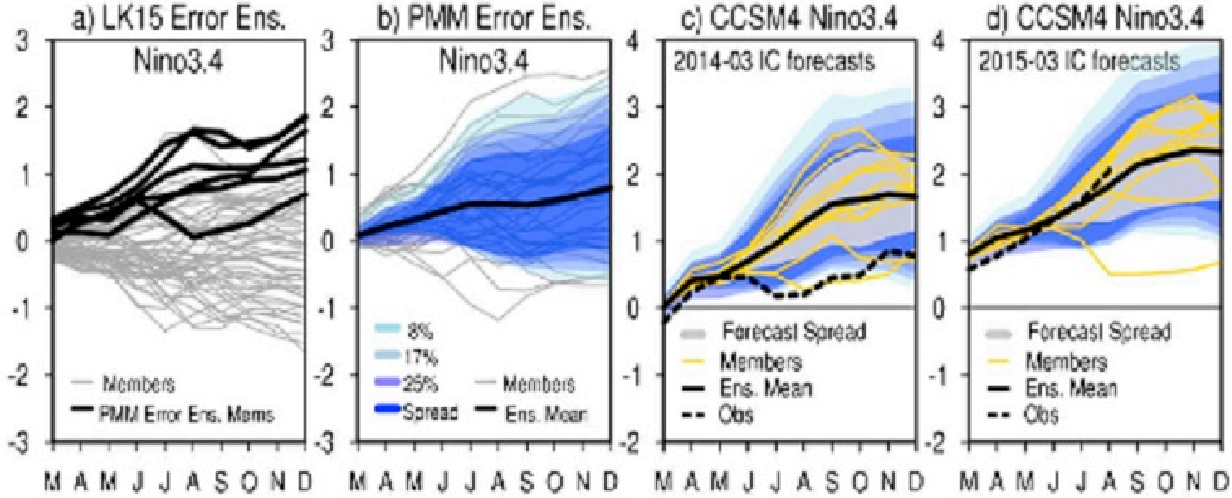


Figure 2: (a) Niño-3.4 SST error swath for the March error growth ensemble in Larson and Kirtman [2015]. Black bold curves indicate the six members whose ocean initial conditions are used in the PMM error ensemble. (b) Niño-3.4 error swath, ensemble mean, spread, and uncertainty thresholds for the PMM error ensemble. Uncertainty thresholds are calculated by averaging the most extreme three, six, and nine warm or cold members corresponding to 8%, 17%, and 25%, respectively. (c) 2014 CCSM4 March initialized Niño-3.4 forecasts from the NMME, forecast spread (grey polygon), ensemble mean (black solid), observations (black dashed), and expected spread and uncertainty thresholds from Figure 1b. (d) Same as Figure 1c but for the 2015 forecasts.

The present study expands on the Larson and Kirtman (2015, J. Climate; LK15) experimental design to produce an expected noise-driven spread for the March initialized 2014 and 2015 CCSM4 NMME predictions of December Niño-3.4. The initial conditions of both forecasts contain Pacific Meridional Mode (PMM) SST signatures and predict December El Niño. A PMM error growth ensemble is constructed from six ensemble members that originally bias warm in the LK15 March error ensemble, each also having PMM-like errors in the initial conditions. The constructed ensemble is essentially a sensitivity test, pairing each base ocean with six different atmospheric noise initial conditions.

We are not suggesting that a new error ensemble must be constructed for each actual forecast but merely demonstrating that the expected spread from initial SST errors with similar structures as the March 2014 and 2015 initial conditions used in the real-time CCSM4 NMME forecasts is large for longer lead times. In fact, the spread in the PMM error ensemble (Figure 2b) is similar to that in the original LK15 March error ensemble (Figure 2a), suggesting that the expected spread is similar for differently constructed noise-driven error ensembles, as long as the initial conditions are ENSO-independent. Thus, the spread of the LK15 ensembles suffice as a benchmark for expected spread from noise-driven processes alone in CCSM4. In this case, more information is gained by using ocean base members with PMM-like initial errors, including that the presence of PMM-like perturbations in March can increase the probability that El Niño will occur (i.e., the warm bias), but does not guarantee it due to the large sensitivity of the coupled system to perturbations in March (i.e., large expected spread).

These results are discussed in detail in Larson and Kirtman (2015), and are part of Larson’s Ph. D. (May 2016).

Research Performance Measure: The CCSM4 forecast produced and delivered to CPO on time all the time. Published paper on seasonal predictability.

Predicting the Potential Impact of Climate Change on the Intra-Americas Sea Under IPCC Climate Change Scenarios

Project Personnel: Y. Liu and R. Domingues (UM/CIMAS)

NOAA Collaborators: S.-K. Lee and G.J. Goni, (NOAA/AOML); J.T. Lamkin, W. Ingram and M. Schirripa (NOAA/SEFSC)

Other Collaborators: B.A. Muhling (Princeton U); 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 Impact (*Primary*)

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

Link to NOAA Strategic Science Goals:

***Goal 3*:** Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts* (*Primary*)

***Goal 1*:** 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 - 27ºC. 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).

In this project, we examine the potential impact of anthropogenic greenhouse warming on the Intra-Americas Sea (IAS, Caribbean Sea and Gulf of Mexico) by downscaling the Coupled Model Intercomparison Project phase-5 (CMIP5) model simulations under historical and two future emission scenarios using an eddy-resolving resolution regional ocean model (Liu et al. 2015; 2016). The simulated volume transport by the western boundary current system in the IAS, including the Caribbean Current, Yucatan Current and LC, is reduced by 20-25% during the 21st century, consistent with a similar rate of reduction in the Atlantic Meridional Overturning Circulation (AMOC). The effect of the LC in the present climate is to warm the Gulf of Mexico (GoM). Therefore, the reduced LC and the associated weakening of the warm transient LC eddies have a cooling impact in the GoM (Fig. 1), particularly during boreal spring in the northern deep basin, in agreement with an earlier dynamic downscaling study. In contrast to the reduced warming in the northern deep GoM, the downscaled model predicts an intense warming in the shallow (≤ 200 m) northeastern shelf of the GoM especially during boreal summer (Fig. 1) since there is no effective mechanism to dissipate the increased surface heating. This warming trend may increase the chance for hurricane intensification during landfall in the northern and eastern Gulf, and may also expose the animals and other organisms living in the GoM to increasing frequency of thermal stress. This work

also explores the effects of 20th century warming and climate variability in the IAS using the regional ocean model forced with observed surface flux fields. The main modes of sea surface temperature variability in the IAS are linked to the Atlantic Multidecadal Oscillation and a meridional dipole pattern between the GoM and Caribbean Sea. It is also shown that variability of the IAS western boundary current system in the 20th century is largely driven by wind stress curl in the Sverdrup interior and the AMOC.

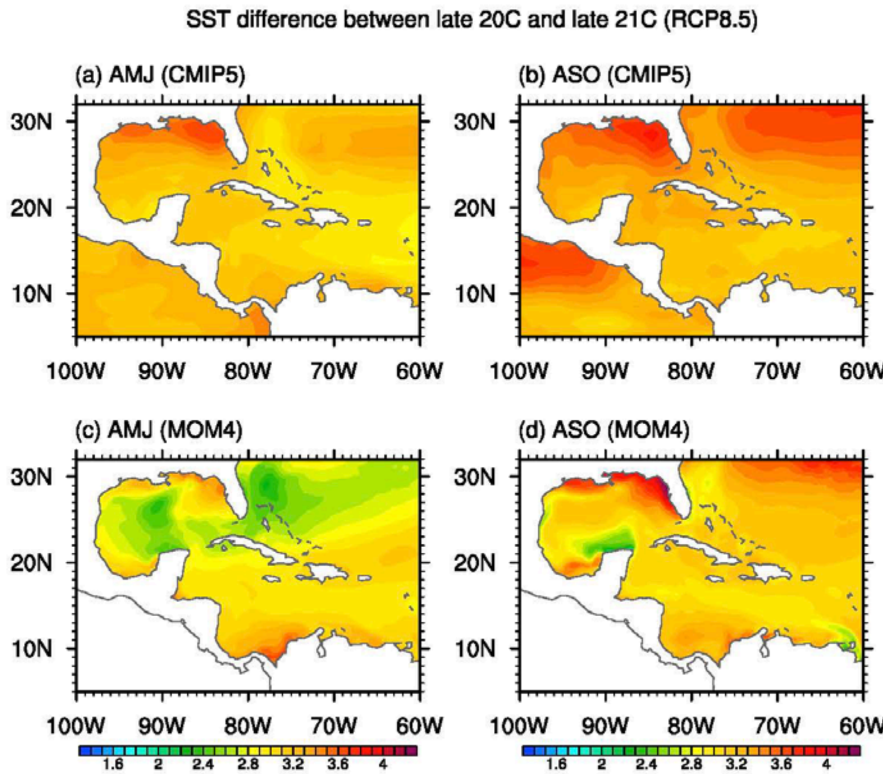


Figure 1: SST difference in the IAS between the late 21st century (2090 ~ 2098) and late 20th century (1990 ~ 1998) for (a) the boreal spring months of AMJ and (b) the boreal summer months of ASO obtained from the weighted ensemble of 18 CMIP5 models simulations under the historical and RCP8.5 scenario, (c) and (d) are same as (a) and (b), except that the SST differences are obtained from the high-resolution MOM4 experiment (EXP_HIS and EXP_8.5). The unit for the temperature is °C.

The increasing water temperatures due to climate change will likely have significant impacts on distributions and life histories of Atlantic tunas. In this project, we combined predictive habitat models with a downscaled climate model to examine potential impacts on adults and larvae of Atlantic BFT and skipjack tuna (*Katsuwonus pelamis*) in the IAS (Muhling et al., 2015). An additional downscaled model covering the 20th century was used to compare habitat fluctuations from natural variability to predicted future changes under two climate change scenarios: Representative Concentration Pathway (RCP) 4.5 (medium-low) and RCP 8.5 (high). Results forecast marked habitat losses for both adult and larval bluefin tuna on their northern Gulf of Mexico spawning grounds during this century because of intense warming (Fig. 2). In contrast, the projected habitat suitability for skipjack tuna increased as temperatures warmed (Fig.2). Impacts of climate change on pelagic habitats of several other Atlantic tuna and billfish species are also being evaluated as part of this project.

Another paper entitled “Variability of preferred environmental conditions for Atlantic bluefin tuna (*Thunnus thynnus*) larvae in the Gulf of Mexico during 1993-2011” by Domingues et al (2016) is published at Fisheries Oceanography. In this study, information reported by previous studies about the preferred environmental conditions for the occurrence of BFT larvae in the GoM were integrated into a dimensionless index, the BFT_Index (Fig. 3). This index was used to evaluate the spatial and temporal variability of areas with favorable environmental conditions for larvae within the GoM during 1993-2011. The main findings of this study were that: (1) the proposed index successfully captured the spatial and temporal variability in the in situ occurrence of bluefin tuna larvae; (2) areas with favorable environmental conditions for larvae in the GoM exhibited year-to-year spatial and temporal variability linked with mesoscale ocean features and sea surface temperature; (3) comparison of the BFT_Index-derived variability with recruitment of age-0 fish estimated from recent stock assessment indicated that

changes in environmental conditions may be linked with a relevant component (~58%) of the recruitment variability. The comparison with the recruitment dataset further revealed the existence of key regions linked with recruitment in the central/northern GoM, and that the LC may function as a trap for larvae, possibly leading to low survival rates. Above (below) average conditions for occurrence of larvae in the GoM during spring were observed in 2000, 2001, 2002, 2006-2008, and 2011 (1994, 1996, 1998, 1999, 2003, and 2010). Results reported by this study have potential applications to assessment of BFT.

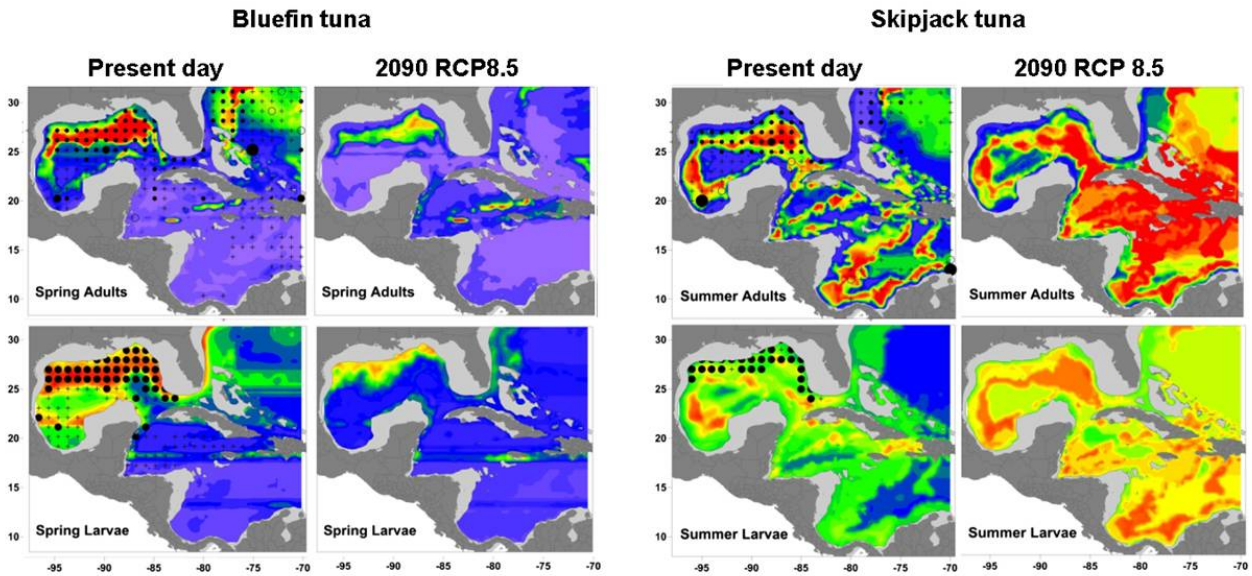


Figure 2: (a) Kriged predicted probabilities of occurrence for adult (1990 – 2009) and larval (2000 – 2013) BFT during spring (contours). (b) Kriged predicted probabilities of occurrence for adult (1990 – 2009) and larval (2000 – 2013) skipjack during summer (contours). Results are shown for the 2000s, and for 2090 under RCP 8.5. Observed data from the ICCAT Task II database (adults) and SEAMAP plankton surveys (larvae) are also shown for the same time period. Locations where adults were recorded, but effort was low, are shown as open circles.

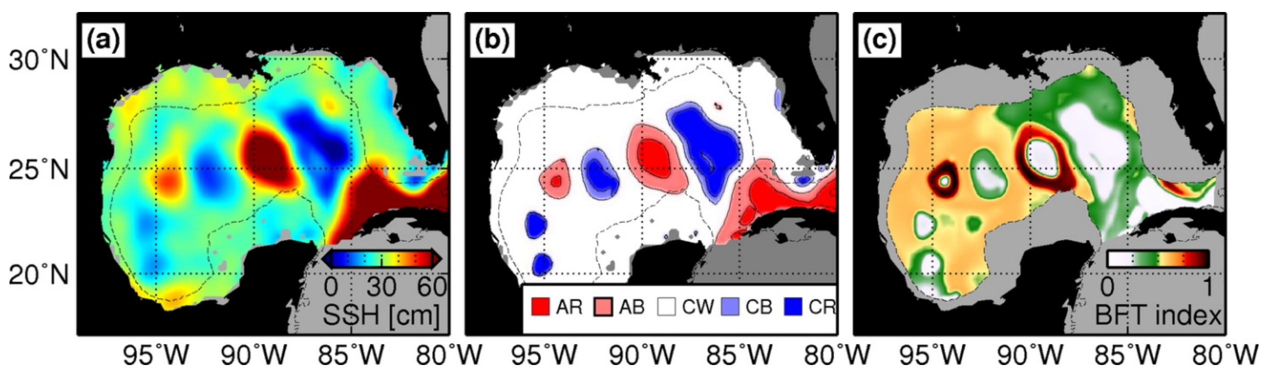


Figure 3: Maps for May 20, 1998 of: (a) Sea Surface Height; (b) type of mesoscale features; and (c) BFT_Index. Overlaid in the maps is the 200 m isobath (dashed line). In (b), AR refers to anticyclonic region, AB to anticyclonic boundary, CW to common waters, CB to cyclonic boundaries and CR to cyclonic regions.

Real-time computation and distribution of the BFT_index and derived parameters is currently being carried out by NOAA/AOML. For more information, please visit:
http://www.aoml.noaa.gov/phod/research/ecosystems/fisheries/bft_monitoring.php

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. Five papers have been published.

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The South Atlantic Overturning Circulation and Monsoons

Project Personnel: H. Lopez (UM/CIMAS)
NOAA Collaborators: G. Goni, S. Dong and S.-K. Lee (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To investigate the relationship between the South Atlantic Overturning Circulation (SAMOC)/South Atlantic Meridional Heat Transport (SAMHT) in modulating the Northern Hemisphere monsoons.
***Strategy*:** Combine data analysis and coupled general circulation model outputs.

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

Link to NOAA Strategic Goals:
***Goal 3*:** Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts*

NOAA Funding Unit: OAR/AOML
NOAA Technical Contact: Molly Baringer

Research Summary:
The objective of this work is to investigate the relationship between South Atlantic Meridional Heat Transport (SAMHT) and the monsoons over the northern hemisphere. The monsoons dominate the global circulation in summer, with far reaching consequences beyond their immediate geographic domain. It is therefore important to find potential factors influencing its modulation. The analysis here is based on several century-long integrations of a state-of-the-art coupled general circulation model, namely CESM1 from the National Center for Atmospheric Research (NCAR).

The study illustrates that multi-decadal variability of the SAMHT plays a key role in modulating global atmospheric circulation via its influence on interhemispheric redistributions of momentum, heat, and moisture. Weaker SAMHT at 30°S produces anomalous ocean heat divergence over the South Atlantic, resulting in cooler ocean surface temperature about 20 years later (Fig. 1). This drives an anomalous Hadley circulation, transporting atmospheric heat from the Northern Hemisphere (NH) to the Southern Hemisphere (SH) and moisture from the SH to the NH, thereby modulating global monsoons. This study illustrates that decadal variations of SAMHT could modulate the strength of global monsoons with about 20 years in advance, suggesting that SAMHT is a potential predictor of global monsoon variability (Figs. 2 and 3). In summary, all NH summer monsoons are enhanced during weaker SAMHT. The results presented in this study highlight the need and value of sustained ocean observational efforts, necessary to improve our knowledge of the complex interaction between the South Atlantic Ocean and global climate variability and monsoons.

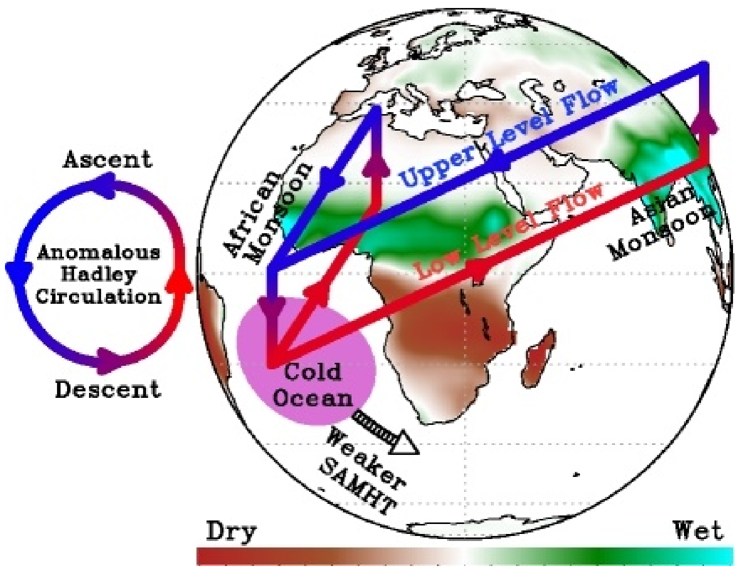


Figure 1: Illustration of the role of weaker-than-normal SAMHT in atmospheric circulation at 20 years lead-time. Weakened SAMHT is shown by thick black arrow. This results in a cooler than normal South Atlantic Ocean (purple shade) which produce an anomalous Hadley circulation labeled by counterclockwise circulation. The lower branch of the circulation (red arrow) brings warm and moist air from the Southern Hemisphere (SH) to the Northern Hemisphere (NH). This circulation sense produces ascent and precipitation in the NH thus enhancing the NH monsoons.

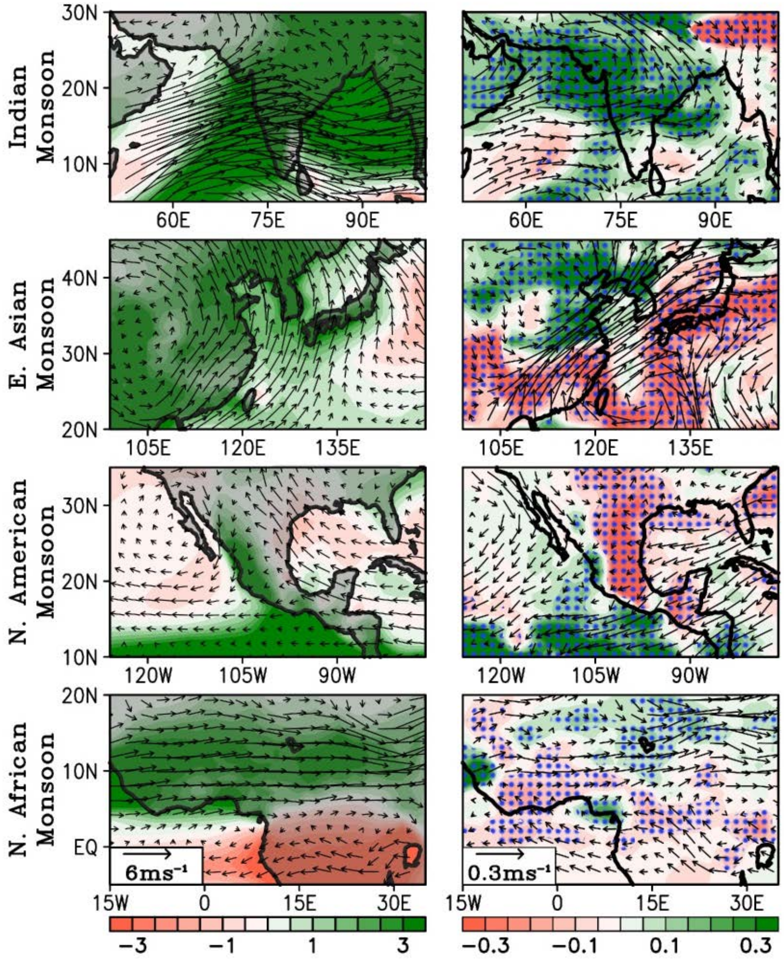
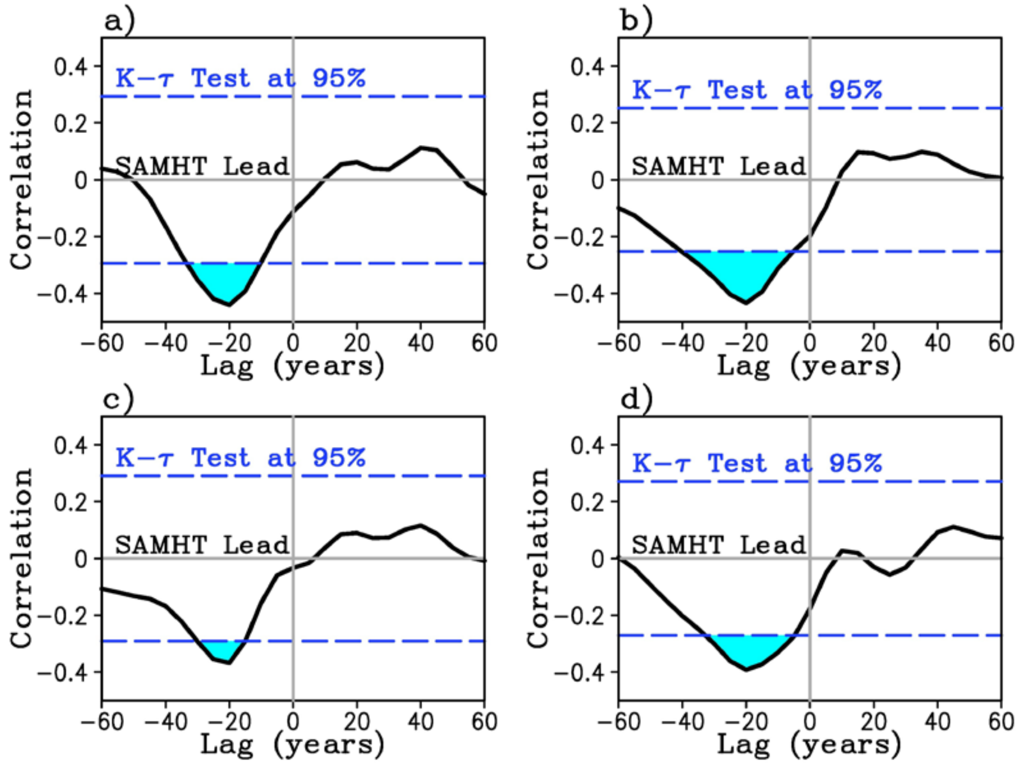


Figure 2: (left-column) seasonality of precipitation and 850mb winds for the monsoon regions. (right-column) composite difference of JJAS precipitation (shaded) and 850mb wind for each monsoon region with respect to weak minus strong SAMHT at lead-time 20 years after the anomalous SAMHT. Blue stipples indicate regions where differences are significant at 95% confidence level based on a non-parametric Kolmogorov-Smirnov test.



Research Performance Measure: The research objectives were met based on the primary objective: to quantify the role of the South Atlantic Ocean in modulating the monsoons. The potential impact of the SAMHT on climate and extreme weather events demonstrates the importance of understanding and monitoring the SAMOC variability in the South Atlantic.

Figure 3: Lag-lead Spearman ranked correlation between SAMHT and Indian (a), East Asian (b), North American (c), and North African (d) monsoon index. The blue dashed lines depict the 95% significance level based on a non-parametric Kendall-tau test. Negative lag indicates periods when SAMHT leads the NH monsoon index. Periods with significant correlation between the SAMHT and monsoon are shaded blue. SAMHT leads all four Northern Hemisphere monsoons by 20 years.

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Global Drifter Program

Project Personnel: S. Dolk, R. Perez, 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 3*:** Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts*

NOAA Funding Unit: OAR/AOML

NOAA Technical Contact: Molly Baringer

Research Summary:

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

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

The design of the Global Drifter Program drifter has continued to evolve - as demonstrated by the recent large-scale deployment of salinity-measuring drifters - while its qualitative characteristics and water-following properties have remained relatively stable since the earliest deployments. Incremental improvements in design and manufacturing continue to increase drifter lifetime. We continue to develop new methodologies for drifter data analysis, aided by increasing information from the ever-growing drifter array and from other sources of complimentary observations. Dense deployments in eddy-rich, frontal regions will help us improve our understanding of eddy fluxes and their role in modifying air-sea heat fluxes and water mass formation.

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

The AOML's DAC is responsible for processing data from all drifters in the project. This specific program focuses on the maintenance and support of a population of ~1250 active drifters (see Fig. 1). The DAC works closely with researchers to provide high-quality drifter data in a rapid and accessible manner. The DAC has four primary objectives: Global Telecommunications System (GTS) data distribution, data quality control, web access, and instrument performance evaluation. The DAC inserts and deletes drifters onto the GTS distribution. The accuracy of data is monitored and data are removed from the GTS once

sensors fail or a drifter runs aground. The DAC also notes drifters that have lost their drogue so that this information can be relayed in the GTS message.

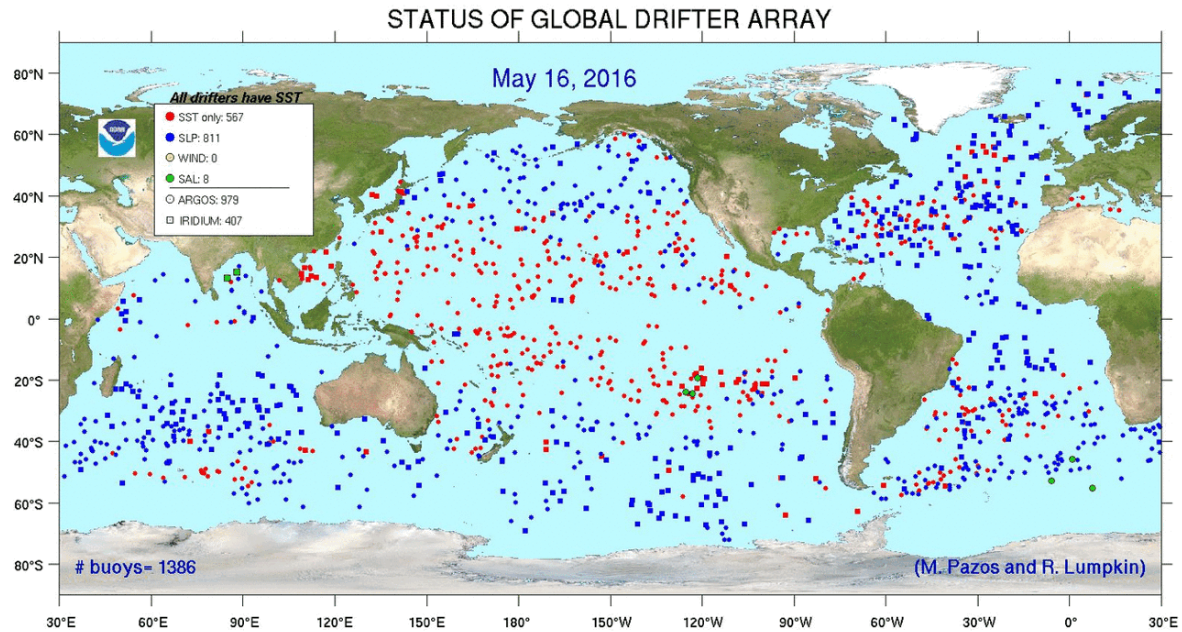

Figure 1: Status of the Global Drifter Array (updated weekly)

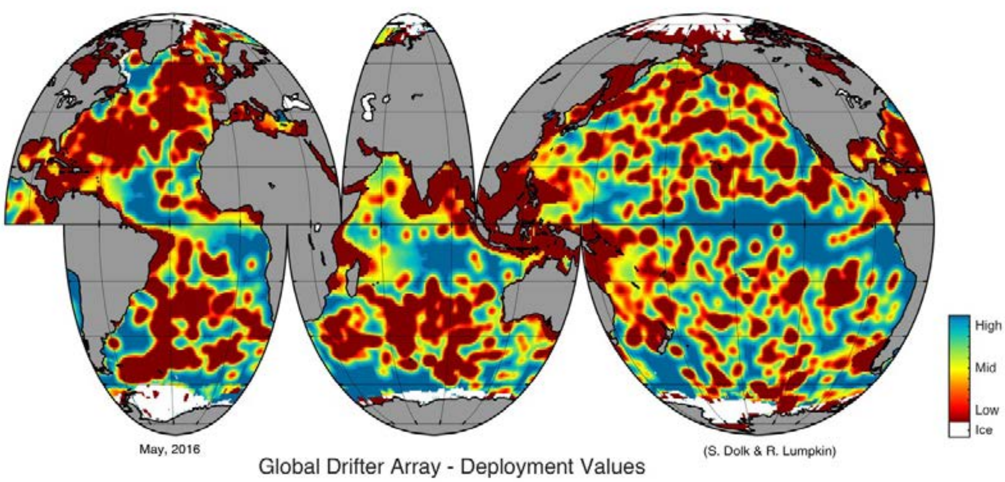

Figure 2: Deployment Value Map(s) (updated monthly)

Research Performance Measure: Regional deployments were conducted to enhance spatial coverage and maximize drifter lifetimes. The goal of making timely quality-controlled data available to the research and operational communities was met.

A new hourly global surface drifter dataset was generated this year by S. Elipot (UM/RSMAS), with collaboration from R. Lumpkin, R. Perez, and other researchers (Elipot et al., 2016). This global dataset provides a new tool for the study of relatively small-scale oceanic processes. The hourly product is freely available via the Data Assembly Center of the Global Drifter Program (http://www.aoml.noaa.gov/phod/dac/dacdata.php).

Southwest Atlantic Meridional Overturning Circulation ("SAM") Project

Project Personnel: R. Garcia, S. L. Garzoli, and R.C. Perez (UM/CIMAS)

NOAA Collaborators: S. Dong, C.S. Meinen, P. Pena, U. Rivero, and R. Smith (NOAA/AOML)

Other Collaborators: I. Ansorge (University of Cape Town, South Africa); E. Campos and O. Sato (University of Sao Paulo, Brazil); M.P. Chidichimo and A. Piola (Naval Hydrographic Service and University of Buenos Aires, Argentina); S. Speich (École Normale Supérieure, France)

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 Science Goals:

***Goal 3*:** Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts*

NOAA Funding Unit: OAR/AOML and OAR/CPO/COD
NOAA Technical Contact: Molly Baringer

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, precipitation patterns, and hurricane intensification in the Atlantic. These changes have strong societal impacts both in the region and around the globe. 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 crucial long-term array measuring the western boundary components of the MOC in the South Atlantic near 34.5°S since 2009 via the 'Southwest Atlantic MOC', or 'SAM', project. 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. The NOAA component of this international effort is focused on the western boundary currents, specifically the Brazil Current in the upper layer and the Deep Western Boundary Current (DWBC) at depth. 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 region. Long-term observations of these key flows will be required to understand the mechanisms leading to changes in the MOC system in the South Atlantic, 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 South Africa along 34.5°S. With nine moorings on the western side of the basin (as of December 2013) and fourteen moorings on the eastern side of the basin (as of September 2014), this trans-basin array

("SAMBA") has achieved a new milestone of collecting multi-year daily trans-basin MOC measurements. Efforts now are focused on mid-deployment data retrievals, instrument recovery and redeployment, and obtaining funds for future augmentations to the array.

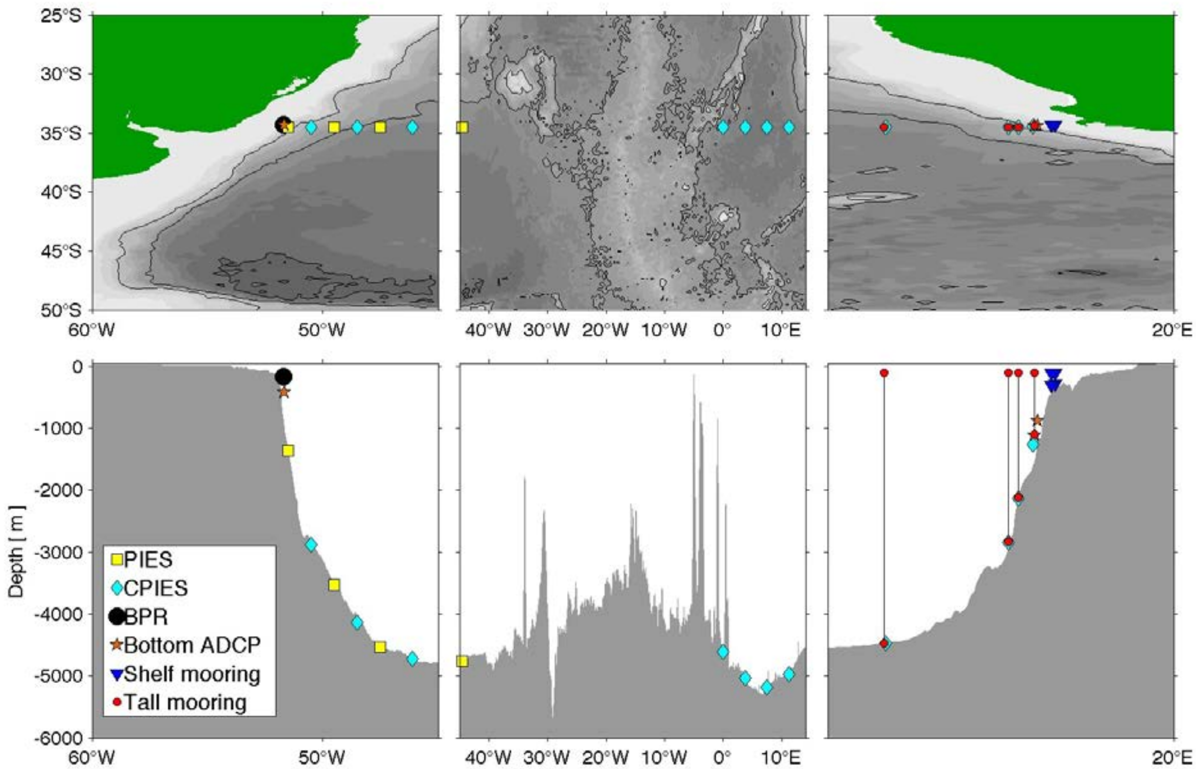

Figure 1: Map indicating the location (top panel) and the vertical distribution (bottom panel) of the four NOAA PIES making up the SAM array at 34.5°S; also shown are the Brazilian CPIES deployed in December 2012, the Brazilian coastal moorings deployed in December 2013, the French CPIES deployed in September 2013, and the South African moorings which were added in September 2014.

Research Performance Measure: Ship time issues in 2015 resulted in only limited PIES data being available during the year. Because of the data limitations, science analysis has focused on combining existing SAM data with other data sets in the region (e.g., Argo, GO-SHIP) as well as numerical models to focus on the larger picture of MOC pathways in the South Atlantic (Garzoli et al., 2015). Project PIs are collaborating with international researchers on manuscripts describing the variability of the Brazil Current along 34.5°S using data from the SAM PIES and Brazilian CPIES, as well as data from Argentinian and Brazilian hydrographic surveys. Project PIs are also leading and co-authoring manuscripts describing the variability in extended time-series of the DWBC and AMOC volume transport from the combined international observed arrays along 34.5°S. Results from several analyses were presented at the IUGG General Assembly in Prague (Czech Republic) in June-July 2015, at the UK RAPID – US AMOC International Science meeting in Bristol, UK in July 2015, at a capacity building meeting (COCOA) in Southampton, UK in July 2015, at the SAMOC VI workshop and 2016 Ocean Science meeting in New Orleans in February 2016.

Global Assessment of Looping Drifter Trajectories

Project Personnel: M.J. Olascoaga and F.J. Beron-Vera (UM/RSMAS)
NOAA Collaborators: R. Lumpkin (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To investigate inertial (i.e., finite-size, buoyancy) effects on the motion of drifting buoys.

***Strategy*:** To accomplish this goal, drifting buoys from the Global Drifter Program are analyzed in light of recent theoretical results based on the Maxey-Riley formalism.

CIMAS Research Theme:

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

Link to NOAA Strategic Goals:

Goal 3: Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts*

NOAA Funding Unit: OAR/CPO
NOAA Technical Contact: Molly Baringer

Research Summary:

Recent surveys of marine plastic debris density have revealed high levels in the center of the subtropical gyres. Earlier studies have argued that the formation of great garbage patches is due to Ekman convergence in such regions. In this work we report, for the first time, a tendency of satellite-tracked surface drifting buoys which have lost their sea anchors (drogues) to accumulate in the same regions of the world oceans that plastic debris accumulate. We show that the observed accumulation is too fast for Ekman convergence to explain it. We demonstrate that the accumulation is controlled by finite-size and buoyancy (i.e., inertial) effects on undrogued drifter motion subjected to ocean current and wind drags. We infer that the motion of flotsam in general is constrained by similar effects.

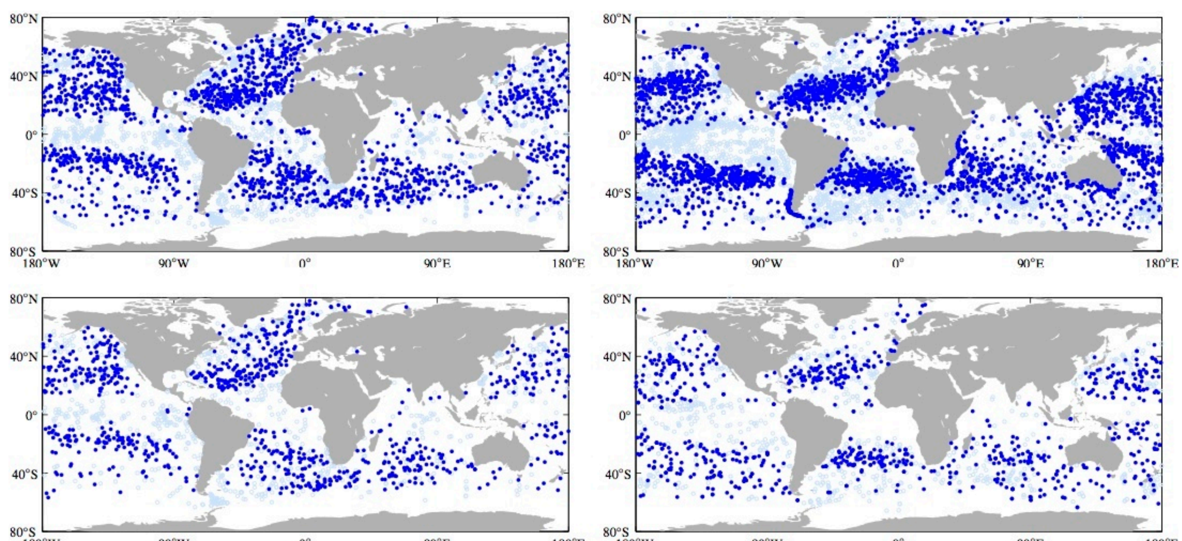

Figure 1. Initial (circles) and final (dots) positions of drogued (left) and undrogued (right) drifters from the NOAA Global Drifter Program over 1979–2015. "Final position" refers to the last recorded position after at least 1 (top) or exactly 1.5 (bottom) yr past the time at the "initial position," which is the deployment position for drogued drifters or the location where a drifter loses the drogue.

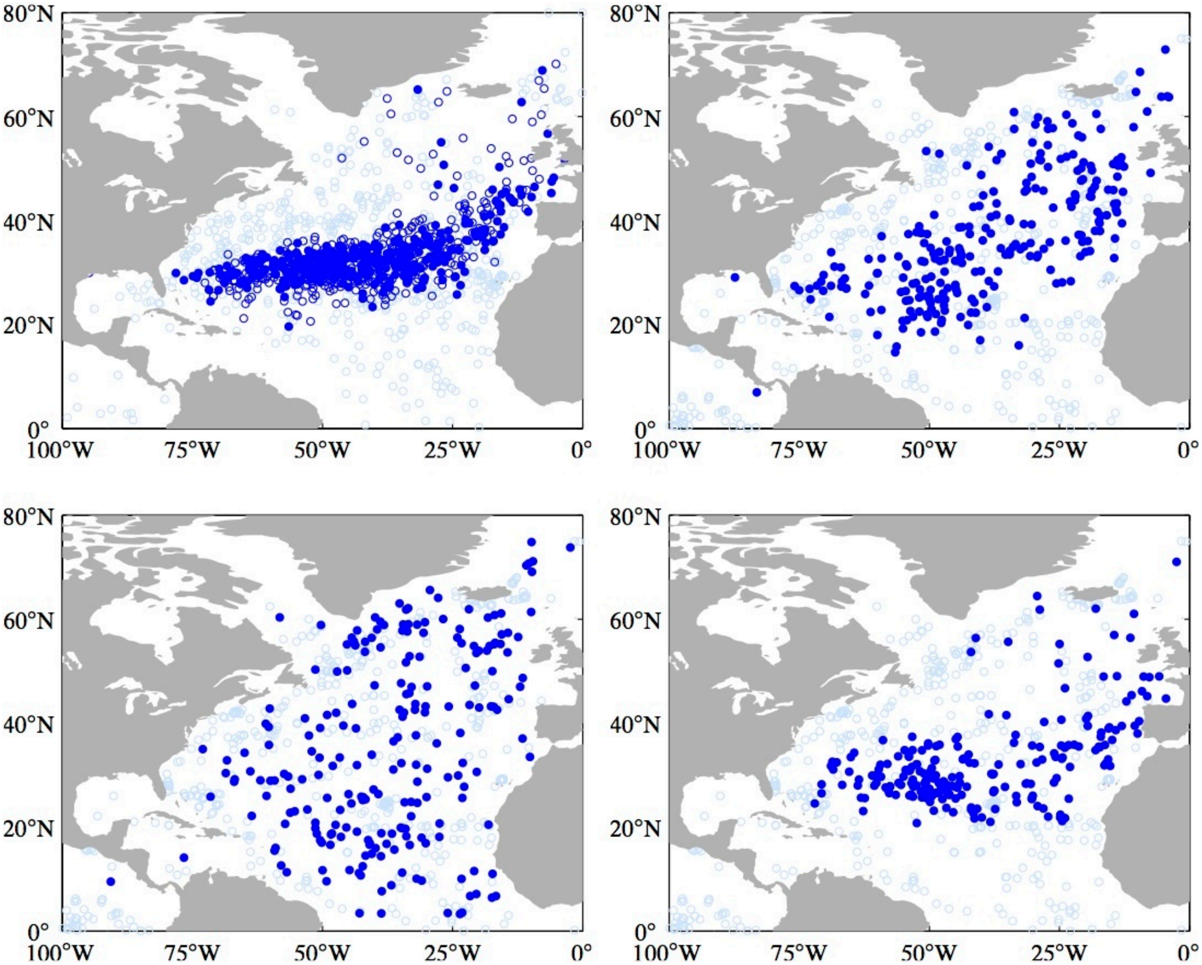

Figure 2: (top left) Positions after 1.5 yr of particles obeying the inertial equation (5) (dots) and the Maxey–Riley equation (dark circles), starting at the initial positions of undrogued drifters in the bottom panel of Fig. 1 (light circles). In both cases the water velocity is given by surface ocean velocity from the 1/12° Global HYCOM+NCOM Ocean Reanalysis, while the air velocity corresponds to the wind velocity from the NCEP/CFSR reanalysis used to construct the wind stress that forces the model. (top right) As in the top-left panel, but for particles advected by water velocity and starting from the initial positions of drogued drifters in the top panel of Fig. 1. (bottom left) As in the top-right panel, but for particles advected by velocity derived geostrophically from model sea-surface height. (bottom right) As in the top-right panel, but after 3.5 yr.

Research Performance Measure: The objectives of the project have been reached with respect to data analysis and comparison with the Maxey-Riley theory. One peer-reviewed paper has been published in *Chaos* (Beron-Vera et al., 2015) and another one has been submitted for publication (Beron-Vera et al., 2016) where the Maxey-Riley theory is developed.

Transport in the Upper Branch of the South Atlantic Meridional Overturning Circulation

Project Personnel: S. Majumder (UM/CIMAS)
NOAA Collaborators: C. Schmid and G. Halliwell (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To understand the variability of Atlantic Meridional Overturning Circulation in the South Atlantic

***Strategy*:** Expansion of a three dimensional velocity field, derived from Argo observations, sea surface heights and wind fields will be carried out. The time series of AMOC transports at different latitudes in the South and in the North will be calculated and their seasonal to inter-annual variability will be studied.

CIMAS Research Theme:

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

Link to NOAA Strategic Goals:

***Goal 3*:** Climate Adaptation and Mitigation **-** *An informed society anticipating and responding to climate and its impacts*

NOAA Funding Unit: OAR/CPO
NOAA Technical Contact: Jennifer Saleem Arrigo

Research Summary:

We use three dimensional velocity fields, derived from Argo observations, satellite sea surface heights, and NCEP reanalysis winds between 2000 and 2014, to estimate volume transport in the upper branch of Meridional Overturning Circulation (MOC) and meridional heat transport (MHT) across four different latitudes (20S, 25S, 30S and, 35S) in the South Atlantic.

Mean MHT and MOC from the observations agree well with the previous estimates. MOC and MHT exhibit linear relationships with each other at all the four latitudes. The corresponding heat transport for 1 Sv change in MOC is about the same (0.046 PW) across 25S to 35S. More heat (0.056 PW) is transferred across 20S for 1 Sv change in MOC (Figure 1). In terms of seasonality both observations and models show annual cycles, however, the timing of the maximum and minimum in the seasonal cycle are different in the models (Figure 2). In terms of inter-annual variability, no significant trend in the MOC time series is found at any of latitudes. A comparison of model-based transports at 35S at the boundaries and in the interior with those from the observations shows significant differences between them with respect to the contributions in the three segments of the section. In addition, the contributions also vary greatly between the different models.

A manuscript entitled "An Observation and Model Based Analysis of Meridional Transports in the South Atlantic" authored by S. Majumder, C. Schmid, and G. Halliwell is accepted with revisions in JGR Oceans.

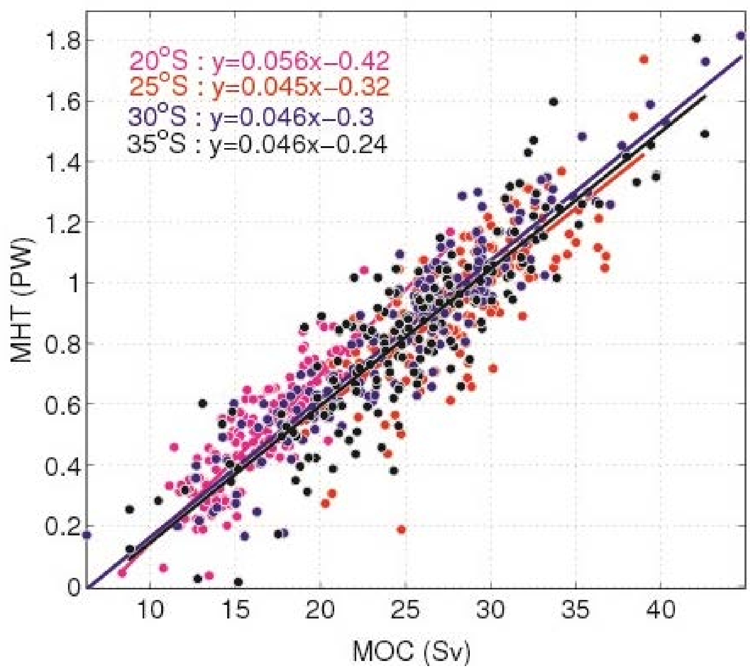

Figure 1: Scatter plot of MOC strengths against MHTs from Argo observations for different latitudes: 20S (magenta), 25S (red), 30S (blue) and 35S (black). Straight lines are the corresponding linear fits.

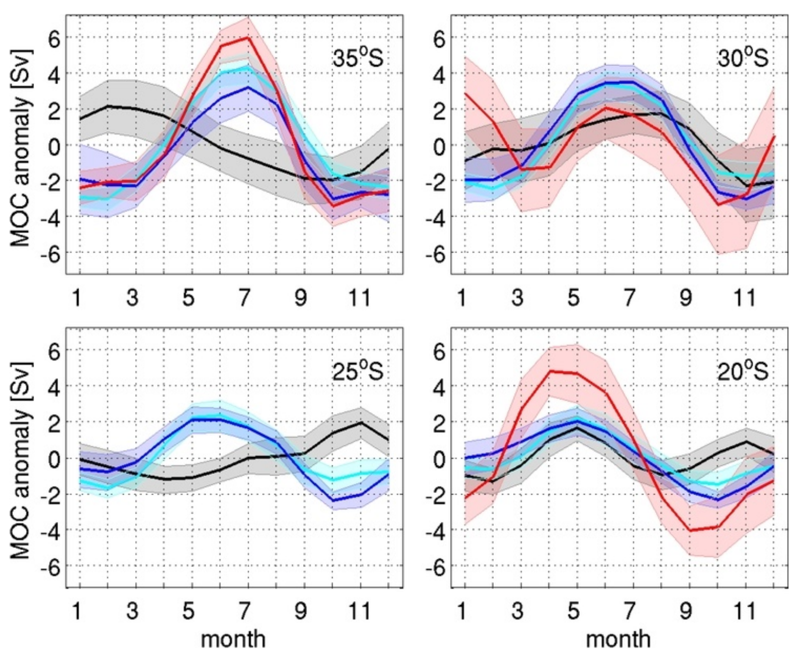

Figure 2: Monthly climatologies of anomalies of MOC strengths across 35S, 30S, 25S, and 20S from the observations (black), National Centers for Environmental Prediction Model (blue), Simple Ocean Data Assimilation Model (cyan) and Hybrid Coordinate Ocean Model (red). Shading indicates 95% confidence interval.

Research Performance Measure: 1) The main objective was to estimate the meridional volume and heat transport at different latitudes in the south Atlantic using observations and data from data assimilation models; and, 2) to prepare a manuscript based on these results. Meridional volume and heat transports were estimated based on the observations, and data assimilation models at four different latitudes (20S, 25S, 30S, and 35S) in the South Atlantic. The results were presented at the AGU Ocean Sciences 2016 meeting, at New Orleans and a manuscript has been accepted with revisions in JGR-Oceans.

2015 National Coral Reef Monitoring Plan: Florida Benthic Sampling

Project Personnel: S.L. Miller, M. Chiappone and L.M. Rutten (NSU)
NOAA Collaborators: J. Schull and J. Bohnsack (NOAA/SEFSC)
Other Collaborators: J. Ault and S. Smith (UM/RSMAS)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** The National Coral Reef Monitoring Program (NCRMP*)* aims to answer the following questions across four monitoring themes (benthic community condition, fish community structure, climate, and human dimensions): 1) What is the status of coral reef ecosystem biota? 2) Is community structure changing over time? 3) What are the trends in temperature and acidification in waters surrounding coral reefs? 4) What is the status of human knowledge, attitudes, and perceptions regarding coral reefs? 5) How are human uses of, interactions with, and dependence on coral reefs changing over time?

***Strateg*y:** When fully implemented over the course of several monitoring cycles, NCRMP will provide information needed to tailor investments and strategies to ensure that NOAA's Coral Reef Conservation Program's (CRCP) goals and objectives are achieved, and that U.S. coral reef ecosystems – and the communities that depend on them – benefit from our collective conservation activities. NCRMP has developed benthic protocols and a sampling design to meet NCRMP monitoring goals that include Line Point Intercept Surveys for benthic cover, Coral Demographic Surveys, Benthic Fauna (for queen conch, spiny lobster, and the sea urchin Diadema antillarum) Surveys, Topographic Complexity Measurements, and Site Photographs.

CIMAS Research Themes

***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*:** 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:

NCRMP benthic LPI and demographic surveys started in 2014 were completed in 2015. Data were transferred to the NCRMP data manager in Florida for entry into the NCRMP database, protocols for future sampling in southeast Florida were prepared, and data analyses for reports and publications was conducted (and are ongoing). Benthic habitat surveys in 2015 were conducted in the Florida Keys and included 103 sites (for a total of 350 sites), using small boats and SCUBA diving on day trips. At each site, one 15-m Line Point Intercept (LPI) transect was surveyed for cover (100 points per transect) and a 10-m x 1-m Coral Demographic transect was surveyed for all corals greater than 4 cm in maximum diameter and identified to species, measured for colony dimensions (max. diameter, perpendicular diameter, and height), as well as conditions including percent live vs. dead tissue and evidence of tissue bleaching and disease. The work contributes to the NCRMP benthic monitoring efforts in Florida and comprises part of a long-term coral reef monitoring program throughout the Florida.

Research Performance Measures: 1) Completed of NCRMP benthic surveys in Florida. 2) Transferred of benthic data into NCRMP data platform. 3) Assisted SEFSC with finalization of Florida

NCRMP protocols. 4) Assisted with final Florida report writing specifically related to development of a draft Coral Reef Report Card. 5) Evaluated tradeoffs and impacts of Florida NCRMP sample design.

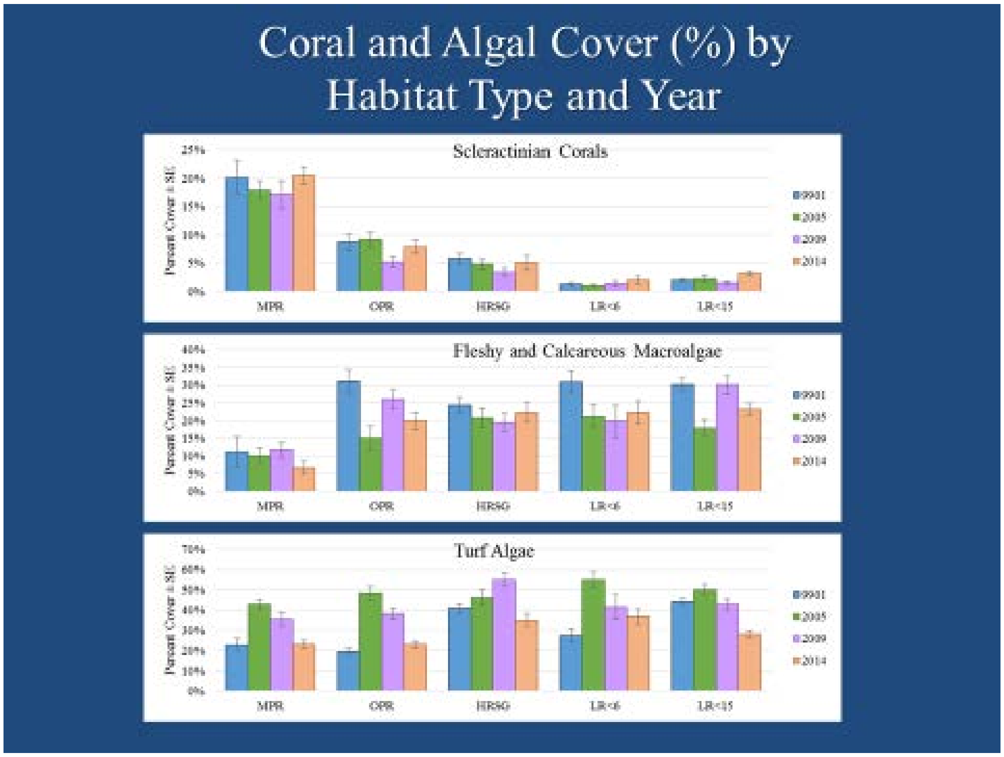

Figure 1: Coral and algal percent cover by habitat type.

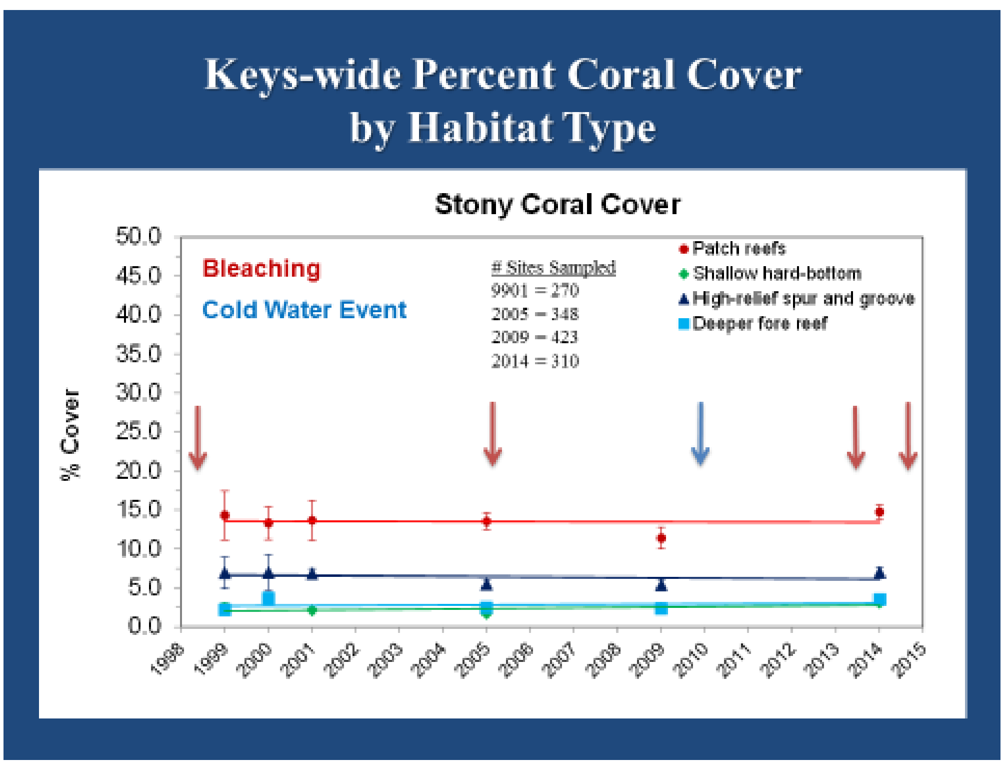

Figure 2: Keys-wide coral cover by habitat type.

RESEARCH REPORTS

THEME 2: Tropical Weather

Preliminary Assessment of the Impact of Coyote Unmanned Aircraft System Observations on Vortex-Scale Data Assimilation

Project Personnel: A. Aksoy (UM/CIMAS)
NOAA Collaborators: J.J. Cione (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To evaluate the impacts of the Coyote UAS observations on tropical cyclone analyses and forecasts.
***Strategy*:** Conduct Observing System Experiments (OSE) and Observing System Simulation Experiments (OSSEs) using data from Coyote field missions and utilizing NOAA/AOML/HRD's in-house HEDAS.

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 Office of Marine and Aviation Operations
NOAA Technical Contact: Joseph J. Cione

Research Summary:
The potential of the Coyote unmanned aircraft systems (UAS) to improve hurricane analyses and forecasts is evaluated in a case study by investigating the impact of Coyote observations for vortex-scale hurricane data assimilation in NOAA's Hurricane Ensemble Data Assimilation System (HEDAS). Manufactured by the Raytheon Company, Coyote has a length of 0.91 m, a wingspan of 1.47 m, and a mass of 6 kg. It is capable of carrying a payload of up to 0.9 kg. Its maximum cruising airspeed is ~31 m s^{-1} in calm wind conditions. To facilitate deployments from NOAA's WP-3D (P-3) aircraft, the wings of the Coyote are folded and it is placed inside a canister that is subsequently released from the

dropwindsonde chute aboard the P-3 (Fig. 1). Once deployed, a parachute slows the descent of the canister. After ~10 s (enough time for the turbulent motion of the canister to stabilize), a signal is sent from the P-3 for the canister to open and release the Coyote. The Coyote's wings then deploy and the UAS begins to sample the environment. The flight path and air speed are controlled by commands issued remotely from the P-3. Data are transmitted in real time back to the P-3 using 1) an Iridium satellite connection and 2) a 900-MHz data stream.

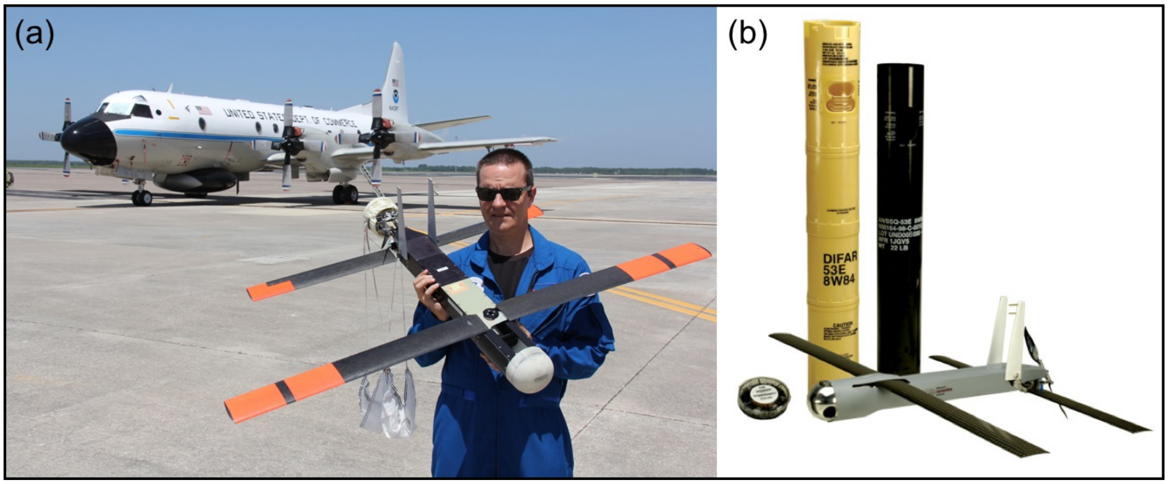

Figure 1: (a) The Coyote is shown with a crew member in front of the NOAA P-3 aircraft that typically deploys it. (b) The Coyote is shown in front of the canister which is used as the housing during deployment from the NOAA P-3 dropwindsonde chute.

The case of choice is Hurricane Edouard (12 UTC on 16 September 2014), when Coyote observations coexisted in the inner core with an extensive suite of observations from the NOAA P-3 and Global Hawk aircraft (Fig. 2).

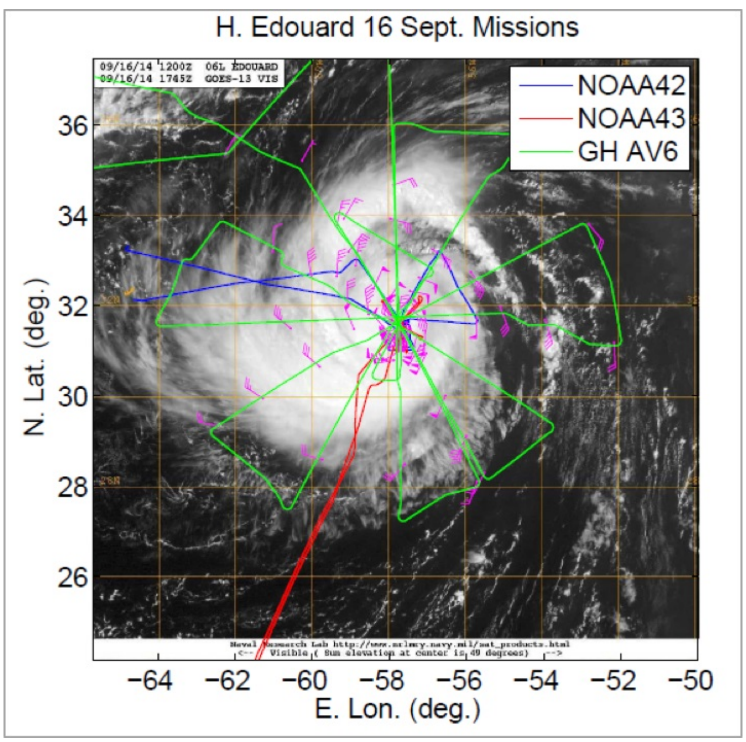

Figure 2: Spatial distribution of the flight tracks of all aircraft that were sampling Hurricane Edouard on 16 September 2014 at 12 UTC. The tracks of the two NOAA P-3 aircraft are shown in blue and red, while the Global Hawk track is shown in green.

The Coyote mission on 16 September mainly comprised of eye/eyewall sampling, lasting for 28 min and a measuring maximum wind speed of 100 kt. The track of the Coyote flight is shown in Fig. 3 along with the observed meridional (north-south) wind speed values on the left. It can be seen that the Coyote was dropped from the parent P-3 aircraft near the center of Hurricane Edouard, where it performed two small circles and then tracked outward into the eyewall region where the strongest winds of a hurricane are typically observed. The Coyote was able to sample the strong gradient of the wind speed as it entered the eyewall as is evident from the sharp darkening of the blue shades (blue indicates wind direction from the north). However, due to communication issues with the parent P-3 aircraft, data transmission after entry into the eyewall region was sparse. When observation-analysis differences are inspected along the same flight track (Fig. 3, right panel), largest departures are observed in the strong wind gradient region. This is indicative of the potential for the Coyote to make significant impacts on vortex-scale analyses as the model depiction of this strong gradient was clearly deficient. This could be due to storm position errors, storm size errors, as well as storm intensity errors, all of which can be potentially improved in such a scenario of effective sampling of strong wind gradient regions.

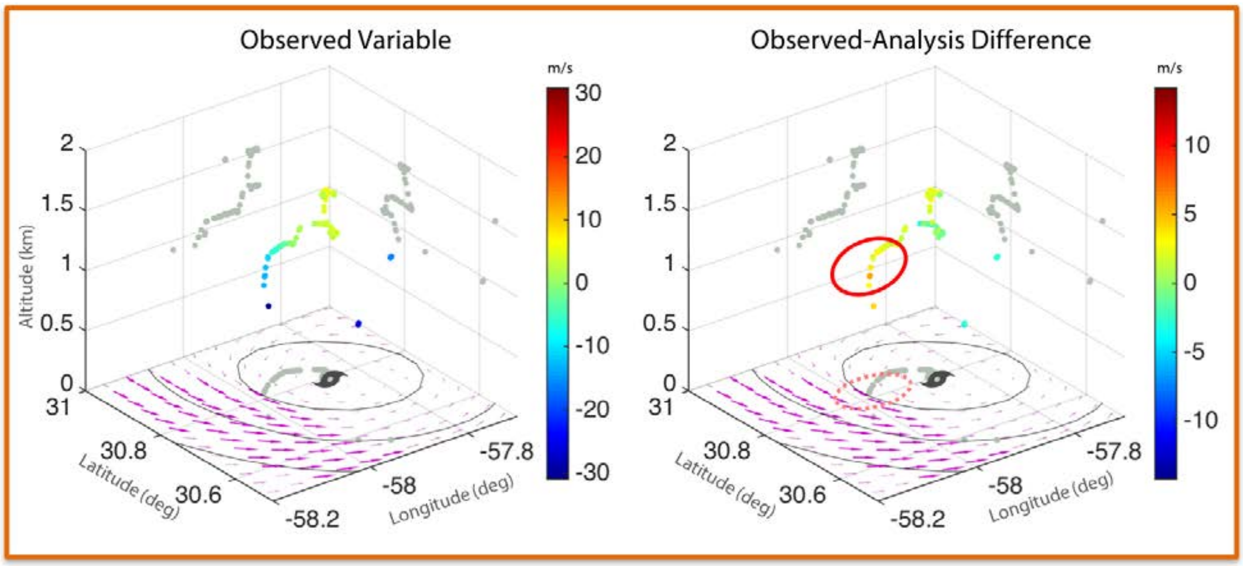

Figure 3: Observed meridional (north to south) wind speed (left panel) and difference of analysis and observations for meridional wind speed (right panel) are shown along the Coyote flight path during its 16 September 2014 mission. Analyzed pressure isobars are shown in black contours while surface wind vectors are shown in purple (darker vectors indicate the region with the strongest 20% of wind speed). Largest model departures from observations are indicated with the red circle, which coincide with the strong wind gradients where model errors of storm position, size, and/or intensity would all lead to significant departures.

When forecasts initialized with and without Coyote observations are compared (Fig. 4), some minor positive impacts are seen for track as well as minimum pressure in the first 48 hours of the forecasts. Although the absolute magnitude of the impacts is small, it should be kept in mind that in this 16 September case, the Coyote provided data for a duration of only 28 min, which is relatively small compared to the large volumes of data that were provided by the other aircraft that were sampling the storm simultaneously. While this is only an anecdotal demonstration, it nevertheless points to the potential for the Coyote platform to provide critical information on storm position, structure, and intensity that can ultimately improve forecasts as well.

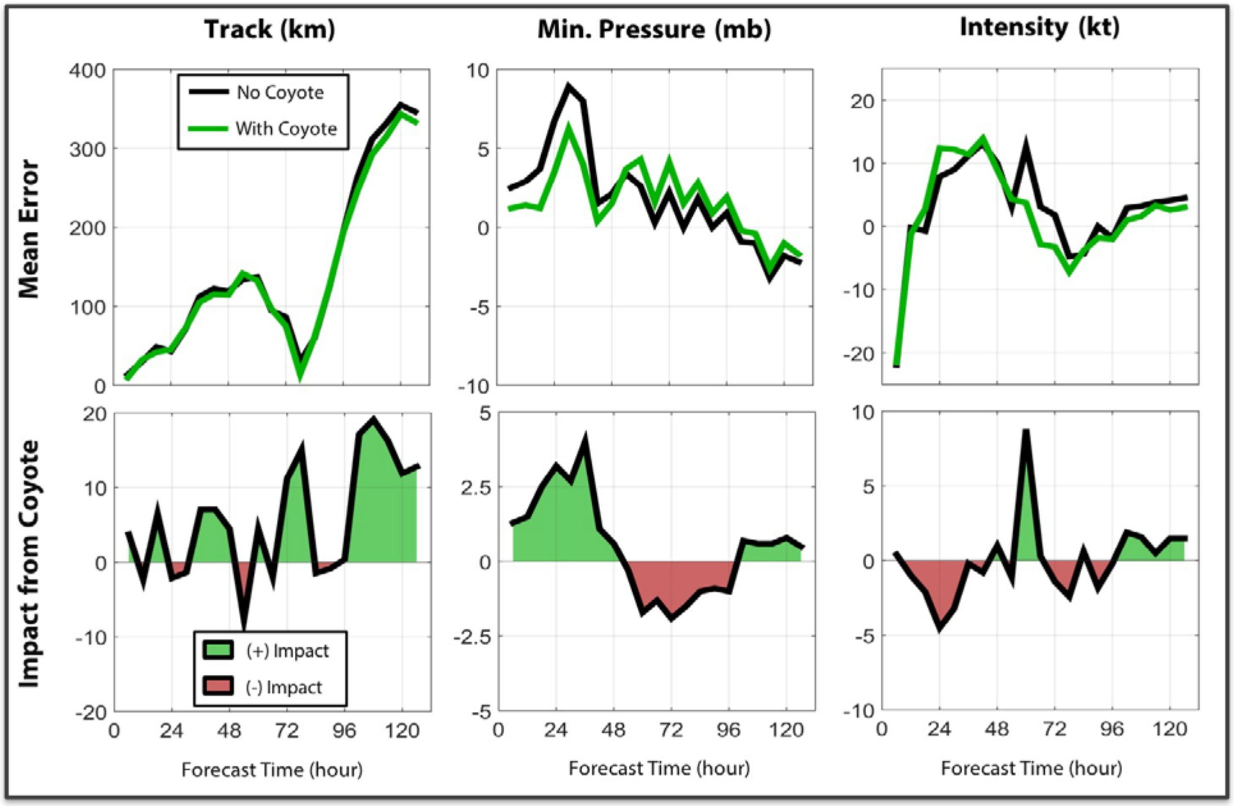

Figure 4: Mean forecast errors of track (left), minimum pressure (middle), and intensity (right), initialized with (green) and without (black) Coyote observations are shown in the upper row. The bottom row indicates percent improvement of forecasts with Coyote versus without Coyote.

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

Investigations of the Performance of the Basin-Scale HWRF

Project Personnel: G. Alaka, X. Zhang, R. St. Fleur, H. Chen and K. Sellwood (UM/CIMAS)
NOAA Collaborators: S.G. Gopalakrishnan, S. Goldenberg, F. Marks and R. Rogers (NOAA/AOML/HRD); V. Tallapragada, S. Trahan, Z. Zhang and J. Sippel (NOAA/NCEP/EMC)
Other Collaborators: C. Holt and M. Biswas (NCAR/DTC)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives: To further advance the capabilities, accuracies and reliability of numerical hurricane forecasting under HFIP.

Strategy: To focus on the hurricane weather research and forecasting (HWRF) model, specifically by studying the performance of the basin-scale HWRF, and to identify valuable model configuration options that can be transitioned to operations.

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: Molly Baringer

Research Summary:
Basin-Scale HWRF Verification

Dr. Alaka added extensive capabilities to the MET-TC verification package, including Brier skill score calculations and several stratification options (e.g., number of additional TCs). Dr. Alaka led the evaluation and verification of 2013 basin-scale HWRF Atlantic track forecasts, using the 2014 operational HWRF as a benchmark. These two versions of HWRF are similar except for the outer domain size and multistorm configurations. For the 2011-2014 hurricane seasons, the 2013 basin-scale HWRF and 2014 operational HWRF had nearly identical mean track skill (Fig. 1). A major finding of the study is that basin-scale HWRF track forecasts outperform those from the operational HWRF when far-field TCs (> 3500 km) are simultaneously active (Fig. 2). Dr. Alaka is also leading an effort to understand the

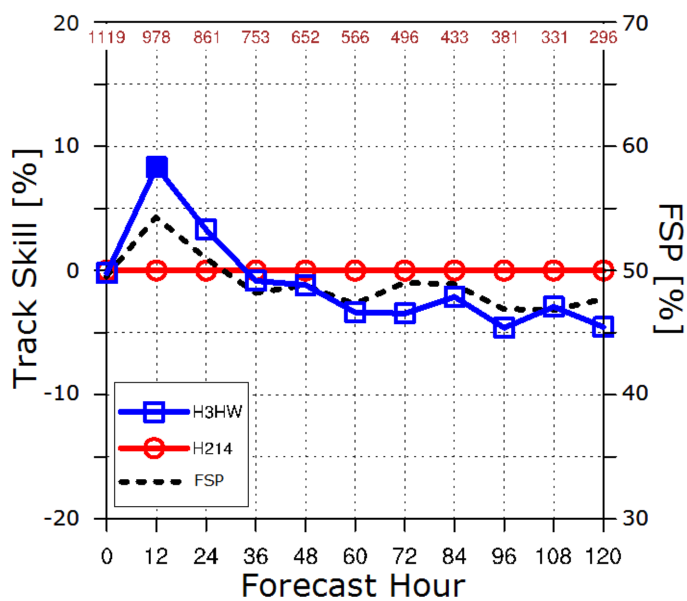

Figure 1: Track skill is verified for Atlantic basin TCs in the 2013 basin-scale HWRF (H3HW; blue square) and the 2014 operational HWRF (H214; red circle) for 2011-2014. H214 is the reference model used to calculate track skill. Frequency of superior performance (FSP; black dashed) uses the right y-axis. Track skill is computed every 12 h. The number of cases at each lead time is given in brown at the top of each column. Significant H3HW track skill values have filled in markers.

independent sensitivity of HWRF track and intensity forecasts to domain size and number of high-resolution nests is being investigated.

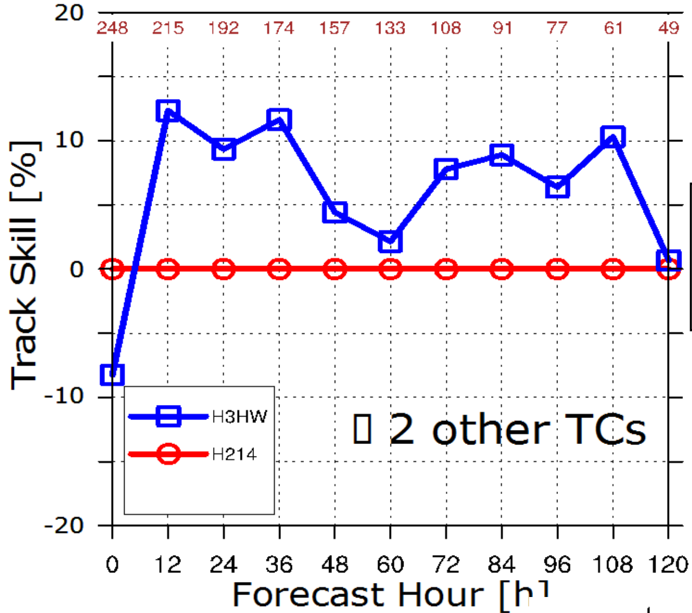

Figure 2: As in Fig. 1, except stratified for 2+ additional far-field TCs in the Atlantic or East Pacific basins. Far-field TCs are at least 3500 km away from the TC being verified.

Basin-Scale HWRF Ensemble
Dr. Alaka successfully developed an ensemble system for the basin-scale HWRF to test forecasts sensitivities to model physics, vortex initialization, and storm-storm interactions. In particular, Dr. Alaka produced a 20-member ensemble forecast for Tropical Storm Joaquin (Fig. 3). So far, the ensemble has highlighted the important relationship between vortex depth and steering flow.

Basin-Scale HWRF Products
Dr. Alaka has developed automated scripts that produce large-scale basin-scale HWRF products to aid the HRD IFEX Team. These products are available on the HRD web site.

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

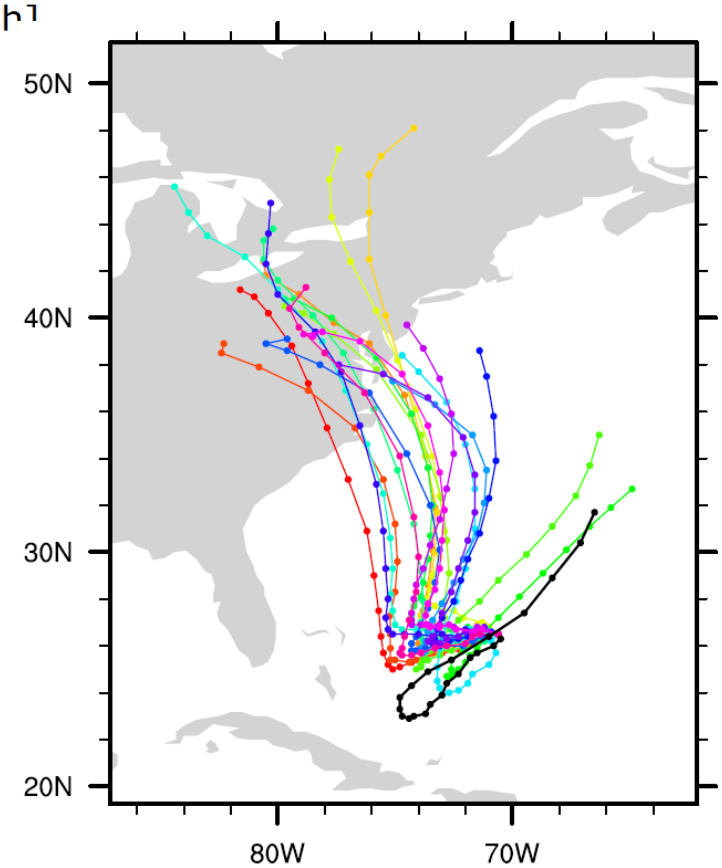

Figure 3: Tracks for 20 Basin-scale HWRF ensemble members run for Tropical Storm Joaquin initialized at 12 UTC 29 September 2015. The Best Track is shown in black.

Impact of Cyclone Global Navigation System on Tropical Cyclone Analyses and Forecasts

Project Personnel: B. Annane, B. McNoldy, L. Bucci, J. Delgado and R. Hoffman (UM/CIMAS)
NOAA Collaborators: R. Atlas and S. Murillo (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To systematically evaluate the impact of Cyclone Global Navigation System (CYGNSS) data on tropical cyclone (TC) analyses and forecasts.

***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: Molly Baringer

Research Summary:

CYGNSS is a planned NASA constellation of micro-satellites that utilizes existing GPS satellites to retrieve surface wind speed. In the OSSE, synthetic CYGNSS wind speed data are generated using output from a “nature run” as truth. Using the regional Hurricane Weather Research and Forecasting (HWRF) modeling system and the Grid point Statistical Interpolation (GSI) data assimilation scheme, it is found that analyses of TC position, structure, and intensity, together with large-scale variables, are improved due to the assimilation of the additional synthetic surface wind data. The results, though available for a small sample, illustrate the potential importance of these ocean surface wind data and suggest that the assimilation of directional information would add further value to TC analyses and forecasts.

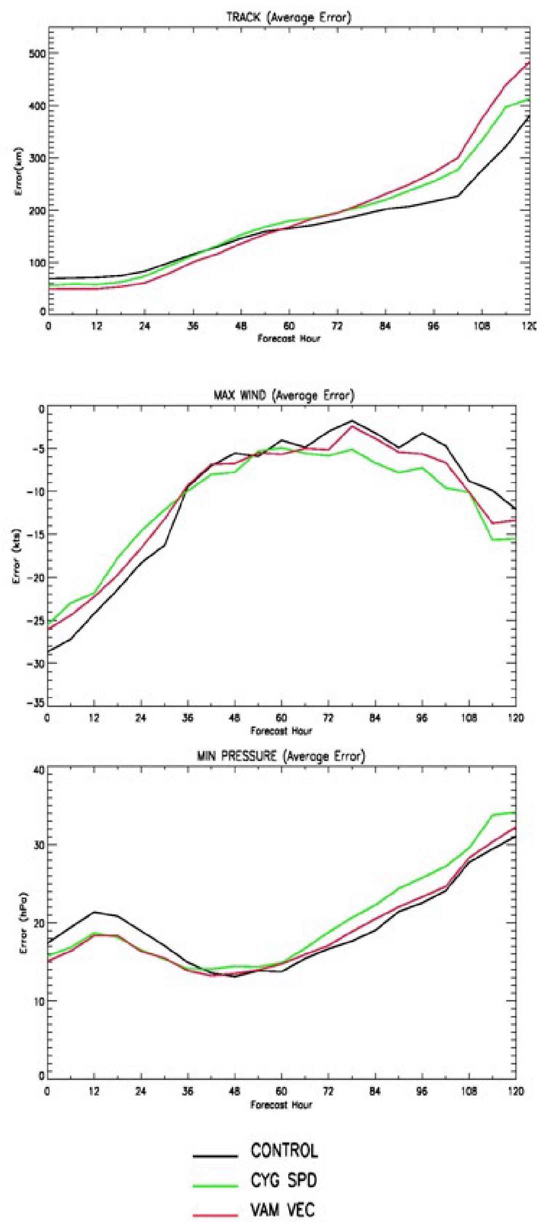

Figure 1: Atlas_T2_TCStats_1June15: (a) Average error over 16 cycles. Position (track) error in km (b) Average error over 16 cycles. Minimum central pressure error in hPa. (c) Average error over 16 cycles. Maximum 10m wind speed error in kts.

Research Performance Measure: The research program is on schedule.

Towards High-Resolution NMM-B Nature Run Weather Forecasts for Hurricane OSSEs

Project Personnel: J. Delgado, S. Diaz and R. Hoffman (UM/CIMAS)
NOAA Collaborators: R. Atlas and S. Gopalakrishnan (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To create a uniform 3km model forecast using the Non-hydrostatic Multiscale Model on the B grid (NMM-B) in order to perform hurricane Observing System Simulation Experiments (OSSEs).

***Strategy*:** To perform the nature run using NASA's GEOS-5 Nature Run as initial and boundary conditions

CIMAS Research Theme:

***Theme 2*:** Tropical Weather

Link to NOAA Strategic Goals:

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

NOAA Funding Unit: OAR/AOML
NOAA Technical Contact: Molly Baringer

Research Summary:

The process of running an Observing System Simulation Experiment (OSSE) is depicted in Figure 1. In an OSSE, the impact of proposed observing systems on model forecasts are evaluated by simulating observations from a *nature run*, generating forecasts using a modeling and data assimilation system that uses the observations, and comparing the forecasts to the nature run. The purpose of this work was to run a uniform-3km *basin scale* model forecast to use as a nature run.

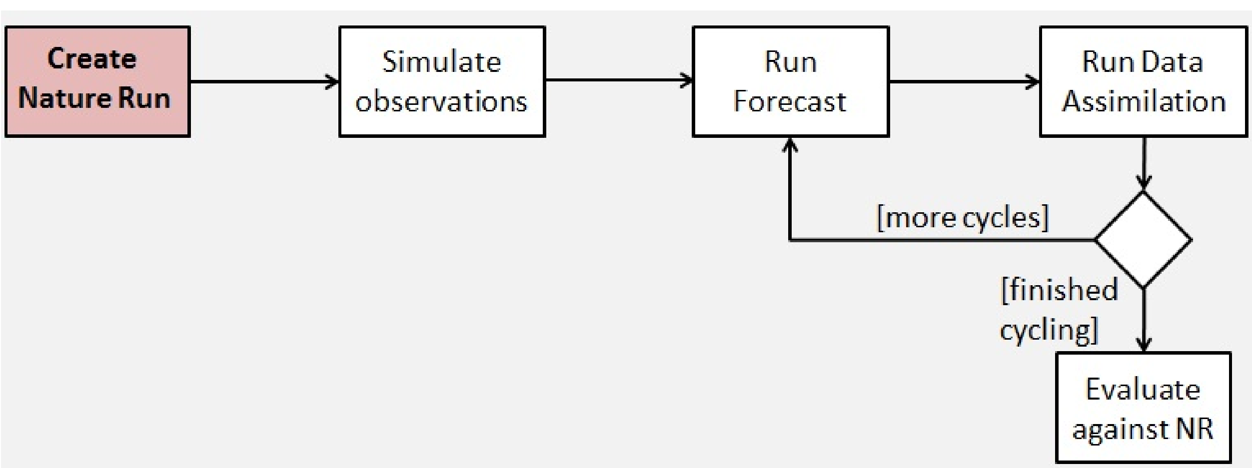

Figure 1: OSSEflowchart – Overview of the process involved in running OSSEs.

Several steps were required to generate the nature run. First, NMM-B and the NEMS Preprocessing System (NPS) had to be modified to support the large grid size used for the uniform-3km run. Then, since no software package was readily available for initializing NMM-B with model output from GEOS-5, utilities had to be created to convert the G5NR output to a format that could be understood by NPS. Third, since the land surface fields produced by GEOS-5 are not compatible with NMM-B, NASA's Land

Information System (LIS) was deployed on our system to run the Noah land surface model, using G5NR data for forcing, to generate the necessary land surface fields.

After modifying NMM-B to support large grids, it was necessary to ensure that it was generating reasonable forecasts, so we ran retrospective forecasts of well-known hurricane cases. One such case, the 29th September 2015 cycle of hurricane Joaquin, is shown in Figure 2.

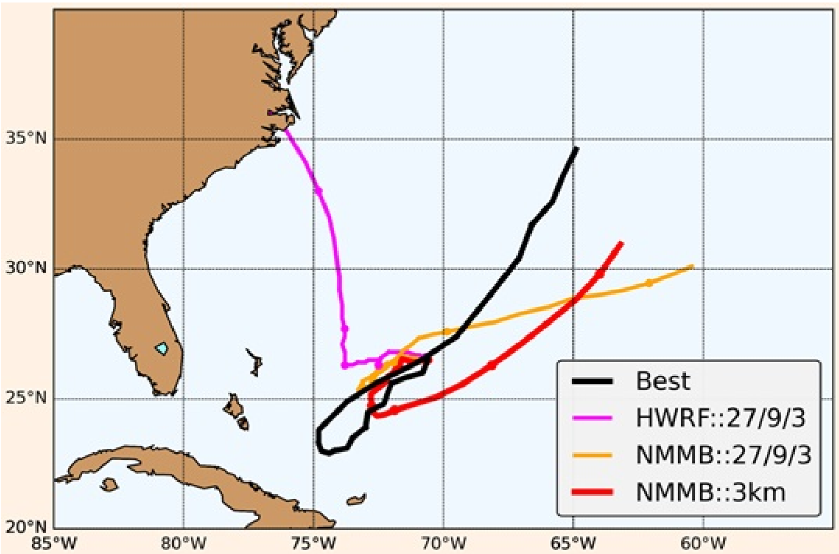

Figure 2: JoaquinTrack – 126-hour track forecast from various hurricane models and configurations shows a significant benefit from the uniform-3km NMM-B configuration (red).

As can be seen, the uniform-3km NMM-B run greatly outperformed the other models. This result prompted us to perform a thorough evaluation of the impact of nesting by running several hurricane cases using uniform-3km and nested NMM-B. Such was the basis for our presentation at the AMS conference on tropical meteorology this year. The RMS track error from all cycles of hurricane Isaac can be seen in Figure 3. There is a clear advantage in track forecast performance for the uniform-3km configuration.

We are currently evaluating the regional nature run and will soon start simulating observations and running our next generation of OSSEs. The lack of nests will ease the process of simulating observations. The fact that this domain is larger than the one in our current nature run will ensure greater coverage. This is particularly important since the HWRF domain has recently increased in size.

Research Performance Measure: We anticipated that this work could take up to a year to complete, so it is on track. It included two major contributions that made it difficult to predict a precise timeline. First, NMM-B had never been used with grids as large as 5000x2500 points, as was required for the uniform-3km basin scale forecast. Also, GEOS-5 model forecasts had never been used to initialize NEMS-based forecast models.

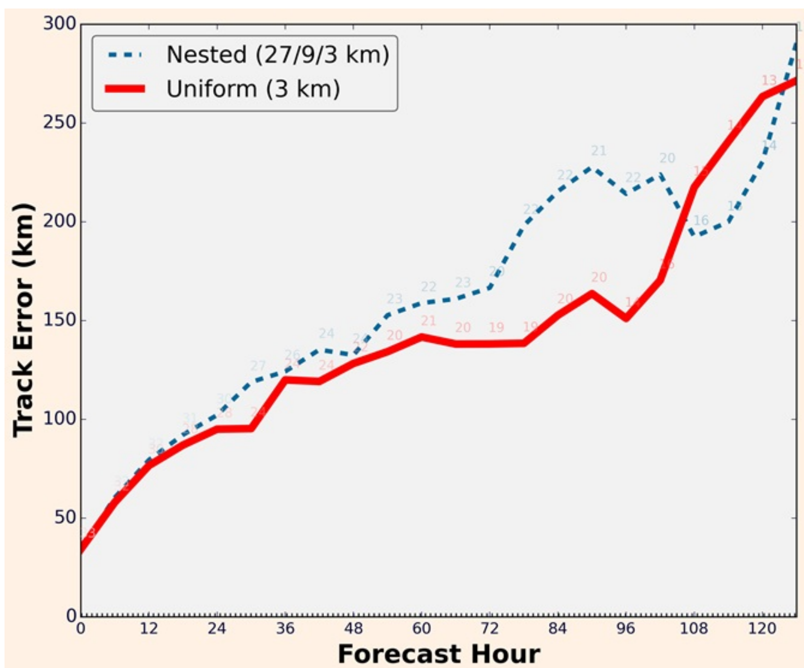

Figure 3: IsaacTrackRMSE – RMS errors of hurricane track from 41 cycles of 126-hour forecasts of Hurricane Isaac, using nested and uniform-3km model configurations.

Reanalysis of the Atlantic Basin Tropical Cyclone Database in the Modern Era

Project Personnel: S. Delgado and B. Moses (UM/CIMAS)
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 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* (*Primary*)

***Goal 3*:** Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts* (*Secondary*)

NOAA Funding Unit: OAR/AOML/HRD
NOAA Technical Contact: Molly Baringer

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 and subtropical cyclones. 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. 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.

Reanalysis of all Atlantic tropical cyclones in 1964, 1966, 1968 and 1969 are complete. We expect to have 1967 done by the end of June. A summary of significant results since July of 2015 follows:

The hurricane season of 1966 was active with several long-lived tropical cyclones. The season also had an early start, with at least (pending complete reanalysis) five tropical cyclones before August. Hurricane Alma formed in early June and made landfall in the Florida panhandle. The hurricane also struck the westernmost part of the Florida Keys where originally in HURDAT had reached a peak intensity of 110 kt, but this has been reduced to 100 kt. Becky, Dorothy and Lois were small hurricanes in the north

Atlantic that had extratropical origins. Faith was a classic Cape Verde hurricane, forming close to the western coast of Africa and recurving east of the United States. Faith also caused damages in Norway and other parts of northern Europe as a potent extratropical cyclone. Inez was also a long-lasting hurricane that formed east of the Lesser Antilles and struck southern Florida before a final landfall in Mexico. Finally, Judith was a weak tropical cyclone east of the Lesser Antilles that was upgraded to a tropical storm and an intensity estimate made based on satellite images, before the reconnaissance aircraft investigated the storm. This may have been the first time that satellite images were used to upgrade and estimate the intensity of a tropical cyclone. Previously, satellite images had been used to complement the information received from ships and reconnaissance aircrafts.

The 1967 hurricane season was below average, but similar to 1960 and 1992, it had an intense and deadly hurricane. Hurricane Beulah crossed the Caribbean Sea and Gulf of Mexico making landfall in Hispaniola, the Yucatan peninsula and near the Mexico-Texas border. The main development region between Africa and the Lesser Antilles was quite active, with the formation of six tropical cyclones. Doria was a long-lasting hurricane near the east coast of the United States that made landfall in the mid-Atlantic as a tropical storm on a rare southward track. Fern quickly intensified in the Bay of Campeche but weakened to a tropical storm before making landfall in western Mexico. Edith was a weak tropical storm that formed east of the Lesser Antilles and dissipated over the eastern Caribbean Sea. Ginger was a rare tropical storm that formed between Africa and the Cape Verde Islands and moved northward, quickly weakening over the cooler waters. Chloe was a long-lived Cape Verde hurricane that remained over the ocean until impacting France as a weak extratropical cyclone. Arlene was an early season Cape Verde system that reached hurricane intensity over the north Atlantic and did not affect land. Heidi and the non-developing tropical depressions in HURDAT are still pending reanalysis.

Figure 1: Satellite image of Hurricane Gladys on October 17, 1968 over the eastern Gulf of Mexico, captured by the NASA Apollo 7.

The 1968 hurricane season was about average with most of the tropical cyclone activity developing over the western Atlantic. Hurricanes Abby and Gladys and Tropical Storm Candy made landfall in the United States. The hurricane season had an active start with three tropical cyclones developing in June. Dolly developed near South Florida but turned to the northeast and passed close to the Outer Banks as a minimal hurricane. Tropical Storm Edna was the only tropical cyclone to develop between Africa and the Lesser Antilles, and was never a threat to land. Frances was a weak tropical storm that developed north of the Bahamas and moved away from the United States, briefly threatening Bermuda. HURDAT originally indicated that a subtropical cyclone formed over the western Atlantic in September. The data available suggests that the system was a hurricane and this is one of the most significant changes for this season. A couple of new tropical storms were added and the most significant impacted New England, but the damage was minimal. 1968 is one of the few seasons on record not to feature a major hurricane.

The 1969 hurricane season was one of the most active seasons on record, but similar to 2004, the first named storm did not develop until late July. Many of the tropical cyclones were long-lived and most stayed over the ocean. Camille was the most intense tropical cyclone of the season, making landfall in the United States as a category 5 hurricane causing significant damages and deaths. Two named tropical cyclones made landfall in Caribbean. Francelia was a category 2 hurricane when it hit Belize in early September and Martha was an atypical hurricane, forming in the southern Caribbean Sea in November. Martha was the first tropical cyclone on record to hit Panama. Hurricane Laurie formed in the western Caribbean Sea and reached peak intensity in the central Gulf of Mexico, where it made a clockwise loop and weakened before impacting southern Mexico. Hurricane Gerda formed near South Florida and accelerated to the northeast reaching major hurricane intensity off Cape Cod before hitting eastern Maine as a weakened system. Hurricane-force winds were experienced in Nova Scotia but the damages were minor. Hurricane Holly formed east of the Lesser Antilles but dissipated before being a threat to land. Inga was one of the longest-lived cyclones on record, forming east of the Lesser Antilles and dissipating northeast of these islands. Five systems of at least tropical storm intensity formed while Inga was still active, four dissipating before Inga died. Kara formed north of the Greater Antilles and moved toward the western Atlantic. Satellite and synoptic data suggests that it acquired subtropical characteristics between the United States and Bermuda. The system intensified into a hurricane as it moved away from land into the north Atlantic. Jenny and a subtropical storm that developed in the eastern Gulf of Mexico were the only systems with winds of at least tropical storm intensity to impact Florida. The subtropical Atlantic was very active this year with the development of five tropical cyclones, two reaching hurricane intensity.

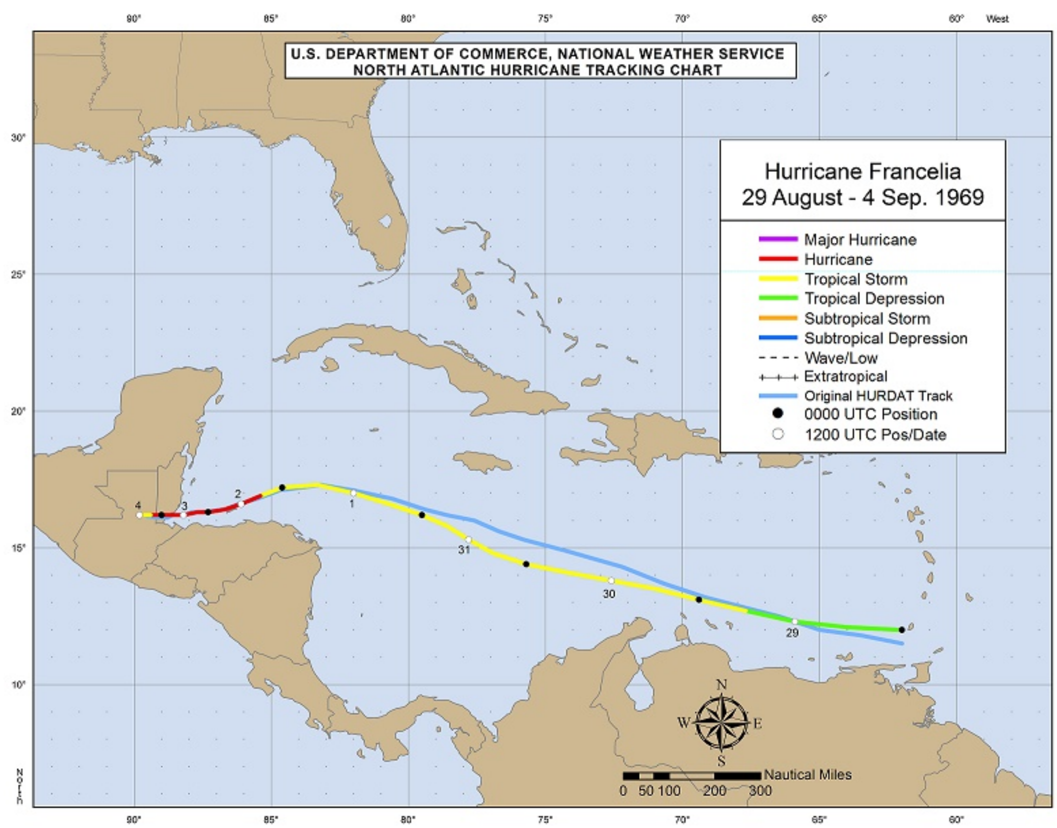

Figure 2: Original and revised track of Hurricane Francelia of 1969, illustrating changing assessments of track due to reanalysis based on the data available.

Mr. Brenden Moses is a full-time undergraduate student at Miami-Dade College and he is assisting in the hurricane database reanalysis project. Mr. Moses' responsibilities include developing hurricane databases, providing website design for the project, and conducting meteorological analyses of the storm' positions, intensities, and structure. He also took the lead on the 1964 hurricane season revisions. The 1964 season operationally featured 12 tropical storms, 6 hurricanes, and 6 major hurricanes. Following reanalysis, a new storm was added; the revised total for the season is 13 tropical storms, 7 hurricanes, and 5 major hurricanes—an above-average year. The most notable storms were Hurricane Cleo, a long-lived major hurricane that caused tremendous loss of life in Haiti and significant damage in the Miami metropolitan area, and Hurricane Dora, another long-lived major hurricane that caused widespread flooding in northern Florida and produced hurricane-force winds in Jacksonville, Florida–the first known instance of such on record in the city.

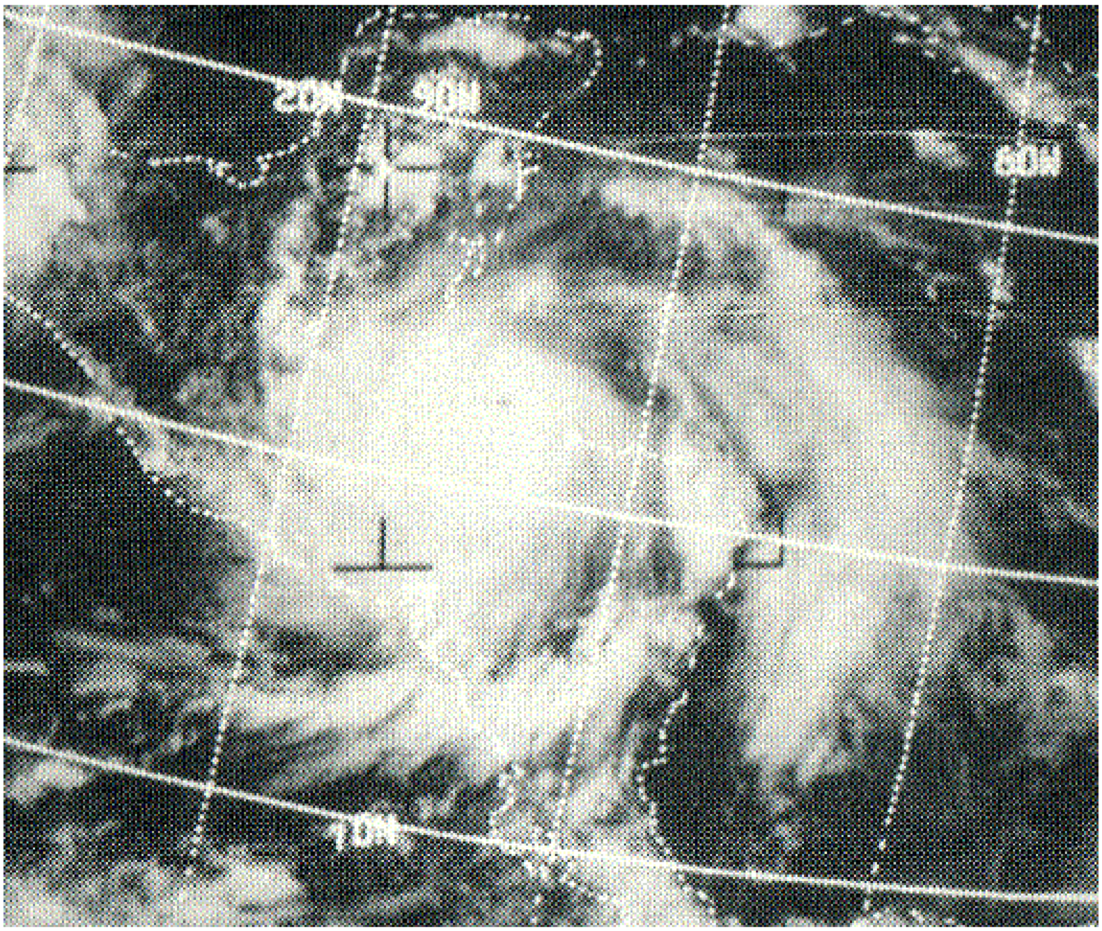

Figure 3: ESSA IX showing Hurricane Francelia on September 2, 1969 affecting the Bay Islands of Honduras on its way to Belize.

Research Performance Measure: The reanalysis of the 1967 hurricane season should be complete in June. By the end of 2016, we are expecting to have completed the reanalysis of the hurricane seasons of 1970-1972. The amount of data available is incrementally growing as we get closer to the present, thus it is taking longer to reanalyze each individual tropical cyclone.

Developments in the High-Impact Weather Prediction Project (HIWPP)

Project Personnel: X. Zhang and S. Diaz (UM/CIMAS)
NOAA Collaborators: S.G. Gopalakrishnan and T. Quirino (AOML/HRD); T. Black, M. Pyle, Q. Liu, W. Liu and V. Tallapragada (NCEP/EMC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To create a multi-scale hurricane prediction system working at cloud-resolving resolution providing improved predictions of tropical cyclones; and to improve our understanding of the processes that influence from these devastating storms through better representation of the physical processes within the HWRF/NMMB under the NEMS framework.

***Strategy*:** To design a modeling system to operate at about 3 km resolution, capable of capturing tropical cyclone inner core processes as well as interactions with the large-scale environment, critical for improving track, intensity, rainfall and size predictions.

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: Molly Baringer

Research Summary:

As of the end of 2015, all major technical milestones of the HIWPP project have been achieved, excepting comprehensive testing and evaluation-- a task that is recommended to be merged with the on-going HNMMB R2O efforts at EMC (HNMMB is a potential replacement for the operational GFDL hurricane model). It should also be noted that there were few land-falling storms in the 2015, the seasons on which much of the developmental efforts were focused. The defined milestones and their respective dates of completion are shown in Table 1.

Table 1: Milestones of the HIWPP project and their completion date.

Milestone	Completed
✓ Configuration & Testing	Dec 2014
✓ HWRF Physics Transitions	Sept 2014
✓ Idealized Framework	April 2015
✓ HWRF Vortex Tracker	Jun 2015
✓ HWRF Vortex Initialization & Cycling	Dec 2015
Semi-Real-time Testing	On-going
Multi-Season Testing, Verification, Rainfall Evaluation	Postponed due to lack of HPC

The NMMB system for Hurricanes, "HNMMB", is a regional hurricane prediction model developed to fulfill the goals and requirements of the *Hurricane Nest Project*, a subcomponent of HIWPP. The system operates within the framework of the NOAA Earth Modeling System (NEMS), combining the dynamical core of the Nonhydrostatic Multiscale Model on the B-grid (NMMB) with hurricane-specific components adopted from the Hurricane Weather Research & Forecasting (HWRF) model. These components include a physics suite tailored for the hurricane problem, the HWRF storm-tracking algorithm, the HWRF vortex cycling and initialization routine for multiple storms, and the capability to model idealized tropical cyclones. The model currently operates at a resolution of 18 km for the fixed outer domain, with resolutions of 6 km and 2 km, respectively, for the storm-following, telescopic nested pairs. The system is version-controlled on the SVN repository, and is scripted to run from a single input file. An automated suite of advanced diagnostic tools is included, which is called at the completion of each forecast cycle and uploads plots, data, and other forecasting tools directly to the HNMMB website at 'www.storm.aoml.noaa.gov/hnmmb'.

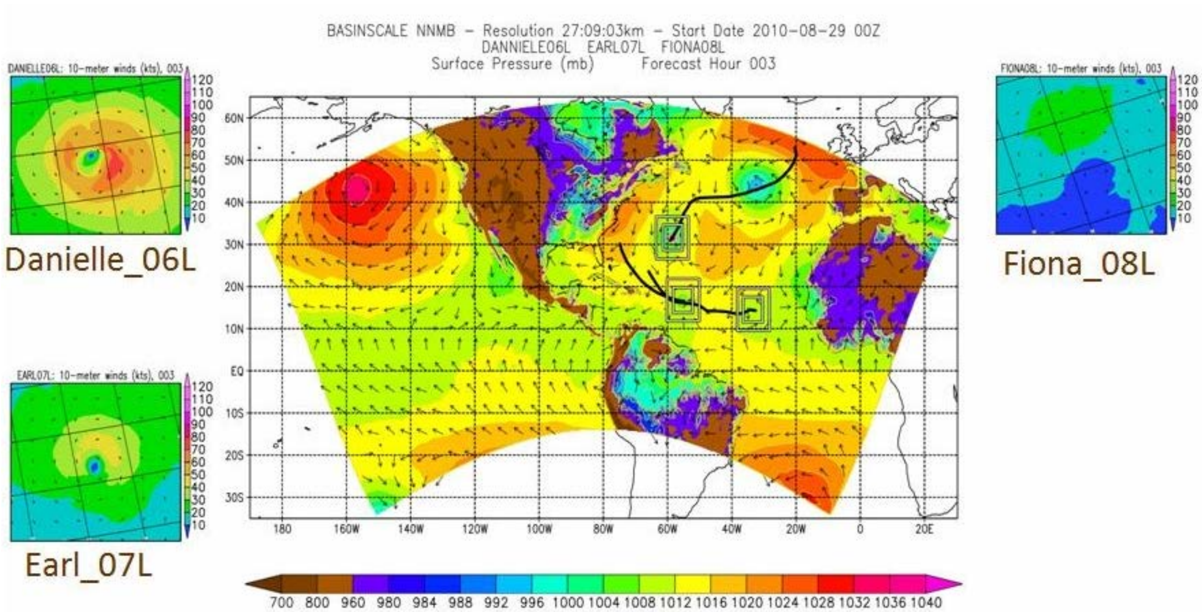

Figure 1: Plot of surface pressure and wind speeds from the region HNMMB model showing multiple nests for Hurricanes Danielle, Earl, and Fiona at 00z on Aug 28, 2010.

In addition to the regional model described above, a 'proof-of-concept' global model with multiple storm-following nests has also been achieved. With the global system, the HIWPP goal of a global-to-local scale hurricane prediction system operating at ~3 km resolution has been demonstrated and validated in a laboratory environment. Future advancements necessary for the HNMMB system to become operational include the addition of ocean coupling and data assimilation. Multi-season testing, verification, and rainfall evaluation are on-going at EMC.

Research Performance Measure: All objectives have been met or are on track. See details in Table 1.

Using NOAA UAS Assets and OSSE/DA Capabilities to Improve Sampling Strategies and Numerical Prediction of Tropical Cyclone Track, Intensity, and Structure

Project Personnel: J.P. Dunion, A. Aksoy, L. Bucci, H. Christophersen, B. Dahl, B. Klotz, K. Sellwood and J. Zhang (UM/CIMAS)
NOAA Collaborators: R. Atlas, S. Aberson and M. Black (NOAA/AOML)
Other Collaborators: L. Bosart and R. Torn (University at Albany-SUNY)

Long Term Research Objectives & Strategy to Achieve Them:

***Objectives*:** To support the NOAA Sensing Hazards with Operational Unmanned Technology (SHOUT) 2015 and 2106 hurricane field campaigns, evaluate the impacts of UAS in-situ and remote sensing observations that are collected during SHOUT on tropical cyclone analyses and forecasts, and investigate signals of the tropical cyclone diurnal cycle in model simulations.

***Strategy*:** Participate in SHOUT field campaign efforts by providing mission science and GPS dropwindsonde processing support, as well as designing flight tracks for the Global Hawk aircraft. Conduct Observing System Experiments (OSE) and Observing System Simulation Experiments (OSSEs) using data from Global Hawk field missions and utilizing NOAA/AOML/HRD's in-house HEDAS. Perform experiments using a version of the idealized Hurricane Weather Research and Forecasting (HWRF) simulation system to characterize the formation and evolution of the tropical cyclone diurnal cycle.

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 UAS Program
NOAA Technical Contact: Robbie Hood, NOAA UAS Program

Research Summary:

The NOAA UAS program successfully conducted its 2015 SHOUT hurricane field program and will utilize the Global Hawk Unmanned Aircraft System (UAS) again in 2016 to observe North Atlantic and possibly eastern North Pacific tropical cyclones (TCs). The Global Hawk will be equipped with multiple instrument platforms that include aircraft-deployed GPS dropwindsondes that measure temperature, pressure, wind, and humidity at a vertical resolution of 2.5-5 m, a microwave sensor for detecting 3-dimensional temperature, moisture and precipitation through the hurricane's upper-level cirrus clouds, and a dual frequency Doppler radar for detecting 3-dimensional winds in the hurricane environment. The project team has provided and will continue to provide a combination of on-site and remote mission science and real-time GPS dropwindsonde processing support during SHOUT Global Hawk missions and will also help design aircraft flight tracks that optimally sample the TC inner core and its surrounding environment. To address this latter effort, the project team is working with the NOAA Environmental Modeling Agency (EMC) to generate 80-member HWRF ensemble forecasts for TCs of interest during SHOUT. These forecasts will be used to calculate optimal GPS dropwindsonde target locations for various forecast lead times during potential periods when the GH would be flying. This output will be used to generate real-time analyses and made available to SHOUT mission scientists to plan Global Hawk flight patterns and GPS dropwindsonde sampling strategies.

The potential for UAS assets to improve hurricane analyses and forecasts is evaluated by investigating the impact of Global Hawk dropwindsondes for vortex-scale hurricane data assimilation in NOAA's Hurricane Ensemble Data Assimilation System (HEDAS). We first carried out some case studies. Two dates from Hurricane Edouard (2014) were chosen for these case studies. In the first case (15 September 0600 UTC), Global Hawk dropwindsondes provided exclusive inner-core observations, while in the second case (16 September 1800 UTC), Global Hawk dropwindsondes coexisted in the inner core with an extensive suite of observations from other aircraft yet remained somewhat exclusive in the near environment (Fig. 1).

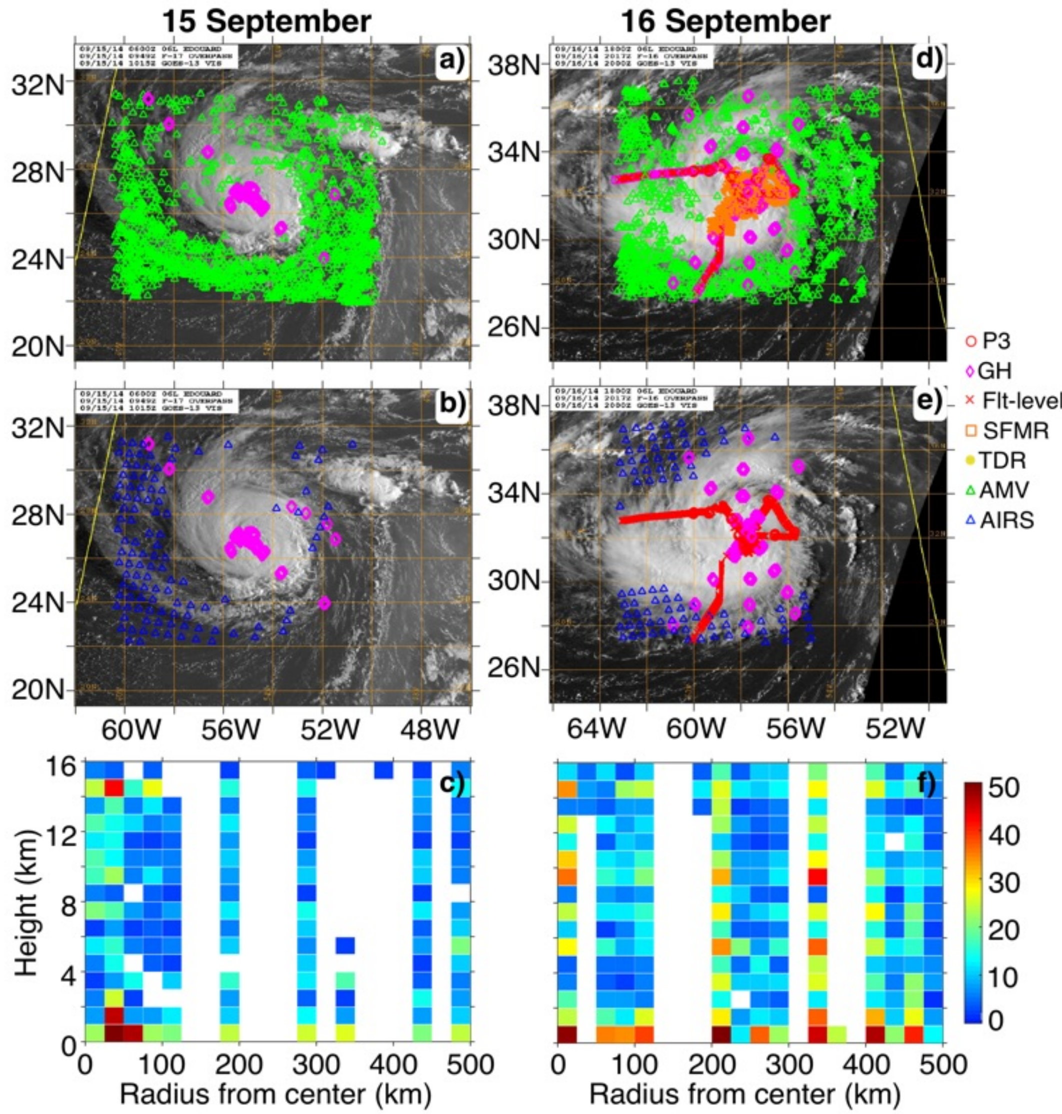

Figure 1: Spatial distribution of assimilated observations overlaid on visible cloud imagery for the experiment All (including all available observations) centered at 6 UTC on 15 September (left panel) and at 18 UTC on 16 September (right panel) for (a,d) wind observations and (b,e) thermodynamic observations. Visible imagery courtesy of Naval Research Laboratory, Monterey, CA. (c,f) Density distribution of the assimilated GH observations (purple diamonds in the top and middle panels) in a radius-height coordinate at every 25 km in radius and 1 km in height.

Large impacts are observed on model kinematic and thermodynamic analyses in the inner-core region of the storm on 15 September when Global Hawk dropwindsondes were assimilated. This leads to a better representation of the storm structure such as warm core anomaly, primary and secondary circulation, etc. Consequently, this contributes to a positive intensity forecast for the 15 September case (Fig. 2). Meanwhile, for the 16 September case, we notice that analysis increments from assimilating Global Hawk dropwindsondes exist both in the inner core and near the environment of the storm, although they are not as large in magnitude as the first case, as an extensive suite of observations from other aircraft and satellite retrievals may have already contributed to the improved analysis. Nonetheless, the assimilation of Global Hawk dropwindsondes leads to a consistent track improvement up to 5 days (Fig. 2). Our initial study presents promising results for incorporating Global Hawk to mitigate the possible observation gaps from NOAA P-3 or satellite observations (e.g., AIRS), and additional advantages even in the presence of satellite observations or reconnaissance observations.

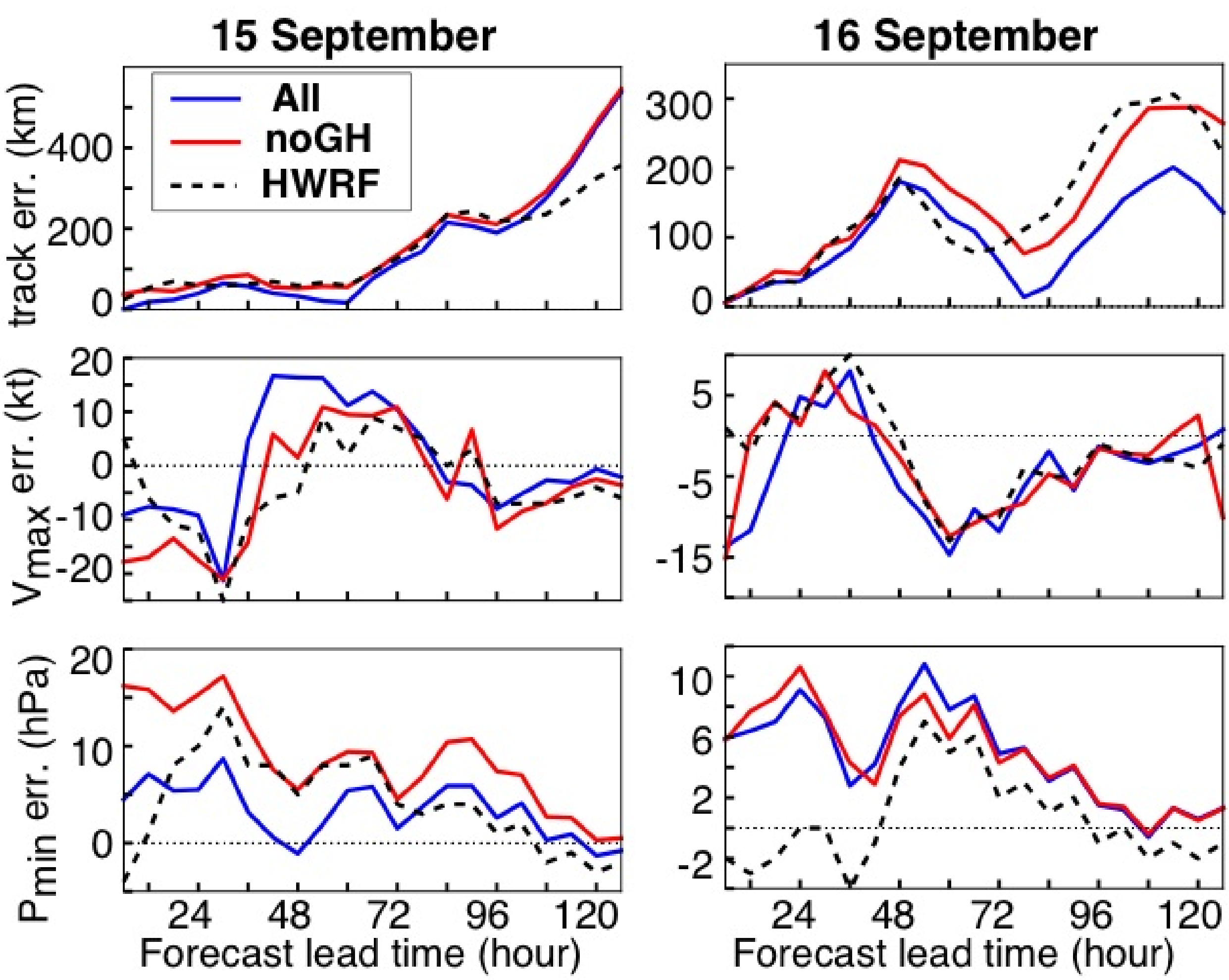

Figure 2: Track error (unit: km), the maximum sustained 10-m wind speed error (v_{max}, unit: kt), and the minimum sea level pressure error (P_{min}, unit: hPa) compared to the best track at every 6 hours from the 124-hour deterministic forecasts of the experiments All (blue solid lines) and noGH (red solid lines), and corresponding operational HWRF forecast (black dashed lines) at 6 UTC 15 September (left panel) and 18 UTC 16 September 2014 (right panel).

We also assessed the impacts of assimilating Global Hawk remote sensing observations, and in particular, retrievals from the Scanning High-resolution Interferometer Sounder (SHIS) instrument. This is an instrument that measures emitted thermal radiation at high spectral resolution for infrared radiation and is similar to the AIRS instrument on NASA's Aqua satellite but capable of sampling at much higher spatial resolution. One case study at 0600 UTC on 12 September 2014 of Hurricane Edouard demonstrates that the assimilation of SHIS retrievals alone leads to similar impacts as assimilating AIRS retrievals and Global Hawk dropwindsonde observations combined, i.e., a consistent positive impact on the track forecasts (Fig. 3). The assimilation of AIRS, Global Hawk dropwindsonde thermodynamic observations and SHIS retrievals together shows the largest impacts on both track and intensity forecasts (Fig. 3), as well as initial analysis fields. This initial assessment of the remote sensing observations onboard Global Hawk suggests that targeting with UAS or recon aircraft should be designed to complement the coverage of available satellite data, which could potentially enhance the impact substantially in some cases. These results also demonstrate the importance of the availability of high-resolution thermodynamic observations in the hurricane inner core.

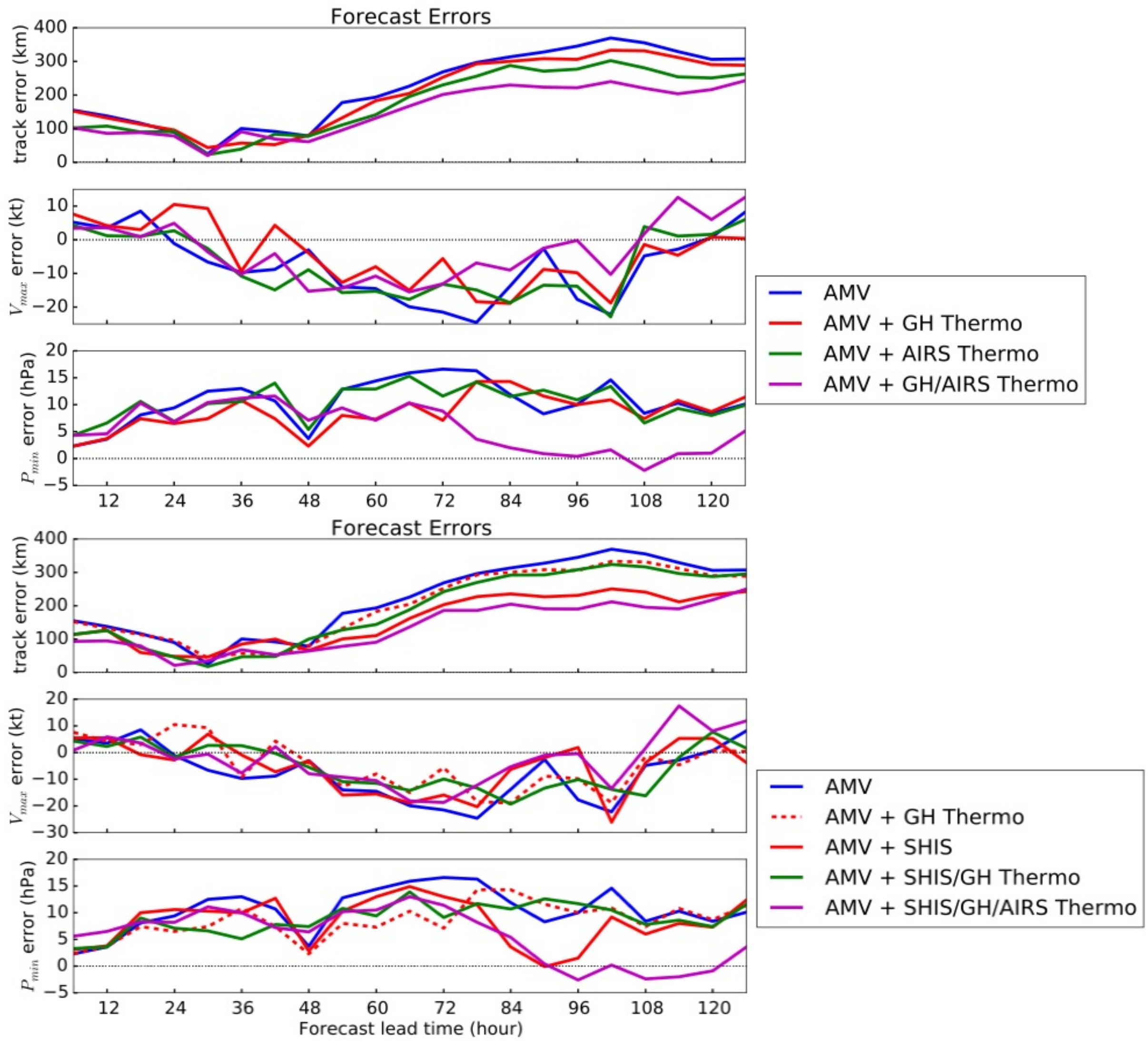

Figure 3: Deterministic forecast errors compared to the best-track at 6 UTC on 12 September, 2014.

HEDAS was also utilized to evaluate the impact of assimilating observations taken using UAS technology on TC surface wind structure. These types of surface wind analyses have the potential to provide important information about the strength, extent and location of the strongest winds within a TC, which can then be used for planning, safety, and insurance mitigation purposes. Two observing system experiments (OSEs) were conducted, one for a well observed storm and another when the primary source of observations was the NASA WB-57 being flown by the Office of Naval Research's TC Intensity (TCI) field campaign. The second experiment was the first time that high-altitude Yankee dropwindsondes and surface wind observations from the Hurricane Imaging Radiometer (HIRAD) have been assimilated into a numerical model. For this purpose, the observation processing capability within HEDAS was extended to be able to utilize these new observation types.

For each experiment two analyses were created, one in which only the conventional data were assimilated and a second where both conventional and UAS data types were assimilated. For the first experiment, the case selected was 2014 Hurricane Edouard verifying at 1800 UTC on 16 September. Both HEDAS analyses for this case capture the secondary wind maxima, the significant wind radii and eye diameter well. However, the addition of UAS dropsondes provides a better analysis of the secondary eye-wall structure seen in the observations (Fig. 4). Although neither analysis contains wind speeds as high as the officially reported intensity at this time, they are consistent with the maximum of the observed winds and are also consistent with the drop in intensity, which is expected during an eyewall replacement cycle. In this case, HEDAS appears to do a good job of representing the state of the vortex at the time it was observed. Although there were plentiful conventional observations at this time, there was still additional benefit derived from including the UAS observations.

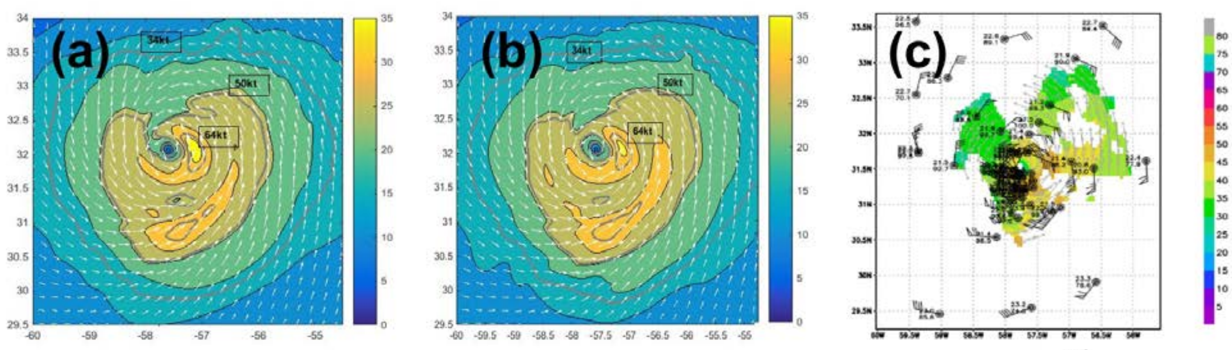

Figure 4: HEDAS surface wind speed analysis for Hurricane Edouard (2014). (a) Conventional observations only; (b) conventional observations plus Global Hawk dropsondes; and (c) P-3 Doppler radar and dropwindsonde observations at 500 m. This is the lowest level for which radar data are available.

The second case, 2015 Hurricane Joaquin, verifying at 18 UTC on 02 October, is one for which unmanned aircraft have the potential to provide the greatest benefit. At this time none of the NOAA aircraft were available, Joaquin was a category-3 major hurricane and the forecasts differed greatly between the operational models. In this case the location of the storm over the many small islands of the Bahamas and the limited number of independent observations made evaluating the surface structure more difficult. Comparing the two HEDAS analyses above the surface at 500 m with the information given by U.S.A.F. vortex messages and with the NHC best track report, we can see that the addition of the UAS observations produces a more realistic wind field than the conventional data alone (Fig. 5). Without these observations the storm is too large, too strong and does not have the wind maximum in the correct location. The official maximum wind estimate was 110 kt while the analysis without NASA WB-57 observations has winds in excess of 135 kt, a difference of two Saffir Simpson scale categories. The analyses which included the TCI observations has maximum wind speeds of 98 kt which keep it a

category-2 storm, which is consistent with the maximum observed winds of 107 kt on the eastern side. Additionally, the analysis with the TCI data produces a smaller storm, although the radius of maximum wind is still greater than the 15-km value given in by the best track. Both analyses contain the observed eastward extension of the 35-kt wind radius. Although this is only a single case it suggests that both the HIRAD and Yankee dropwindsonde observations are capable of adding value to the analysis of TC winds within the HWRF model.

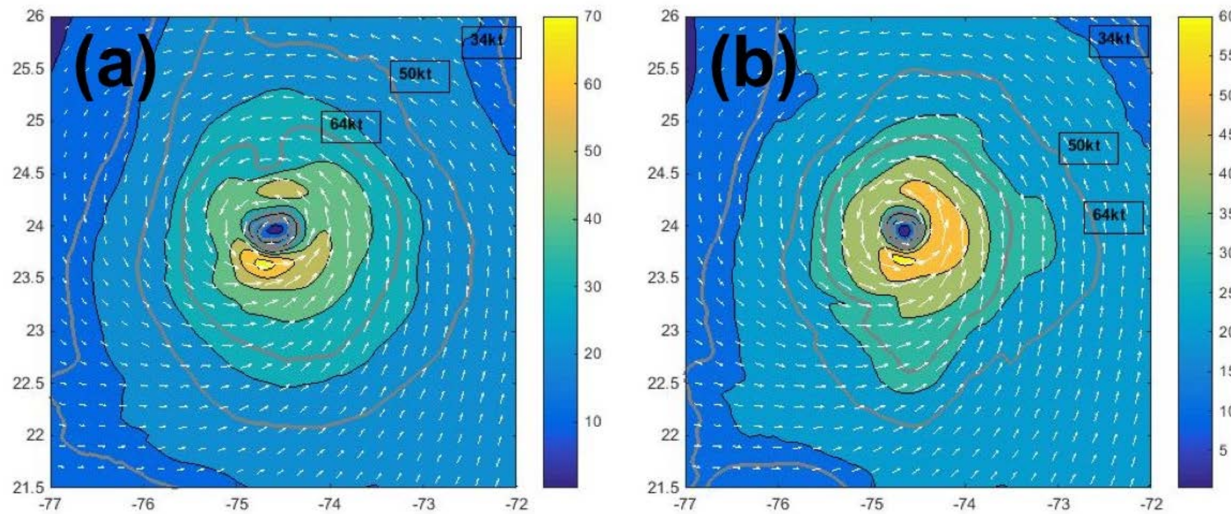

Figure 5: HEDAS 500-m wind speed analysis for Hurricane Joaquin (2015). (a) Conventional observations only; (b) conventional observations plus TCI dropwindsondes and HIRAD surface winds.

Observing system simulation experiments (OSSEs) are also being conducted to assess how altering the Global Hawk sampling pattern for a given mission impacts the forecast after the data are assimilated. The data are generated by sampling the Nolan et al. (2013) nature run with the aircraft simulation code developed at AOML and then assimilated with HEDAS. The first of these experiments compares two different Global Hawk flight tracks that occur in conjunction with the flight of a NOAA P-3 aircraft. Adding Global Hawk dropwindsondes improves the structure and intensity of the storm in the final analysis after data assimilation compared to using NOAA P-3 dropwindsonde, flight-level, and SFMR data alone (Fig. 6). The location of the improvement was shown to be sensitive to the placement of the dropsondes, which depends both on the flight pattern itself and the timing of the flight relative to the window during which data are assimilated into the model. The impact of shifting the timing of the flight pattern is currently under further investigation.

As part of the assessment of the TC diurnal cycle, a version of an idealized HWRF simulation system was modified to give the user control over the development and progression of the diurnal cycle. This idealized model framework incorporates several standard features, including the GFDL radiation scheme and three nested domains with 27, 9, and 3 km horizontal resolution, respectively. Three simulations were executed, which all experienced very weak vertical wind shear (1.4 m s^{-1}), high SSTs (30.9 °C), and had an initially strong but slowly moving (west at 2.1 m s^{-1}) category 3 hurricane with radius of maximum wind of 44 km. Our experiments include a control simulation that is allowed to run for seven days with no modifications to the standard radiation setup, a day only experiment that keeps the solar zenith angle constant at 1600 UTC (1200 local time, 20°N, 75°W), and a night only experiment that keeps the solar zenith angle constant at 0400 UTC (0000 local time).

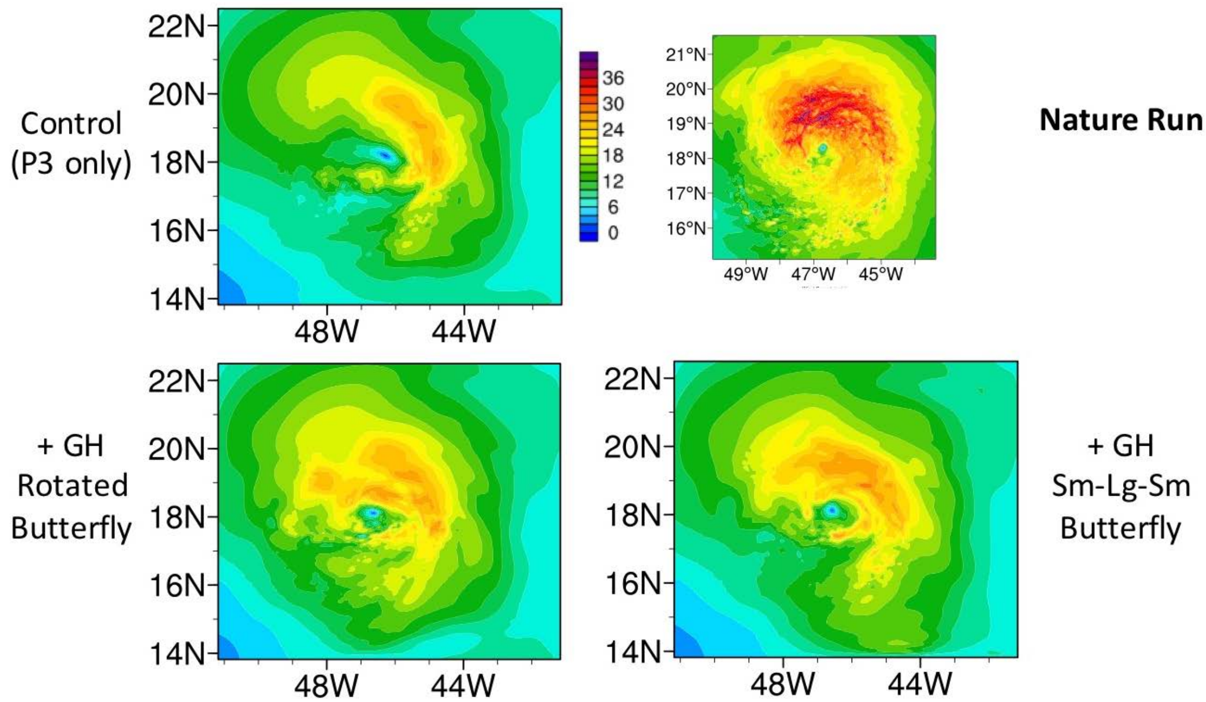

Figure 6: HEDAS surface wind speed analyses are compared when only P-3 observations are assimilated (Control) versus two types of Global Hawk flight patterns (rotated butterfly and small-large-small butterfly). For reference, the plan view of surface wind speed in the Nature Run (truth reference) valid at the same time is also shown.

The diurnal cycle appears in several fields within the model, one of which is the upper-level radial wind. Examining this field for the night and day only experiments, which are shown in Fig. 7, several differences are clearly depicted. With the night only experiment (left panel), the outflow is weakened considerably, especially near the end of the simulation period. The hurricane outflow slightly intensifies around 96 hours, but overall, this pattern is not conducive for any further intensification. For the day only experiment (right panel), the diurnal signature is again not present, but the radial wind pattern remains fairly constant in magnitude throughout the forecast period. In theory, a fairly strong outflow signature aloft would be conducive for intensification or at least maintenance of the vortex, but the intensity trace (not shown) indicates that the presence of a diurnal cycle provides the best mechanism for this process.

Research Performance Measure: This project is in the year-2 phase of a proposed 3-year effort. Objectives that focus on the providing SHOUT hurricane field program support were successfully completed in 2015 and are planned for 2016. In 2015, real-time objective guidance using HWRF model ensemble information was successfully implemented to help plan NOAA SHOUT Global Hawk flight tracks and GPS dropwindsonde sampling strategies in and around TCs and improve model forecasts of storm track and intensity. This effort will be also carried out again during the 2016 SHOUT hurricane field campaign. Studies of the formation and evolution of the TC diurnal cycle have begun and will continue during the year-2 and 3 phases of this project.

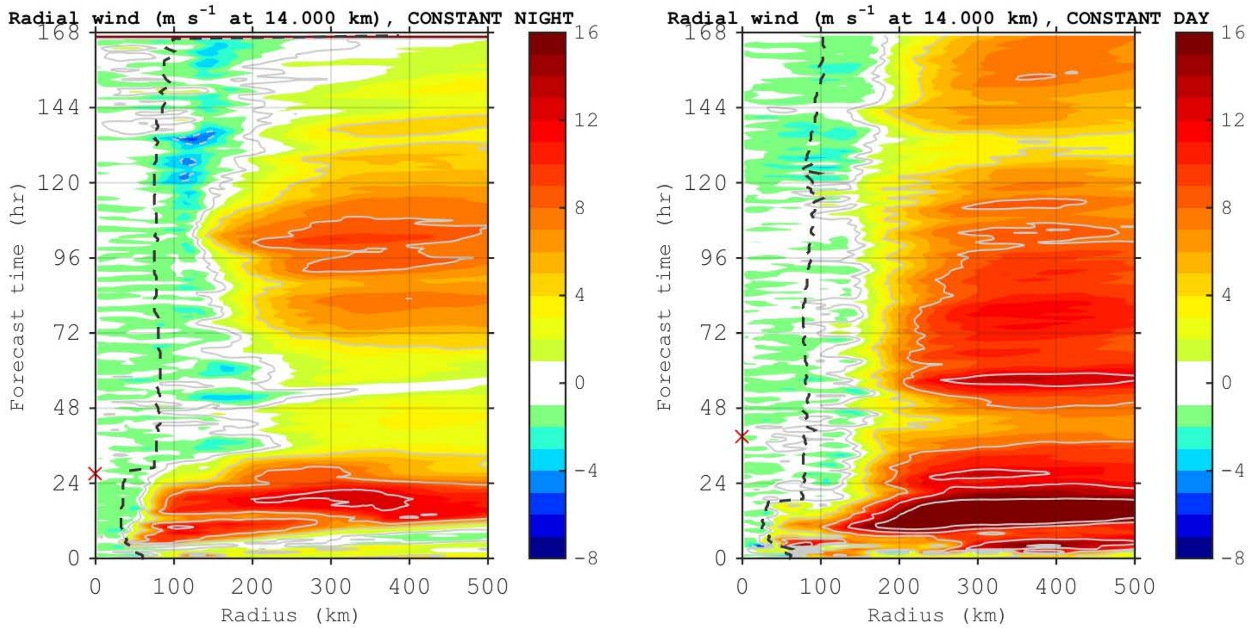

Figure 7: The 14 km radial wind (m s^{-1}) in the experiments for night only (left) and day only (right) are provided as a function of radius (km) and forecast time (hours). The red 'X' indicates the hour at which the solar zenith angle was set to a constant value. Positive values indicate winds moving away from the vortex center.

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Improvement to the Tropical Cyclone Genesis Index (TCGI)

Project Personnel: J.P. Dunion (UM/CIMAS)
NOAA Collaborators: J. Kaplan and P. Leighton (NOAA/AOML)
Other Collaborators: A. Schumacher and K. Musgrave (Colorado State University/CIRA); J. Cossuth (Naval Research Laboratory-Monterey)

Long Term Research Objectives & Strategy to Achieve Them:
***Objectives*:** To implement improvements to the Tropical Cyclone Genesis Index (TCGI) so that it can continue to provide real-time guidance for the likelihood of tropical cyclone formation to forecasters at the NOAA National Hurricane Center (NHC).
***Strategy*:** Collaborate with forecasters at the NOAA National Hurricane Center to implement improvements to TCGI and test the updated version of the model in a semi-operational environment.

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 Joint Hurricane Testbed
NOAA Technical Contact: Christopher Landsea, NOAA/JHT

Research Summary:

The main goal of this project is to implement improvements to the Tropical Cyclone (TC) Genesis Index (TCGI) that was transitioned to operations at NOAA NHC in October 2014. TCGI is a disturbance-following scheme designed to provide forecasters with an objective tool for identifying the 2- and 5-day probabilities of TC genesis in the North Atlantic. Project objectives include expanding the TCGI Atlantic database of developing and non-developing storms to include the years 2001-2014, creating a new Pacific TCGI database of developing and non-developing storms, identifying new predictors to test in both the Atlantic and Pacific versions of TCGI, deriving a real-time Pacific version of TCGI, and developing a real-time graphical version of TCGI (Fig. 1).

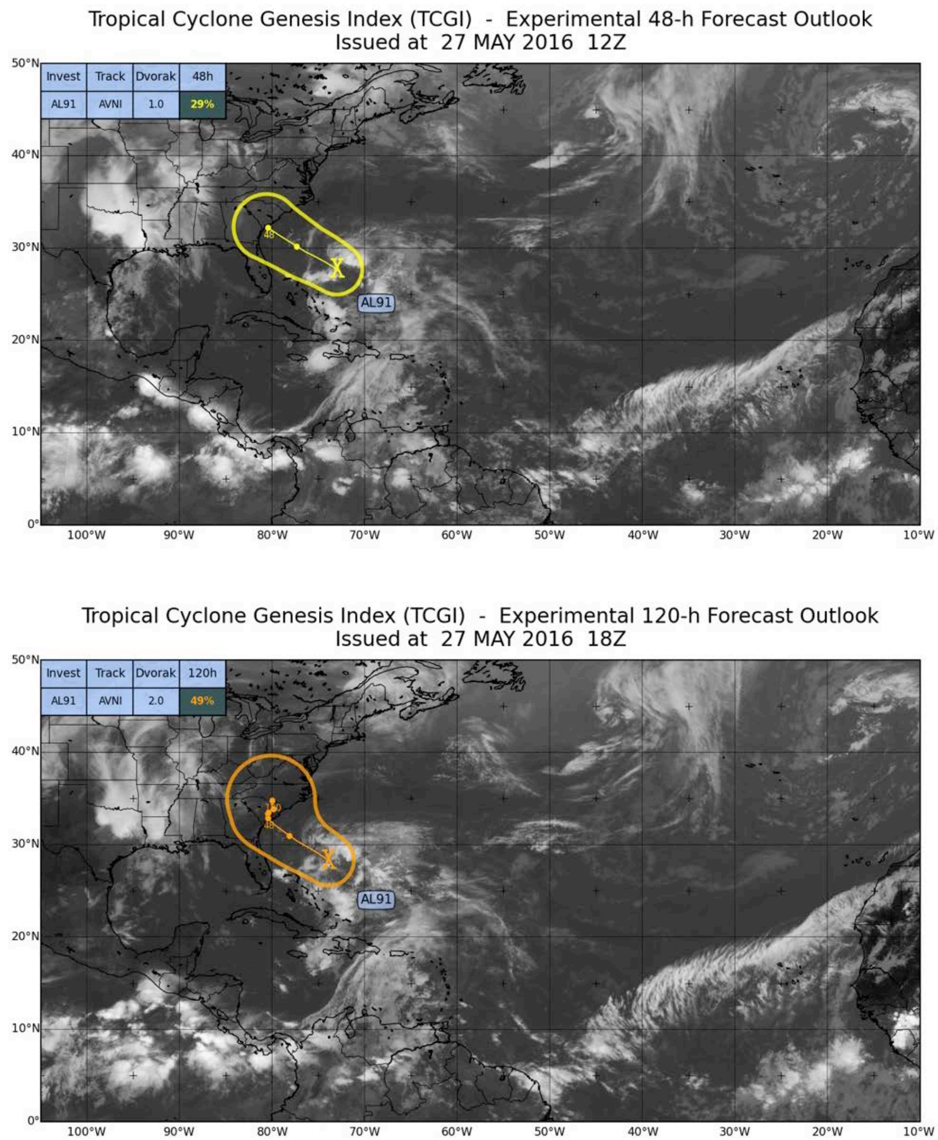

Figure 1: TCGI experimental graphical forecast showing 2016 Atlantic tropical disturbance AL91 on 27 May at 1200 UTC. The "Xs" mark the initial location of AL91 at the forecast time, while the curved lines show the forecast track at 24-hr increments and are colored according to the TCGI genesis probabilities (using NOAA NHC's operational color scheme). The legend shows the active tropical disturbances and the (top) 2-day and (bottom) 5-day TCGI forecast probabilities for AL91.

Research Performance Measure: This project is in the year-1 phase of a proposed 2-year effort and deliverables are on track for the year-1 period. The project team presented an update of the proposed and planned deliverables at the 2016 *Tropical Cyclone Operations and Research Forum (TCORF), the 70th Interdept. Hurr. Conf.*, Miami, FL in March 2016 and submitted a mid-year report to NOAA in April 2016. The team has completed the expansion of the TCGI Atlantic database of developing and non-developing storms to include the years 2001-2014, created a new Pacific TCGI database of developing and non-developing storms which will permit the planned improvement (development) of the Atlantic (Pacific) versions of TCGI, and has developed an experimental graphical version of TCGI that is running in real-time. Ongoing year-1 efforts include identifying new predictors to test in both the Atlantic and Pacific versions of TCGI and deriving a real-time Pacific version of TCGI.

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Addressing Deficiencies in in Forecasting Tropical Cyclone Rapid Intensification in HWRF

Project Personnel: J. Zhang (UM/CIMAS), H. Chen (UM/CIMAS), and D.S. Nolan (UM/RSMAS)
NOAA Collaborators: R.F. Rogers (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** The overall object this project is to evaluate and improve the model performance of the HWRF model in forecasting rapid intensification (RI) of tropical cyclones.
***Strategy*:** To achieve this objective, we will focus on: (1) to identify key physical processes associated with RI using HWRF forecasts and the hurricane nature runs; (2) to quantitatively evaluate deficiencies and biases in inner-core structure and environmental conditions associated with RI forecasts by the HRWF model.

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:
Improving the intensity and track forecast of TCs undergoing RI is important because underprediction of RI could lead to a heavy toll of human lives and cause tremendous financial loss, especially if RI takes place shortly before a TC makes landfall on a heavily populated coastal city. However, forecasting RI has long remained a challenge because of the lack of understanding of the processes underlying RI and the deficiency in hurricane models to reproduce these processes. The objective of this project is to address deficiencies in forecasting RI by the HWRF model. This project emphasizes the use of the HWRF ensemble forecast product from EMC, and airborne flight-level, dropsonde and Doppler radar data to pinpoint the deficiencies and improve the performance of the operational HWRF model.

Cases are selected from the retrospective simulations using the HWRF model in three groups: 1) HWRF captured RI (*Hit*), 2) HWRF missed RI (*Miss*), and 3) HWRF predicted RI that did not occur (*False Alarm*). Cases in group 1 (*Hit*) with substantial aircraft observations are analyzed to identify important processes underlying RI (Fig. 1). The HWRF ensemble forecasts are also analyzed to document key physical processes associated with RI (Fig. 2). Cases in groups 2 (*Miss*) and 3 (*False Alarm*) are analyzed in comparison with the findings learned through analyzing cases in group 1 in order to identify deficiencies in the simulated multi-scale structures. Model errors believed to contribute to these deficiencies will be identified and reduced, with the goal of producing improved multi-scale structures and better forecasts of RI. Composite analysis of the HWRF forecasts with different physics setups is also conducted to investigate the impact of model physics on RI forecasts (Fig. 3). Feedbacks are sent to HWRF model developers for improvement of the model physics. The result from this project led to improvement in the boundary layer parameterization scheme in HWRF.

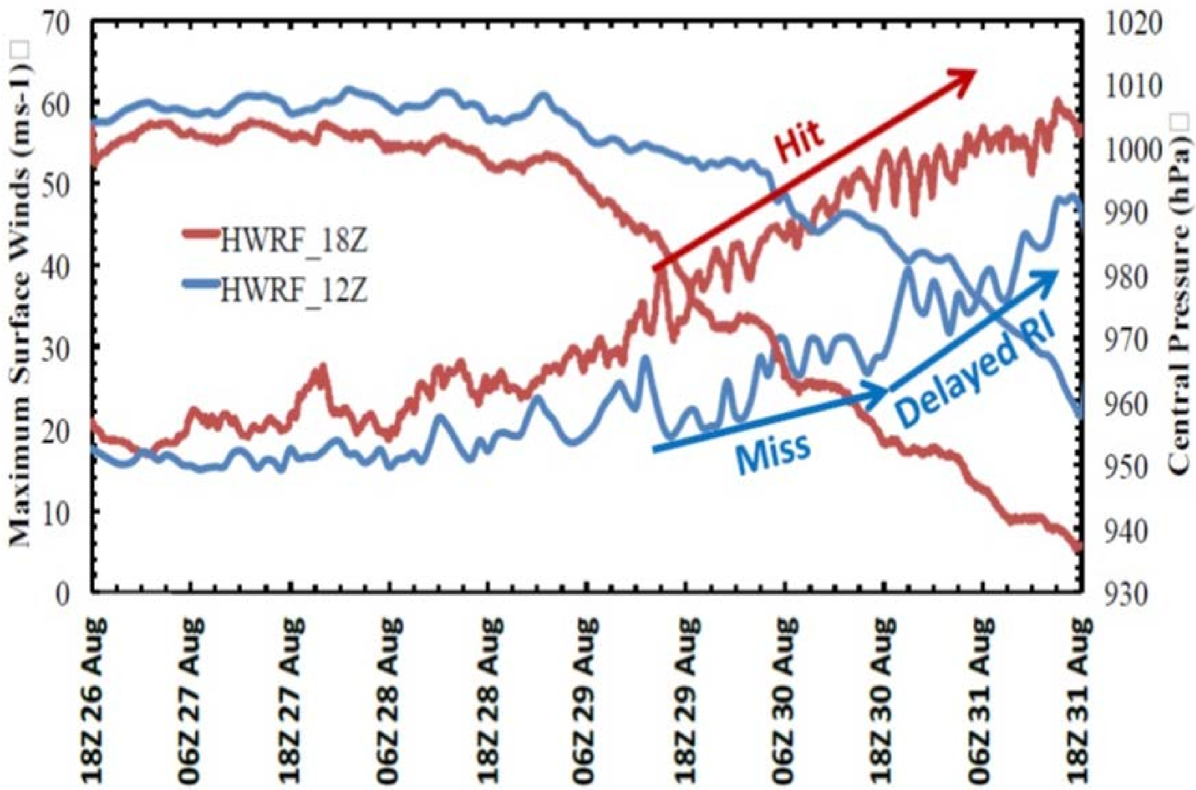


Figure 1: Time series of minimum central pressure and maximum 10-m winds for the Hit (i.e., 18 UTC 26 August initial time; red) and Miss (i.e., 12 UTC 26 August initial time; blue) HWRF forecasts.

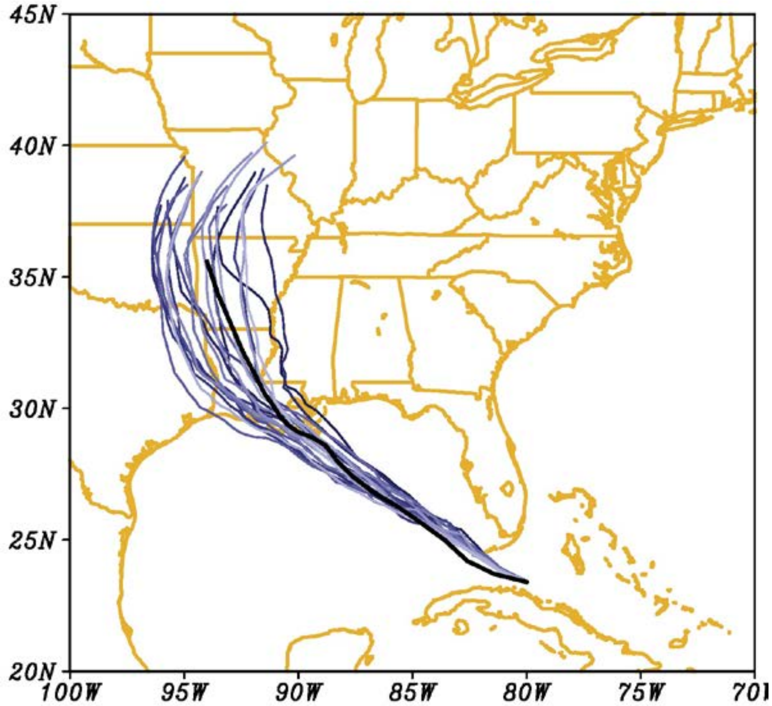


Figure 2: Storm tracks from HWRF ensemble forecast of Hurricane Isaac (2012).

Research Performance Measure: The program is on schedule. Three peer-reviewed articles have been published in *Monthly Weather Review* and *Weather Forecasting*.

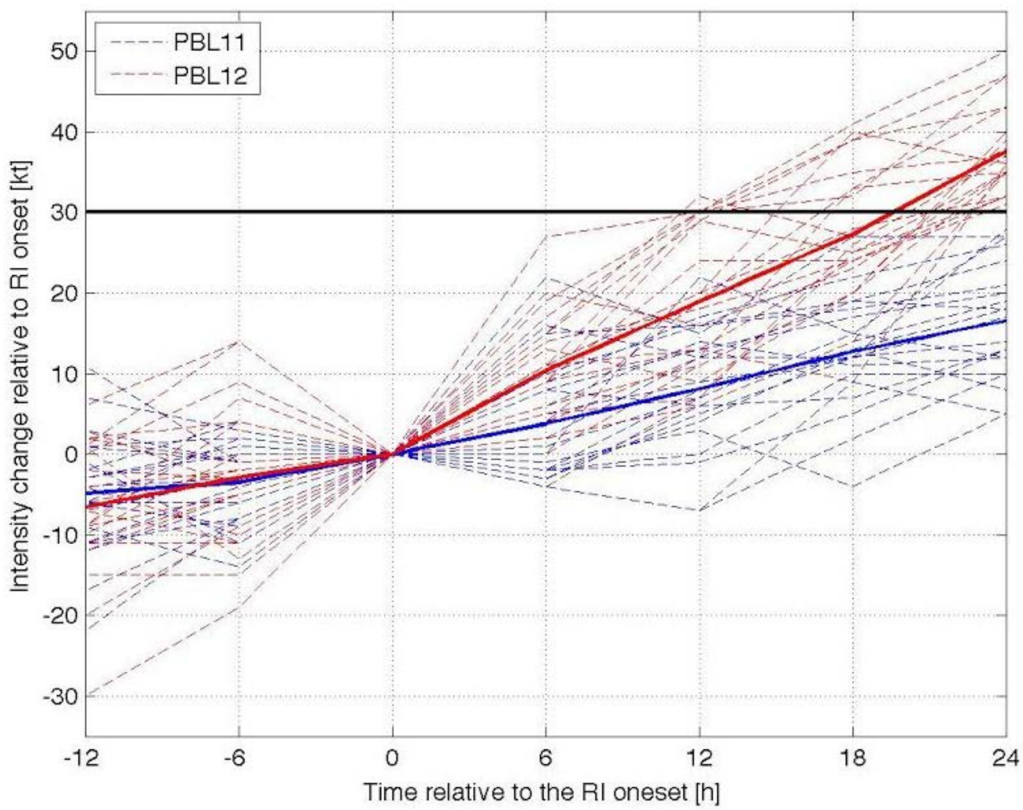


Figure 3: Plot of intensity change in kt for PBL11 (blue) and PBL12 (red) HWRF forecasts as a function of time relative to the onset of RI events that are seen in PBL12 not in PBL11. Note that the boundary layer vertical diffusion in HWRF was upgraded based on aircraft observations for PBL12.

Near-Automation of Real-Time Airborne Radar Analysis Onboard NOAA Aircraft

Project Personnel: S. Otero (UM/CIMAS)
NOAA Collaborators: J. Gamache and S. Murillo (NOAA/AOML).

Long Term Research Objectives & 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 and the National Weather Service in real-time.

CIMAS Research Theme:

***Theme 2*:** Tropical Weather

Link to NOAA Strategic Goals:

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

NOAA Funding Unit: OAR/AOML/HRD
NOAA Technical Contact: Molly Baringer

Research Summary:

Airborne Doppler radar has been on the NOAA WP-3D aircraft since 1981. Since then, the Doppler radar system has been updated and more fully integrated with the radar system aboard the WP-3D, and on the NOAA G-IV aircraft since 2011. These radars have been powerful research tools for decades, and since 2005 data and analyses have been sent from the aircraft in real time. Doppler superobs were first assimilated in a real-time research model in 2008 during Tropical Storm Fay. HWRF (Hurricane Weather Research and Forecasting Model) assimilation of Doppler radial velocities first occurred in a real-time parallel run during Hurricane Tomas of 2010, and since 2013, they have been assimilated in the operational runs of HWRF.

Providing analyses and Doppler radial velocities in real time requires an automated analysis and quality control system. To use the Doppler velocities, a great deal of quality control is needed, including removal of side-lobe noise, removal of sea-surface reflection, and de-aliasing. Several passes through the Doppler data are required to be able to quality control the radial velocities correctly.

The initial submission of a radar task does require human interaction, however. A java application allows data entry of the required information or of parameter customization: storm center and motion, beginning and end time of input data, the radial directions of flight tracks from the storm center, the resolution of the analysis, and the stringency of the quality control (based upon the gradients of wind velocity, more stringent in hurricanes and even more stringent in major hurricanes). Nonetheless, the application strives to minimize human error by taking advantage of the real-time 1Hz feed archived at the NOAA AOC (Aircraft Operations Center) website for each mission. Operators are forced to link a radar job to one of those flight missions, not only for routing job to the target aircraft, but also to acquire the mission and storm description as filled by the flight director.

Once a radar job file is uploaded at the AOC website, the rest of the steps are fully automated to completion. AOC has developed scripts where, once the radar workstation is started on the aircraft, a person on the ground can submit a job file, the transmission software aboard the aircraft detects a new job file, the quality-control/analysis process takes place, and once it is finished the various products are transmitted off the aircraft to the appropriate agencies.

The quality-controlled Doppler radial velocities are sent to NCEP (National Centers for Environmental Prediction) Central Operations (NCO) for assimilation into HWRF. They are also used to produce superobs for HRD and its research partners.

To facilitate NCEP being warned that Doppler radar data is to be included for one of their established daily HWRF runs, operators can now issue a trigger from the ground identifying the new storm event.

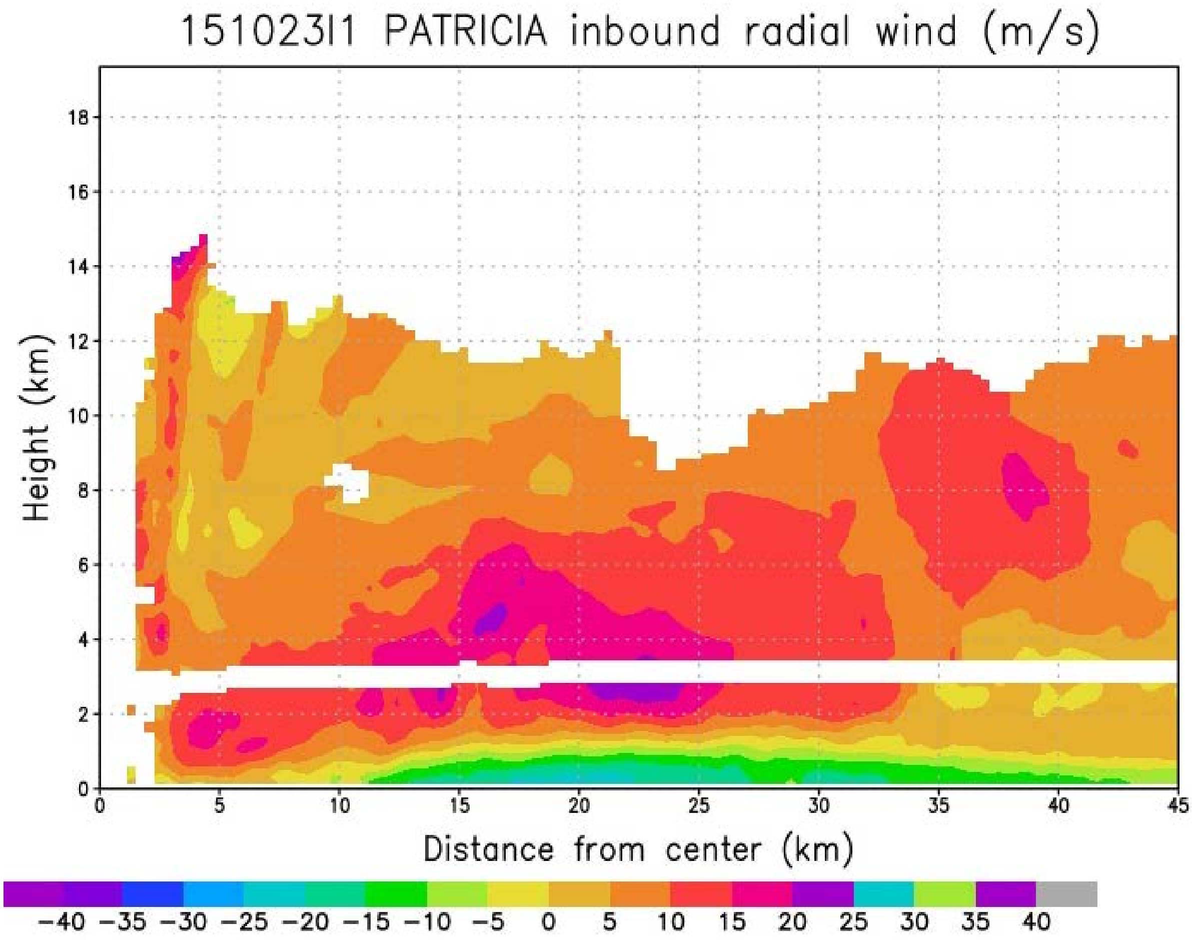


Figure 1: Inbound radial winds of Hurricane Patricia, October 23, 2015. X-coordinate is distance from storm center and y-coordinate is height above sea surface.

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

Guidance on Observational Undersampling Over the Tropical Cyclone Lifecycle

Project Personnel: B. Klotz (UM/CIMAS); D. Nolan (UM/RSMAS)
NOAA Collaborator: E. Uhlhorn (formerly NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives: To evaluate the observational undersampling of surface and flight-level wind speeds at various stages of tropical cyclone development, size, structure and model configuration.

***Strategy*:** To produce statistics and evaluations of the undersampling using the hurricane nature run simulation as well as with several other numerical 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: NOAA/OAR/USWRP/JHT
NOAA Technical Contact: Molly Baringer and Chris Landsea

Research Summary:

Tropical cyclone (TC) intensity is an operational requirement of the National Hurricane Center (NHC) and is based on determining a maximum sustained surface wind (i.e. 1-minute, 10 m). Aircraft reconnaissance missions offer the best opportunity to provide this estimate, but due to limitations of timing and flight patterns, it is almost impossible to observe the maximum surface wind speed in a TC. Therefore, forecasters at NHC often expect that the true maximum wind speed is higher than observed. To quantify the undersampling by aircraft reconnaissance, a previous study utilized a high resolution simulation of Hurricane Isabel (2003), simulated stepped frequency microwave radiometer (SFMR) flight tracks, and compared the highest observed surface wind speed along the track to the maximum 1-minute sustained surface wind speed at any location in the surface wind field. Their results revealed an average underestimate of 7.8 ± 1.2%. Isabel was an intense, symmetric, and mature hurricane during the simulation window and model output was only provided hourly. A follow-on study found that the underestimation is also dependent on the size, structure, and intensity of the wind field. Because SFMR measurements are the standard for TC surface wind observations, this goal of this project is to expand on these studies to examine how the variations in storm size, intensity, asymmetric structure, and model improvements impact the underestimate of maximum surface wind speed.

SFMR flight tracks are simulated in the single figure-4 pattern at eight initial incidence angles within each specified time window of a simulation. An example of one such figure-4 is shown in Figure 1. In this study, for example, flight times are initiated every three hours instead of the six used previously. Because each figure-4 is completed in ~2.5 hours, sampling periods without a simulated aircraft in storm are reduced significantly (minutes instead of hours). This reduction can help better address specific changes that occur over short periods of time, such as rapid intensification or weakening. To obtain the underestimation through the TC lifecycle, we use the high resolution Hurricane Nature Run (HNR1), which includes periods of genesis, rapid intensification, an eyewall replacement cycle, and recurvature. A variant of this simulation (HNR2) provides a simulation that is impacted by land. Several other simulations, including intense Hurricane Bill (2009) and idealized simulations at Category 2 and 5 strengths, are used for comparison.

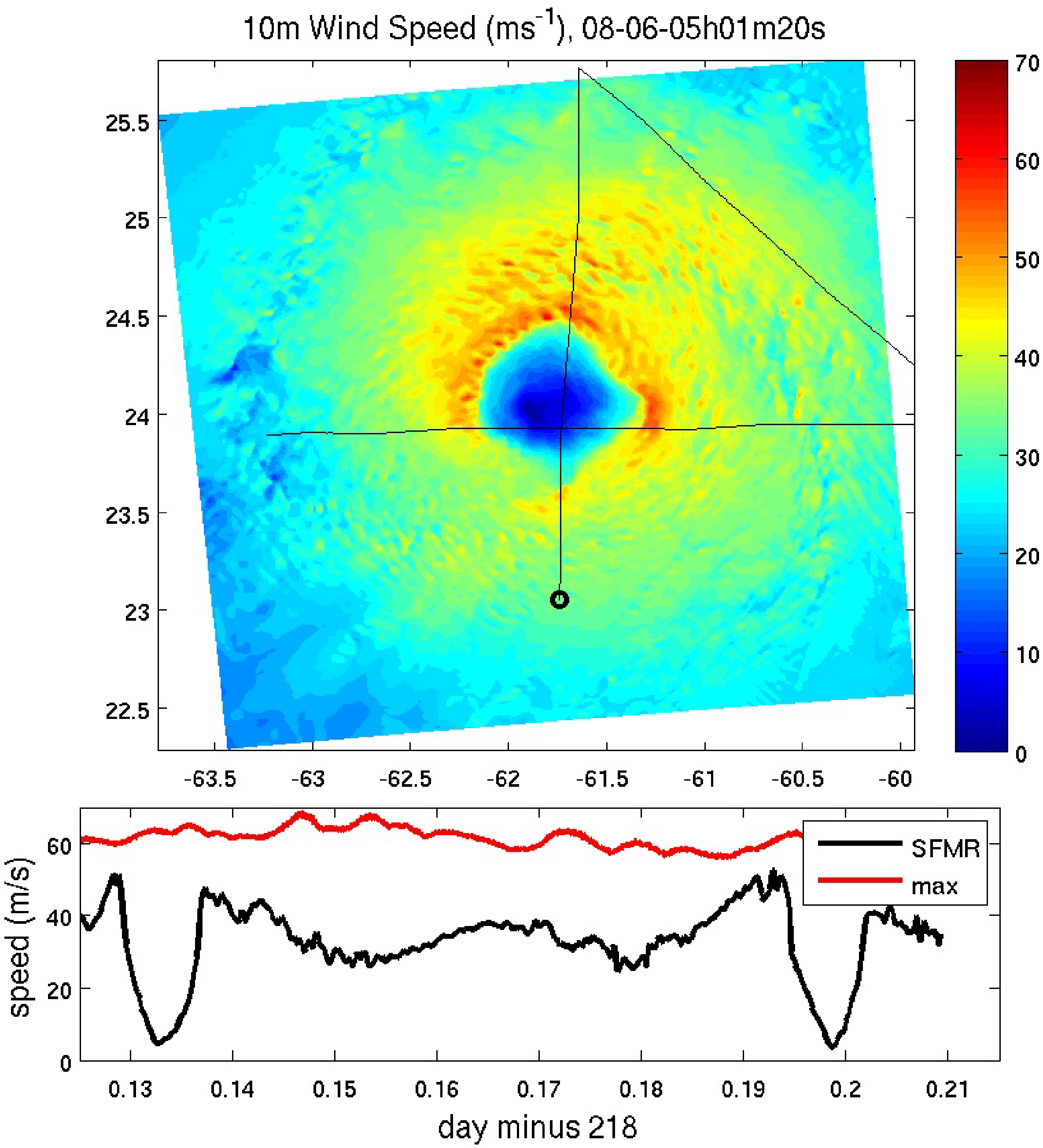


Figure 1: The flight track of a single figure-4 pattern is overlaid on an image of the surface wind speeds produced during the mature stage of HNR1 in the top panel. The trace of the observed maximum (black) and the model maximum (red) wind speed for the complete pattern are shown to convey the amount of underestimate produced during a single flight simulation.

To quantify the underestimation of the 1-minute maximum, the average of the eight observed maxima within each 3-hour sampling window is calculated. As an example, Fig. 2 shows the time-series from HNR1 and indicates the observed average maximum (with errorbars) and the model maximum wind speeds. Initial results reveal that the average underestimate for Isabel is ~0.5% better when using the 3-hour sampling. Bill gets the closest to the 1-minute winds (~4% underestimate) and HNR2 has the largest

underestimate (16.1%) due to the asymmetric structure and interaction with land. HNR1 (Fig. 2) has a 10.9% mean underestimate of the maximum, which is 3.5% higher than Isabel's. This difference is indicative of model configuration differences, mostly pertaining to increased model resolution in HNR1. To quantify these differences in model configuration, Fourier decompositions at normalized radii are plotted as a function of wavenumber and normalized power in Fig. 2. Comparing Isabel to HNR1, it is clear that HNR1 is able to maintain a higher power at larger wavenumbers, which is indicative of HNR1's ability to resolve smaller scale features.

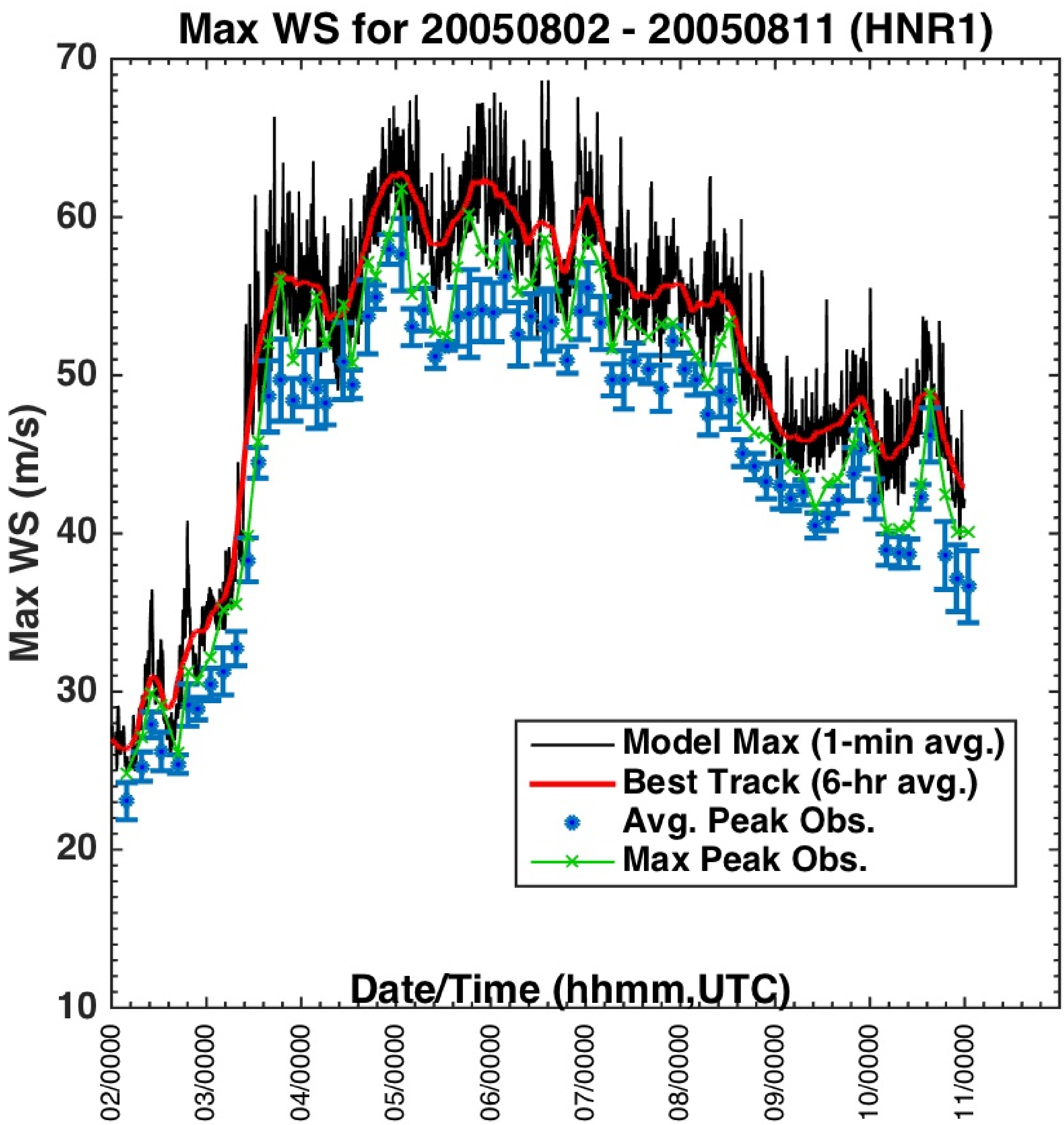


Figure 2: Time-series of the 1-minute and 6-hour model maximum wind speed (black and red lines, respectively) from HNR1 are shown in comparison with the mean observed maximum (blue markers). Error bars indicate the 95% confidence interval, and the green line is the time-series of the maximum observed wind speed during each time window.

One final objective for the first year of this study is to improve central pressure correction based on dropsondes. Typically, the surface pressure estimate is reduced 1 hPa for every 10 kt of wind at "splash." To evaluate this rule, the surface wind speed and difference from the true minimum pressure are computed at every grid point within 40 km of the center over a 6-hour period. These data points are binned into a joint histogram, which are then normalized by a total number within each bin. A two-dimensional probability density function (PDF) of pressure correction for each wind speed (not shown) indicates that at wind speeds of 25-40 kt, 1 hPa per 10 kt is a reasonable estimate for the pressure correction. At very low wind speeds, a correction is still needed because the chance of hitting the true pressure minimum is very small. In conclusion, the observational undersampling of a TC produces varying degrees of underestimates of the absolute maximum based on the model configuration (i.e. Fig. 3) and on the structure and stage of the storm's development.

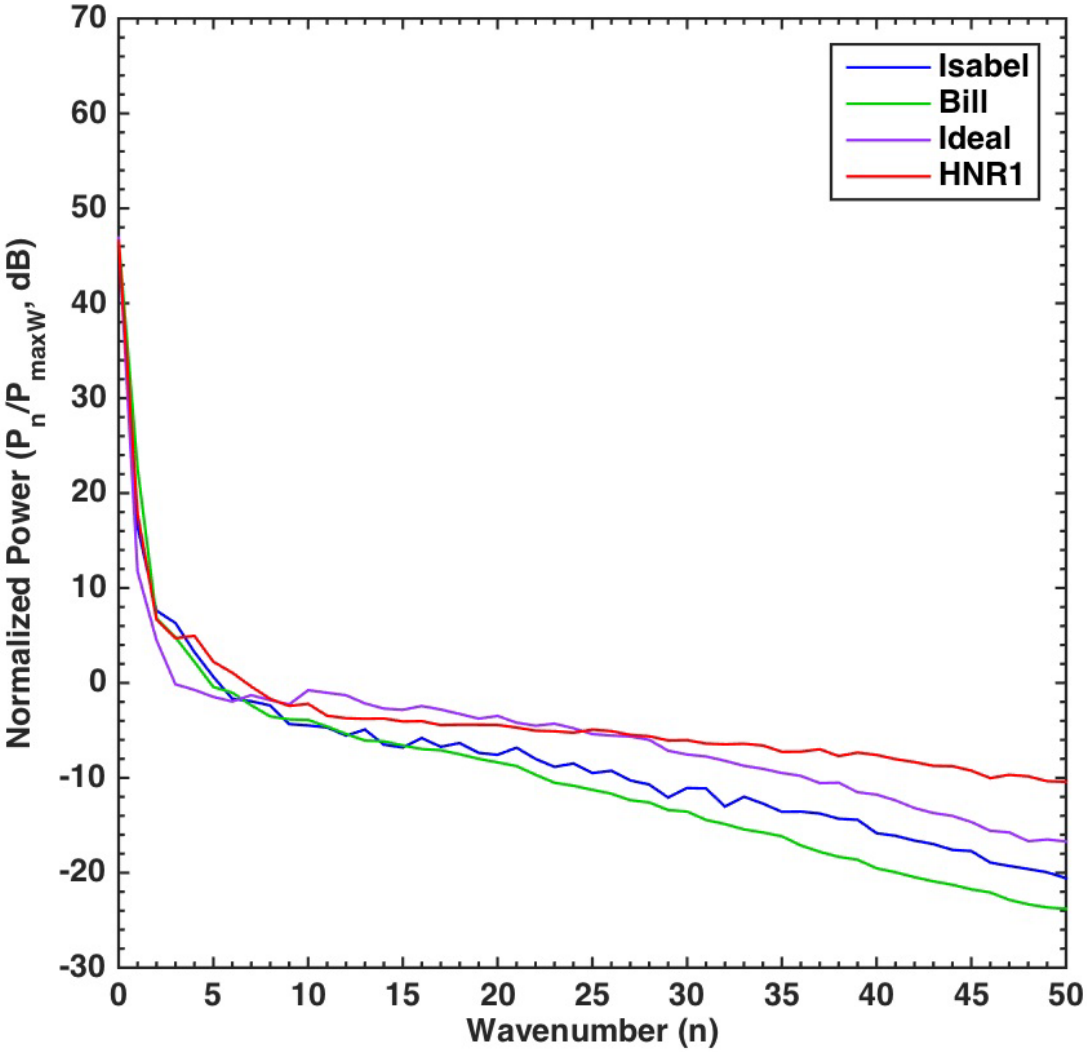


Figure 3: Normalized power as a function of wavenumber is shown for Fourier decomposed surface winds from a normalized polar grid. The various model simulations are indicated in the legend.

Research Performance Measure: All research goals for year-1 have been met. Successful evaluation of the observational underestimation of intensity for various TC stages, sizes, and model configurations was completed.

Performance of the Revised SFMR Algorithm: 2015 Season in Review

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

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To evaluate the new wind and rain models in the SFMR algorithm that removes the high surface wind speed bias in heavy rain in an operational setting.

***Strategy*:** To evaluate and produce statistics on the current operational SFMR algorithm during the 2015 hurricane season and compare with the previous algorithm results.

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/AOML
NOAA Technical Contact: Molly Baringer

Research Summary:

The Stepped Frequency Microwave Radiometer (SFMR) has been a mainstay on the NOAA WP-3D hurricane hunter aircraft for the past 16+ years and is a unique and reliable operational instrument for observing surface wind speeds in tropical cyclones (TCs). A recent study examined an SFMR wind speed overestimation problem and found that a high bias of ~2 m s^{-1} was present in non-raining conditions and of > 5 m s^{-1} when rain rates exceeded 20 mm h^{-1} at wind speeds below 33 m s^{-1}. Based on this examination, one major contributor to the overestimation was an improper application of signal absorption due to rain. This issue was remedied in the updated version of the algorithm along with an improvement to the wind portion. The outcome of these updates was a more realistic and larger range of attainable rain rates and a significant reduction of the high bias at low wind speeds within moderate to heavy precipitation. The Joint Hurricane Testbed (JHT) approved the transition of this updated algorithm to operations, and it was utilized during the 2015 hurricane season on all NOAA and Air Force Reserve (AFRC) aircraft. Comparisons of these data to the results processed with the previous algorithm are provided herein.

During the 2015 hurricane season, 85 TC missions were conducted over the North Atlantic, Northeast Pacific, and Central Pacific basins. SFMR data from these missions were post-processed, quality controlled, and made available on NOAA's Hurricane Research Division data page. Following previous methodology, the wind speeds and rain rates from each flight are paired with a surface-adjusted wind speed from co-located (based on launch time) GPS dropsondes. These paired samples allow for direct comparison of two independent measurements of wind speed. Figure 1 shows the scatter of the paired samples and the statistics of the linear regression fit for the current (left) and previous (right) algorithm. The key result here is that improvements are visible throughout the entire wind spectrum. The reduction is root mean squared error (RMSE) is a clear representation of this improvement.

In Figure 2, the probability density functions (PDFs) and cumulative distribution functions (CDFs) of the two processing versions are plotted for wind speeds below hurricane strength (< 33 m s^{-1}, left panel) and for those at minimal hurricane strength or greater (> 33 m s^{-1}, right panel). The original expectation of the algorithm improvement was to significantly reduce the overestimation within the weaker wind regime

while maintaining the performance at the stronger wind regime. Figure 1 indicates that in the operational setting, this was accomplished. The PDFs for the weak wind regime indicate an average improvement of 3 m s^{-1} and 80% of the wind speed differences between the SFMR and dropsondes are within ±3 m s^{-1}, which is essentially the RMSE of the fit of the entire dataset (Fig. 1). The hurricane wind regime results confirm that the updated algorithm wind speeds are mostly unchanged compared to the previous algorithm.

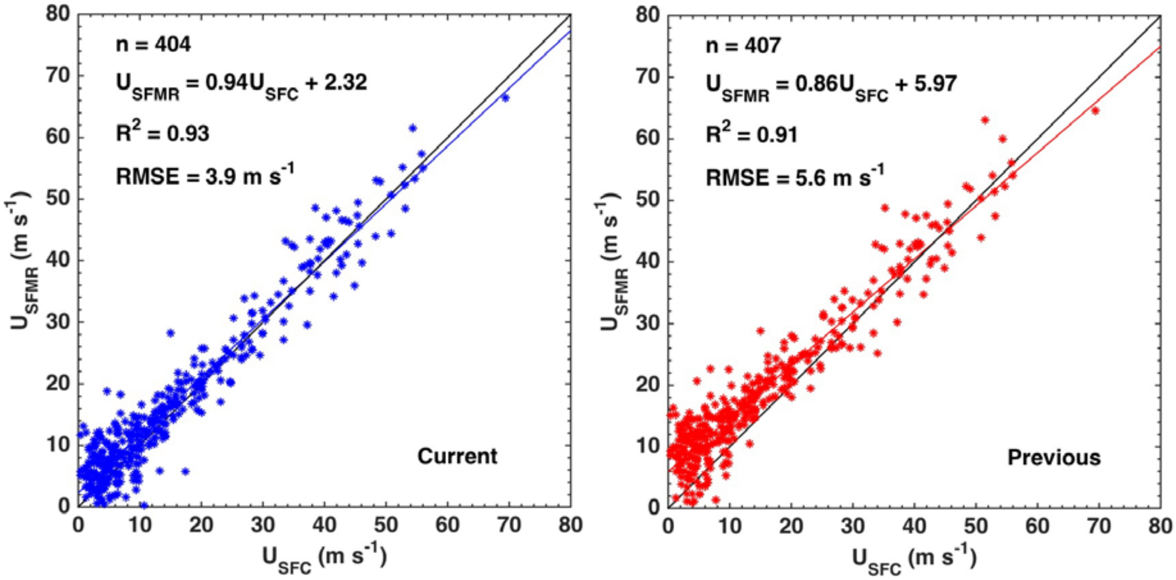


Figure 1: Paired SFMR (U_{SFMR}, m s^{-1}) and GPS dropsonde surface wind speeds (U_{SFC}, m s^{-1}) for the current (left) and previous (right) SFMR algorithm configurations are shown. Linear regression fits are provided with the red and blue lines, and the black line indicates a one-to-one fit. Basic statistics are indicated with text for each panel.

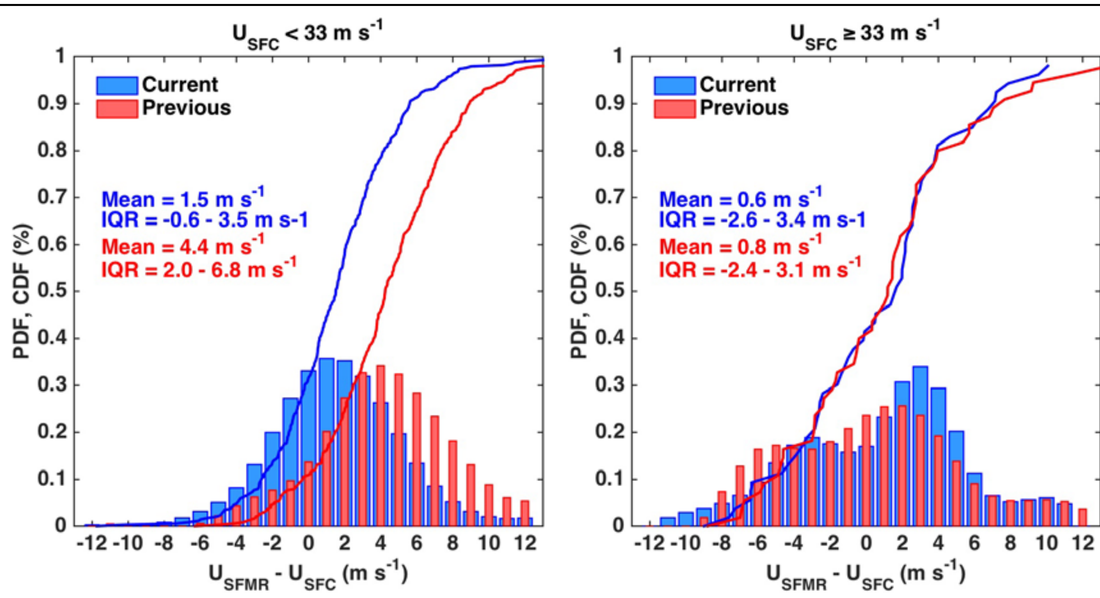


Figure 2: Probability density functions and cumulative distribution functions are plotted for non-hurricane wind speeds (< 33 m s^{-1}, left) and hurricane wind speeds (> 33 m s^{-1}, right) for the previous (red) and current (blue) processing algorithm versions. The average SFMR bias and middle 50% of the bias is indicated for each version in their respective color. Positive biases indicate SFMR wind speeds are stronger than GPS dropsonde wind speeds.

Because the larger overestimation was in rainy conditions, evaluations of wind speed bias as a function of rain rate are provided. Figure 3 displays bin-averaged wind speed differences for several wind speed and rain rate bins. For these comparisons regarding rain rate, the previous algorithm rain rates are scaled to the current version using a 3rd order least squares fit (not shown). This fit has an error of < 1 mm h^{-1}, indicating the scaled rain rates adequately represent the rain rates determined from the current algorithm. Figure 3 indicates that as wind speed decreases and rain rate increases, the wind speed bias is reduced significantly (~ 4 m s^{-1}) when using the current algorithm (left panel). While the bias was not completely eliminated, this reduction provides evidence for increasing our confidence in the weak wind speed regime in rainy conditions. Additionally, the bias at the stronger wind speeds as well as in lightly to non-raining conditions was reduced when using the updated algorithm. Therefore, the SFMR algorithm used during the 2015 hurricane season provides superior estimates of wind speeds and rain rates when compared to the previous algorithm, and continued use of this algorithm in operations will improve our estimation of maximum surface wind speeds in TCs.

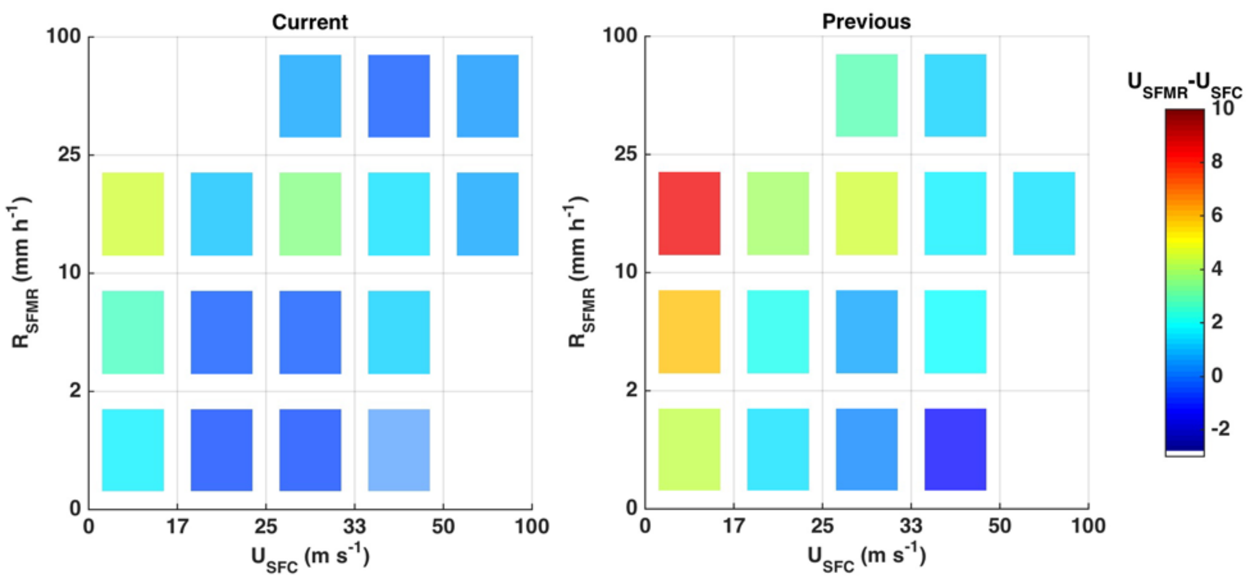


Figure 3: Two-dimensional, bin-averaged histograms are displayed as a function of wind speed and rain rate for the current (left) and previous (right) algorithm versions. Warmer colors indicate high SFMR biases while cooler colors indicate low biases.

Research Performance Measure: All research goals have been met. Evaluation of the operational algorithm performance indicates an improved wind speed and rain rate estimate from SFMR.

Development of an Integrated Coastal Inundation Forecast Demonstration System in Caribbean Region – Pilot Project for the Dominican Republic and Haiti
Subcomponent 3: Development of a GIS Database for the Hispaniola SLOSH Basin

Project Personnel: K. Zhang, Y. Li and Y.C. Teng (FIU)
NOAA Collaborators: J. Rhome (NOAA/NHC); A. J. Westhuysen (NOAA/NCEP)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To help National Hurricane Center (NHC) to develop the Sea, Lake, and Overland Surges from Hurricanes (SLOSH) and wave model basin for Hispaniola by integrating the boundary condition data from various remote sensing platforms and the related agencies in Haiti and the Dominican Republic in geographic information system (GIS) and updating current basin development tools used by NHC.

***Strategy*:** To build a GIS database for the basin development based on the data from open sources, various remote sensing platforms, and related agencies of Haiti and the Dominican Republic.

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/NHC
NOAA Technical Contact: Jamie Rhome

Research Summary:

NHC, NCEP, and FIU proposes to develop the Maximum Envelope of Water (MEOW) and Maximum of MEOWs storm surge products for planning and warning in Hispaniola countries using SLOSH and a coupled wave model through World Meteorological Organization's Caribbean Coastal Inundation and Forecast Demonstration Project. The high quality bathymetric and topographic data, and geometric measurements of major rivers connected to the ocean, shorelines, manmade features such as major highways, and land cover and land use are essential for representing the boundary condition for surge and wave model to derive reliable products. We have developed a baseline geodatabase based on the data sources from NOAA, USA, NASA, USA, METI, JAPAN GEBCO, UK, and National Geomatics Center of China. The preliminary SLOSH basin for Hispaniola was also developed to test the storm surge model.

Research Performance Measure: Most components of the project are on schedule, but the DTM development is delayed because we planned to use the data from TanDEM-X mission conducted by German Space Agency (DLR) that was completed in 2014 to generate 12m DTM. DLR delayed the release of the digital elevation model data. We have learned by contacting DLR that DLR would release the products soon. We will apply for the data as soon as the call for data requisition from DLR is announced.

Development of the Basin-Scale HWRF Modeling System

Project Personnel: X. Zhang, G. Alaka, R. St. Fleur, H. Chen, K. Sellwood and R. Gall (UM/CIMAS)

NOAA Collaborators: S.G. Gopalakrishnan, S. Goldenberg, F. Marks and R. Rogers (NOAA/AOML); V. Tallapragada, S. Trahan, Z. Zhang and Q. Liu (EMC/NCEP)

Other Collaborators: C. Holt, L. Bernardet, M. Biswas and K. Newman (DTC/NCAR); M. Montgomery and M. Boothe (NPS); I. Ginis and B. Thimas (URI)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To further advance the capabilities, accuracies and reliability of numerical hurricane forecasting under HFIP.

***Strategy*:** To focus on development of the basin-scale Hurricane Weather Research and Forecasting (HWRF) modeling system, specifically by developing new forecast capabilities within the operational HWRF system, evaluating the performance of the basin-scale HWRF system, and identifying the model errors, testing model configuration that can be transitioned to operations.

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: Molly Bringer

Research Summary:

Development of the Basin-Scale HWRF system (HWRF-B)

In this project, Dr. X. Zhang led the development and design of the movable multi-level nesting (MMLN) in the Hurricane Weather Research and Forecasting (HWRF) modeling system. He, along with collaborators from AOML/HRD, NCEP/EMC, DTC, and URI, developed a new experimental HWRF system with a much larger horizontal outer domain and multiple sets of MMLN, referred to as the "basin-scale" HWRF (HWRF-B) (Figure 1). The performance of HWRF-B can be applied for various difficult forecast scenarios such as 1) simulating multiple storms and their interactions, 2) forecasting Tropical Cyclone (TC) to extratropical cyclone transitions, and 3) predicting tropical cyclone genesis. Verification of track forecasts for the 2011-2014 Atlantic and East Pacific hurricane seasons

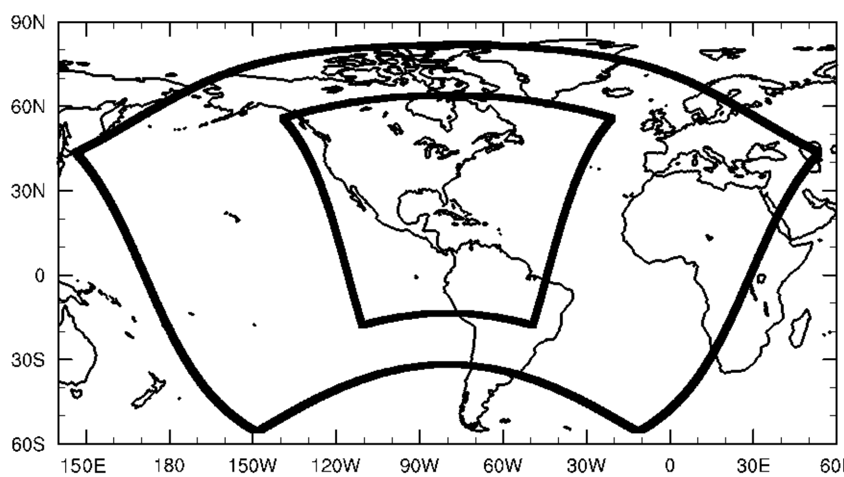


Figure 1: Schematic domains of basin-scale HWRF, operational HWRF, and NHC's areas of responsibility (AOR).

demonstrates that the basin-scale HWRF produces similar overall results to the 2014 operational HWRF, the best operational HWRF at the same resolution (Figure 2). The HWRF-B ran HFIP demo forecasts during the 2015 hurricane season.

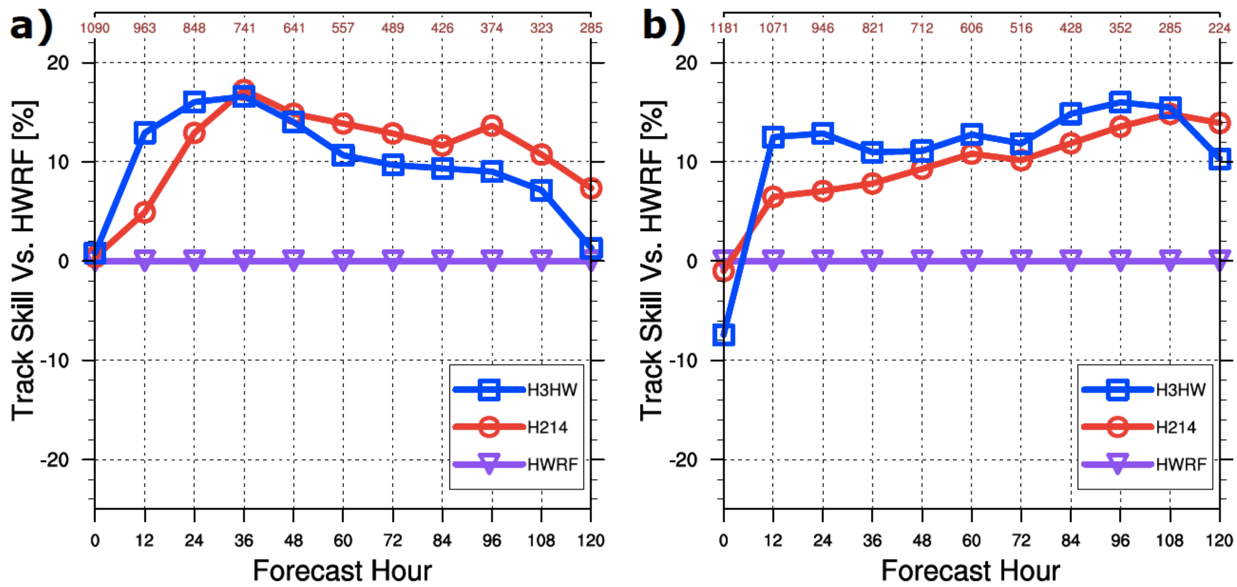


Figure 2: Track verification for Atlantic and East Pacific basin TCs (a and b, respectively) during the 2011-2014 hurricane seasons. H3HW is the basin-scale HWRF (blue line), H214 is the 2014 operational HWRF (red line), HWRF is a combination of the various versions of the operational HWRF (purple line) during 2011-2014. The track skills are defined as the skill vs. the combination operational HWRF.

Basin-Scale HWRF Verification and Evaluation

Dr. Alaka led the evaluation and verification of 2013 basin-scale HWRF Atlantic track forecasts, using the 2014 operational HWRF as a benchmark. A major finding is that HWRF-B track forecasts outperform those from the operational HWRF when far-field TCs (> 3500 km) are simultaneously active.

Basin-Scale HWRF Products

Dr. Alaka and R. St. Fleur developed automated scripts that produce HWRF-B products to aid the HRD hurricane field program. These products are available on the HRD web site: http://storm.aoml.noaa.gov/basin.

Basin-Scale HWRF Genesis Products

Prof. Montgomery and his group at NPS generated HWRF-B genesis products by collaborating with CIMAS and HRD modeling team.

Basin-Scale HWRF Coupling system

Dr. Zhang, along with scientists from CIMAS, HRD, URI, EMC, and DTC, is developing the basin-scale HWRF coupling system. The development is targeting to 2017 potential operational transition.

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

Expanding NIDIS Drought Early Warning System in the Southeast

Project Personnel: C.J. Martinez (UF); V. Misra (FSU)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** The overarching objective of this work is to build capacity in drought early warning in the Apalachicola-Chattahoochee-Flint (ACF) river basin.

***Strategy*:** Towards the objective of this work, this project focuses on the delivery of educational products, convening drought-related forums, assessing lessons learned from existing stakeholder-scientist working groups, and objectively evaluating the impacts of our efforts.

CIMAS Research Theme:

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

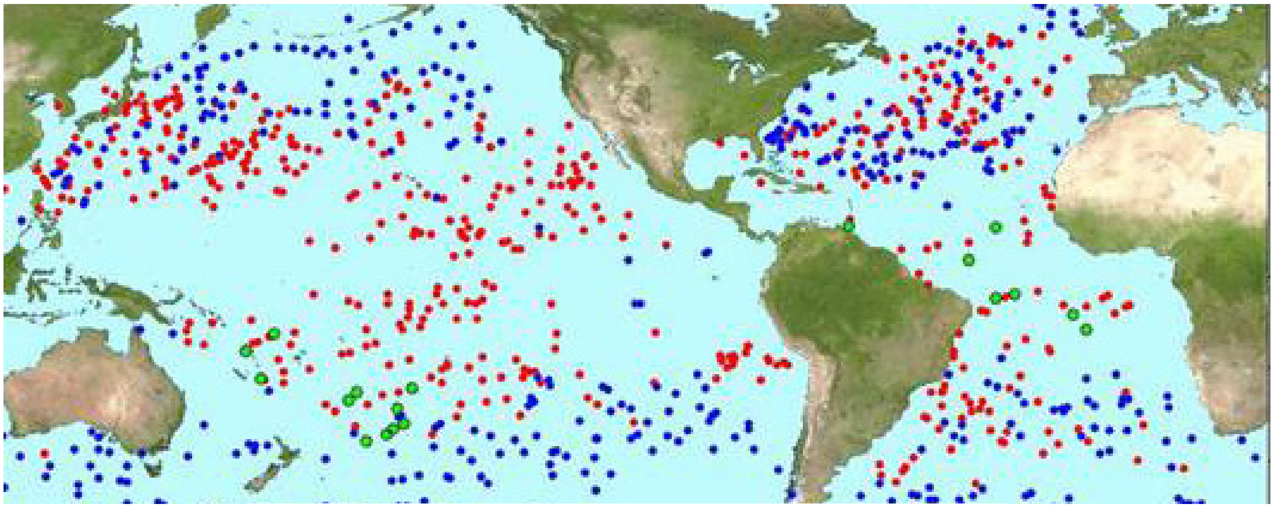
Link to NOAA Strategic Goals:

***Goal 3*:** Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts*

NOAA Funding Unit: CPO/NIDIS
NOAA Technical Contact: Courtney Black (courtney.black@noaa.gov)

Research Summary:

This work has not yet begun due to revisions to our scope of work that were requested by personnel from the National Integrated Drought Information System of NOAA.



RESEARCH REPORTS

THEME 3: Sustained Ocean and Coastal Observations

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

Project Personnel: L. Barbero, D. Pierrot, K. Sullivan, Y. Liu and R. van Hooidonk (UM/RSMAS/CIMAS)
NOAA Collaborators: R. Wanninkhof and S.-K. Lee (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 1*:** Healthy Oceans: *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems*

NOAA Funding Unit: OAP/OAR
NOAA Technical Contact: Dr. Libby Jewett, OAP/OAR

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 is used to determine patterns and trends in key

indicators of ocean acidification. The observing network of the East and Gulf Coast is comprised of the following elements:

- Surface water measurements of ocean acidification using autonomous systems on 2 ships of opportunity (SOOP-OA).
- A dedicated research cruise, the East Coast Ocean Acidification (ECOA) cruise on the *NOAA ship Gordon Gunter* 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 pH, total alkalinity (TA) and dissolved inorganic carbon (DIC) samples taken on the SOOP-OA and other cruises. 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. All data from these analyses have been submitted to data repositories and made publicly available.

During the performance period the first ECOA cruise along the East coast of the US took place (Figure 1). The data have already been quality checked and sent to NOAA's NCEI (National Center for Environmental Information) (formerly NODC). The comprehensive determination of inorganic carbon system parameters provides needed inputs to determine the aragonite saturation state.

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

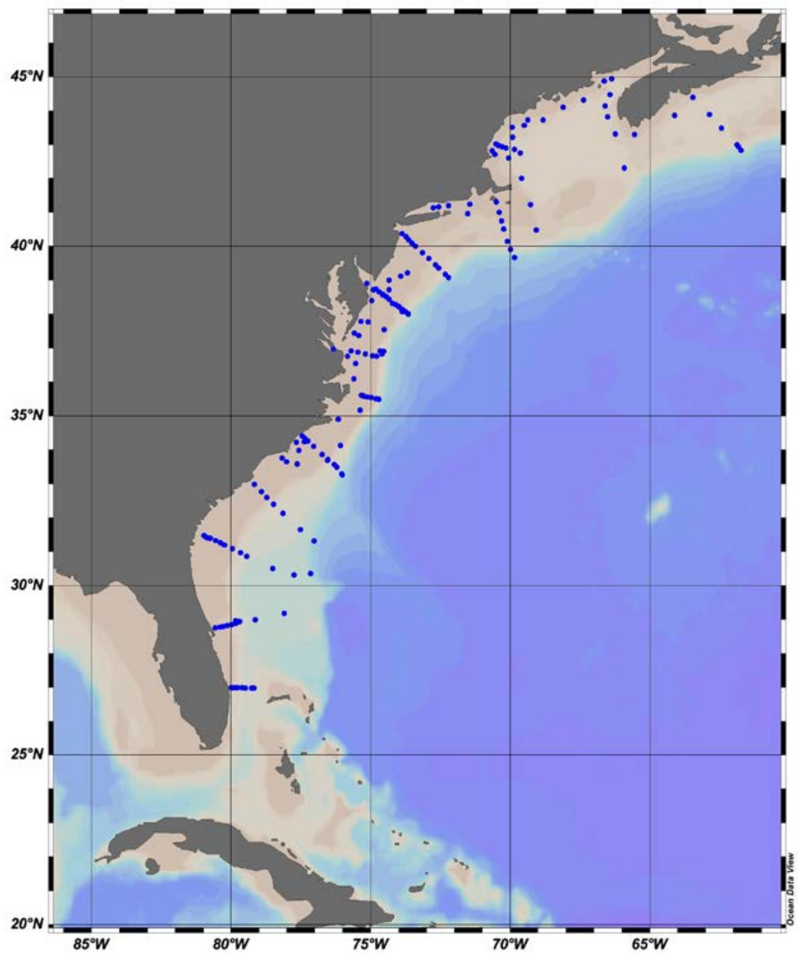


Figure 1: Map of the stations occupied during the ECOA-1 cruise. In total, 163 stations were sampled.

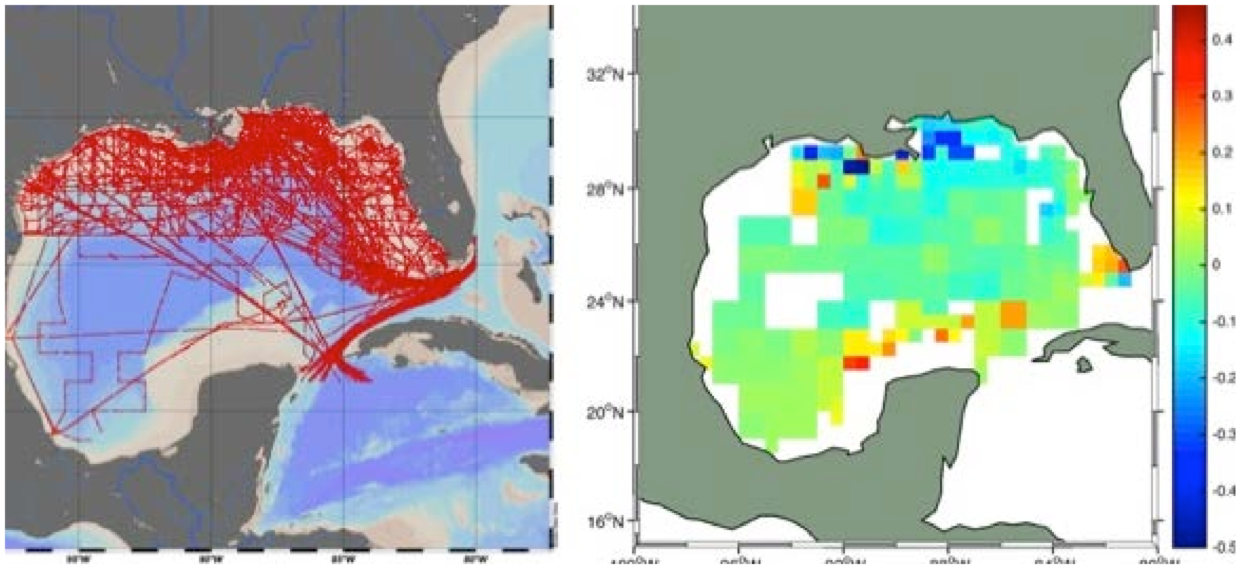


Figure 2: Left) Map of cruise tracks in the Gulf of Mexico where surface pCO_2 measurements have been gathered. Over 2/3 of these data (>500K data points) have been obtained by our group. Right) Climatological air-sea CO_2 fluxes (mol C/m^2y) in the Gulf of Mexico for the month of April calculated using our pCO_2 measurements and monthly CCMP winds. The influence of the Mississippi river influx on the fluxes is apparent.

Research Performance Measure: Provide quality-controlled data that are used to determine patterns and rates of OA in the realm. The data from the cruises have been submitted on time to the NCEI and were released to the public in 2016.

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The GO-SHIP Repeat Hydrography Program

Project Personnel: L. Barbero, G. Berberian, J. Hooper, K. Sullivan (UM/CIMAS)
NOAA Collaborators: R. Wanninkhof, J.-Z. Zhang, M. Baringer (NOAA/AOML)
Other Collaborators: C, Langdon (UM/RSMAS)

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

NOAA Funding Unit: COD/CPO
NOAA Technical Contact: Dr. Kathy Tedesco, NOAA CPO

Research Summary:

The Global Ocean Ship-based Hydrographic Investigations Program (GO-SHIP) 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 July 2015 the Pacific meridional P16N transect from 20 ˚S to 56 ˚N was completed in full. In February-April 2016 the Indian meridional transects I08S and I09N were completed (Figure 1).

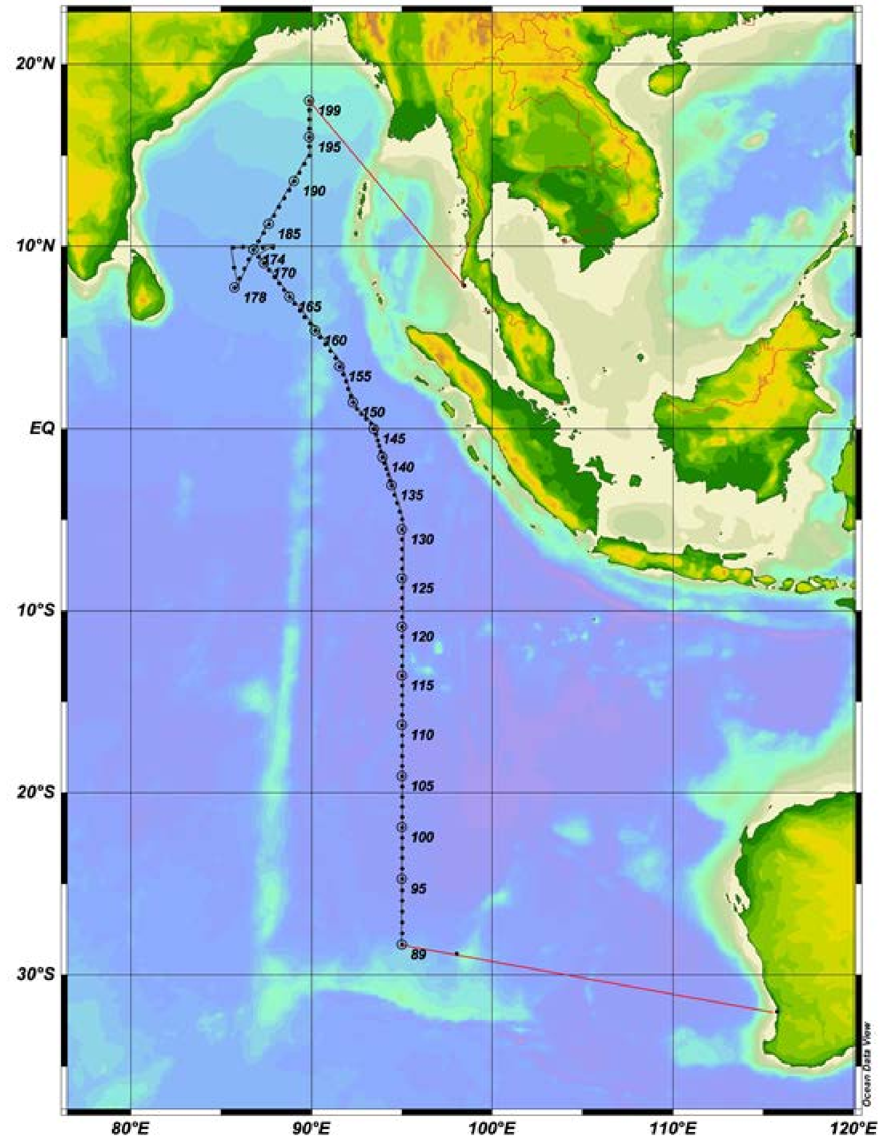

Figure 1: Track of the 2016 GO-SHIP I09N cruise in the Indian Ocean, departing from Fremantle (Australia) and arriving in Phuket (Thailand).

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 and the CLIVAR/CO2 campaign from 2003-2012) 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-2016 we completed one meridional section in the Pacific Ocean, P16N, and two meridional sections in the Indian Ocean from 60 ˚S to 18 ˚N called I08S and I09N with full physical and chemical characterization of over 110 water column profiles. Dr. Leticia Barbero was chief scientist on I09N (Figure 1). CIMAS project personnel and NOAA collaborators were responsible for CTD, ADCP, O_2, nutrients, and inorganic carbon measurements.

Research Performance Measure: The Repeat Hydrography Sections are progressing according to the timeline provided by the GO-SHIP (http://www.go-ship.org/). The performance measure for FY-16 of completing the re-occupation of the I08S and I09N cruises was met.

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Sustained and Targeted Ocean Observations for Improving Atlantic Tropical Cyclone Intensity and Hurricane Seasonal Forecasts

Project Personnel: R. Domingues, G. Rawson, T. Sevilla and J. Dong (UM/CIMAS)
NOAA Collaborators: G. Goni, S.-K. Lee, F. Bringas, G. Halliwell and U. Rivero (NOAA/AOML); R. Bouchard (NOAA/NWS)
Other Collaborators: J. Morell and L. Pomales (U. Puerto Rico Mayaguez), H.-S. Kim (NCEP/EMC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To obtain targeted and sustained ocean observations in the Caribbean Sea and Tropical North Atlantic Ocean to enhance our knowledge about the role that the ocean plays in the intensification of tropical cyclones (TC), and to assess the impact of these observations on the TC intensity forecast, and of seasonal forecasts.

***Strategy*:** To implement an array of underwater gliders (hereafter referred as gliders) to carry out sustained and targeted upper-ocean profiling of temperature, and salinity in the Atlantic Warm Pool region. The proposed work aims to provide 4,500 to 5,500 profile observations per year using two gliders in the Caribbean Sea and north of Puerto Rico. Data transmissions are performed in real-time into the Global Telecommunication System (GTS) for assimilation in the forecast system

CIMAS Research Theme:

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

Link to NOAA Strategic Goals

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

***Goal 3*:** Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts* (*Secondary*)

NOAA Funding Unit: NOAA/OAR

NOAA Technical Contact: Molly Baringer

Research Summary:

Tropical Cyclones (TC) are very often observed to travel and intensify over areas in the Tropical North Atlantic Ocean and in the Caribbean Sea, which are generally characterized by large upper-ocean heat content. Yet, no sustained ocean observation efforts were in place in these areas, which have been very poorly sampled during past decades. To address this lack of observations, NOAA/AOML proposed a multi-institution effort to implement a pilot network of Underwater Gliders. An underwater glider is an autonomous underwater vehicle (AUV, Figure 1) that uses small changes in buoyancy together with wings to propel itself by converting vertical motion into horizontal motion. These vehicles can be configured with customized oceanographic sensors and thanks to a very small consumption of energy, they are able to measure several ocean parameters during a period of weeks or months along thousands of kilometers.

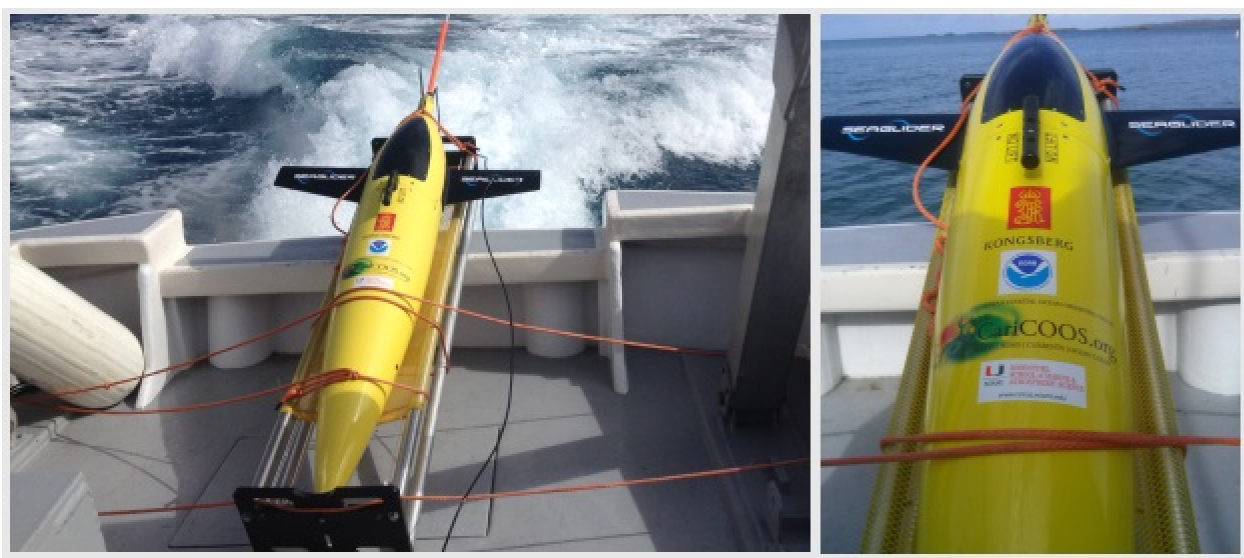

Figure 1: CIMAS / AOML's Underwater gliders aboard R/V La Sultana from University of Puerto Rico Mayaguez.

The main goal of this project is to carry out sustained and targeted upper-ocean observations in the Caribbean Sea and Tropical North Atlantic Ocean using a network of gliders to: (i) enhance our knowledge about the role that the ocean plays in the intensification of TCs; (ii) and to assess the impact of underwater gliders ocean observations on the TC intensity and seasonal forecasts. To accomplish this, a pilot network of underwater gliders was implemented in July 2014. To date, **four glider missions** have been successfully completed with the collection of over **9,000** temperature and salinity profiles.

During July 1st, 2015 – June 30, 2016, two underwater glider missions were successfully carried out: one during the 2015 Hurricane Season from July-November, 2015, and another mission off-Hurricane Season, from March – June, 2016. The mission during Hurricane Season 2015 (Figure 2a) took place between July 15 – August 11, 2015, and ended with the collection of 2,690 temperature, salinity, and dissolved oxygen profiles, including observations collected for ocean conditions under Tropical Storm Erika (2015). The mission off-Hurricane Season (Figure 2b) took place from March 10 – June 2, 2016, and ended with the collection of over 1,450 temperature, salinity, and dissolved oxygen profiles. Data collected by the underwater gliders were made available in real-time through AOML website (http://www.aoml.noaa.gov/phod/-gliders) and through the Global Telecommunications System (GTS). Data were also distributed through NOAA Integrated Ocean Observing System - IOOS (http://www.ioos.noaa.gov/).

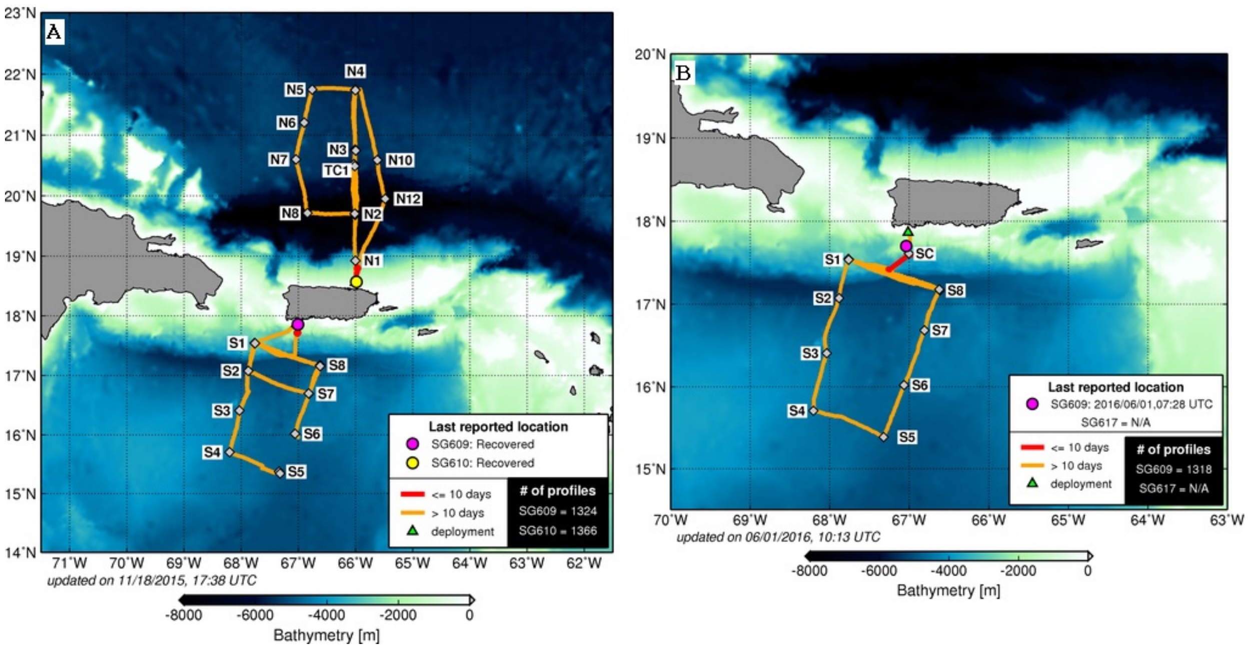

Figure 2: Track travelled by two underwater gliders during (A) the Hurricane Season (July-November) mission from 2015, and (B) during the off-Hurricane Season (March-June) mission from 2016.

Before the July 2015 deployment, tests were conducted on the gliders to determine the cause of voltage drops in the secondary battery pack. The battery packs were removed from the gliders and an electrical load applied and recorded in order to measure the performance of the batteries. It was determined that the batteries performed as expected and the characteristics of lithium battery voltage drop is what we were experiencing during the mission. The main reason it was not seen in previous missions is because the gliders were switched to a bused 15V system from a 24V/10V system. The provided the glider team an additional learning experience about the power draw and reserve energy of the gliders. Additional spare parts were also purchased before the off-Hurricane Season deployment, including hull sections, transducers, GPS, and Electronic assemblies to prolong the usable life of the glider systems and prevent downtime.

During the 2015 Hurricane Season mission, glider SG609 had an encounter with a shark and sustained some damage to wings and hull (Figure 3). In December 2015 the glider was refurbished and the shark damage was repaired. This included removing a shark tooth from the fiberglass fairing, replacing a wing, potting the holes in the fiberglass and re-painting portions of the glider. The glider was deployed in March 2016 without issues.

Figure 3: (right) Shark tooth embedded on body of the glider. (left) Damage on SG609 after the shark encounter.

In June 2016, Glider 610 was converted into a pumped CTD system from the passive CT sail. Glider 609 will remain as a CT sail system in order to carry out comparison studies of the pumped vs passive systems. Both gliders were also upgraded to include a WetLabs Fluorometer which measures Chlorophyll A, CDOM, and backscatter in the 700nm wavelength. Each channel is significant in it's own right but combined the channels can be used to detect the presence of crude oil in the water column.

Science Update

During July 1st, 2015 – June 30, 2016, the scientific advances from this project were geared towards (i) enhancing our knowledge about the role that the ocean plays in the intensification of TCs; (ii) and on assessing the impact of underwater gliders ocean observations on the TC intensity and seasonal forecasts.

Observational component

In one study published on Geophysical Research Letters (Domingues et al., 2015), researchers from AOML, CIMAS, and their colleagues at the University of Puerto Rico Mayaguez and at the Environmental Modeling Center, identified the importance of salinity effects in reducing the upper-ocean cooling during Hurricane Gonzalo (2014) using the observations collected by one glider. Hurricane Gonzalo formed on October 12, and traveled within 85 km from the location of the glider situated north of Puerto Rico on October 14 (Figure 4a). At that stage, Hurricane Gonzalo was a category 3 hurricane with maximum sustained winds of 115 mph. Observations collected before, during, and after the passage of this hurricane were analyzed to help improve understanding of the upper-ocean response to hurricane winds and of the ocean recovery after the passage of the storm. The study revealed that salinity conditions below the surface of the ocean created a barrier against the strong wind forcing of the hurricane, which in oceanographic terms is simply named as a “barrier layer”. The presence of this barrier layer prevented the strong mixing forced by the hurricane. As a consequence, cooling of surface waters (Figure 4b) was small

(~0.4ºC) compared to cooling forced by other hurricanes with similar strength in areas where the barrier layer was not present. This is important because the small cooling of surface waters may have favored the intensification of Gonzalo. In fact, a second study (Goni et al., 2015) revealed that Hurricane Gonzalo continued to intensify until it reached maximum intensity as a category 4 Hurricane.

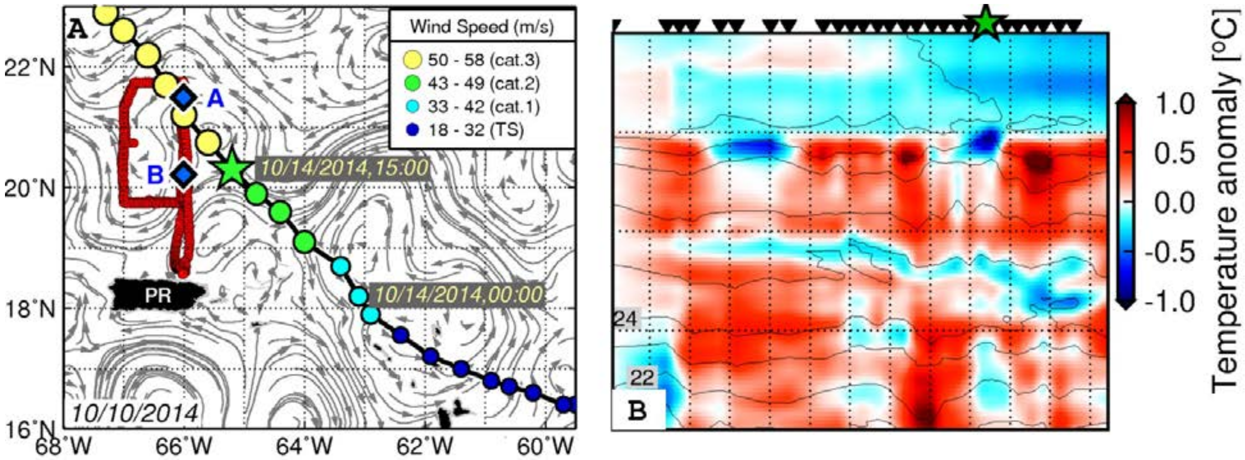

Figure 4: (A) Track followed by the glider (red points) north of Puerto Rico (PR) during July-November 2014, overlaid on altimetry-derived geostrophic currents. During October 8-28, the glider sampled ocean conditions between sites A and B (blue diamonds). The track of Hurricane Gonzalo is shown by colored circles (every 3hrs). The star highlights the closest location of the hurricane with respect to the glider. (B) Temperature anomalies in the upper 200m at site B during October 13-15, 2014, with respect to initial conditions in this location.

The study by Domingues et al., (2015) further revealed that salinity effects observed in the real ocean were not properly represented in one of the ocean models that is used for hurricane forecast, the HYbrid Coordinate Ocean Model (HYCOM) coupled to the Hurricane Weather Research Forecast model (HWRF), HWRF-HYCOM. As a consequence, HWRF-HYCOM overestimated the surface cooling forced by winds of Hurricane Gonzalo, which ultimately caused an underestimation in the intensity forecast of Gonzalo. Identifying such discrepancies and understanding the mechanism behind them is one way for improving tropical cyclone intensity forecasts. The study concludes that "a better model representation of salinity conditions may improve simulations of the ocean response and future hurricane forecasts in this region, given the important role of salinity suggested by the observations analyzed in this study". Results presented in this study emphasize the value of underwater glider observations for improving our knowledge of how the ocean responds to tropical cyclone winds and for tropical cyclone intensification studies and forecasts.

Modeling component

The modelling component of this project aims to investigate the impact of ocean observation assimilation, especially underwater gliders assimilation, on hurricane forecast using a high resolution coupled atmospheric-ocean numerical model system. A study currently in preparation (Dong et al., in preparation) has addressed the impact assimilating glider observations on the forecast of Hurricane Gonzalo (2014). Hurricane Gonzalo (2014) is first simulated with a high resolution Hurricane Weather and Research Forecast (HWRF)-Hybrid Coordinate ocean model (HYCOM) coupled forecast system. The ocean initial conditions are from the forecast-data assimilation system maintained by NOAA/AOML. The conventional ocean observations are assimilated daily from 00 UTC March 15 of 2014 throughout 00 UTC October 13 2014. The T/S data from two underwater gliders were assimilated from 00 UTC July 15 to 00 UTC October 13 2014. Only the glider T/S data collected close to 00 UTC of each day were

assimilated. All the ocean data assimilation is performed with the ocean forecast only. An ocean forecast from 2009 to 2014 without any observation assimilated is denoted as NODA as the benchmark experiment. Three data assimilation experiments were designed to examine the impact of assimilating underwater glider T/S data and conventional observations, denoted as GLID, CTRL and ALL (Table 1). After the initialization of both atmospheric and ocean models, the 126 hours coupled forecast started from 00 UTC October 13 to 06 UTC October 18, covering most of the life cycle of Gonzalo as a hurricane.

Table 2: Experiments Assimilating Different Ocean Observations

Experiment Name	**Obs assimilated/Remark**
NODA	No obs
GLID	Two underwater gliders
CTRL	Conventional ocean obs (Jason altimeter, MCSST, AXBT, AXCTD etc.)
ALL	Gliders+conventional ocean obs

The pre-storm ocean profile has a mixed layer with around 55 m depth and an SST of 29 ºC (Figure. 5a). The temperature profile of NODA has a shallow mixed layer of 10 m deep and shows negative bias across the upper 150m depth of the ocean. SST is 0.2 ºC colder than observed (Figure 5a). The assimilation of glider observations in GLID improves the thermal structure by reducing the bias throughout most of the upper 150 m depth (Figure 5a). The SST of GLID is warmer than observed by 0.3 ºC. The bias is always below 0.4 ºC between 60 to 120 m and increased to 1 ºC down to 150 m. The temperature profile of CTRL is similar to GLID above the MLD base but has bias always higher than 0.5 ºC from 60 m to 150 m, which suggests the assimilation of conventional observations also improves the pre-storm thermal structure of this region but not as much as assimilating the glider observation. The assimilation of additional glider observation data based on conventional observations further improves the initial thermal structure: the mixed layer depth of ALL is around 30 m, deeper than CTRL (Figure 5a). The bias is further reduced over most of the upper 150 m depth compared to CTRL.

The observed subsurface salinity quickly increases from the surface to a local maximum at 20 m (Figure 5b). NODA underestimates the salinity with negative bias over 0.5 from 20 m down to 150 m depth. The assimilation of glider T/S data in either GLID or ALL limits the negative bias down to 0.2 (Figure 5b). The conventional observations also help to reduce the error but not as much as the assimilation of glider observation. The salinity of ALL is very close to the observation from 20 to 105 m with near-zero errors (Figure 5b).

During the 126 hours forecast, the predicted track is close to the best track and shows little sensitivity to different ocean initial conditions. On the other hand, the assimilation of conventional ocean observations significantly improves Gonzalo’s intensity forecasts (Figure 6) by reducing the averaged absolute error of minimum sea level pressure and maximum surface wind 47% and 46% respectively. The predicted storms initialized from ocean conditions with conventional ocean observations assimilated (CTRL) are category 3 and closer to the best track, compared to a category 2 storm predicted in NODA. The assimilation of underwater glider observations shows marginal impact (Figure 6). The improvement on Gonzalo’s intensity forecast is partly from a stronger surface enthalpy heat flux induced by the warmer upper ocean condition, especially after 36 hours.

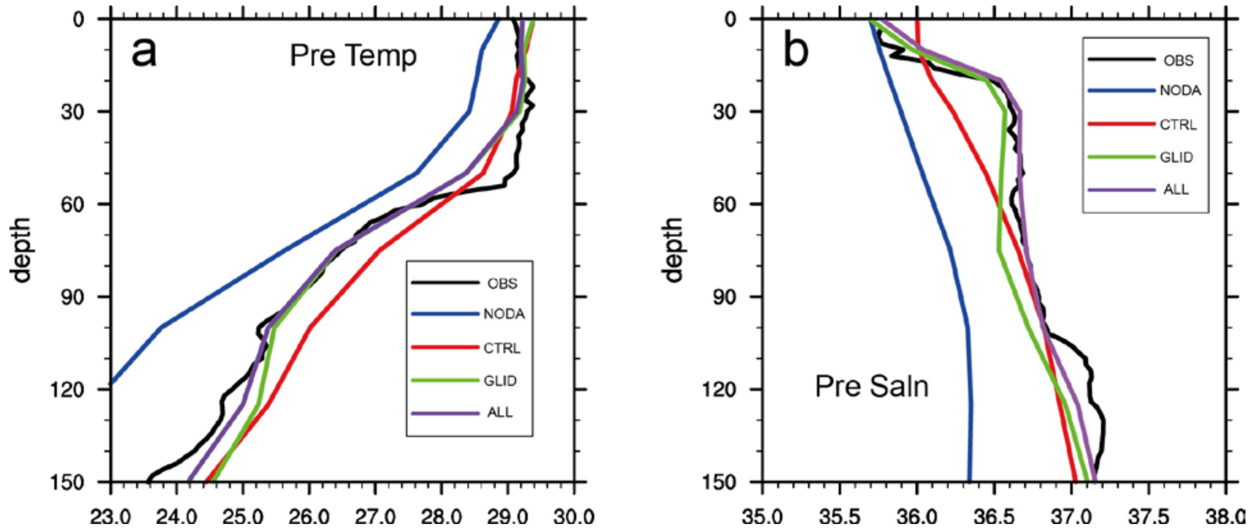

Figure 5: (a) Temperature and (b) salinity profiles at 00 UTC October 13 2014 from four experiments, compared to the glider observation.

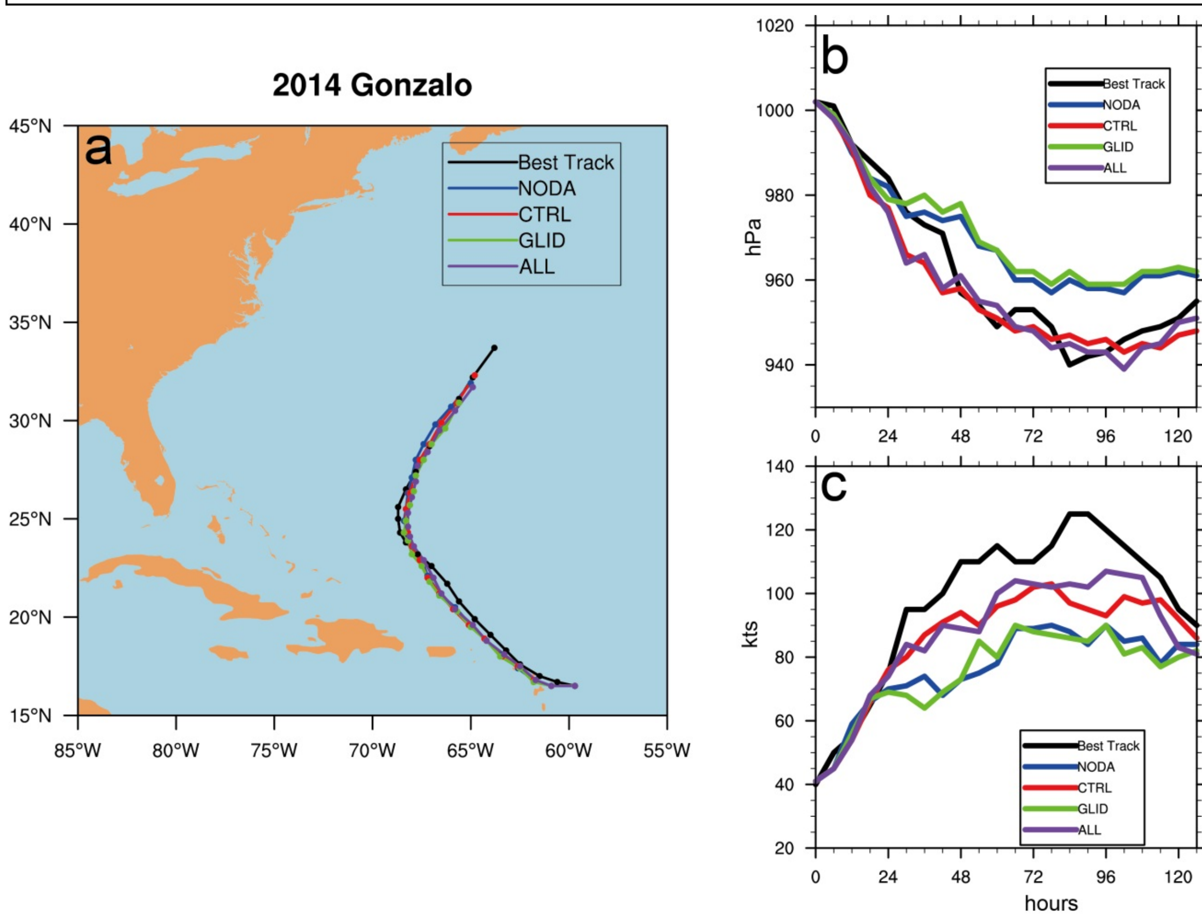

Figure 6: (a) Hurricane Gonzalo's track forecast, (b) minimum sea level pressure (center pressure), and (c) maximum wind forecasts, along with the best track data.

In summary, the assimilation of underwater glider observations significantly improves pre-storm ocean thermal and saline structure for Hurricane Gonzalo (2014). The intensity forecast of Gonzalo is also greatly improved by assimilation of ocean observations, highlighting the importance of ocean initialization on coupled hurricane forecast.

Research Performance Measure: All goals were met during this year with respect to real-time data transmissions and to the percentage recovery of good data. During July 1st, 2014 to June 30, 2015, over 4,800 temperature and salinity profiles were collected in the Caribbean Sea and Tropical North Atlantic.

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Ship of Opportunity Program

Project Personnel: C. Gonzalez, Z. Barton, R. Domingues, M. Goes, H. Lopez, J. Christophersen, G. Rawson, R. Roddy, P. Halsall, T. Sevilla, D. Volkov and R. Sabina (UM/CIMAS)

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

Other Collaborators: J. Trinanes (U. 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 the long-term mean and variability of major ocean currents, and of the transport of mass, heat, and freshwater 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: Molly Baringer

Research Summary:

The global atmospheric and oceanic data from Ships Of Opportunity Program (SOOP) provides key observations for understanding long-term changes in climate. The XBT Network is component of SOOP that supports the design, implementation, maintenance, evaluation, and data acquisition, transmission, and distribution of a network of eXpendable BathyThermographs (XBTs) that obtains temperature profiles along fixed predetermined transects. 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 transport of heat, mass, and freshwater, b) assessing variability of boundary currents, and c) contributing with approximately 15% of the global upper ocean heat content data. Deployments are carried out from a network of cargo vessels, cruise ships, and research vessels. Transects are repeated several times per year, to measure the water temperature from the sea surface to a maximum depth of usually 850m.

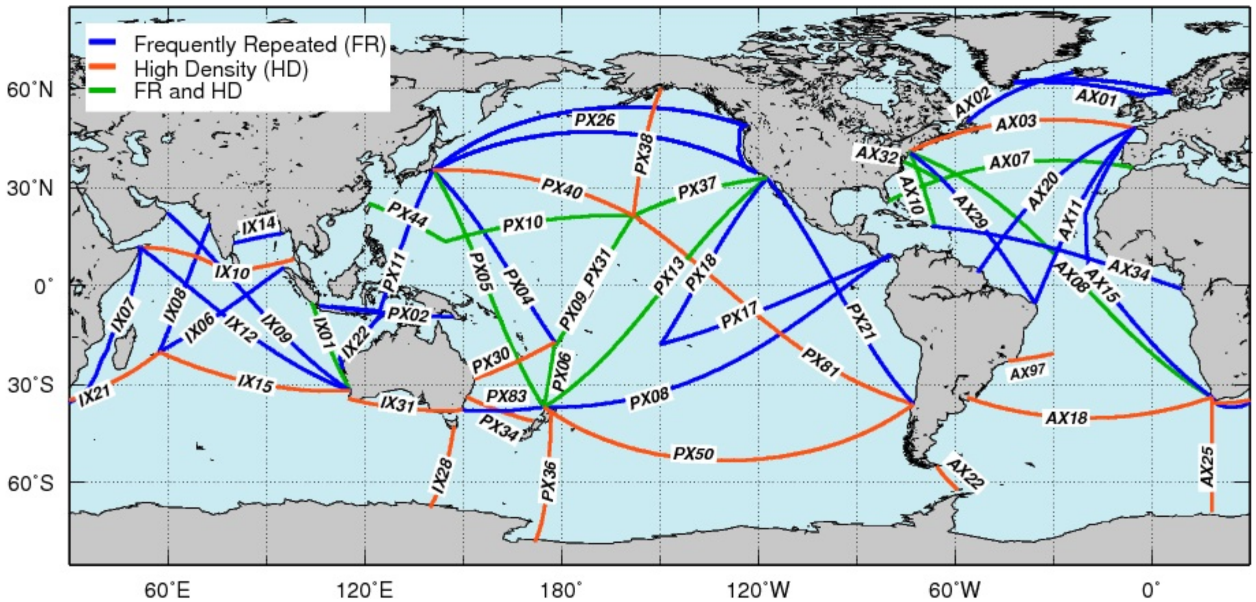

Figure 1: OceanObs09 XBT transects recommended by the scientific community to be occupied in frequently repeated mode (FR, in blue), high density mode (HD, in orange) or both (in green).

The XBT network currently in place has been recommended by the international scientific community during the OceanObs99 and OceanObs09 meetings (Figure 1), and discussed during the four XBT science meetings that have already taken place since 2011. NOAA/AOML is involved with the deployment of approximately 8000 XBTs in Frequently Repeated and High Density modes. 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.*

NOAA/AOML currently maintains, exclusively or as part of international and/or multi-institutional collaborations, the following transects (Figure 2) in High Density mode: AX01, AX02, AX07, AX08, AX10, AX18, AX20, AX22, AX25, AX32, AX97, MX01, MX02, and MX04. NOAA/AOML 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 the main ocean currents and the upper thermal structure in the Pacific Ocean.

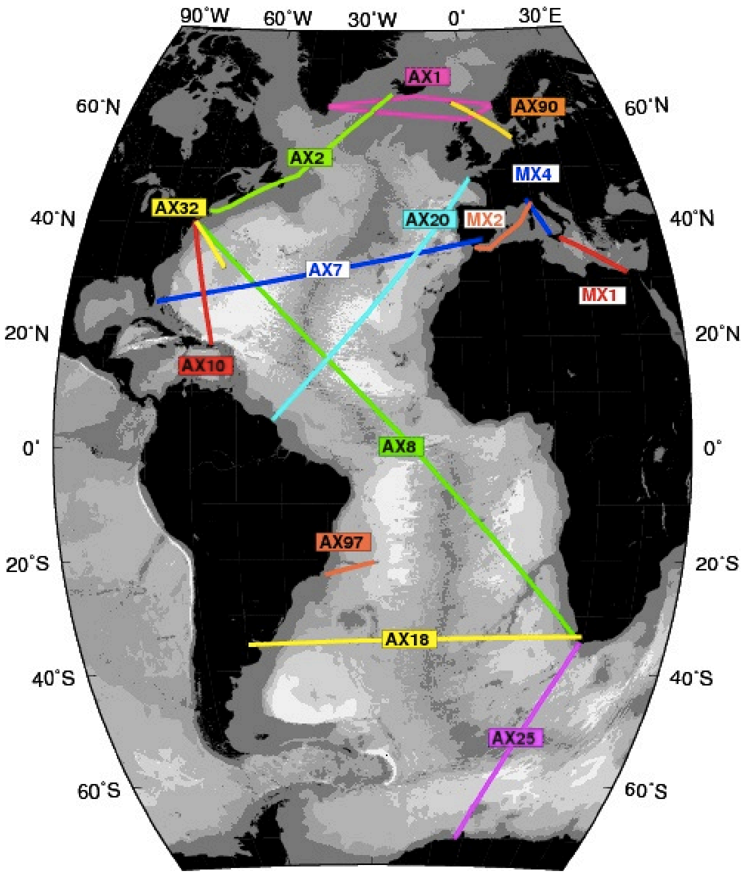

Figure 2: Location of the 4 High Density XBT transects (AX07, AX08, AX10, and AX18) maintained solely by NOAA/AOML, and the 7 transects (AX01, AX02, AX20, AX25, AX32, AX90, AX97, IX01, IX12, IX28, MX01, MX02, and MX04) maintained by NOAA/AOML in collaboration with the University of Paris, IRD/France, NOAA/NEFSC, University of Cape Town, Federal University of Rio Grande, Australia's Bureau of Meteorology and CSIRO, and ENEA/Italy.

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 ocean currents correspond to important components of the Meridional Overturning Circulation in the Atlantic Ocean.

The SOOP includes extensive operations that collect, organize, and distribute the data, which are gathered from as many as eighteen cruises conducted by AOML each year, including in excess of 200 days at sea and approximately 8000 XBTs deployed. Figure 3 shows the location of XBT deployments by the international community during calendar year 2015 **(total of 17,043 XBT deployments**). AOML operate XBT deployments in transects AX10, AX07, AX08, AX18, and support deployments and transmissions in several additional transects carried out in partnership with national and international collaborators (Figure 4).

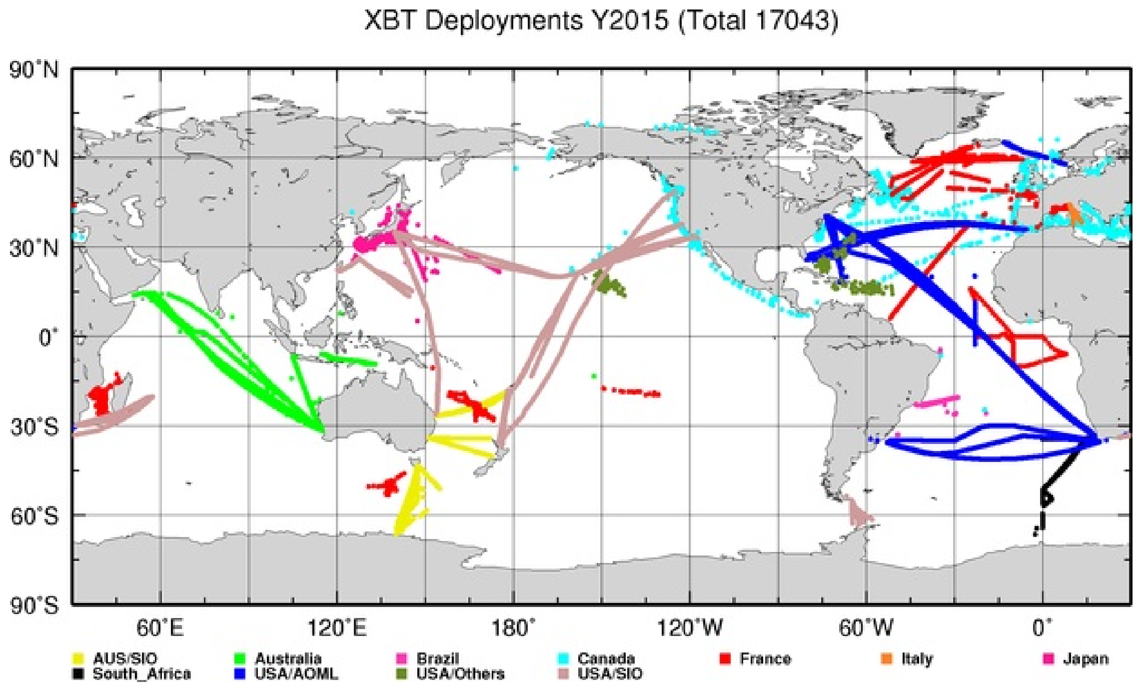

Figure 3: Locations of XBT deployments by AOML and the international community during calendar year 2015.

The data obtained though this project are distributed into the GTS within 24 hours of their acquisition, providing critical input for weather and climate forecasts models and scientific applications. Data are also provided to the scientific community to investigate the variability and upper ocean thermal structure of boundary current, subtropical gyres, equatorial current system to study and understand the role that the ocean plays in climate fluctuations, and to improve the ability to predict important climatic signals, such as the North Atlantic Oscillation. For more details about the XBT network, please see *www.aoml.noaa.gov/phod/hdenxbt/*.

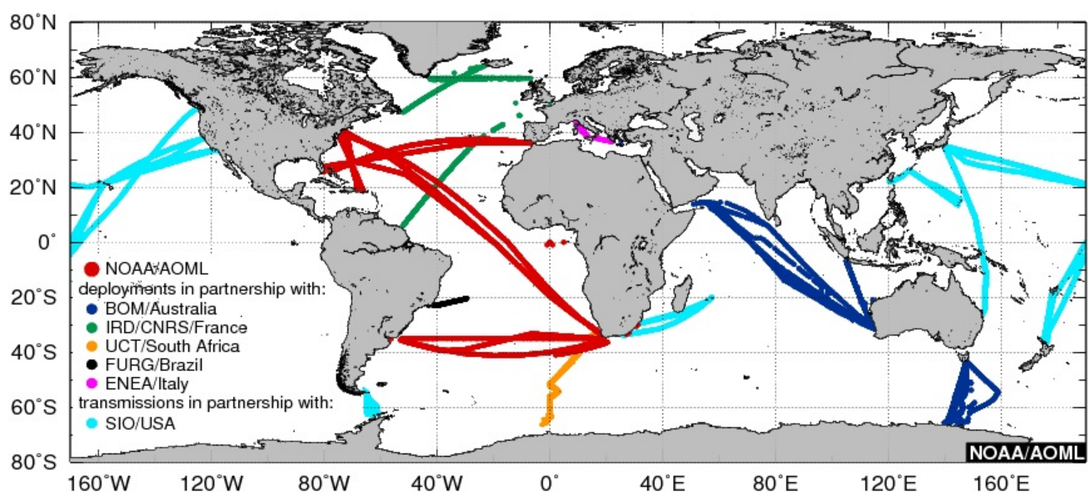

Figure 4: Location of the AOML XBT deployments and AOML-supported XBT deployments/transmissions during FY2015 carried out by AOML or in partnership with national and international collaborators.

In addition, observations from other in situ and remote observing platforms are used to complement the observations provided by the XBT transects. The SOOP also supports other observational networks, such as the global drifter array, and Argo profiling floats by performing deployment of instruments at no cost along the XBT transects.

One of the most important contributions of the XBT network is the monitoring and study of the Meridional Overturning Circulation (MOC) and the Meridional Heat Transport (MHT). The MOC is the main mechanism for global redistribution of heat in the ocean. The Atlantic Ocean is the major ocean basin involved in large-scale northward transports of heat typically associated with the MOC, where warm upper layer water flows northwards, and is compensated for by southward flowing North Atlantic Deep Water. This large-scale circulation is responsible for the northward heat flux through the entire Atlantic Ocean. The MHT is continuously monitored in the South and North Atlantic using data from two XBT transects: AX18 in the South Atlantic (Figure 5), and AX07 in the North Atlantic (Figure 6).

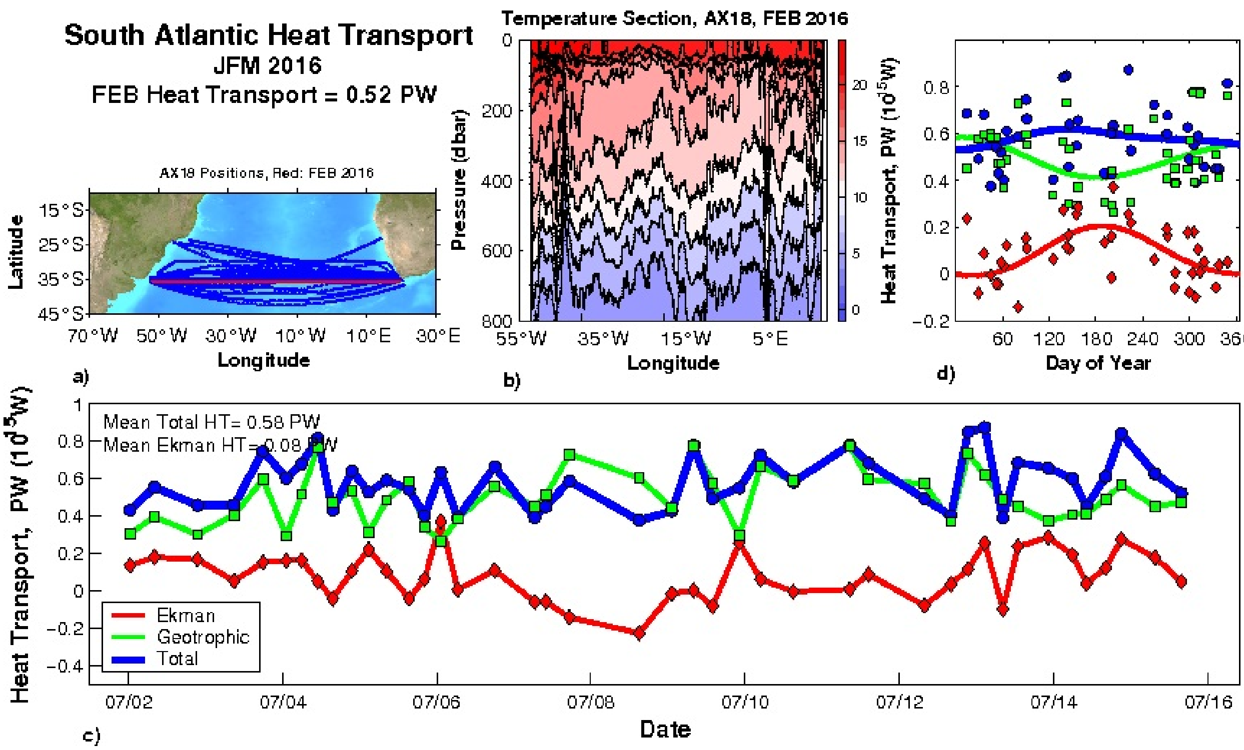

Figure 5: South Atlantic MHT calculated using data from the AX18 high density XBT transect, which runs from the Rio de la Plata region to South Africa.

During FY2015, AOML also continued the TSG operation in support of pCO_2 operations. During this period AOML received, processed, and distributed TSG data from 7 ships of the SOOP (MV Oleander, MV Barcelona Express, MV Reykjafoss, MV Bernardo Houssay of the Argentinean Coast Guard, and Royal Caribbean's Explorer of the Seas and Allure of the Seas in collaboration with University of Miami/RSMAS) and 11 ships of the NOAA fleet (RV Okeanos Explorer, RV Pisces, RV Oregon II, RV Ronald H Brown, RV Bell M Shimada, RV Oscar Elton Sette, RV Rainier, RV Gordon Gunter, RV Oscar Dyson, RV Nancy Foster, RV Hi'ialakai). More than 8 million TSG records were processed at AOML during FY2015 (Figure 7), and distributed through several data centers. The operation of TSG equipment is performed with the SEAS software.

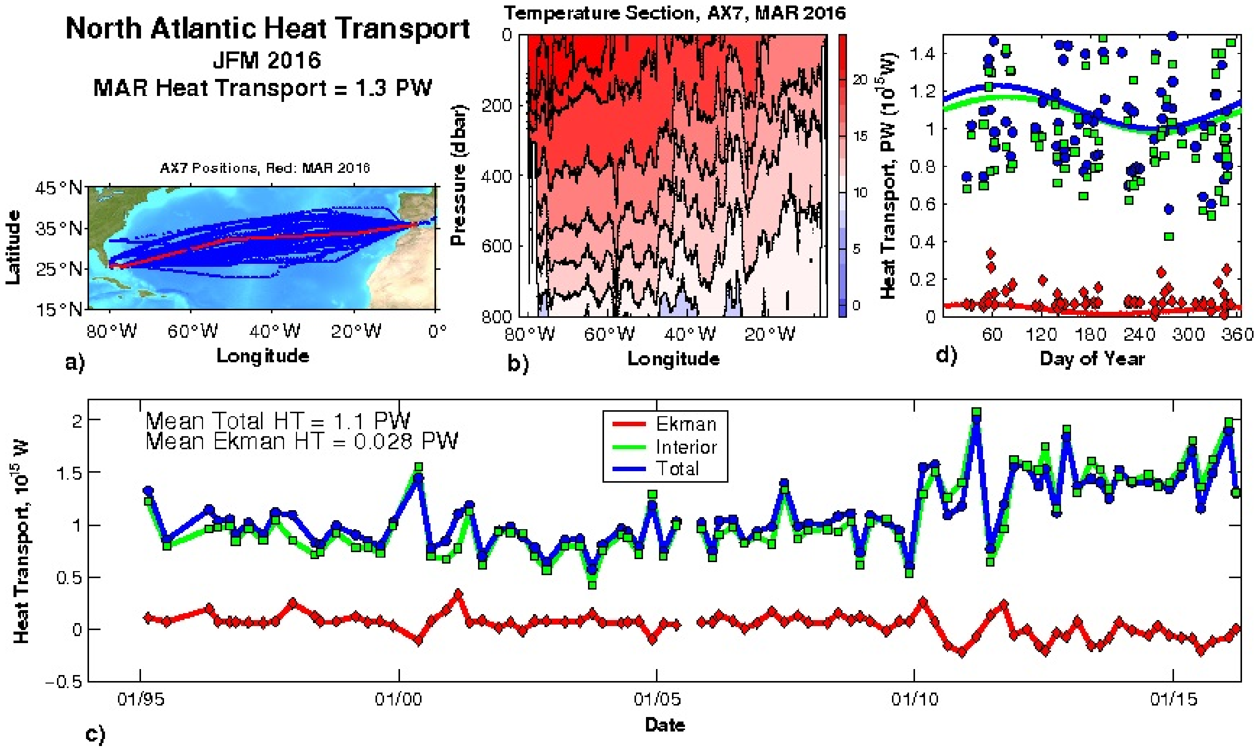

Figure 6: North Atlantic MHT calculated using data from the AX07 high density XBT transect, which runs from Florida, USA, to Gibraltar.

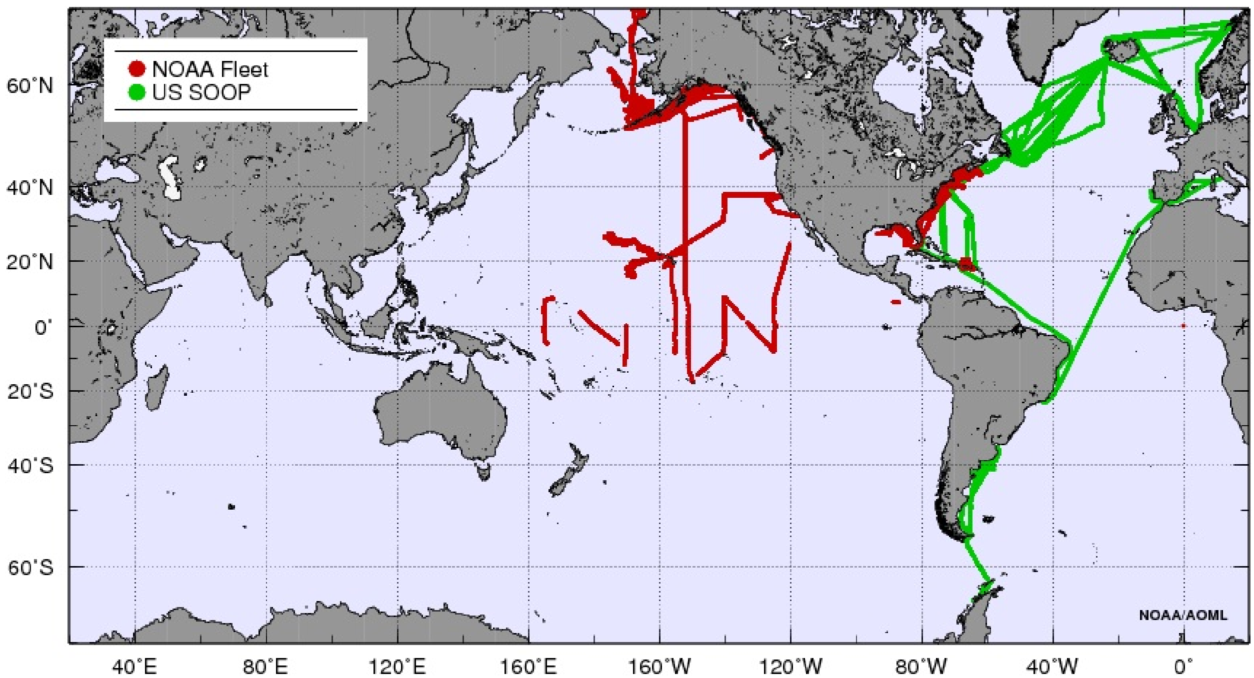

Figure 7: Locations of TSG records received, processed, and distributed by AOML during fiscal year 2015.

In addition to observational efforts, the AMVERSEAS software, which is supported by SOOP, is also used to: (i) provide regular reports to the US Coast Guard's Automated Mutual-Assistance Vessel Rescue System (AMVER), which aids in finding ships in the vicinity of vessels in distress; and .(ii) transmit meteorological observations from vessels through the Shipboard Environmental data Acquisition System (SEAS), which contributes to the largest source of marine meteorological observations used by the NOAA National Weather Service for marine forecast.

During the reporting period, the components of the project linked with the operations and data distribution were marked by:

(i) The development of a proprietary XBT data acquisition device, which aims to improve current methods for acquiring data, while reducing associated costs of operations. The new instrument called Real-time Data Acquisition Device performs the same operations as the MK-21 by Lockheed Martin. Production cost for the current Real-time Data Acquisition Device prototype is less than $100 per unit, which may potentially translate in a major savings of operating costs, given that each MK21 unit costs approximately $8,000.

(ii) Multiple tests of a new Linux-based computer system to deploy and monitor XBTs during a cruise with Amverseas. This new system has proven more stable than windows-based operating systems. Once the testing phase is over, it will be assessed as an alternative to windows-based operating systems where needed. The new setup also includes the newly developed Ethernet DAQ Mk21 from Sippican. This is currently the only sippican-supported version of the XBT acquisition hardware.

(iii) Updates in software used for real-time monitoring of XBT transects. The software decodes the binary files from a FTP server transmitted via Iridium, and is able to identify problems during cruises like gaps between deployments and equipment failures. This software is currently used by NOAA/AOML to identify issues with the data and to support riders.

(iv) A new software package used for quality control of XBT data. Quality control proceedures were updated and translated from FORTRAN to PYTHON. The new software aims to simplify troubleshooting, maintenance, and accessibility, while still complying with requirements to transmit in BUFR formatted files to GTS.

(v) Updates in the AMVERSEAS software used for data acquisition. Updates included implementing the command-dispatcher module Remote Command System, which will increase the flexibility of AMVERSEAS, and including a Distance Drop Plan in the XBT Program, which simplifies the sampling setup for the rider.

(vi) A sea trial was performed to test the new accuracy of the Enhanced XBT (EXBT) probes during the PIRATE Northeast Extension 2015 cruise. A series of 40 EXBTs was deployed to examine the gain in temperature and depth accuracy of the new probes. These probes include a new thermistor parameterization, and a tighter weight tolerance for the weight variability of the probes noses. Preliminary results show that the new probes improved the median temperature accuracy (Figure 8).

The research component of the project provided advances in the following topics:

(a) Dong et al. (2015a): surface salinity variations and processes affecting surface salinity in the high-salinity region of the subtropical North Atlantic (the SPURS-1 area) were investigated by combining data from in situ observations and satellite remote-sensing measurements. The seasonal evolution of the mixed-layer salinity, which is characterized by high values from April to August and low values from September to March, is largely controlled by the freshwater flux term, with

vertical entrainment playing a secondary role. On interannual timescales, ocean advection plays a larger role in salinity changes during 2008–2012, whereas the surface freshwater flux term dominates surface salinity evolution during 2004–2007 and in 2013. Sustained XBT measurements in the North Atlantic also showed strong interannual variations in subsurface temperatures (Figure 9). The SPURS-1 region exhibits colder temperature anomalies are observed in the north of the SPURS-1 region (AX07), and warmer anomalies in the southwestern region (AX08). Altimeter, Argo and XBT transect data demonstrates that the Gulf Stream was relative weak and had a more southerly position during 2012-2013, suggesting a significant anticorrelation of the salinity changes between the two transect regions on interannual time scales, with changes in the subtropical gyre region (25°N−40°N, 80°W−50°W) leading the SPURS-1 region by five months.

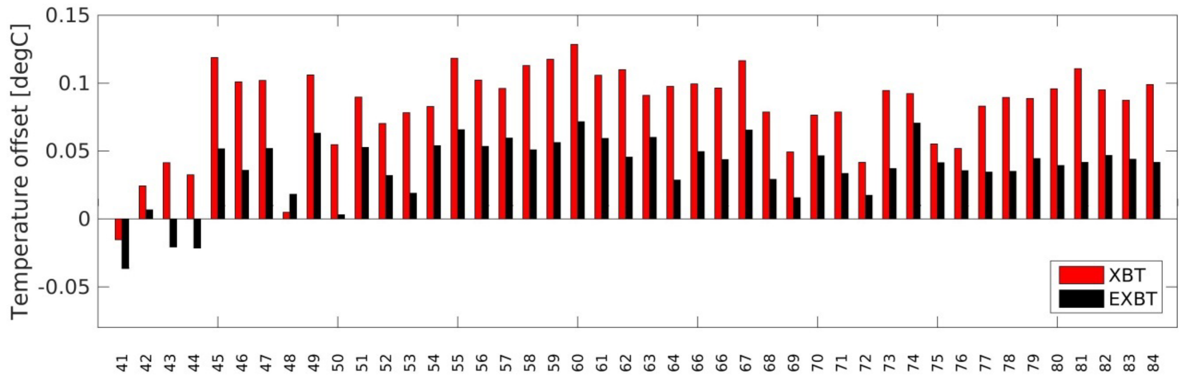

Figure 8: Temperature offset (deg C) calculated between the XBTs and CTDs profiles deployed during the PNE 2015 experiment. Red bars are for the uncalibrated thermistors, and black bars are for the post-calibrated thermistors.

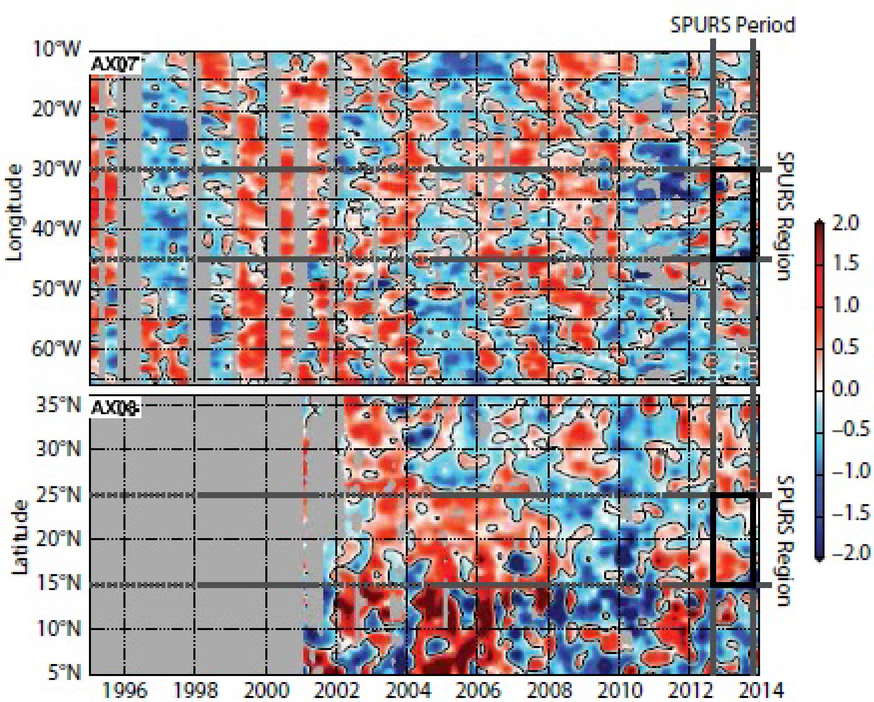

Figure 9: Hovmoller diagram of subsurface temperature anomalies at 100 m depth from XBT transects AX07 (top panel) and AX08 (bottom panel). Black boxes indicate the SPURS-1 period/region.

(b) Dong et al., (2015b): Altimetry-derived synthetic temperature and salinity profiles between 20°S and 34.5°S are used to estimate the Meridional Overturning Circulation (MOC) and meridional heat transport (MHT), which are assessed against estimates obtained from expendable bathythermograph (XBT) measurements. Consistent with studies from XBTs and Argo data, both the geostrophic and Ekman contributions to the MOC exhibit annual cycles and play an equal role in the MOC seasonal variations. The strongest variations on seasonal and interannual time scales in our study region are found at 34.5°S. The dominance of the geostrophic and Ekman components on the interannual variations in the MOC and MHT varies with time and latitude (Figure 10), with the geostrophic component being dominant during 1993–2006 and the Ekman component dominant between 2006 and 2011 at 34.5°S.

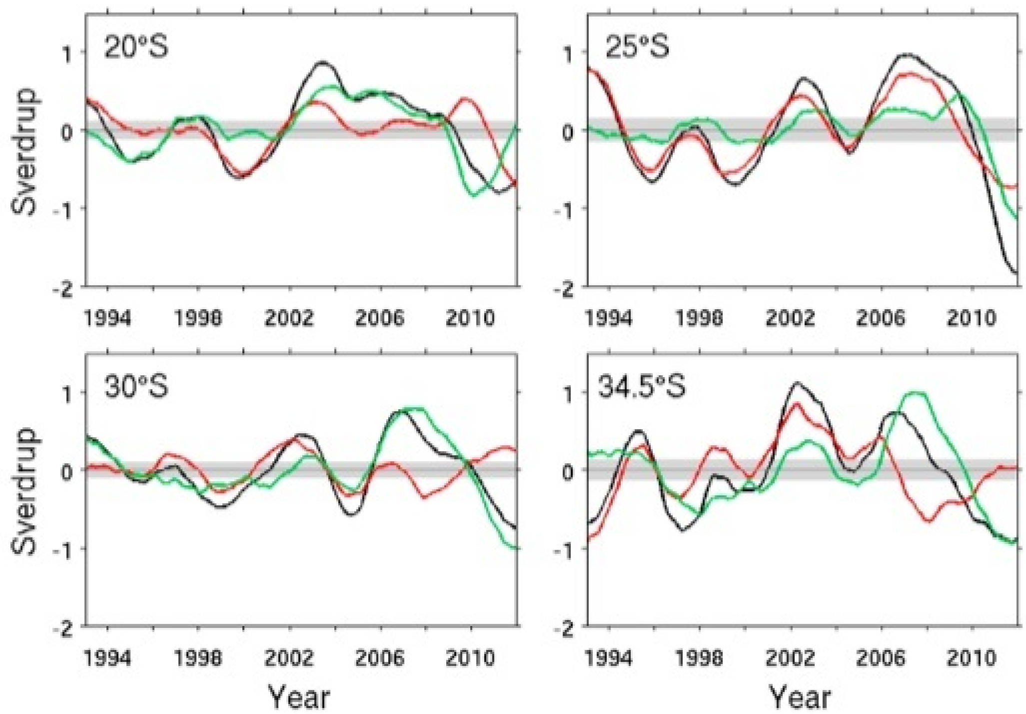

Figure 10 – Interannual variations of the MOC (black) and contributions from the geostrophic (red) and Ekman (green) components at 20°S, 25°S, 30°S, and 34.5°S, respectively. The gray shading denotes the range where anomalies are not significantly different from zero.

(c) Lopez et. al. (2016): This study presents a physical mechanism on how low-frequency variability of the South Atlantic meridional heat transport (SAMHT) may influence decadal variability of atmospheric circulation. A multicentury simulation of a coupled general circulation model is used as basis for the analysis. The highlight of the findings herein is that multidecadal variability of SAMHT plays a key role in modulating global atmospheric circulation via its influence on interhemispheric redistributions of momentum, heat, and moisture. Weaker SAMHT at 30°S produces anomalous ocean heat divergence over the South Atlantic, resulting in negative ocean heat content anomalies about 15–20 years later. This forces a thermally direct anomalous interhemispheric Hadley circulation, transporting anomalous atmospheric heat from the Northern Hemisphere (NH) to the Southern Hemisphere (SH) and moisture from the SH to the NH, thereby modulating global monsoons. Further analysis shows that anomalous atmospheric eddies transport heat northward in both hemispheres, producing eddy heat flux convergence (divergence) in the NH

(SH) around 15°–30°, reinforcing the anomalous Hadley circulation. The effect of eddies on the NH (SH) poleward of 30° depicts heat flux divergence (convergence), which must be balanced by sinking (rising) motion, consistent with a poleward (equatorward) displacement of the jet stream. A schematic diagram showing the mechanism uncovered by this study is shown in Figure 11. This study illustrates that decadal variations of SAMHT could modulate the strength of global monsoons with 15–20 years of lead time, suggesting that SAMHT is a potential predictor of global monsoon variability. A similar mechanistic link exists between the North Atlantic meridional heat transport (NAMHT) at 30°N and global monsoons.

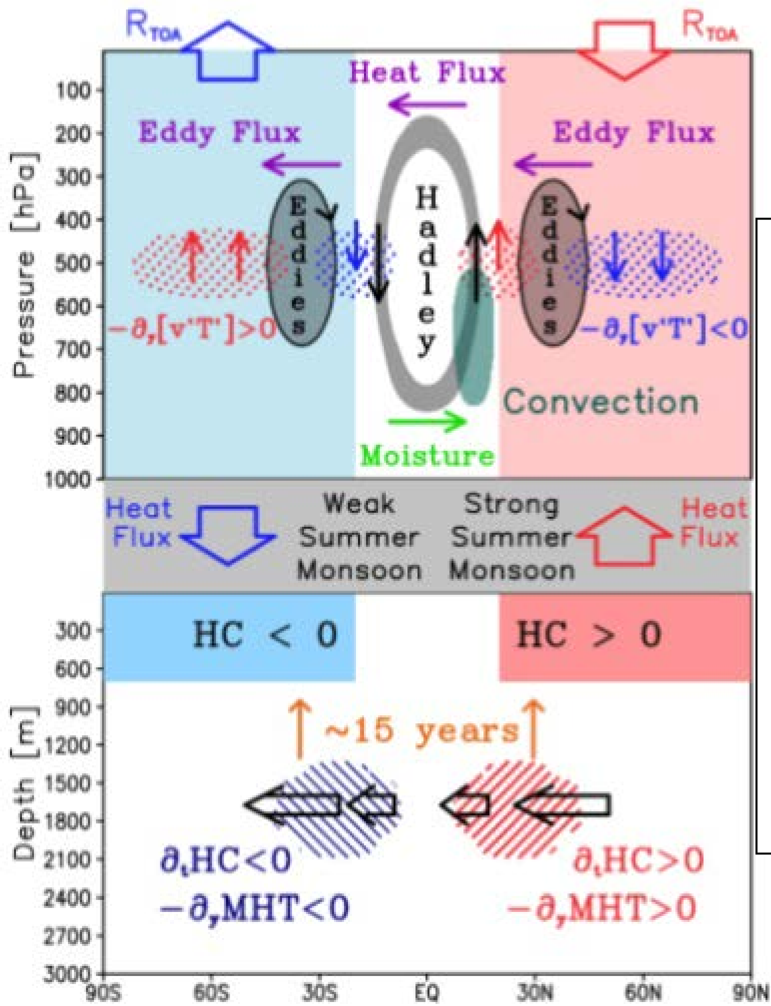

Figure 11 – Schematic diagram of the role of weaker-than-normal MHT in the anomalous atmospheric circulation at 15-20 years lead-time. Weakened MHT is shown by thick lack arrows on the bottom panel. Negative (positive) tendency in heat content is labeled by dark-blue (red) hatching. There is negative (positive) heat content in the SH (NH) about 15-20 years after the heat transport anomaly labeled here by blue (red) rectangle. Anomalous Hadley circulation is labeled by gray oval a counterclockwise circulation. Moisture and heat fluxes are shown by green and purple arrows, respectively. The TOA and surface radiative fluxes are shown by thick red and blue arrows. Purple arrows depict atmospheric eddy heat transports. Eddy forced vertical motion is shown by red and blue stipples.

(d) Lima et al. (2016): This study assesses the structure and variability of the BC across the nominal latitude of 22ºS using data from the high density XBT AX97 transect and from three numerical ocean models with data assimilation (HYCOM-NCODA, GLORYS2V3 and FOAM). These Ocean Forecasting and Analysis Systems (OFAS) are able to capture the mean observed features in the 22°S region, showing a BC core confined to the west of 39°W and an Intermediate Western Boundary Current between the depths of 200 and 800 m (Figure 12). However, the OFAS tend to overestimate the mean BC geostrophic baroclinic volume transport across the AX97 reference transect, and underestimate its variability. The OFAS show that the coastal region between the coastline and the western edge of the AX97 transect plays an important role in the mean BC total

transport, contributing to up to 30% of its value, and further confirming that this transport is not sampled by the XBT data. In order to understand the variability of the BC, a statistical classification of the BC is proposed, with the creation of three different scenarios.

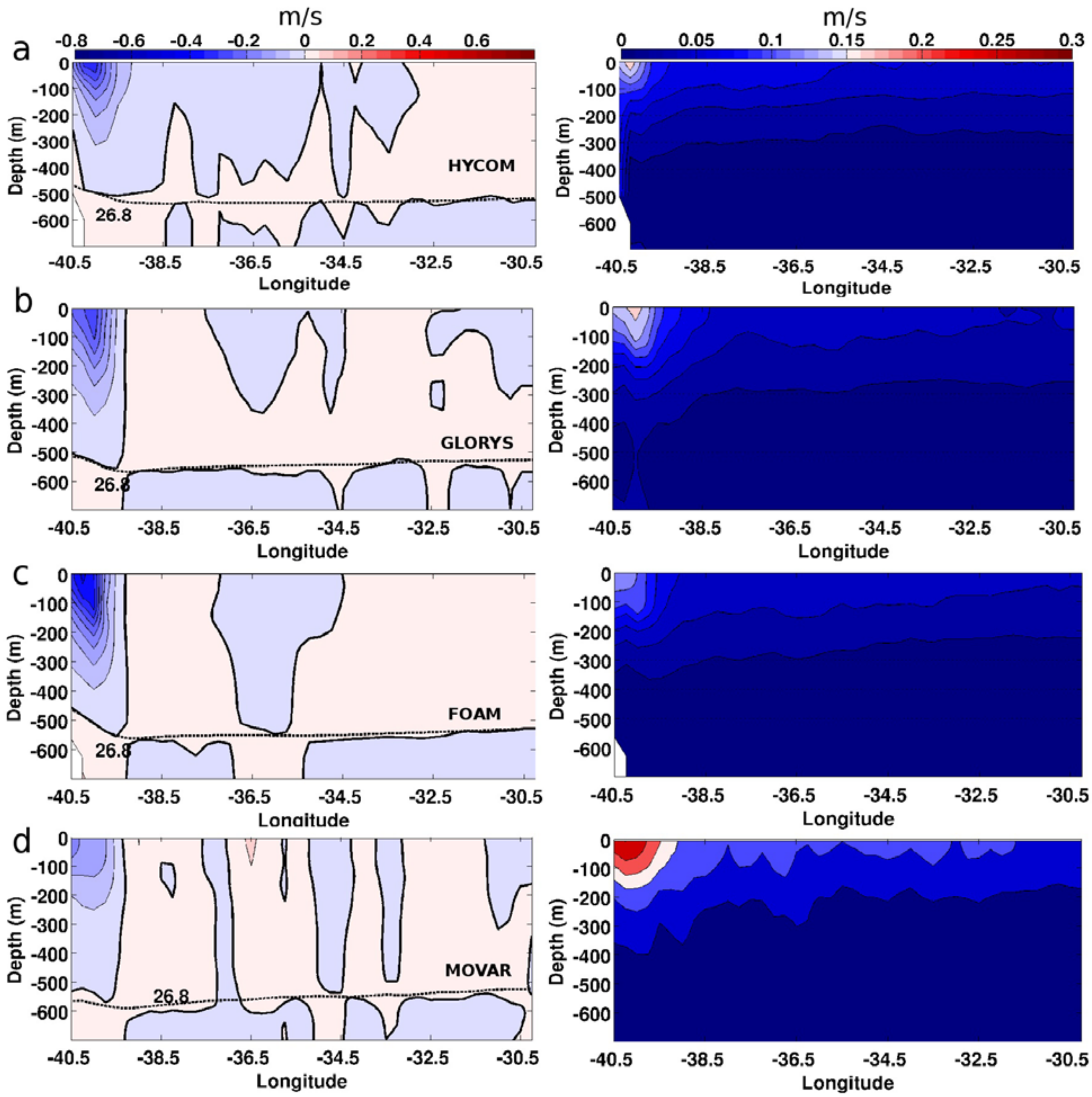

Figure 12 - Mean cross-sectional component of the baroclinic velocity (left panels) and associated standard deviation (right panels) for the OFAS and MOVAR at the AX97 reference transect for the whole period (2004-2012). The OFAS are represented in the vertical panel panels from top to bottom in the following sequence: (a) HYCOM (b) GLORYS and (c) FOAM. (d) Same distribution for MOVAR during the cruise periods. Units are in m/s, with negative (positive) values indicating a southward (northward) flow. A solid bold line represents the zero contour of the velocity. The reference level of no motion is the σ_θ = 26.8 kg/m3. A black dashed line in the left panels represents the mean depth of this isopycnal, for each data.

(e) Bringas et al. (2015): Expendable bathythermographs (XBTs) are probes widely used to monitor global ocean heat content, variability of ocean currents, and meridional heat transports. In the XBT temperature profile, the depth is estimated from the time of descent in the water using a fall-rate equation. There are two main errors in these profiles: temperature and depth errors. The reduction of error in the estimates of the depth allows a corresponding reduction in the errors in the computations in which XBTs are used. Two experiments were carried out to study the effect of the deployment height on the depth estimates of Deep Blue XBT probes. During these experiments, XBTs were deployed from different heights. The motion of the probes after entering the water was analyzed to determine the position and the velocity of the probes as a function of time, which was compared to that obtained using the Hanawa et al. fall-rate equation. Results showed a difference or offset between the experimentally observed depths and those derived from Hanawa et al. This offset was found to be linked to the deployment height. To eliminate the offset in the fall-rate equation for XBTs deployed from different heights, a methodology is proposed here based on the initial velocities of the probes in the water (or deployment height). Results indicate that the depth estimates in the profiles need to be corrected for an offset, which in addition to having a launch height dependence is time dependent during the first 1.5 s of descent of the probe in the water, and constant after that.

(f) Cheng et al., (2015): Recommendations for correcting biases in XBT data, and the impact on applications and ongoing research to improve the quality of future XBT data are provided. eXpendable BathyThermograph (XBT) data were the major component of the ocean temperature profile observations from the late 1960s through early 2000s, and XBTs still continue to provide critical data to monitor surface and subsurface currents, meridional heat transport, and ocean heat content. Systematic errors have been identified in the XBT data, some of which originate from computing the depth in the profile using a theoretically- and experimentally derived fall rate equation (FRE). After in-depth studies of these biases and discussions held in several workshops dedicated to discuss XBT biases, the XBT science community met at the Fourth XBT Science Workshop and concluded that XBT biases consist of: 1) errors in depth values due to the inadequacy of the probe motion description done by standard FRE, and 2) independent pure temperature biases. The depth error and temperature bias are temperature dependent and may depend on the data acquisition and recording system. In addition, the depth bias also includes an offset term. Some biases affecting the XBT-derived temperature profiles vary with manufacturer/probe type and have been shown to have a time dependence. Best practices for historical XBT data corrections, recommendations for future collection of metadata to accompany XBT data, impact of XBT biases on scientific applications, and challenges encountered are presented in this manuscript. Analysis of XBT data shows that, despite the existence of these biases, historical XBT data without bias corrections are still suitable for many scientific applications, and that bias corrected data can be used for climate research.

Research Performance Measure: All operational research goals were met during this year with respect to real-time data transmissions and 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.

Coral Associated Environmental Microbiology and Genomics

Project Personnel: M. Gidley (UM/CIMAS)
NOAA Collaborators: J. Hendee, C. Sinigalliano and K. Goodwin (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

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

Strategy: To perform extensive coastal water quality and current measurements, and inlet water quality and flow measurements in specific areas 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 1: Healthy Oceans - *Increase our knowledge and understanding of the mechanisms and impacts of environmental changes on marine species and ecosystems* (*Primary*)

Goal 4: Resilient Coastal Communities and Economies - *Understand the impacts of land-based sources of pollution* (*Secondary*)

NOAA Funding Unit: NOAA/CRCP and NOAA/CHAMP
NOAA Technical Contact: Molly Baringer

Research Summary:

This project measures specific microbial contaminants from land-based sources of pollution within the water column of coastal inlets, outfalls, and coral reef tracks of the Southeast Florida region, and within the coral itself of four regional reefs. Additional sites in the Florida Keys are being added as the project transitions to CGON/MBON – Coral Genomics Observing Network/Microbial Biodiversity Observing Network. For both, specific pathogens and microbial source tracking markers are measured by quantitative PCR, and microbial diversity and community composition are being determined by metagenomic sequencing analysis of bacteria, fungal, and algal populations. This project ultimately is intended to aid management with new molecular tools to help identify and mitigate sources of land-based microbial contaminants impacting coral reefs.

This project is genetically characterizing LBSP microbial contaminants in the SEFCRI region by measuring the relative abundance of fecal indicators, fecal and non-fecal pathogens, and fecal host-source tracking markers in the discharge waters of three coastal inlets and two treated wastewater oceanic outfalls; by measuring the same microbial contaminants in the coral mucus and polyp tissues of reefs in this coastal region; and by identifying the microbial community composition and population structures of these inlet, outfall, and coral samples to better characterize impacts and sources of microbial pollutants. Molecular genetic tracking of LBSP microbial contaminants observed to impact these coral reef study sties are conducted by both target-specific qPCR source tracking assays, and by novel metagenomic community sequence microbial source tracking methods.

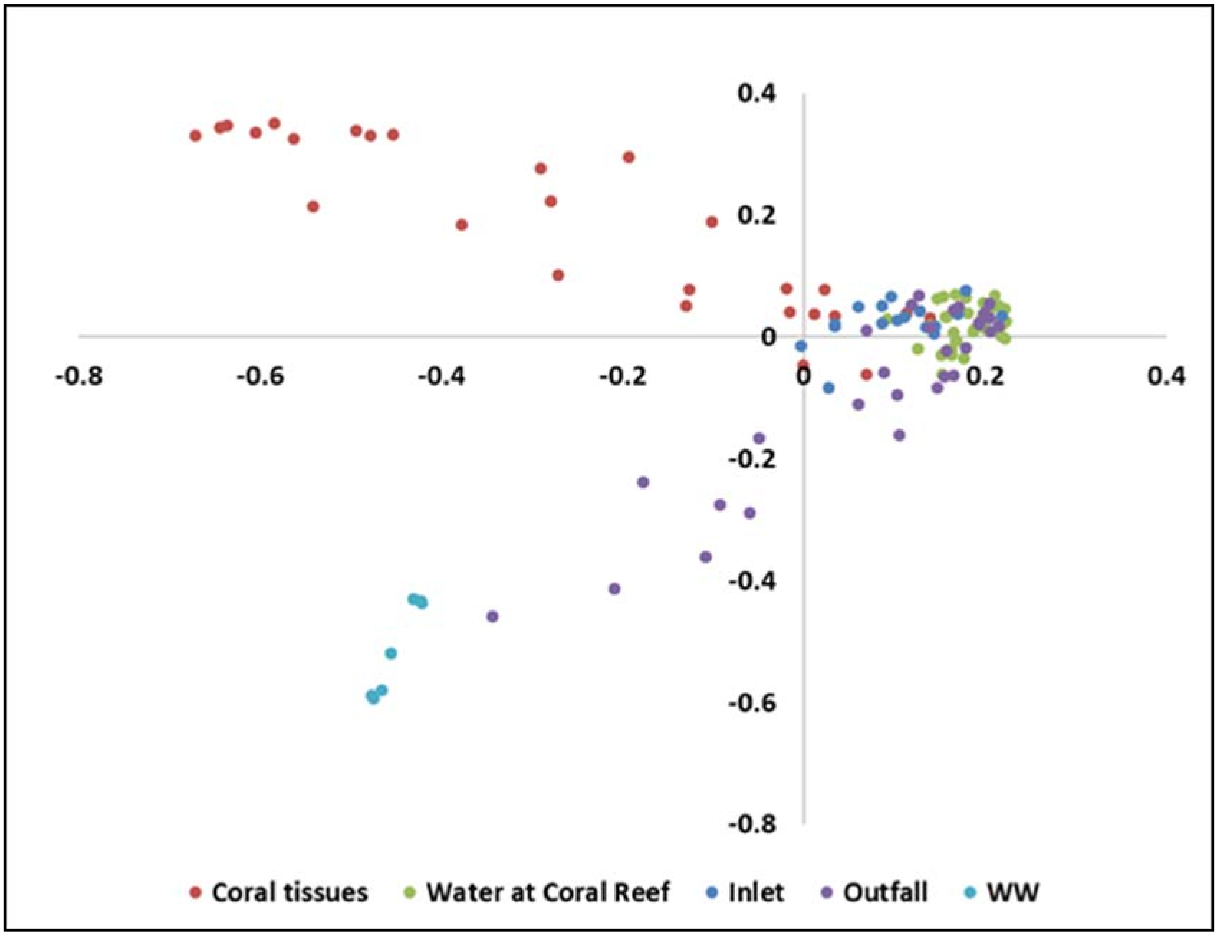

Figure 1: Principal coordinate analysis of bacterial community structure from 16S rDNA metagenomic sequencing of water samples and coral tissue from 4 sentinel reefs offshore of Broward and Miami-Dade Counties. Treated wastewater effluent shows unique community structure as does coastal inlet discharge waters. surface water from both wastewater oceanic outfalls and surface waters from coral reefs show more similarity to bacterial community structure from background oceanic waters. A total of fifteen axis accounted for all differences among samples.

Research Performance Measure: More than five hundred samples have been processed, with various stages of analysis underway. Performance Measures include total number of samples obtained, number of qPCR source tracking markers run, and range of metagenomic analysis. Original metagenomic analysis was delayed due to equipment issues, but is now more than 50% complete.

Investigation of the Movement of Adult Billfish in Potential Spawning Areas

Project Personnel: J. Hoolihan (UM/CIMAS); J. Luo (UM/RSMAS)
NOAA Collaborators: C. Brown and E. Prince (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 1*:** 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 analyzed data garnered from pop-up satellite archival tags (PSATs) to understand behavior and movement of large pelagic predators PSATs use light-based geolocation methods to estimate movement tracks of tagged fish. There are inherent restrictions to this method that limit accuracy to around 60 nm. Latitudinal points are particularly difficult to determine. Further processing using Kalman, bathymetric, and sea-surface temperature (SST) filtering improves track estimates. One problem with estimating tracks in tropical areas is that SST is often uniform across large areas, reducing its usefulness as a filtering tool. To address this, we used ocean heat content (OHC), a habitat metric that is a fundamental part of hurricane intensity forecasting. Combining PSAT data with OHC in an optimization framework substantially improved geoloca-

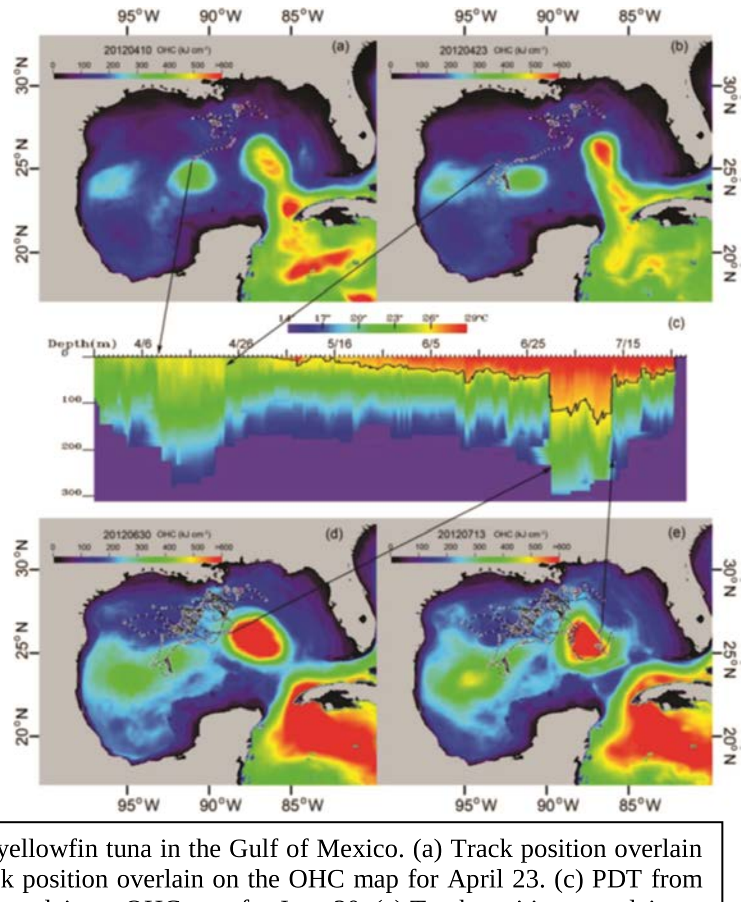

Figure 1: OHC refined movement track of a yellowfin tuna in the Gulf of Mexico. (a) Track position overlain on the OHC map for April 10, 2012. (b) Track position overlain on the OHC map for April 23. (c) PDT from the tagged yellowfin tuna. (d) Track positions overlain on OHC map for June 30. (e) Track positions overlain on OHC map for July 13. Reprinted from PLOS ONE| DOI: 10.1371/journal.pone.0141101 October 20, 2015.

tion estimates previously based on SST (Luo et al., 2015); and, provided the first quantitative evidence showing many of our PSAT monitored fishes associating with ocean fronts and eddies (Figure 1).

In 2016, a study was undertaken to determine the maximum size and longevity attained by blue marlin *makaira nigicans*. Blue marlins are large, long-lived, vagile, predatory billfish inhabiting tropical and subtropical waters worldwide. They represent an economically important recreational fishery, and are overexploited as bycatch by commercial longline fleets targeting swordfish and tunas (Anon. 2011). The most recent assessment results reported by the International Commission for the Conservation of Atlantic Tunas (ICCAT) indicates the Atlantic blue marlin stock is below B_{MSY} and that fishing mortality is above F_{MSY} (Anon. 2011). Improved stock assessment methods are needed to ensure the conservation of this species. Accurate estimates of population age-structure and fish growth rates are fundamental for advanced stock assessment methods. These estimates have typically been difficult to attain for billfishes due small sample sizes, lack of very young and very old individuals, and problems associated with interpreting growth annuli present in hard parts.

We have at our disposal high resolution photomicrographs of anal fin spine cross sections from Atlantic blue marlin (n = 1620) gathered from Venezuelan fisheries. Further, an additional 64 samples that require sectioning and imaging are available at the Southeast Fisheries Science Center (SEFSC) Miami lab. Within these collections are over 20 very large individuals ranging from about 800 to 1300 lbs. whole weight. In total, this sample set represents an unprecedented number from which to estimate growth rates, maximum size and longevity. Capture location, sex, and lower jaw-fork length are known for nearly all these fish. We are currently in the process of evaluating and assigning age estimations to these samples (Figure 2).

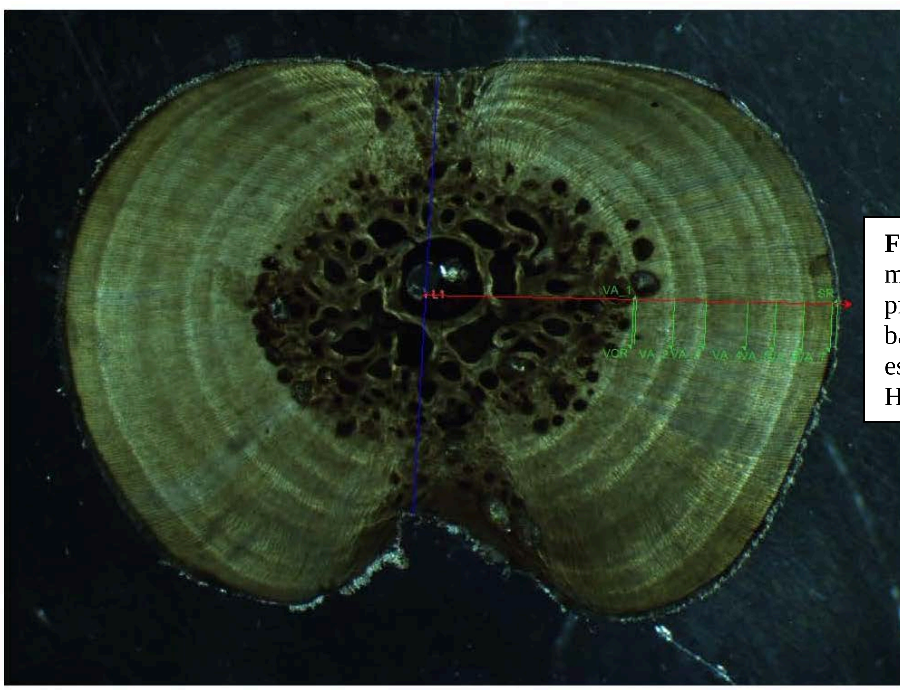

Figure 2: Cross section of blue marlin anal fin spine showing presumptive annual growth bands used for age and growth estimations (*photo by* J. Hoolihan).

Research Performance Measure: 1) High recovery rate for data collected by pop-up satellite tags indicates that fish tagging protocols and deployment durations are appropriate. 2) Many joint authored (NOAA/RSMAS) peer review papers have resulted over the last few years. Those from 2015-2016 are listed in the Publications section of this report. Others can be accessed at:
http://www.sefsc.noaa.gov/fisheriesbiology.jsp

Calibration/Validation Support for NPP VIIRS Data Product Continuity

Project Personnel: C. Hu (USF)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To assess VIIRS data product continuity from its predecessors, diagnose reasons for discrepancy; 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 1*:** Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems*

NOAA Funding Unit: NOAA/NESDIS
NOAA Technical Contact: Menghua Wang

Research Summary:

To date, the following activities have been conducted to achieve the project objectives:

- Collected water samples to determine chlorophyll *a* concentrations, CDOM absorption, and particle absorptions. These data have been and will be used to evaluate VIIRS performance in coastal waters.
- Participated in the cruise survey onboard the NOAA ship Nancy Foster to collect bio-optical data in the South Atlantic Bight and Bahamas in December 2015. Most data have been processed, quality controlled, and submitted to NOAA/NESDIS to support VIIRS cal/val. Some optical profiling data are still being diagnosed to assure calibration accuracy.
- Attended most bi-weekly telecons to report results to the whole team, and learn from other team members. Provided comments and suggestions to NOAA/NESDIS algorithm refinement.
- Attended NOAA JPSS/VIIRS team meeting in August 2015 and reported progress.
- Evaluated performance of SeaWiFS, MODIS, and VIIRS performance as a function of viewing angle. In general, cross-sensor discrepency increases when viewing angle from one of the sensors exceedes 50 degrees (Barnes and Hu, 2016).
- Developed and validated a new algorithm to detect and quantify a harmful algal bloom in CDOM-rich waters using VIIRS measurements in the absence of a fluorescence band (Qi et al., 2015). The approach was originally developed for Tampa Bay, but it was found applicable in coastal waters off Suwannee estuary where CDOM is very high and traditional blue/green band ratio algorithms are not applicable. The red/green band ratio avoids the interference of CDOM to first order, and therefore shows much improved performance for VIIRS.
- We also devoted efforts to work on oil spills using VIIRS. Wang and Hu (2015) developed a technique to delineate oil slicks from noisy VIIRS imagery by combining image filters and morphology operators. Sun and Hu (2016) compared hundreds of VIIRS and MODIS images collected over the same locations within 2-3 hours, and determined the sun glint threshold required to observe thin oil films in both VIIRS and MODIS imagery. Fig. 1 shows two pairs of examples where in one case oil slicks are detected by VIIRS but not by MODIS, and in the other case oil slicks are detected by MODIS but not by VIIRS. Such a discrepancy is due to the sun glint strength on different images, a result of different solar/viewing geometry. From statistics of hundreds of image pairs, the sun glint strength required to

observe thin oil slicks has been determined to be > 10^{-6} sr^{-1} for VIIRS and > 10^{-5} sr^{-1} for MODIS. VIIRS imaging bands tend to be more sensitive in detecting oil slicks than MODIS imaging bands.

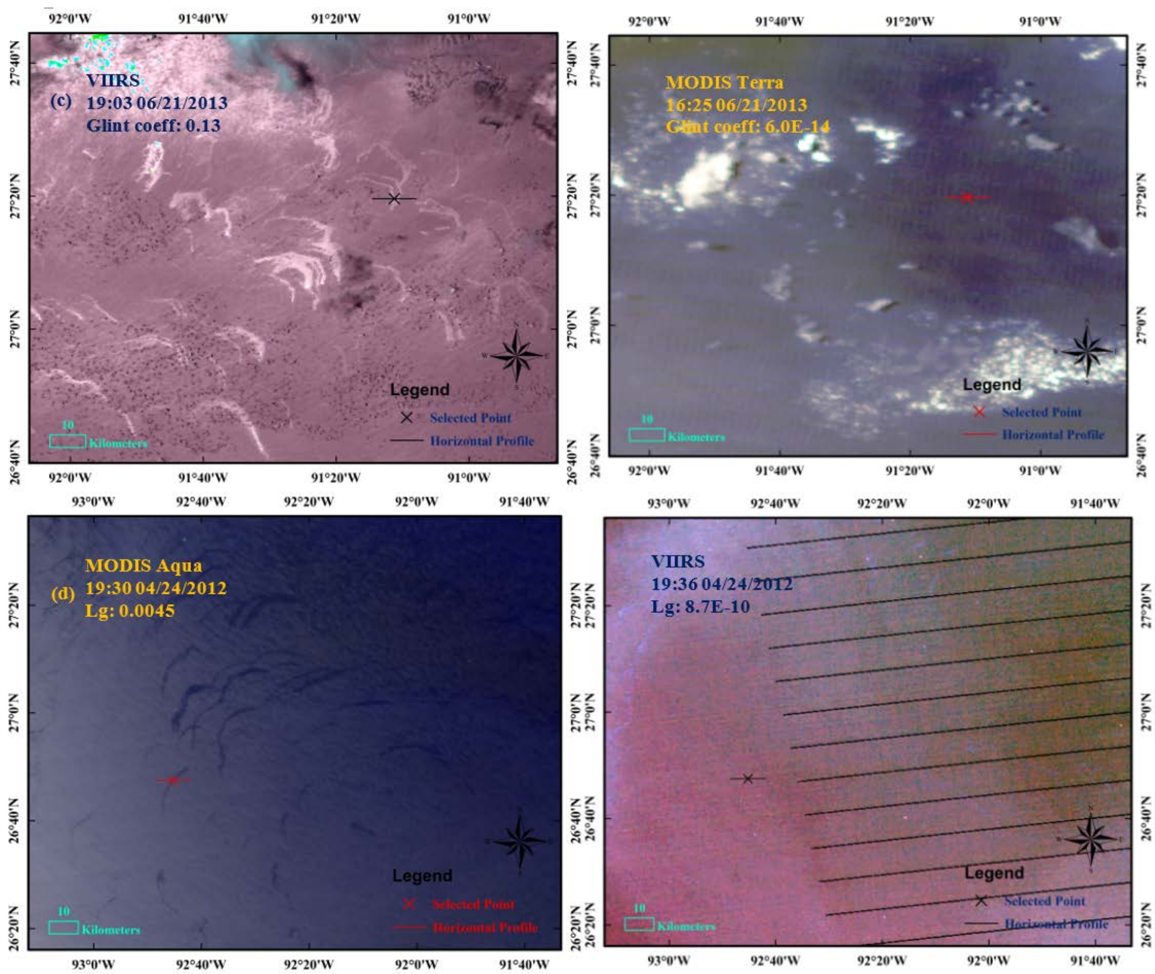

Figure 1: Surface oil slicks detected by VIIRS and MODIS. Top: detected by VIIRS but not by MODIS on the same day; Bottom: detected by MODIS but not by VIIRS on the same day. The key parameter to determine the detectability is sun glint strength. Figure from Sun and Hu (2016).

Research Performance Measure: The accomplishments have 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: 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 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 1*:** Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems*

NOAA Funding Unit: OAR and NMAO
NOAA Technical Contact: Molly Baringer

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.

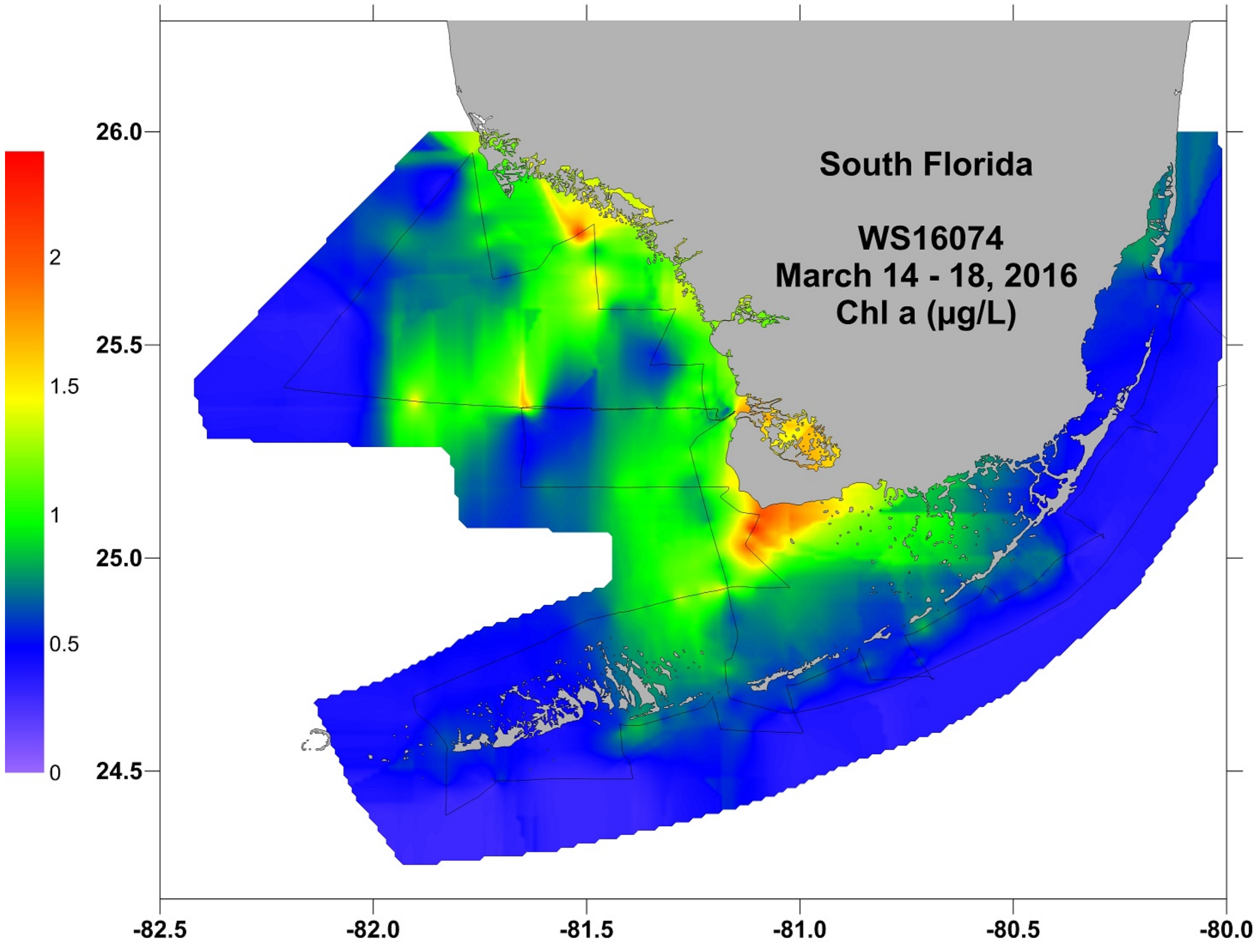

Figure 1: Chlorophyll a contour of South Florida coastal waters showing a harmful algal bloom on the northernmost transect on the Gulf of Mexico side. These maps and numerous other measured parameters are posted on the SFP web site at www.aoml.noaa.gov/sfp.

Research Performance Measure: All major research objectives are being met on schedule. The emphasis during this report period (1 October 2015 – 30 June 2016) has been on data collection and processing, as regular sampling on the R/V Walton Smith resumed in December 2014. 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: L. Visser, I. Zink and T. Creed (UM/CIMAS)
NOAA Collaborators: J. Browder 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 (*Secondary*)
***Theme 6*:** Ecosystem Management (*Tertiary*)
***Theme 7*:** Protection and Restoration of Resources

Link to NOAA Strategic Goals:

***Goal 1*:** 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 Molly Baringer

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 have been slightly higher in the west sub-region from 2008 through 2015. 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 some of 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. In 2014 there were significantly less spotted seatrout collected than any other year sampled. The year 2015 had the highest recorded salinities in Florida Bay during the entire sixteen-year sampling period, and there were subsequent fish kills and seagrass die-offs in parts of Rankin and west sub-regions.

Three sub-regions showed juvenile spotted seatrout population inversely correlated with salinity, but the West did not. 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 such as seagrass percent cover and diversity. This could be in part, because the salinities in the west are more stable.

There was a significant positive linear relationship of spotted seatrout density, frequency of occurrence, and concentration, between seagrass percent cover throughout Florida Bay. This suggests that as percent cover increases juvenile spotted seatrout are caught more frequently and at higher densities (Fig 1). 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.

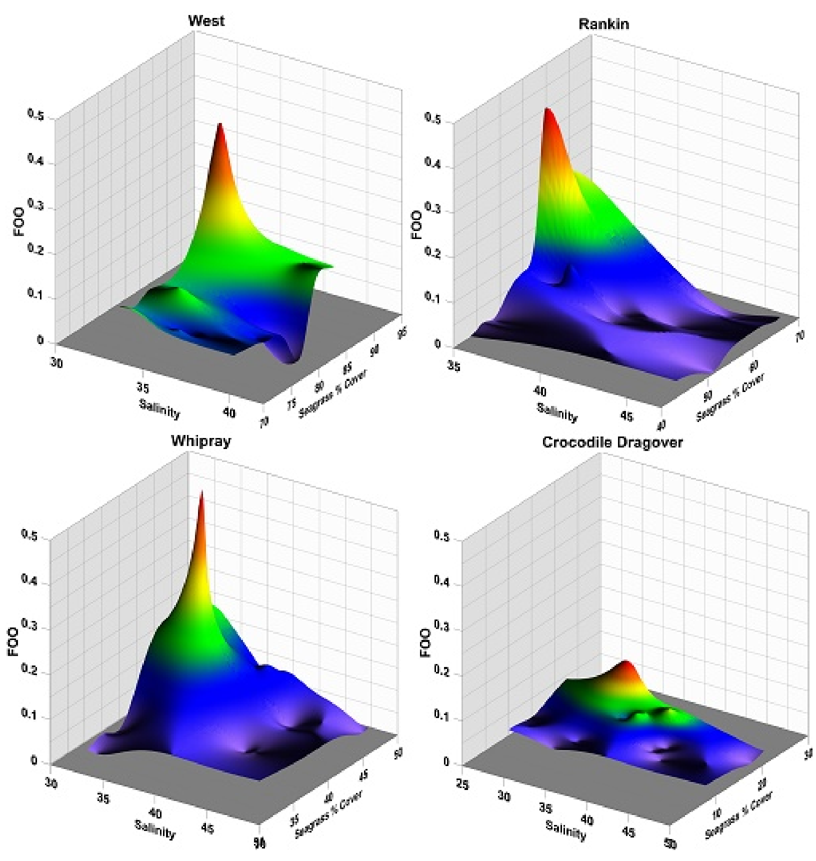

Figure 1: Contour plots depict the relationship between the juvenile spotted seatrout population, salinity, and seagrass within each sub-region of Florida Bay. Spotted seatrout occur more frequently with lower salinities and higher seagrass percent cover.

A logistic regression was employed on the data collected from 2004 to 2010 to quantify the impact of salinity and 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, the 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: 1) We have quantified a significant relationship with juvenile spotted seatrout to salinity that has allowed for the development of a testable hypothesis 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 2015 System Status Report, indicating that this project is contributing to science-based management within CERP. 2) 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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PIRATA Northeast Extension

Project Personnel: S. Dolk, R.C. Perez and E. Valdes (UM/CIMAS)
NOAA Collaborators: R. Lumpkin, C. Schmid, G. R. Foltz (NOAA/AOML); P. Freitag, M. McPhaden, M. Strick, L. Stratton (NOAA/PMEL)

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*)
Theme 2**:** Tropical Weather (*Tertiary*)

Link to NOAA Strategic Goals:
Goal 3**:** 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: Sid Thurston

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.

CIMAS and AOML personnel participated in the PNE cruise aboard the NATO ship NRV Alliance this past November-December 2015. Claudia Schmid (AOML) served as Chief Scientist, with scientific support provided by Shaun Dolk, Erik Valdes, and Thomas Sevilla (CIMAS), as well as scientists from NOAA/PMEL and the Aerosols and Ocean Science Expeditions (AEROSE) team. A University of Miami/RSMAS graduate student, Michael Cohen, and a volunteer, Vera Schmid-Dannert, also participated in the cruise. Four PNE buoys were recovered and redeployed, and an additional T-FLEX mooring (part of the validation process as the array transitions from ATLAS moorings to T-FLEX moorings) was recovered. Conductivity-temperature-depth (CTD) casts were conducted at 41 stations. Two expendable bathythermograph (XBT) experiments were performed to improve the quality of the XBT data. Planning is underway for the January-February 2016 PNE cruise aboard the NOAA R/V Ronald H. Brown.

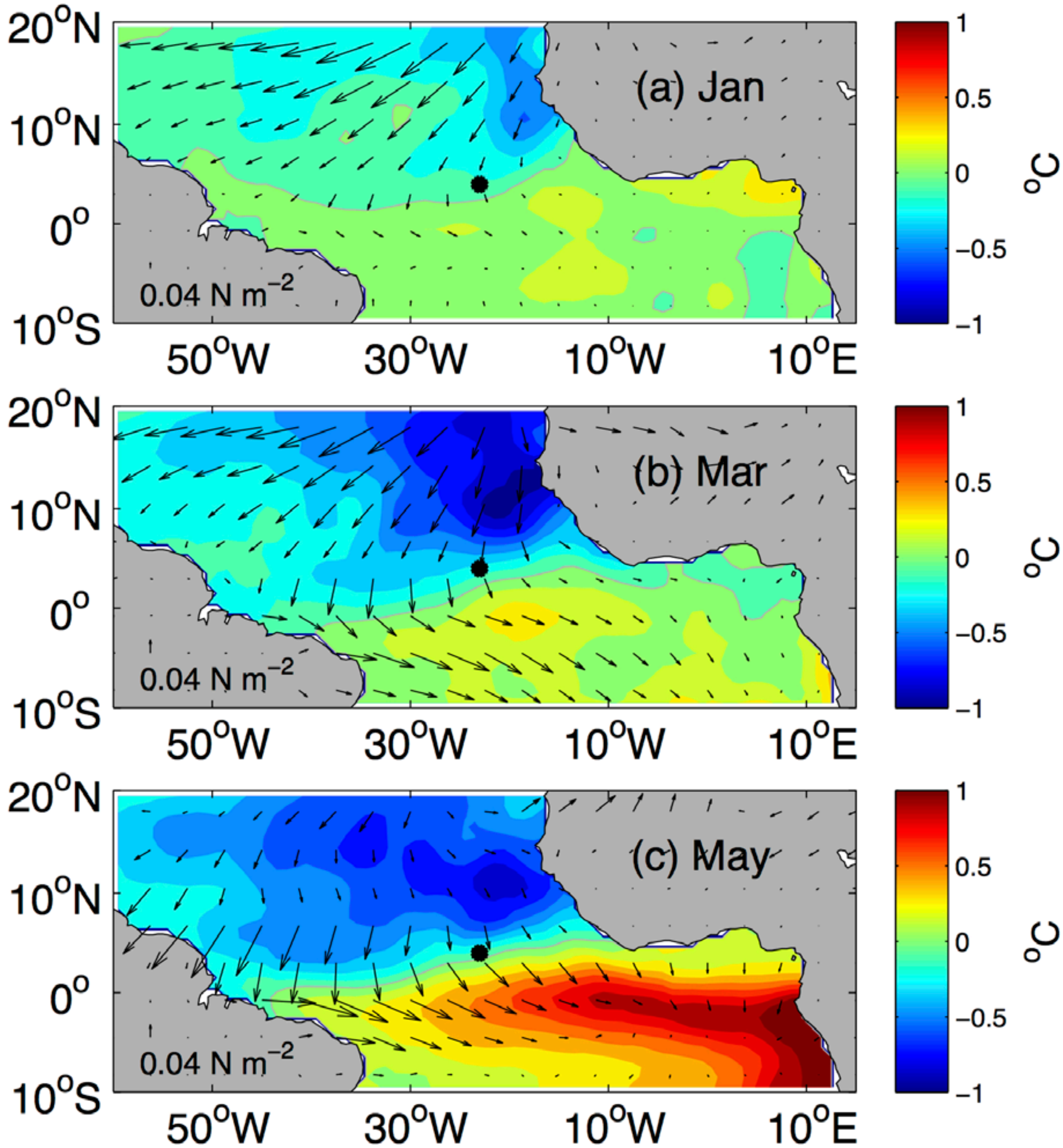

Figure 1: Composite maps of Atlantic Meridional Mode (AMM, anomalous cross-equatorial SST gradient in the Atlantic) events during January, March, and May for 1982-2014. Signs shown are for typical AMM negative events. (a) SST anomalies (shaded) and wind stress anomalies (vectors). (b) rainfall anomalies (shaded).

Research Performance Measure: All major objectives are being met. One PNE-related paper was submitted to the Journal of Climate (Rugg, Foltz, and Perez, 2016). The lead author of this paper was an undergraduate NOAA Hollings Scholar, Allyson Rugg. Allyson interned with Gregory Foltz and Renellys Perez at AOML in June-July 2015, and presented her results at the 2016 AMS (January 2016) and AGU Ocean Sciences (February 2016) meetings.

Developing the Operational Calibration/Validation Components for VIIRS SST Retrievals

Project Personnel: P.J. Minnett (UM/RSMAS)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To provide consistent, accurate SST fields derived from infra-red measurements from the VIIRS (Visible Infrared Imaging Radiometer Suite) on the Suomi-NPP satellite.

***Strategy*:** To acquire in situ measurements from drifting buoys, moorings and radiometers on ships, coincident with VIIRS satellite measurements, to support the development of accurate cloud identification algorithms and clear-sky atmospheric correction algorithms to derive SST's from VIIRS and to validate the VIIRS SST retrievals.

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* (*Primary*)

***Goal 3*:** Climate Adaptation and Mitigation: *An informed society anticipating and responding to climate and its impacts* (*Secondary*)

NOAA Funding Unit: NESDIS/STAR
NOAA Technical Contact: Alexander Ignatov

Research Summary:

The VIIRS was launched on the Suomi-National Polar-orbiting Partnership (S-NPP) satellite in October, 2011, and the infrared detectors were activated in February, 2012. The S-NPP is the prototype satellite of the future NOAA polar orbiting weather satellites, called JPSS (Joint Polar Satellite System), the first of which is scheduled for launch in 2017. The satellite series is planned to extend to 2038. Thus assessing the performance and improving the accuracy of VIIRS geophysical measurements is important and has long-term benefits. Our activities are focused on providing SST retrieval algorithms and associated coefficients based on matchups with in situ measurements from drifting and moored buoys, and ship-board infrared radiometers. We have continued to develop enhanced atmospheric correction algorithms to improve accuracies across the entire swath; VIIRS has a wider swath than the heritage sensors AVHRR and MODIS, meaning there is complete coverage of the globe twice per day without gaps between the swaths of adjacent orbits. We have developed new cloud screening algorithms that improve the SST retrievals, especially at high latitudes. Our efforts to provide more ship-board radiometric data continue, two M-AERI Mk2's installed on the *Allure of the Seas* and the *Celebrity Equinox* have provided over a year's worth of data in an unattended mode. These data are currently being processed. Another M-AERI Mk2 was deployed on the R/V *Alliance* (Figure 1) in collaboration with colleagues at NOAA/AOML in November and December 2015, and comparisons with skin SST derived from VIIRS give a median discrepancy of 0.009 K and a robust standard deviation of 0.142 K. These are better than heritage sensors.

Figure 1: The R/V *Alliance* in the Tropical Atlantic during the PIRATA refurbishment cruise off West Africa. The yellow arrow indicates the position of the Marine-Atmospheric Emitted Radiance Interferometer (M-AERI) Mk2.

Research Performance Measure: Our progress and accomplishments are in-line with the original objectives.

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Autonomous Marine Sampling Technology Testbed: Integrating Advanced Biomedical Sensor Technologies with Advances in Drop Probe Methodology

Project Personnel: P. Ortner and M. Goes (UM/CIMAS)
NOAA Collaborators: G. Goni (NOAA/AOML)
Other Collaborators: T. Rossby (URI/GSO); Deirdre Meldrum (ASU)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives**:** To develop an expendable multi-parameter (pH, Oxygen, Chlorinity, Depth) dropped probe yielding climate quality data from repeat transects of high speed (>20kts) commercial ships of opportunity during repeat transects of the global ocean.

Strategy**:** To assemble a collaborative multi-institutional team to incorporate cutting edge biomedical technology into oceanographic sensor systems leveraging upon present OceanScope activities and ongoing probe analytical and deployment advances by team members and their research groups.

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

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

NOAA Funding Unit: OAR/HQ
NOAA Technical Contact: Alan Leonardi, OAR/OER

Research Summary:
The objective is "next generation" measurement systems amenable not only to ROVs, AUVs, gliders and WaveGliders but ultimately for automated deployment from rapidly moving (>20kts) ocean platforms. Pilot-Testbed OceanScope vessels are already using automated XBT launchers and UM/RSMAS/CIMAS is working with NOAA/AOML to fully integrate these with shipboard networks controlling oceanographic and meterological instrumentation and using algorithm based decision-making to automatically determine sampling patterns. The ASU team has successfully developed various fluorescent sensors for both pH and oxygen[3-6] for cell metabolism studies and express confidence they can do so for chlorophyll. These are thin-films on glass and/or polymer support surfaces chemically immobilized in crosslinked polymers. Chemical immobilization enables high reversibility and stability by alleviating leakage of sensor molecules from the matrices. The sensors can be deposited on flexible substrates such as polyethylene terephthalate (PET) with sensor dimensions as small as cm and thickness of only 100 nm. They are 1) disposable; 2) sensitive and specific; and 3) stable. Initial benchtop tests indicate that climate quality precision is attainable. See Figures 1 and 2 for benchtop results obtained for pH and Oxygen sensors respectively. The Chloride sensor is still under development. Response times are sufficient for expendable probes (drop rate ca. 6m/s) and sensors have been unaffected after months under deep ocean pressures in artificial seawater. In addition, considerable progress has been made with respect to design and prototype construction of an in situ unit with the appropriate dimensions for integration with commercial XBT probes. See Figure 3 for the conceptual design.

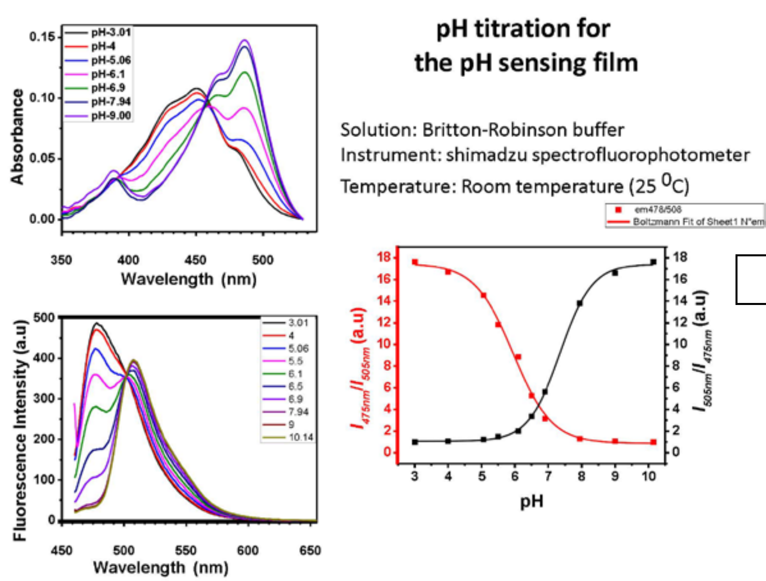
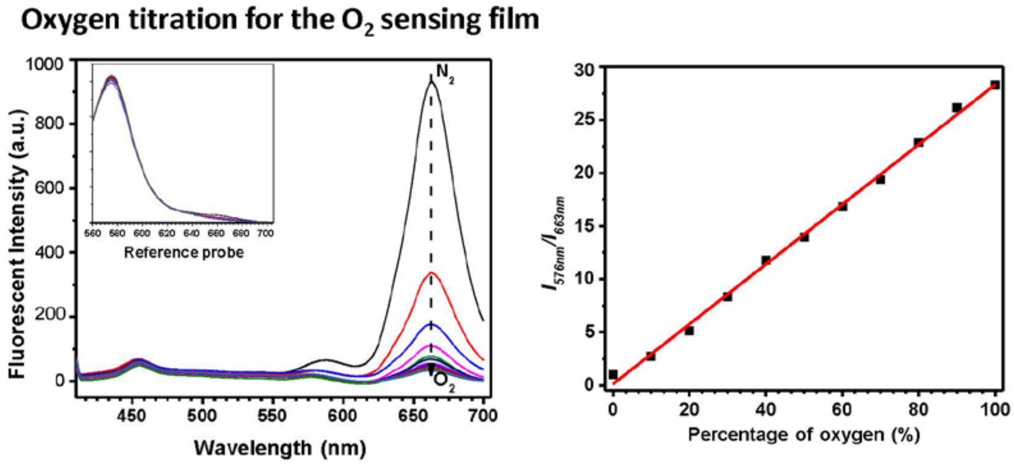


Figure 1: Thin Film pH sensor titration



Solution: Britton-Robinson buffer
Instrument: Shimadzu spectrofluorophotometer
Temperature: Room temperature (25 ^{0}C)

Figure 2: Thin Film Oxygen sensor titration

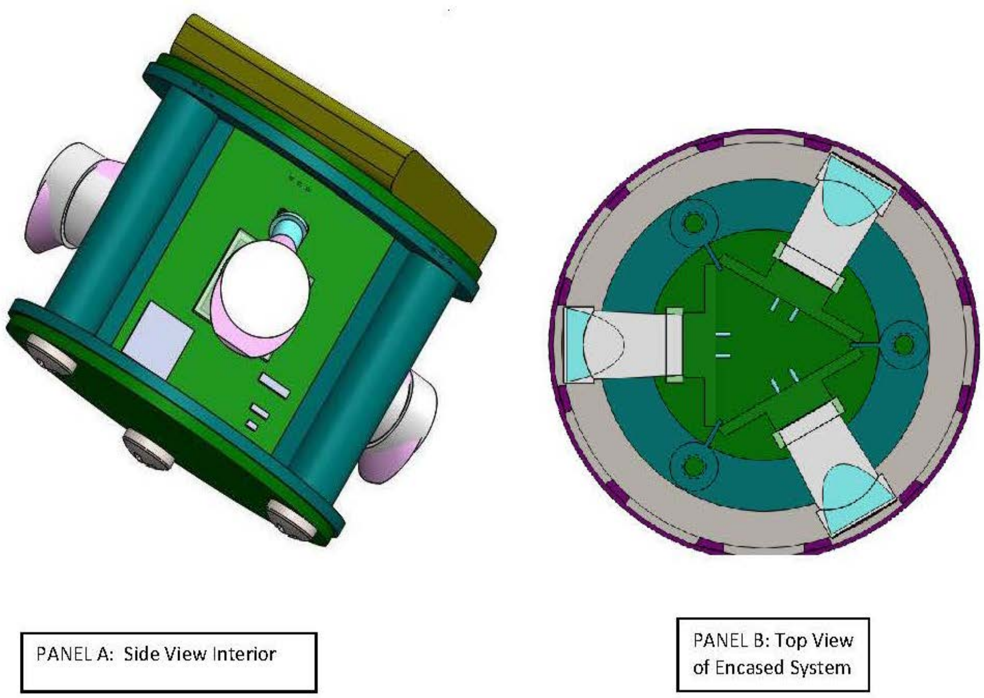


Figure 3: Conceptual Design for XBT probe sensor package.

Research Performance Measure: This ambitious three-year development effort was initiated only seven months ago. Communication between collaborators has been good, progress has been steady and initial objectives have been met on or ahead of schedule with respect to finalizing design criteria and benchtop sensor performance.

Surface Water Partial Pressure of CO_2 (pCO_2) Measurements from Ships

Project Personnel: Denis Pierrot, K. Sullivan and L. Barbero (UM/CIMAS); F.J. Millero and R.J. Woosley (UM/RSMAS)
NOAA Collaborators: R. Wanninkhof and G. Goni (NOAA/AOML)
Other Collaborators: T. Takahashi (LDEO); N. Bates (BIOS)

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

NOAA Funding Unit: COD/CPO
NOAA Technical Contact: Kathy Tedesco

Research Summary:
The ship-based surface pCO_2 program is designed to provide sustained measurements of regional oceanic carbon sources and sinks on seasonal timescales by measuring surface water and marine boundary pCO_2 on ships of opportunity (SOOP). It is a collaboration of investigators at the NOAA laboratories AOML and PMEL, and the following academic institutions: Columbia University, the University of Miami, and the Bermuda Institute of Ocean Sciences. It is the largest program of its kind in the world. The program contributes to the goal of creating regional flux maps on seasonal timescales to quantify uptake of anthropogenic CO_2 by the ocean and short-term changes thereof. In the performance period the NOAA funded participants maintained instrumentation and reduced the data from thirteen 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 sea-air fluxes on seasonal time scales.

An appreciable focus continues to be global coordination of similar efforts. We have taken the lead in providing uniform autonomous instrumentation for installation on ships of opportunity. Through a successful technology transfer and continued guidance, General Oceanics, Inc. in Miami is producing units for the community at large and to date has sold 60 units worldwide. We are also 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 3 containing over 19 million pCO_2 data points, was released in September 2015 (Fig. 1). Efforts to produce SOCAT version 4 are underway with a release in the summer of 2016.

As part of the project, improvements in auxiliary data such as sea surface temperature (SST) and sea surface salinity (SSS) from thermosalinographs (TSG) have been made. Currently the NOAA ships *Ronald H Brown* and *Gordon Gunter*, cruise ships *Equinox* and *Allure of the Seas* and the container ship *Skogafoss* have been transmitting TSG data in near-real time. All of the ships that are part of the project send complete daily files of pCO_2 to shore via internet or Iridium.

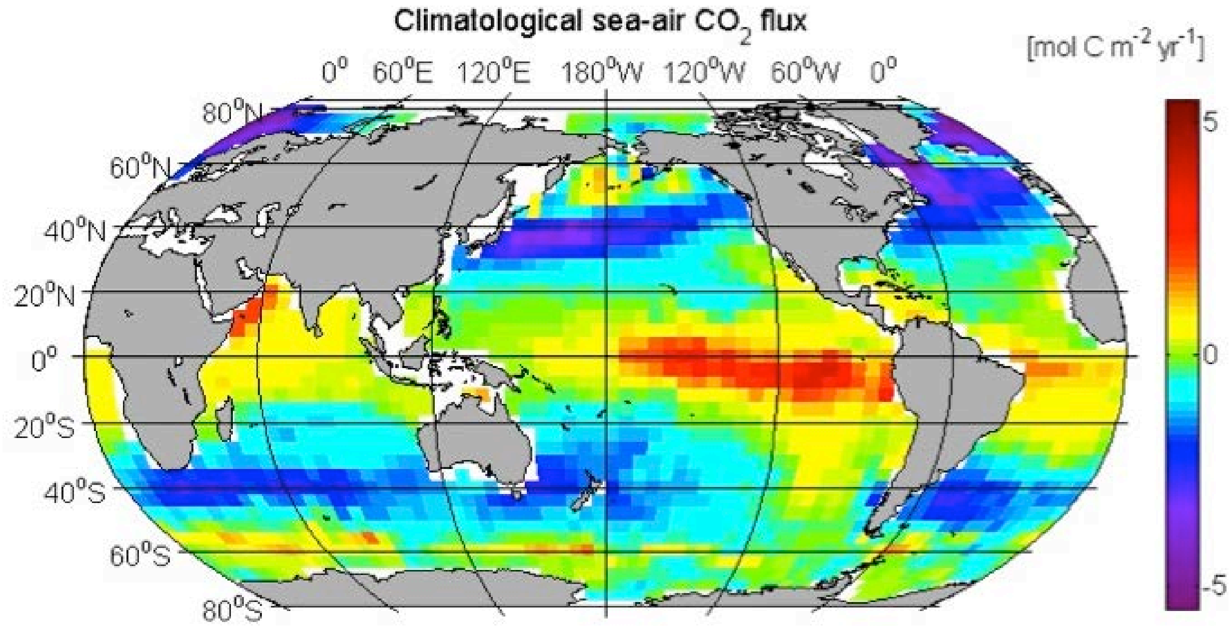


Figure 1: Climatological sea-air CO_2 fluxes (mol C / m^2 y) centered on the year 2005, computed using SOOP pCO_2 measurements and interpolated CCMP winds.

Taro Takahashi, Lamont-Doherty Earth Observatory of Columbia University (LDEO), Palisades, NY 10964:

About 9 peta-grams of carbon in the form of CO_2 are emitted annually into the atmosphere by various human activities, affecting the Earth's climate. About 2 peta-grams of carbon are absorbed annually by the global oceans, thus slowing the rapid accumulation of CO_2 in the atmosphere. The equatorial waters are major CO_2 source emitting about 0.7 Pg C/yr. This is counteracted by the two major sinks located over colder ocean regions: a 1 Pg C/yr sink centered around 40ºS in the southern hemisphere and a 0.7 Pg C/yr sink centered around 40ºN in the northern hemisphere. It is important to know how these CO_2 source and sink areas are changing in response to climate change.

The partial pressure of CO_2 (pCO_2) in seawater is a measure of chemical driving force for sea-air CO_2 gas exchange. The net sea-air CO_2 flux is governed primarily by the wind speed and pCO_2 difference between seawater and air. The primary objective for our proposed investigation is to observe and document a long-term change in ocean pCO_2 in different areas. Its seasonal change and interannual variation need to be characterized. Because of the importance of the high latitude areas as sinks for atmospheric CO_2, the Lamont field program is focused on the measurements of surface water pCO_2 in the high latitude Southern Ocean and the Arctic Ocean. Combination of the new data with our data accumulated since 1957 will yield a reliable estimate for multi-decadal mean rate of change in the oceanic CO_2 sink flux. Approximately 10 million pCO_2 measurements made to date have been assembled and archived at the Carbon Dioxide Information and Analysis Center (CDIAC), Oak Ridge, TN, for public access (Takahashi et al., 2016). The results are used to test and validate Ocean General Circulation models (OGCM) coupled with biogeochemistry models for the future prognosis for atmospheric CO_2 levels (e.g. Landschützer et al., 2015).

Nicholas Bates, Bermuda Institute of Ocean Sciences (BIOS):

The contribution of the Bermuda Institute of Ocean Sciences (BIOS) to the SOOP project has an overarching objective of supporting the measurements of seawater and atmospheric pCO_2 measurements on two vessels, the UNOLS research vessel R/V *Atlantic Explorer*, and the merchant vessel M/V *Oleander*. The primary aim of this effort is focused on improving scientific understanding of the time and spatial variability of air-sea gas exchange of CO_2 in the subtropical gyre of the North Atlantic Ocean, across the Gulf Stream and Middle Atlantic Bight (MAB) of the Eastern Seaboard, but also with research cruises to the seas north of the Caribbean (Puerto Rico, Bahamas) and occasional cruises to the U.S. continental shelf (e.g., Florida to Maryland).

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, E. Forteza, S. L. Garzoli, V. Halliwell, S. Majumder, J. Nair and R. Sabina (UM/CIMAS)
NOAA Collaborators: C. Schmid and M. Baringer (NOAA/AOML)

Long Term Research Objectives & 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 o 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 3*:** 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: Molly Baringer

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 float. Recently new deep profiling Argo floats, capable of diving and recording temperature and salinity down to 6000 m depth have been deployed and are now part of the Argo array.

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:

- 377 floats were deployed by the USA institutions.
- 65 of these floats were deployed jointly by AOML and CIMAS.
- 2,464 US floats actively reported data during this period.
- 83,855 profiles approximately have been distributed on Global Data Centers.
- 67,467 profiles were sent to GTS by the US DAC where 84% of them were distributed during the first 24 hours since the profiles were obtained.

Changes in the quality control/file production include:

- Improvements in producing the Real-time Profile NeCDF files, and compliance with the ARGO Users Guide v3.03. Production of NetCDF files for both Meta files and Technical files were finalized and User Manual v3.1 meta and tech files are being produced operationally.
- Development of the final element, Trajectory files, is nearing completion and is expected to be added to the operational processing in a matter of weeks. The traj files will also be v3.1.
- Preliminary addition of Bio-ARGO files for profiles (BR files), meta files (Bmeta) and trajectory files (Btraj) have been added to the main program.
- Extensive changes were made to nearly all software elements to accommodate new functions of the software as well as transition to a new computer. Efficiency gains in processing (and also in hardware capabilities) allowed us to run the operational system more frequently, and adjustments were necessary as additional runs were added.
- Netcdf Trajectory Software package was developed. It is being tested and will be moved to production soon.
- Meta and Technical Netcdf Software package is developed, tested and operational

In addition to the changes in the quality control/product in software, improvements were made in the areas of:

- A system to process incoming meta data to improve the time the new floats are introduced to the operational processing system and consequently speed the availability of their data in the distribution sites for the National Weather Service and research community.
- Implementation of numerous changes and additions, and transition to a new computer required extensive modification of the scripts that control the operational processing.
- Changes were made to improve the method used to prepare input files for the QC process.
- Modification and testing of existing programs to migrate from "ftp" to "ftps" for data transmission to the National Weather Service.
- Software was implemented to distribute real-time profiles (NetCDF 3.1 version) to the GDAC (Global Data Centers) in BUFR format via GTS (Global Telecommunications System)
- A system for archiving inactive floats data is under development.

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.

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.

Results from scientific studies that used Argo data:

Meridional volume and heat transports at four different latitudes (20S, 25S, 30S, and 35S) are estimated using Argo observations, sea surface heights, and winds in the years 2000-2015. The variability and co-variability of meridional volume and heat transports are analyzed at these latitudes and compared with that from global numerical ocean models with data assimilation. Meridional volume and heat transports correlate strongly at all the four latitudes. For every 1 Sv increase in the meridional volume transport about 0.046 PW increase in meridional heat transport is observed at 25S, 30S, and 35S. More heat about 0.056 PW is transferred further north across 20S for the same increase in the meridional volume transport. Meridional volume transport exhibits strong annual cycles both in the observations and in the models. However, the timing of the maxima and minima and the amplitude of the annual cycles are different in the observations and models.

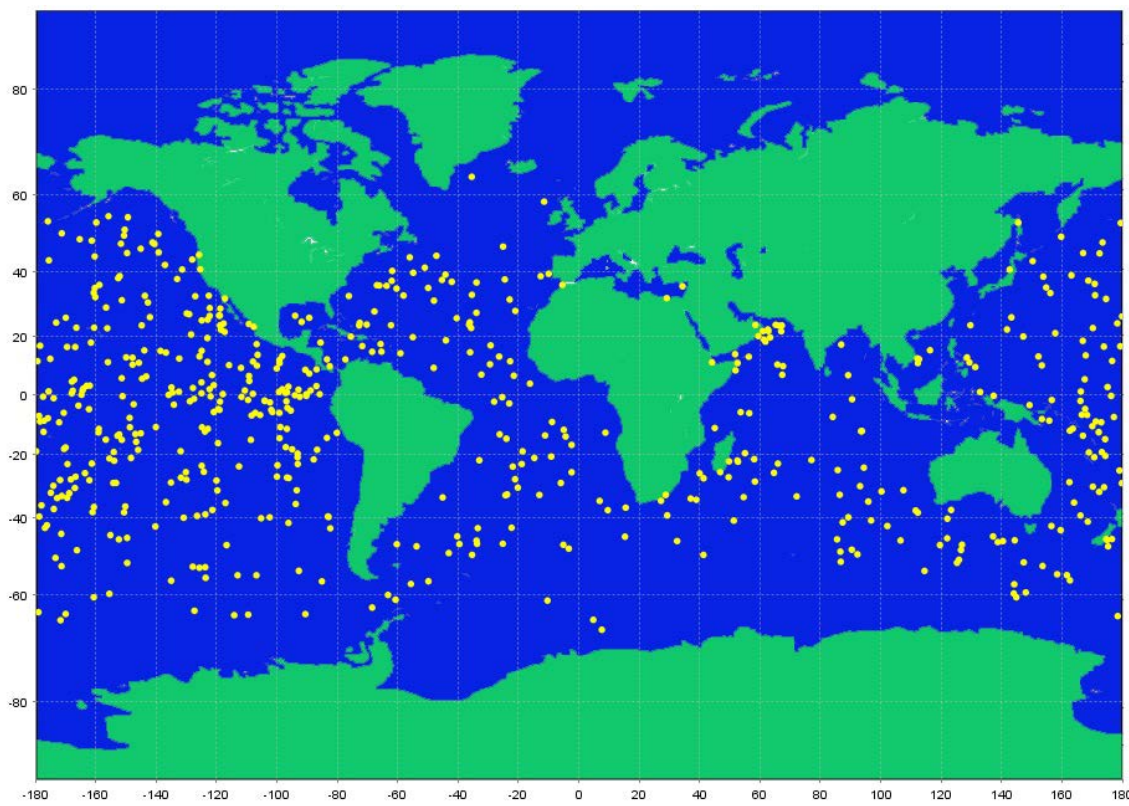


Figure 1: Location of US Argo floats in May 2016.

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

Remote Sensing in Support of Climate Research

Project Personnel: S-K. Lee and M. Goes (UM/CIMAS),
NOAA Collaborators: Gustavo J. Goni (NOAA/AOML)
Other Collaborators: J.A. Trinanes (University of Santiago de Compostela)

Long Term Research Objectives & Strategy to Achieve Them:

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

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

CIMAS Research Theme:

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

Link to NOAA Strategic Goals:

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

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

NOAA Funding Unit: OAR/AOML and NOAA/NESDIS
NOAA Technical Contact: Molly Baringer

Research Summary:

A key outcome of this project is to develop and implement the technologies to provide raw and processed quality satellite products to scientists, decision-makers and the general public, ensuring reliable data availability and accessibility. AOML has managed the CoastWatch Caribbean regional node since 2000; it serves as a pathway for accessing near-real-time and science-quality data and products such as sea surface temperatures, ocean color, winds, and sea surface height anomalies. The node was expanded few years later to include the Gulf of Mexico. In 2015, the Atlantic OceanWatch node was created at AOML, with Gustavo Goni and Joaquin Trinanes serving as node manager and operations manager, respectively. The new framework expands the capabilities of the CoastWatch node, as well as the range of its products, to include larger areas, focusing on both near-real-time and historical datasets and developing new technologies for data sharing and visualization.

The range of primary satellite products used by this project includes sea surface height, sea surface temperature, ocean color and surface winds. Work associated with this project involves management and operation of the High Resolution Picture Transmission (HRPT) satellite receiving station at NOAA/AOML and the development of operational products from the real time telemetry received through the X&L-Band antenna recently installed at AOML, which is managed by UW-Madison/SSEC. During this last year, we have continually received direct broadcast data from NOAA&EUMETSAT/POES satellites. Within this project, we provide NOAA/NESDIS Office of Satellite Data Processing and Distribution with rapid access to the raw telemetry and Level-1 products

from a variety of sensors (HIRS, AMSU, MHS, DCS, SEM, ASCAT, etc.). Additionally, all data collected from the Argos Data Collection System is sent to the Argos Data Processing and Distribution Centers in the U.S. and France.

The processing and creation of products from the Visible Infrared Imaging Radiometer Suite (VIIRS) on S-NPP required the installation and configuration of the International Polar Orbiter Processing Package (IPOPP) and the Community Satellite Processing Package (CSPP). These products are currently being integrated within our data distribution schema (Figure 1). Besides the data from the station in Miami, VIIRS data is also being pulled from the satellite receiving station in Mayaguez, Puerto Rico, expanding the geographical coverage.

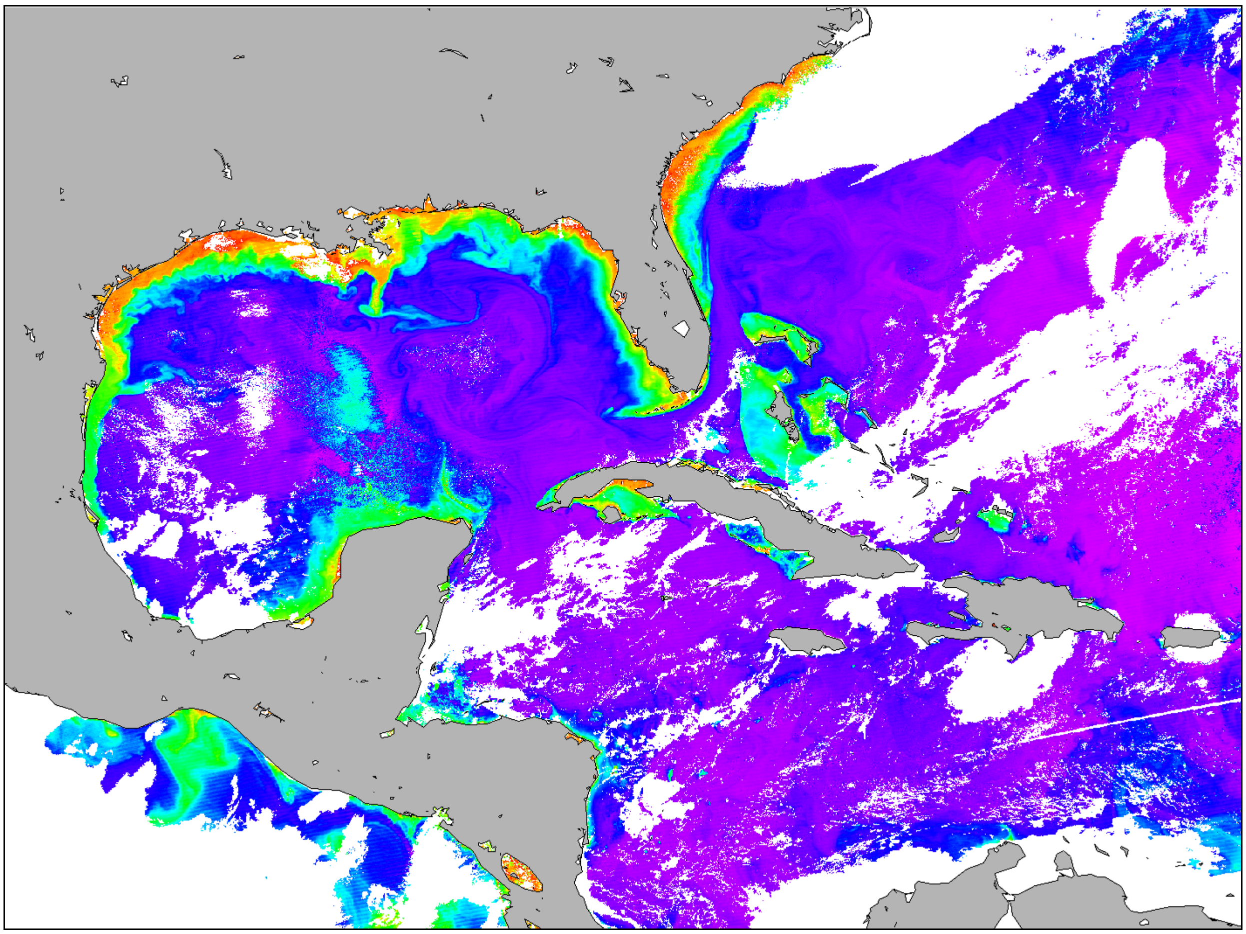


Figure 1: 750-m Chlorophyll-a field from VIIRS/S-NPP created in near-real-time using in-house processing.

A new study published in the journal Nature Microbiology highlights how emerging, devastating outbreaks of Vibrio infection in Latin America might be linked to El Niño. Vibrios are rod-shaped bacteria present in the marine environment that proliferate in warm and low-salinity seawater. In the U.S. alone, Vibrio infections cause an estimated 80,000 illnesses and 100 deaths annually. There are many species of Vibrio, the best known being V. cholerae, V. vulnificus, and V. parahaemolyticus. During the last three more significant El Niño episodes (1990-1991, 1997-1998 and 2010), new Asian variants of pathogenic Vibrio have emerged in Latin America (Figure 2). They include a variant of V. cholerae, which resulted in more than 13,000 deaths in Peru in 1990, and two variants of V. parahaemolyticus,

which triggered widespread gastrointestinal illness associated with contaminated shellfish in 1997 and 2010. We observed that declared illnesses caused by waterborne bacteria reported in Latin America moved in tandem with where and when warm El Niño waters made contact with the land. Whole-genome sequencing of bacterial strains suggest there may indeed be a link between organisms that cause illness in Asia and those that emerge in Latin America, in particular, Peru and Chile. Other authors involved in the study include Drs. Jaime Martinez-Urtaza of the UK's University of Bath, Narjol Gonzalez Escalona of the US Food and Drug Administration, and Craig Baker-Austin of the UK's Centre for Environment, Fisheries and Aquaculture Science. The Atlantic OceanWatch node at AOML routinely generates and distributes operational global vibrio risk fields using remote sensing and models as primary inputs.

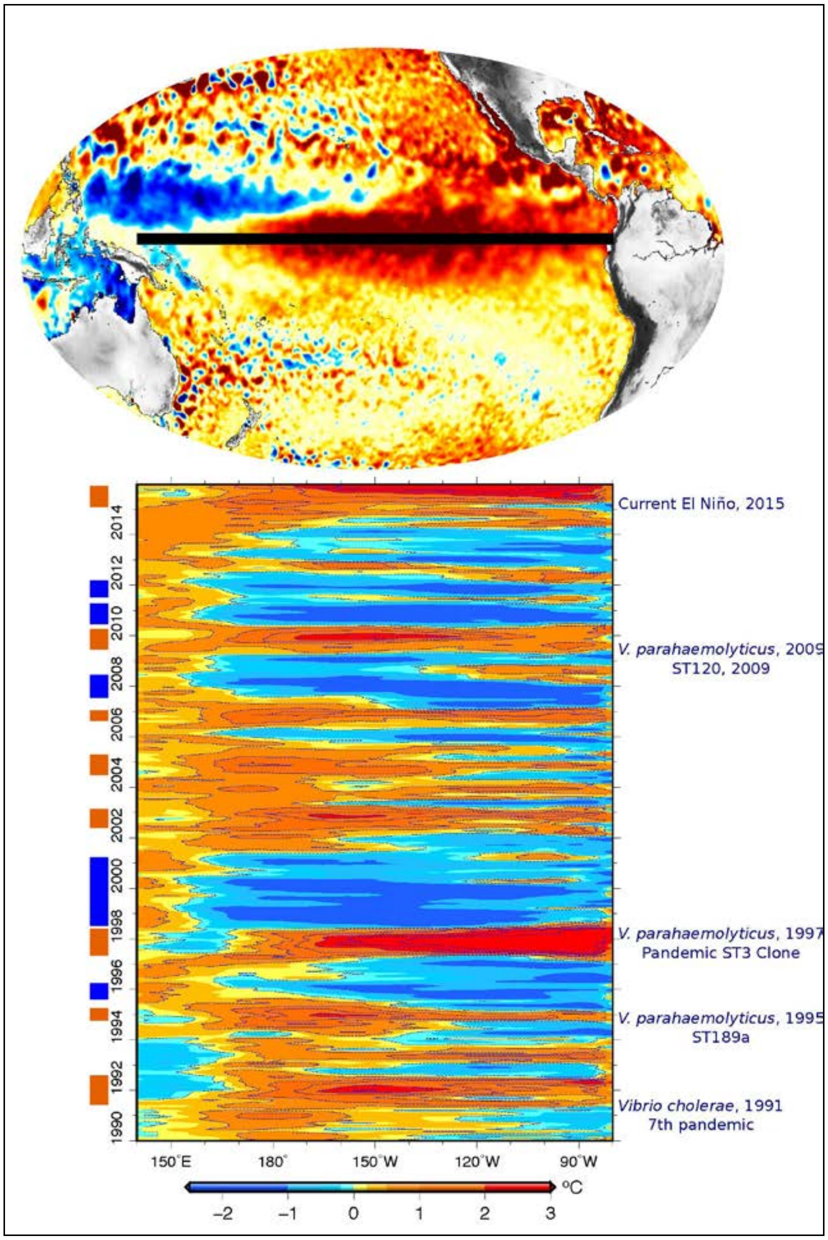


Figure 2: Correlation between El Niño and the emergence of new Vibrio infections in South America (Martinez-Urtaza et al, 2016).

On January 27th-29th, we organized and hosted the 17th CoastWatch/OceanWatch Science Workshop. Presentations highlighted the large suite of products distributed by the CoastWatch/OceanWatch programs, while subsequent discussions brought greater awareness of the robust frameworks and methodologies for satellite data processing, and of robust approaches to identify, understand, support, and meet user needs and requirements. This workshop highlighted the importance of regular, direct interaction between node managers to improve the program's objectives and quality of its products, as well as provide a common ground for sharing expertise and knowledge. Presenters and remote participants also recognized AOML's role in organizing and leading the workshop; they expressed confidence in meeting the challenges posed by a new generation of satellites, the advent of new technologies for data management and processing, and an increasing need for international cooperation and compulsory data quality requirements.

Other activities related to this project include the processing of wind datasets to assess the carbon fluxes at regional scales in the Gulf of Mexico and other parts of the globe (e.g. Greenland), and the migration of the global flux and regional ocean acidification processing to VM. For fluxes studies, techniques were developed and implemented to collocate in-situ data Southern Ocean with high resolution SST data from MODIS and VIIRS.

The online data visualization package has been improved with new features. It supports datasets from external servers, additional baselayers and protocols. The current release adds Climate Data Records (CDRs) from the National Centers for Environmental Information, and multiple satellite layers from NASA, served through Web Map Tile Services (WMTS). This effort expands including the development of mobile applications for Android and IOS.

Following NOAA/NESDIS/CoastWatch and NOAA/AOML requirements and goals towards promoting interoperability and information sharing, data distribution combines the traditional approach that provide direct access to data files through a URL, with other state-of-the-art technologies such as OPeNDAP, THREDDS, ERDDAP and OGC Web services (e.g. http://cwcgom.aoml.noaa.gov/thredds/catalog.html, http://cwcgom.aoml.noaa.gov/erddap/info/index.html). Through the implemented interfaces, users can download satellite products in a variety of commonly-used data and image formats such as MAT-files, NetCDF, and KML.

Europe's Copernicus program relies on data from a constellation of satellites, the Sentinels, which will provide global monitoring capabilities. Currently, 4 satellites of this constellation are in orbit: S-1A&B (radar imagery), S-2A (high resolution multispectral) and S-3A (sea surface height, sea surface temperature and ocean color). NOAA is testing and assessing European Space Agency data distribution framework and the quality of the products being provided. From the perspective of our CoastWatch/OceanWatch node, S-1 SAR data has multiple applications (such as oil detection, coastal winds from flux studies, waves, sea ice) and advantages, such as its all-weather capability. We have developed software to select, download and process S-1 data and are working on developing similar routines for S-3A. They will allow us to access S-3A products in real-real-time from ESA and EUMETSAT servers once this satellite is commissioned.

Research Performance Measure: The research goals were met during this last year. New products have been developed and included for online distribution using open standards and protocols. New tools have been developed and improved for visualization and data access. These solutions have been integrated within a SOA framework.

Marine Optical Buoy (MOBY) Operations and Technology Refresh

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

Long Term Research Objectives & 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 for the 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 working on 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 NOAA VIIRS instrument on the Suomi NPP platform and follow on JPS platforms. 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.

We have also been working 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.

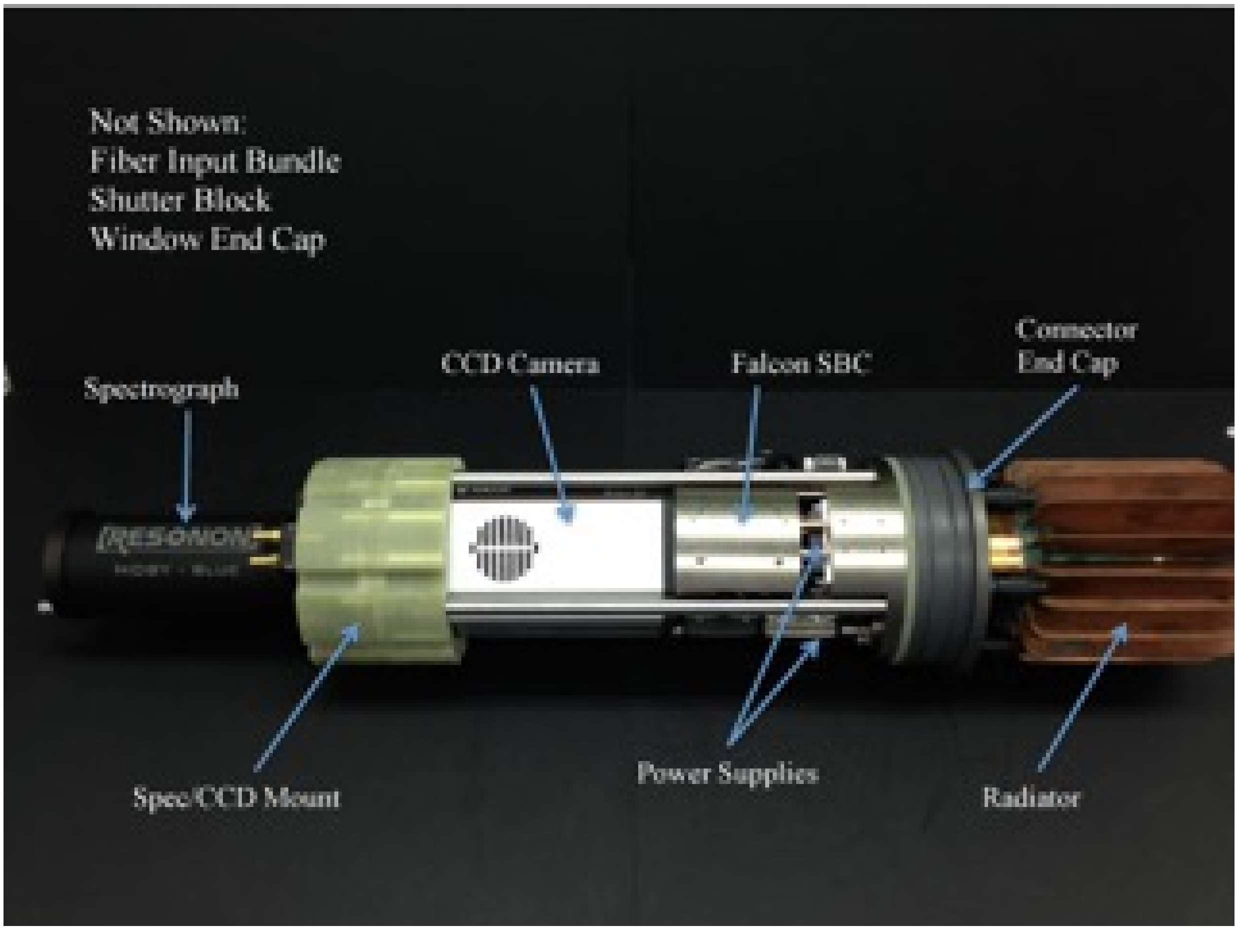
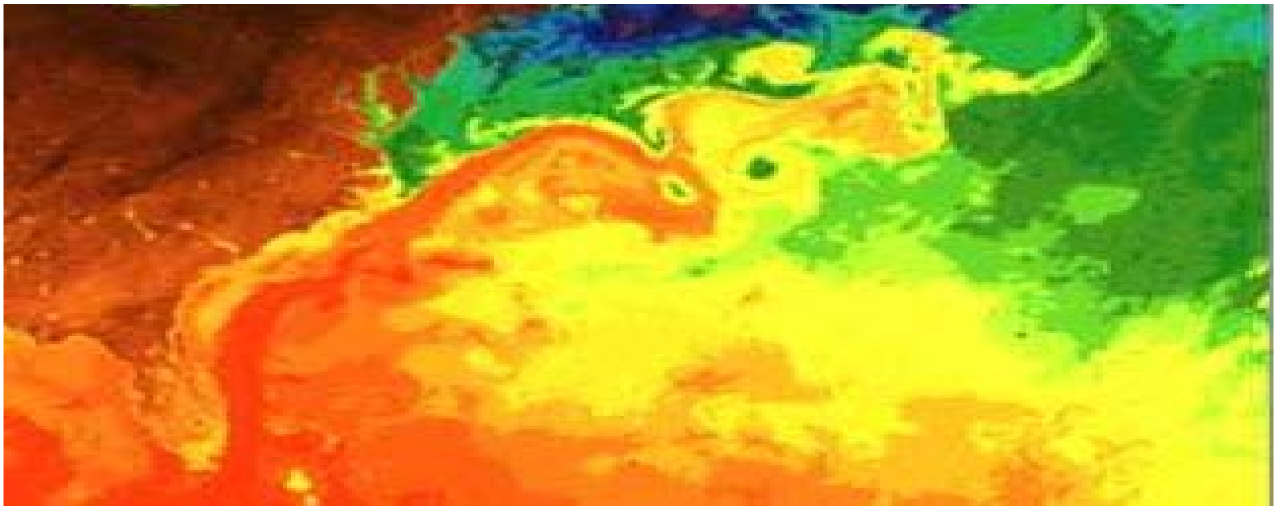


Figure 1: A picture of the new blue wavelength in-line spectrometer for MOBY-Refresh, with major components labeled. This system allows multiple light measurements to be made simultaneously, with 1 nm spectral resolution over a range from 350- 700 nm. The fiber input comes in from the left, through the spectrograph, whose image is displayed on the CCD camera and collected by the single board computer.

Research Performance Measure: We have been maintaining MOBY operations over this period, meeting our objectives of maintaining the accurate time-series for satellite vicarious calibration. In addition, we have been making progress on the MOBY-Refresh effort. During the last year we have installed the new, modern control system for MOBY, and have begun characterization of the new optical spectrometers that will be installed in this system to replace the old optical system. Our first trial deployment of the blue spectrometers will occur at the end of June 2016.



RESEARCH REPORTS

THEME 4: Ocean Modeling

Variability and Coherence of the Atlantic Meridional Overturning Circulation

Project Personnel: S. Dong (UM/CIMAS)
NOAA Collaborators: M. Baringer and G. Goni (NOAA/AOML)
Other Collaborators: X. Xu and E.P. Chassignet (FSU/COAPS)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To quantify to what extent is the AMOC variability coherent throughout the whole Atlantic and to determine whether the variability of the Agulhas leakage is directly connected to the AMOC variability at 35°S.

***Strategy*:** To perform a detailed model-data syntheses/comparison study using the observations at 26.5°N and 35°S and global high-resolution, eddy-resolving numerical simulations integrated with the HYbrid Coordinate Ocean Model (HYCOM).

CIMAS Research Theme:

***Theme 4*:** Ocean Modeling

Link to NOAA Strategic Goals:

***Goal 3*:** Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts*

NOAA Funding Unit: OAR/ESPC
NOAA Technical Contact: Molly Baringer

Research Summary:

The goal over the first year of this project was to establish a baseline evaluation of the high-resolution eddy-resolving global HYCOM simulations in representing the circulation of the Southern Atlantic Ocean. We documented that the model represents the magnitude and vertical structure of the trans-basin

AMOC at 34.5°S, the transport and the horizontal/vertical structure of the Antarctic Circumpolar Current (ACC) through the Drake Passage at 65°W, and the net transport across 20°E, and used the model results to explore the source of the upper AMOC water and the modification the water mass in this region.

In the first part of year 2, we examined the coherence of the AMOC variability. We found that on seasonal time scale (Figure 1), the variations are high and coherent from 35°S to ~15°N. In the North Atlantic, the variations are also coherent from 65°N to near 20°N, this coherence is similar to the results based on basin-scale Atlantic model. In the area from 15°N to 20°N the variation is generally weaker and the phase of the variation changes. On interannual and longer time scale (Figure 2), the variation is generally weaker and there is not a clear pattern for the first 4 years. From 2008 to 2013, however, the variation is significantly more coherent from 35°S to about 35°N with generally similar variation phase, and further to about 60°N with a shift in the variation phase. It is also clear that the AMOC transport is higher in 2003-2008 than 2009-2013 throughout the whole Atlantic domain.

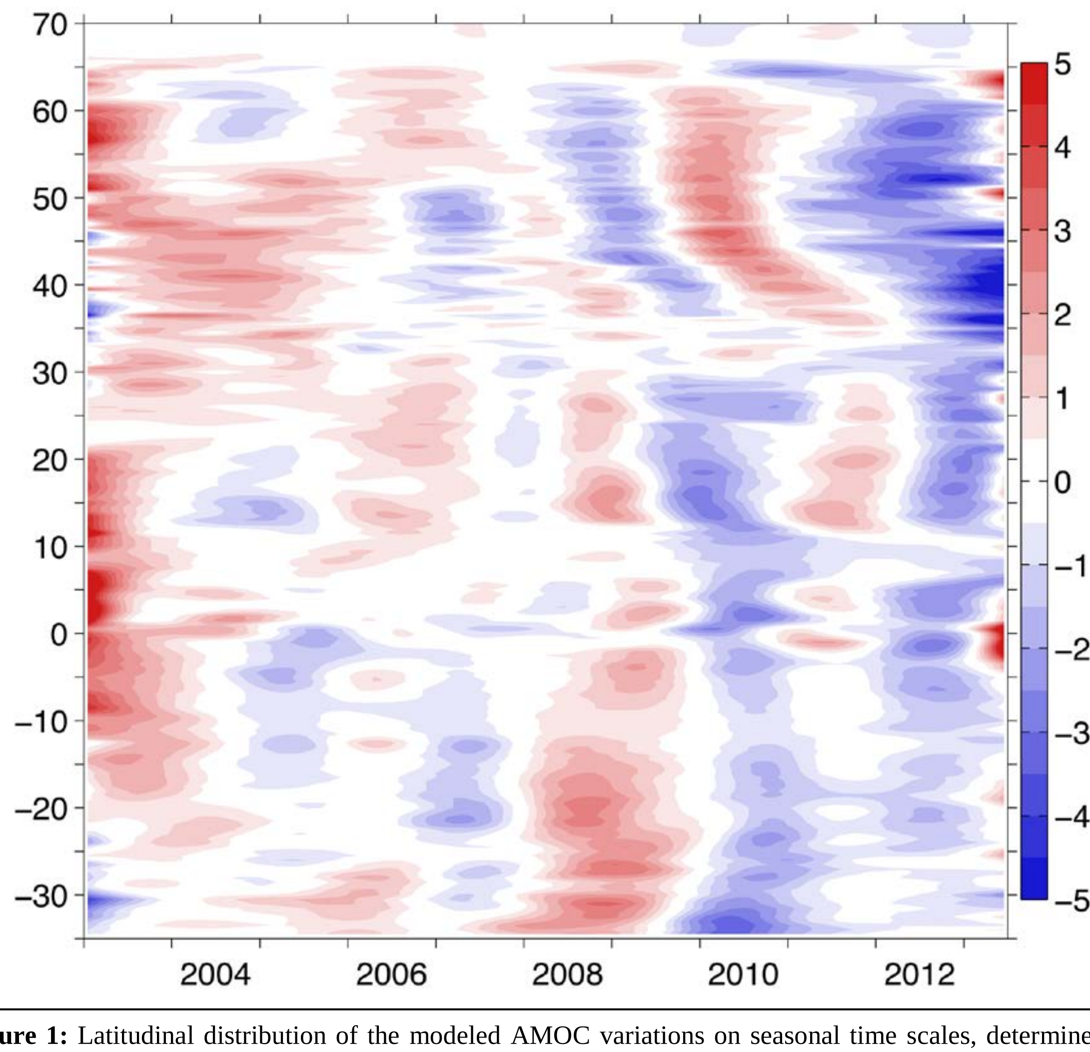


Figure 1: Latitudinal distribution of the modeled AMOC variations on seasonal time scales, determined from decomposing the AMOC transport time series (at each latitude) using the ensemble empirical mode decomposition (EEMD); see Xu et al. (2014) for details.

We are currently preparing a manuscript that summarizes these research results based on the existing 10-year long model simulation (2003-2012). Separately, we are working on a long-term (1958-2015) global simulation at 1/12° resolution in order to study the coherence and variability of the AMOC on decadal-to-interdecadal time scales. Results from this new simulation will be compared to a) similarly configured global simulation with a resolution of 0.72°, which is the resolution used in most of the current climate models; as well as to b) similarly configured global simulation with same horizontal resolution and atmospheric forcing but using the NEMO ocean model in the DRAKKAR project.

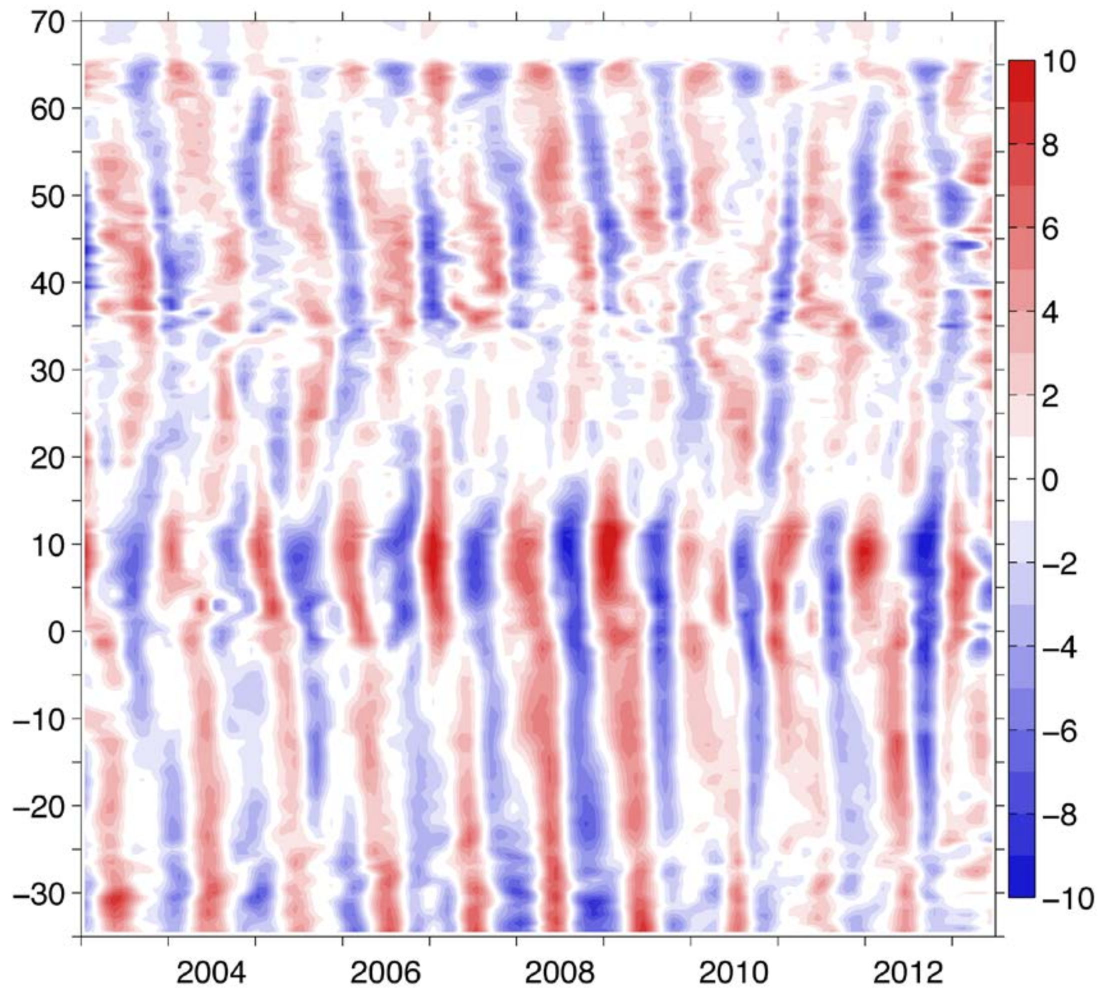


Figure 2: The same as in Figure 1 but for interannual time scales.

Research Performance Measure: We have met our original near-term objective, which is to establish an overall evaluation of current 1/12° eddy-resolving global HYCOM simulation in representing the southern Atlantic Ocean circulation, and working on the 2nd year objective, which is to perform a multi-decadal integration of the global simulation at 1/12°.

Development of an Earth System Component for Medium-Range Predictability in Coastal Seas: Initial Application on Gulf of Mexico Harmful Algal Blooms and Hypoxia Episodes

Project Personnel: V. Kourafalou, H.-S. Kang and I. Androulidakis (UM/RSMAS)
NOAA Collaborators: G. Halliwell, R. Atlas and C. Kelble (NOAA/AOML)
Other Collaborators: S. deRada (NRL/SSC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To develop a comprehensive modeling tool that can be incorporated in an Earth System framework for medium-range (1-6 weeks) prediction of coastal circulation in environments subject to Harmful Algal Bloom (HAB) and hypoxia episodes.

***Strategy*:** To expand the Observing Systems Simulation Experiments (OSSE) system (developed under the Joint UM/RSMAS/CIMAS and NOAA/AOML Ocean Modeling and OSSE Center) to biophysical capabilities, with initial application in the Gulf of Mexico.

CIMAS Research Theme:

***Theme 4*:** Ocean Modeling

Link to NOAA Strategic Goals:

***Goal 1*:** 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: Molly Baringer

Research Summary:

The Gulf of Mexico (GoM), and particularly the Northern GoM shelf, is used as a test case study area for the development of a biophysical component within an Earth System modeling framework. This particular area is chosen for the frequent Harmful Algal Bloom (HAB) and hypoxia episodes associated with Mississippi River (MR) nutrient loads. Work has focused on model simulations and analyses in the coastal areas around the MR Delta, including coastal to offshore interactions that influence broader biophysical connectivity. These are controlled by fronts and eddies associated with the Loop Current, which further influence cross-shelf nutrient exchanges and the ventilation of shelf waters. The hydrodynamic modeling component is based on the HYbrid Coordinate Ocean Model (HYCOM), which has been previously applied on the Northern GoM in high resolution ($1/50^0$) and with an advanced parameterization of river plume dynamics that includes both salinity and momentum fluxes. This model has been validated with several observations (eg. work in this project at Smith et al., 2016); through an ancillary NOAA project, it has been expanded to include the entire GoM. For the purposes of this study, additional work on river plume dynamics has been performed on the full GoM implementation, to achieve the most realistic representation of the transport and fate of MR waters, which are primarily responsible for the water quality of the shelf areas surrounding the Delta (Le Hénaff and Kourafalou, 2016).

Processes influenced the spreading of Mississippi waters (a large source of nutrients, linked to hypoxia episodes) have been studied in detail. In particular, baseline river discharge and flooding conditions have been simulated, characterizing the similarities and differences on the transport and fate of the riverine waters that are of low salinity and high nutrient content. An example is given in Figure 1, where the

distribution of density anomaly is shown, as computed for baseline and flood conditions (Androulidakis et al., 2015). The prevailing buoyancy-driven patterns show influence on surrounding areas towards Louisiana-Texas (LATEX shelf, "downstream" for river plume development) and Mississippi-Alabama-Florida (MAFLA shelf, "upstream" for river plume development) in both cases. However, the influence toward the LATEX shelf prevails in the baseline, while the tendency toward MAFLA substantially increases during flooding conditions. These process oriented studies are important as a basis for the complex biophysical simulations that follow.

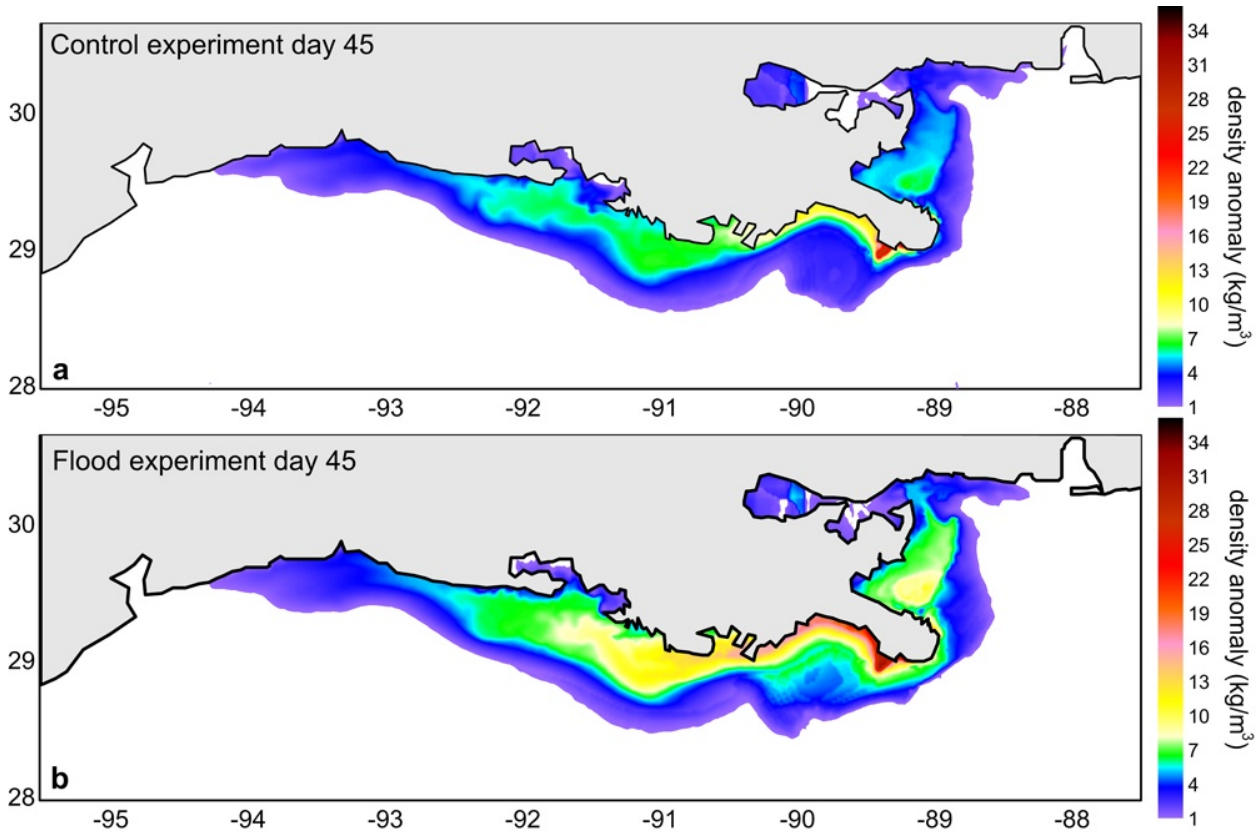


Figure 1: Distribution of density anomaly (kg/m^3) from a baseline (upper) and flooding (lower) experiment on the transport and fate of Mississippi River waters; the density anomaly is a proxy for the influence of riverine waters in the surrounding shelf areas.

The HYCOM hydrodynamic model was coupled with the Carbon, Silicate, Nitrogen Ecosystem (CoSiNE) model. This work has been mainly carried out by NRL (UM sub-contract), in collaboration with RSMAS and AOML. The coupled model has been applied on the entire GoM, first at a lower resolution of 1/25^0 (NRL GoM-HYCOM setup); coupled simulations have been performed at NRL, with the physical results compared to data validated simulations performed at RSMAS. The comparisons show that the results were generally reproduced and matched; improvements are in progress, both in the biological parameters and transitioning to the higher resolution (1/50^0) GoM-HYCOM model developed at RSMAS. The biophysical coupling effort has first focused on the NPZD (Nutrients Phytoplankton Zooplankton Detritus) model representation of the biological processes, so the mechanics of the various elements (input fields, IC/BC, parameters, parallelization) are in place before the much more sophisticated and involved ecosystem within CoSiNE is implemented. As an initial step, a passive tracer (i.e. no biology right-hand-side) simulation was performed using a plankton tracer. The coupling implementation was found to work properly as the tracer was clearly advected (and diffused) by the

physical model. Then, the biological processes were added and a fully coupled HYCOM and CoSiNE model code was developed. Figure 2 shows an example of a coupled simulation for the entire Gulf of Mexico (a zoom in the Northern Gulf is shown). This is the first time that HYCOM has been coupled with a comprehensive nutrient transport model, resulting in a modeling tool that can have broad applications in the scientific community. The hydrodynamic simulations used are currently free-running (ie no data assimilation). An ancillary project under the RESTORE act is already implementing the coupled model for Observing System Simulation Experiment (OSSEs), using the methodology framework developed by UM/RSMAS/CIMAS and NOAA/AOML through the joint Ocean Modeling and OSSE Center (OMOC). This OSSE biophysical system will be available for several applications in an Earth System modeling framework, toward improving the accuracy of both physical and biochemical analyses and forecasts in medium range (1 to 6 weeks).

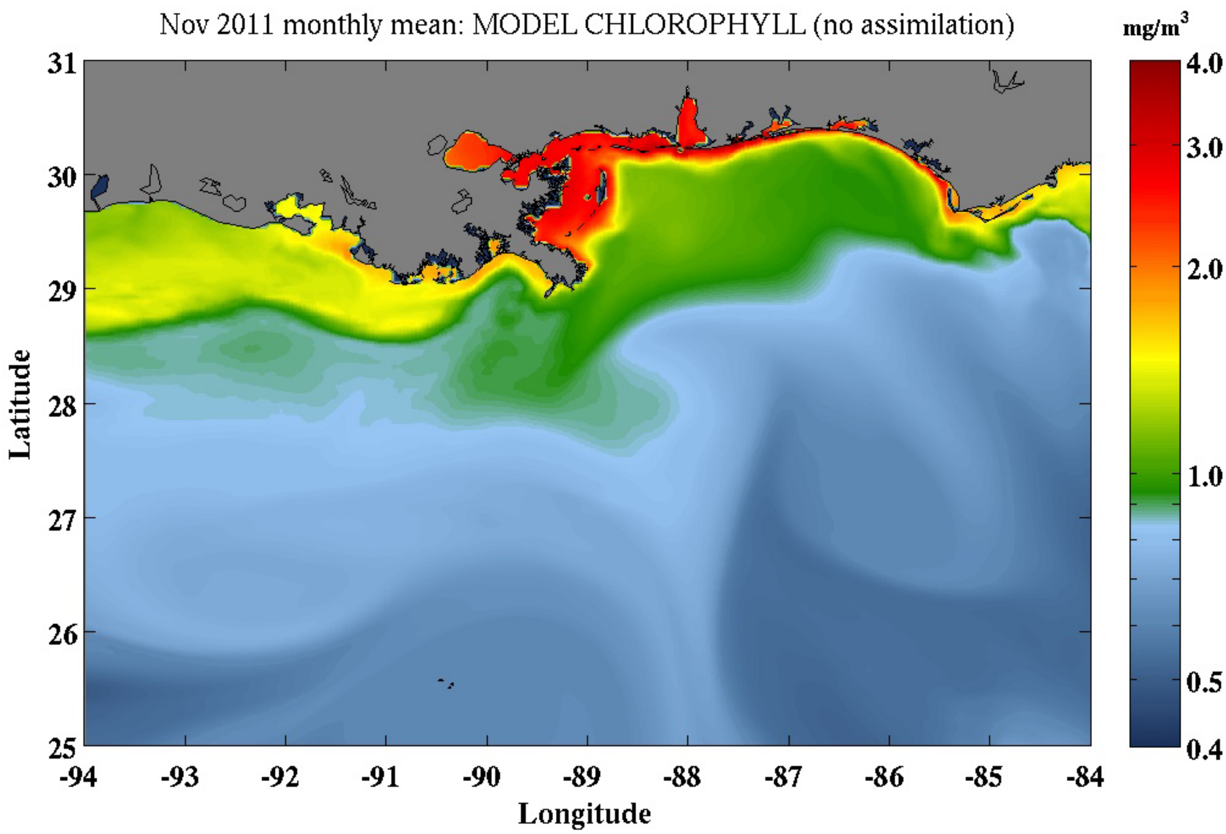


Figure 2: Chlorophyll distribution around the Mississippi Delta from the coupled HYCOM-CoSiNE simulation (based on a free-running HYCOM implementation in the GoM); monthly mean for November 2011.

Research Performance Measure: All major objectives have been met.

Ocean OSSE Development for Quantitative Observing System Assessment

Project Personnel: V. Kourafalou, H.-S. Kang and I. Androulidakis (UM/RSMAS)
NOAA Collaborators: R. Atlas (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To develop tools for quantitative ocean observing and forecasting.
***Strategy*:** To integrate ocean model forecasting and Observing System Simulation Experiments under the Quantitative Observing System Assessment Program (QOSAP)

CIMAS Research Theme:

***Theme 4*:** Ocean Modeling

Link to NOAA Strategic Goals:

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

Research Summary:

Comprehensive observational networks and appropriate modeling systems are needed to ensure the continuous monitoring of ocean variability and support forecasting activities that can deliver useful and reliable ocean services. This project aims at the development of methodologies and tools to quantitatively evaluate ocean observing systems and model forecasts. The overarching goal is to contribute to the Quantitative Observing System Assessment Program (QOSAP), by integrating ocean model forecasting and observing system design, optimization and evaluation. This integration is being achieved under the framework of Observing System Simulation Experiments (OSSEs), rigorously applied in the ocean for the first time through the joint UM/RSMAS/CIMAS and NOAA/AOML Ocean Modeling and OSSE Center (OMOC).

Two forecasting models have been developed within the North Atlantic OMOC OSSE domain. The first one (developed during the last reporting period) has very high resolution ($1/100^0$, ~900m) and covers both coastal and deep sea areas, over a limited domain within the Gulf of Mexico covering the deep Florida Straits and all shelf and coastal areas around South Florida, the Florida Keys, northern Cuba and the western Bahamas. This is a free-running model (no data assimilation), that has been publicly serving 7-day forecast fields for the last year. The second one (developed during the current reporting period) includes the entire Gulf of Mexico (GoM), with the data assimilation scheme adopted by OMOC. The domain is also high resolution ($1/50^0$, ~1.8 km) and both models use the HYbrid Coordinate Ocean Model (HYCOM) code. This GoM-HYCOM model is the highest resolution currently available for near real-time forecasting. We use the operational GFS (Global Forecast System) atmospheric forcing from the National Center for Environmental Prediction (NCEP), with the output on equally spaced $1/2^0$ horizontal grid at 3-h intervals to 240-h. The ocean initial and lateral boundary conditions come from the Navy's global HYCOM model on $1/12^0$ grid; data are hosted at FSU/COAPS. Boundary conditions are updated daily from the global HYCOM model, up to a 7-day period. Maps for Sea Surface Height (SSH), Sea Surface Temperature (SST), temperature at 50m and surface currents are being publicly displayed.

An example of GoM-HYCOM forecast fields is displayed in Fig. 1. The initial and 7th forecast day are given for Sea Surface Height (SSH) and near-surface currents (only a few velocity vectors plotted to indicate the circulation that accompanies the SSH changes; more detailed surface currents are displayed on accompanying web pages, see link under "Outreach"). The initial GoM state was dominated by a detachment process of an anticyclonic Loop Current (LC) Eddy (LCE), partially under the influence of a cyclonic LC Frontal Eddy (LCFE) immediately north of the Yucatan Strait. The model predicted the change in LCFE orientation and size and the subsequent re-attachment of the LCE to the main LC body. Predicting the LC variability, which is dominated by the LCE separation process, is crucial for predicting the circulation in the GoM and monitoring the connectivity of remote GoM ecosystems. Further improvements are in progress, through advancing the data assimilation scheme. These activities are under our ocean modeling and OSSE framework, which allows the advancement of strategies for observing system design and quantitative evaluation of observing systems, by quantifying the improvement of model forecasts through the assimilation of specific observations.

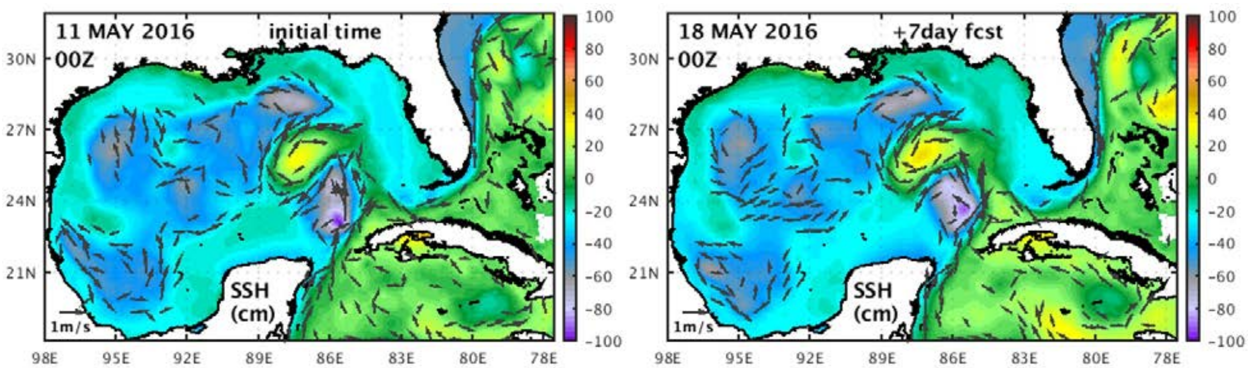


Figure 1: Sea Surface Height and near surface currents (only a few vectors are plotted for clarity) from the GoM-HYCOM forecast modeling system. Example is for the initial and 7th-day forecast, starting from 18 May, 2016.

Research Performance Measure: All major objectives have been met.

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South Atlantic Meridional Overturning Circulation: Pathways and Modes of Variability

Project Personnel: R.C. Perez, S.L. Garzoli and R. Garcia (UM/CIMAS)
NOAA Collaborators: C.S. Meinen and S Dong (NOAA/AOML)
Other Collaborators: R. Msadek (CERFACS/CNRS); R.P. Matano (OSU/CEOAS)

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 Atlantic Meridional Overturning Circulation (AMOC) in the South Atlantic.

***Strategy*:** 1) To characterize the pathways of the upper and lower limb of the AMOC in the South Atlantic and identify the dynamical mechanisms that control these pathways. 2) To identify the natural modes of variability in the South Atlantic and their impact on the AMOC. 3) To determine the response of

the South Atlantic pathways to predicted climate change scenarios and assess the impact of this response on the AMOC.

CIMAS Research Theme:

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

Link to NOAA Strategic Goals:

***Goal 3*:** Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts*

NOAA Funding Unit: OAR/CPO
NOAA Technical Contact: Sandy Lucas

Research Summary:

Previous observational and modeling efforts on the Atlantic meridional overturning circulation (AMOC) have been focused on the North Atlantic and the Southern Oceans, which are 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 AMOC in the South Atlantic Ocean, which are the most important links between them. The South Atlantic 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.

As part of the project we are 1) characterizing the pathways of the upper and lower limb of the AMOC in the South Atlantic and identify the dynamical mechanisms that control these pathways, 2) identifying the natural modes of variability in the South Atlantic and their impact on the AMOC, and 3) determining the response of the South Atlantic pathways to predicted climate change scenarios and assess the impact of this response on the AMOC. 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), process-oriented numerical experiments using global and regional ocean models (OFES, ROMS), and global in-situ and satellite observations.

In work led by R. Matano to characterize the leading modes of low-frequency variability of the South Atlantic circulation in the SODA analysis product, we computed empirical orthogonal function (EOF) modes of the model's sea surface height (SSH) and sea surface temperature (SST) fields as well as of its forcing field (wind stress, wind stress curl and freshwater fluxes). The dominant model of low-frequency variability is an inter-decadal variation of the subtropical gyre. The dynamical manifestations of the Brazil-Malvinas Confluence and the Agulhas Retroflection variability appear in the second and third mode. The structure of the wind stress curl show changes related mostly to the first SSH mode. The lack of significant correlation between the SSH and wind curl for the second and third modes indicates that these patterns are more influenced by the internal variability of the geostrophic flow. There are significant correlations between SSH and SST anomalies, suggesting that an important portion of the SST variability are driven by advective effects associated with the geostrophic circulation. Our analysis also shows a strong correlation between the AMOC and the meridional heat transport (MHT) in the South Atlantic, with a latitudinal volume and heat increase that is close to observations. The anomalies and the meridional gradient of the AMOC and MHT appear stronger during El Niño years and weaker during La Niña ones.

South Atlantic Subtropical Gyre

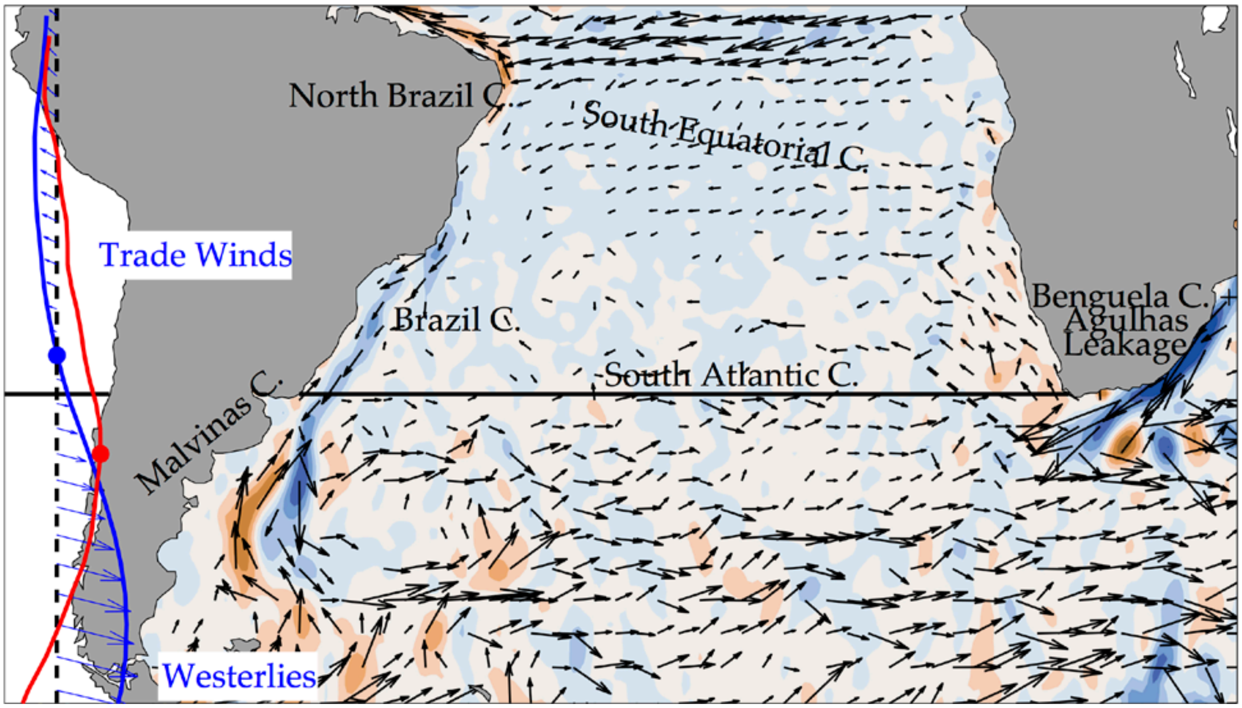
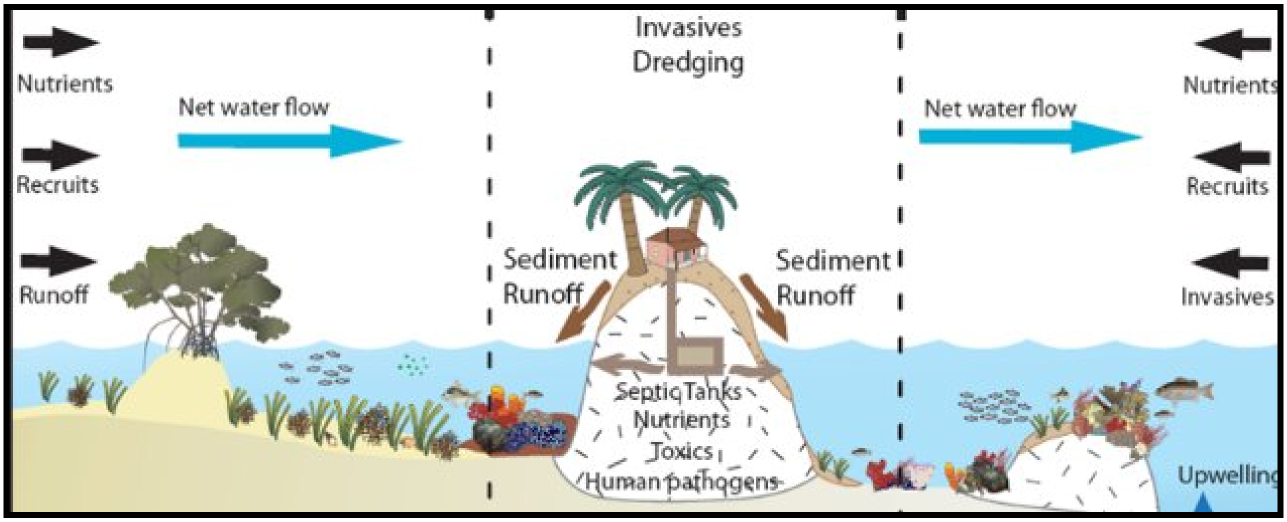


Figure 1: Map of mean near-surface currents delineating the boundaries of the South Atlantic subtropical gyre generated from the Lumpkin and Johnson (2013) drifter climatology. Color shading: meridional velocity (blue indicates southward and brown indicates northward). Vectors show horizontal currents with magnitudes in excess of 10 cm/sec. Blue vectors: Mean wind stress from NCEP reanalysis averaged across the basin, blue curve: mean zonal wind stress, red curve: mean wind stress curl. Labels indicate the major wind (blue) and circulation (black) features.

A parallel study is being led by R. Perez using observed SSH anomalies (SSHA) from AVISO, as well as, simulated SSHA from NOAA/GFDL's CM2.5 simulation forced with COREII atmospheric forcing and their ECDA analysis product to study the low-frequency variability of the South Atlantic circulation and its impact on AMOC in the South Atlantic. Much of our analysis confirms the SODA results described above, specifically the observed and simulated variability in the South Atlantic is dominated by steadily increasing sea level increase across the entire basin, while the interannual to decadal (and in the models multidecadal) subtropical gyre changes are the next largest source of variability. SSHA trends and the modes of variability create zonal density gradients across the basin, and impact the strength and structure of the boundary currents and AMOC. The western boundary currents (i.e., the southward flowing Brazil Current and northward flowing North Brazil Current) are particularly influenced by the first mode of variability of the gyre such that the magnitudes of their transports increase when the first mode of SSHA increases. These gyre scale changes significantly influence the strength of the AMOC in the South Atlantic. Specifically, the AMOC volume transport is strengthened when the first mode is positive, with largest transport increases found to the north of the South Atlantic subtropical gyre (north of 15°S). Increasing AMOC anomalies between 35°S and 15°S suggest interaction between the gyre circulation and AMOC on interannual to multidecadal time scales.

In work led by R. Matano, we continued using our regional eddy-resolving (1/12˚) ROMS simulations of the tropical and subtropical South Atlantic. Previously, we reported the finding of a strong correlation between the time variability of the surface, westward mean flow generated by the passage of Agulhas eddies and the time variability of the deep eastward current that detrains North Atlantic Deep Water (NADW) from the western boundary region. Our analysis indicated that these mean flows (westward at the surface and eastward at NADW levels) are in thermal wind equilibrium and, therefore, are a manifestation of the same dynamical phenomena (Agulhas eddies). To investigate the causality of such equilibrium we conducted process-oriented experiments in a flat-bottomed basin with different formulations of the density structure. These experiments, which are in progress, aim to discriminate the role of bottom topography and inter-ocean density fluxes in the coupling between the upper and deep circulation. In collaboration with R. Perez, the co-variability of the surface westward and deep eastward flows are being examined in several of the NOAA/GFDL simulations, as well as, gridded Argo-altimetry velocity products.

Research Performance Measure: Progress has been made in all of the areas mentioned above and research objectives are being met. Research findings were presented at the UK RAPID – US AMOC International Science meeting in Bristol, UK in July 2015, and at the 2016 Ocean Sciences meeting in New Orleans, LA in February 2016.



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)
NOAA Collaborators: M. Schirripa, J. Walter and S. Cass-Calay (NOAA/AOML)
Other Collaborators: J. Hoenig and J. McDowell (Virginia Institute of Marine Science), C. Davies (CSIRO-Australia); S. Lowerre-Barbieri (Florida FWC, Florida Fish and Wildlife Research Institute)

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, to use DNA sequencing with close-kin analysis to evaluate bluefin tuna population dynamics, to evaluate red snapper spatial distributions, and to gather data on the maturity of reef fishes in the U.S. Virgin Islands.

CIMAS Research Theme:

***Theme 5*:** Ecosystem Modeling and Forecasting (*Primary*)
***Theme 6*:** Ecosystem Management (*Secondary*)
***Theme 7*:** Protection and Restoration of Resources (*Secondary*)

Link to NOAA Strategic Goals:

***Goal 1*:** 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: NMFS/SEFSC
NOAA Technical Contact: Theo Brainerd

Research Summary:

UM Ecosystem modeling: (PI: E. Babcock)

We collaborated 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. U.M. Ph.D. student Holly Perryman contributed to the Atlantis model and is now using the model to simulation-test the ecosystem impact of several proposed and existing marine protected areas, focusing on pelagic species. She also modeled the spatial distribution of pelagic fish in the Gulf based on both surveys and fisheries data; the analysis of shark distribution will be submitted for publication soon, and the analysis of billfish and tuna distributions was presented at the ICCAT (International Commission for the Conservation of Atlantic Tunas) sailfish stock assessment in May 2016 (Perryman and Babcock, 2016). She is expected to defend her dissertation in summer of 2016. We also developed spatial simulation models for conducting management strategy evaluation. Management strategy evaluation enables various interacting components of a fishery system to be evaluated collectively, including resource monitoring, stock assessment and decision-making. These simulation models described the population dynamics of queen conch and Caribbean spiny lobster and enabled evaluation of a proposed adaptive management decision-making framework. We found that empirical control rules that adjusted the fishing season based on observed changes in mean size, catch per unit of effort and catch performed well in avoiding overfishing and rebuilding depleted populations. Finally, we evaluated individual variation in albacore growth, based on fin spine increment data (Ortiz de Zarate and Babcock, 2016).

VIMS reef fish life history in the Virgin Islands (PI. J. Hoenig)

For the project on life history of reef fishes in the U.S. Virgin Islands, 109 gonad samples were collected in October, 2015, and 514 gonad and otolith samples were collected in February, 2016. In addition, spines were collected from Queen triggerfish in February. The otoliths and spines were given to Dr. Virginia Shervette to aid in her study of age and growth. Another collecting trip is scheduled for July, 2016. For the bluefin tuna growth project, all available otolith data has been collated and the problem with ring interpretation has been resolved. The otolith and tagging data have been used simultaneously to estimate growth parameters using the most recent methodology. A manuscript will be submitted for publication shortly. For the red snapper tagging project, red snapper tagging data has been analyzed and found to suggest different selectivity patterns from what has been published. Further work to resolve the selectivity is ongoing.

Bluefin tuna close-kin analysis (P.I.s J. McDowell, VIMS and C. Davies, CSIRO-Australia)

The project to evaluate the feasibility of using samples from larval surveys for close-knit kin analysis is nearing completion. The range of PCR and sequencing analyses done by CSIRO and VIMS demonstrated that the DNA quality of samples provided was poor (denatured/cross contamination) and unsuitable for close kin genetics unless the quality of the DNA preservation can be improved. Grewe reported to John Walter at SEFSC and suggested refinements to preservation protocols, which have been implemented. Notwithstanding this, given the very small size of the larvae, cross contamination with other species from stomach contents cannot be discounted at this stage. DNA from larval samples have also been provided to VIMS (McDowell) who are running blind comparison with alternative genotyping approach. Results should be available by June.

The project to develop an East - West marker is also approaching completion. The initial round of marker development was inconclusive given issues with DNA quality/provenance of samples for eastern stock. New adult tissue samples set provided in January by John Walter (collected from GOM by NOAA observers) and Haritz Arrizabalaga (Eastern adults from AZTI) have been extracted (good quality) and

run by CSIRO using DArT sequencing. Preliminary analysis of DNA quality looks promising. Analyses of these data will be complete by end of June. DNA from these samples has been provided to VIMS (McDowell) who are running blind comparison with alternative genotyping approach. Results should be available by June.

Red snapper spatial distribution (P.I. Barbieri, FWRI)

Two acoustic arrays have been developed: (1) one in the Florida Keys (n=61 receivers) to help support on-going telemetry research in the area; and (2) a second in the Madison Swanson marine protected area (n=33) to assess how red snapper home ranges and site fidelity are affected by habitat context (i.e., proximity of artificial and natural structure) as part of a larger study with collaborators Jay Rooker and Will Patterson. Funds from CIMAS are being used to cover travel, boat time, and supplies needed to maintain these arrays. The receivers will be downloaded in May and June of 2016.

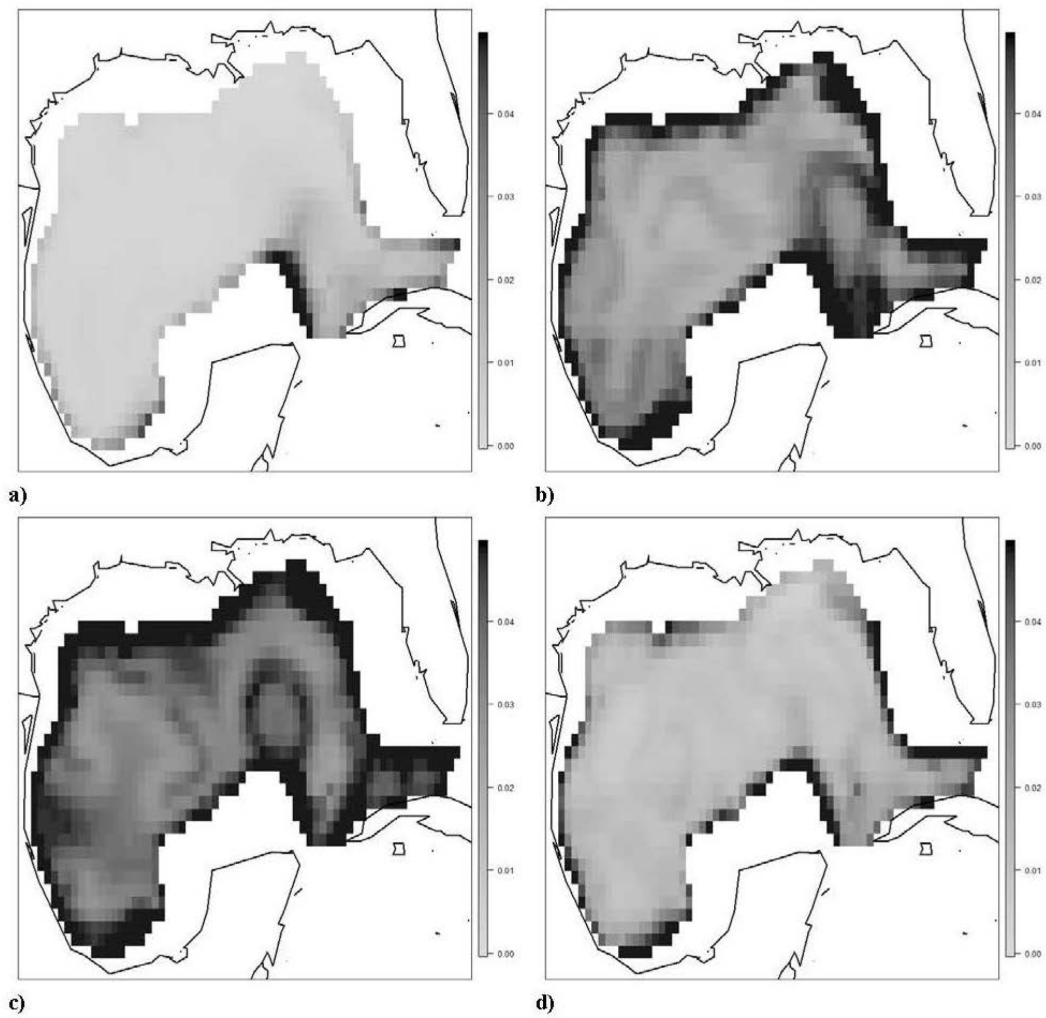


Figure 1: Abundance patterns for sailfish *Istiophorus albicans* predicted from a generalized additive mixed model fitted to U.S. longline observer data for Jan. – Mar. (a), Apr. – Jun. (b), Jul. – Sep. (c), and Oct. – Dec. (d). From Perryman and Babcock (2016).

Research Performance Measure: All of the objectives of this proposal were met or are in progress. For the current year, the objectives were: (1) Develop ecosystem models for the Gulf of Mexico and Florida using Atlantis, individual-based models and other modeling frameworks. The Atlantis work will be finished as Holly Perryman completes her dissertation in summer 2016. Spatial analysis was submitted to ICCAT. (2) Asses maturity of commercially & recreationally important reef fishes in the U.S. Virgin Islands. Samples are being collected and analyzed. (3) Assess spatial dynamics of red snapper in the Gulf of Mexico. Acoustic telemetry arrays are deployed, and are monitoring movements of red snapper tagged with other funds.

Objectives that are ongoing from the previous year include objective one as well as: (4) Pilot project on Bluefin tuna close-kin analysis. This work is ongoing at VIMS and CSIRO.

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Length-Based Assessment and Harvest Control Rules for Severely Data-Limited Fisheries of the South Atlantic, Gulf of Mexico, and U.S. Caribbean

Project Personnel: W.J. Harford (UM/CIMAS), E.A. Babcock (UM/MBE)

NOAA Collaborators: M. Karnauskas, J.F. Walter, S. Sagarese, M. Bryan, N. Cummings (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives: To tailor the Stock-Synthesis MSE procedure to life histories of fishery stocks managed by the Gulf & Caribbean Fisheries branch of the SEFSC. To evaluate the feasibility of identifying harvest control rules that can link length-based inputs to ACL specification.

Strategy: Preliminary stages of the project have focused on understanding and coding the existing harvest control rules already in use in the region, to identify how simple proxies (e.g., broken stick rules) might be developed.

CIMAS Research Theme:

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

Link to NOAA Strategic Goals:

***Goal 1*:** 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 detailed MSE framework has been developed, life history characteristics have been compiled for a suite of species relevant to our study (26 data-rich stocks within Gulf of Mexico and South Atlantic regions to be used as data-limited test cases), and initial management strategy evaluations have been carried out. A life history review was also carried out for a recent data- poor Caribbean assessment (SEDAR 46) and we intend to incorporate this review into the project. Preliminary simulations have revealed some interesting findings with regard to uncertainty in rebuilding trajectories when stock productivity cannot be reliably estimated, which is the case for most species in the study area. We found that recovery trajectories vary greatly depending on the assumed level of steepness in the stock-recruitment relationship.

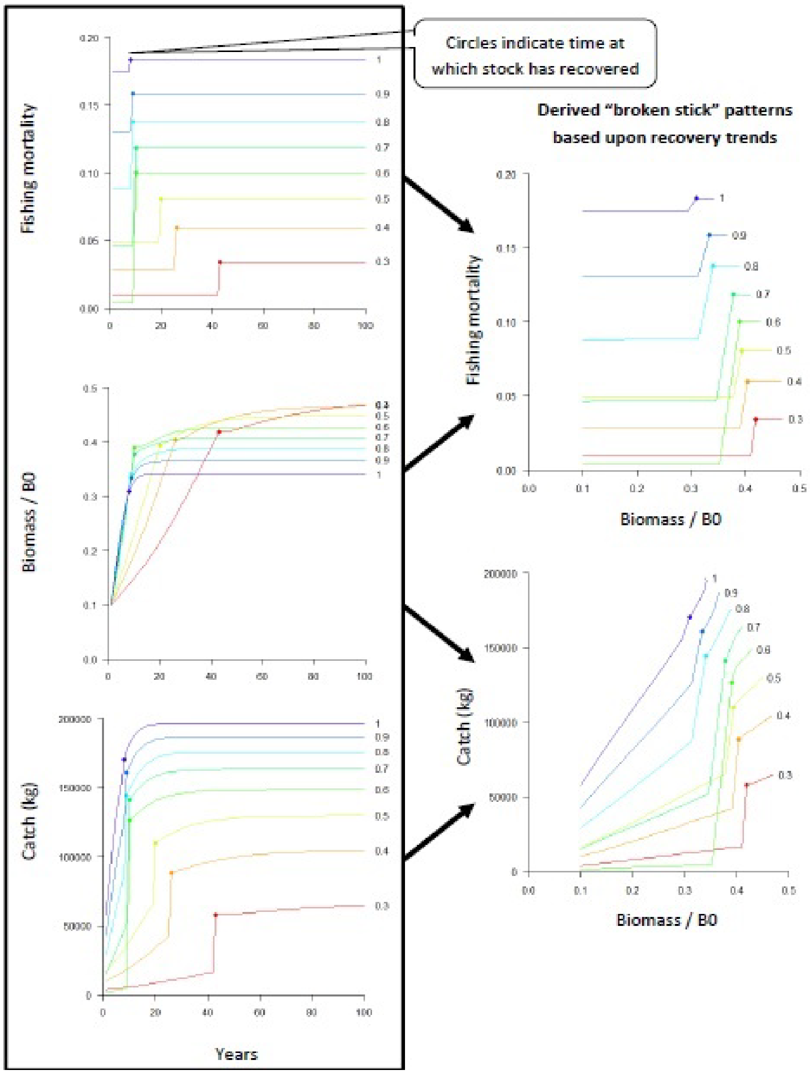

Figure 1: We simulated National standard 1 guidelines (NSG), as implemented in the Gulf of Mexico, using management strategy evaluation. Recovery of depleted stocks was simulated using a range of Beverton- Holt steepness parameter values (range 0.3 – 1.0). Temporal patterns illustrate the possibility of deriving "broken-stick" type harvest control rules that conform to NSG. The potential application of this idea is to data-limited stocks where life history information (i.e. stock productivity) is too uncertain to make projections necessary during rebuilding phases. We anticipate examining whether rebuilding plans can achieve NSG criteria in the absence of knowledge of stock productivity.

Research Performance Measure: The initial research explorations were intended to aid in understanding how various harvest control rules behave under different life histories and stock productivities, and this **will** provide the basis for understanding which control rules are robust in situations of extreme data-limitation. Continuing work will focus on meeting the specific objectives outlined. Dr. Harford began working on the project starting in Q4 (October 2015), and thus it is still in an initialization phase.

This project is constantly undergoing a degree of adaptation as it seeks to provide relevant support to the Southeast Fisheries Science Center's data-limited stock assessment methods – an area that itself is constantly evolving. For example, the original project proposed to focus largely on length-based assessment methods which were currently the most commonly used for management in the region. However, recently a much broader suite of data-limited models has become operationally used in the region, and the project has thus broadened its expanse to provide relevant advice on a wider range of methods.

Caribbean Sea and Gulf of Mexico Bluefin Tuna Research

Project Personnel: L. Rasmuson, K. Shulzitski, E. Malca, S. Privoznik, A. Shiroza, J. Mostowy, K. Doering, A. Spera, J. Suca and A. Ender (UM/CIMAS)

NOAA Collaborators: J. Lamkin, T. Gerard and A. Zygas (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives**:** To define and investigate bluefin tuna and other highly migratory species' 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 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 1**:** Healthy Oceans – Marine fisheries, habitats, and biodiversity sustained within healthy and reproductive ecosystems

NOAA Funding Unit: NMFS/SEFSC

NOAA Technical Contact: Theo Brainerd

Research Summary:

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 Mexican Caribbean, Cuba and north of the Bahamas. In 2016, we focused our sampling efforts our sampling efforts on unique circulation features near the Loop Current and south of Cuba.

The 2016 research cruise conducted intensive sampling of circulation features, collecting and preserving larvae for studies of growth, isotopic trophodynamics, condition and feeding patterns. A comparison between sampling gears was conducted to provide a correction factor the NOAA-led annual spring survey, which was completed on the NOAA ship Oregon II. Scientists from UM/CIMAS, NOAA-SEFSC, NOAA-AOML, WHOI, City University of New York, IEO (Instituto Español Oceanográfico, Spain), National Research Institute of Far Seas Fisheries (Japan), Centro de Investigaciones Pesqueras (Cuba), GEOCUBA Marine Studies (Cuba), and El Colegio de la Frontera Sur **-** ECOSUR (México) participated during the research cruise. The NOAA research vessel Nancy Foster was used for the 29 days of sampling completing 64 stations (including 3 stations that were sampled continuously for 24 hours).

Similarly, to cruises completed in previous years (2009-2015), physical data from CTD casts, and biological data from plankton net tows were collected *in situ*. This year at select stations, the ship remained at a specific station (based on the regional oceanography) for 24-hrs and conducted repeated plankton tows in order to better understand how patterns change over the course of a day. We collected vertically stratified plankton tows in order to let us better understand where in the water column larvae are located. Samples were sorted at sea and subsets of larvae were either frozen separately in liquid nitrogen for tissue stable isotope analyses or frozen in pure ethanol to preserve high quality DNA for next-generation sequencing. We will continue our collaborations with the Instituto Español Oceanográfico in Spain to compare results between the Gulf of Mexico, the Western Caribbean and the Mediterranean Sea.

These results suggest that spawning of bluefin tuna is more restricted in time and space than for other Atlantic tunas, including congeners. Bluefin were most prevalent in the upper 20 m of the water column where as other species are more dispersed throughout the water column (Fig. 1). For our targeted 24-hr studies, it appears that lobster larvae are most abundant on the edges of oceanic circulations. All of the samples have been preserved, and will be used for future ecological studies.

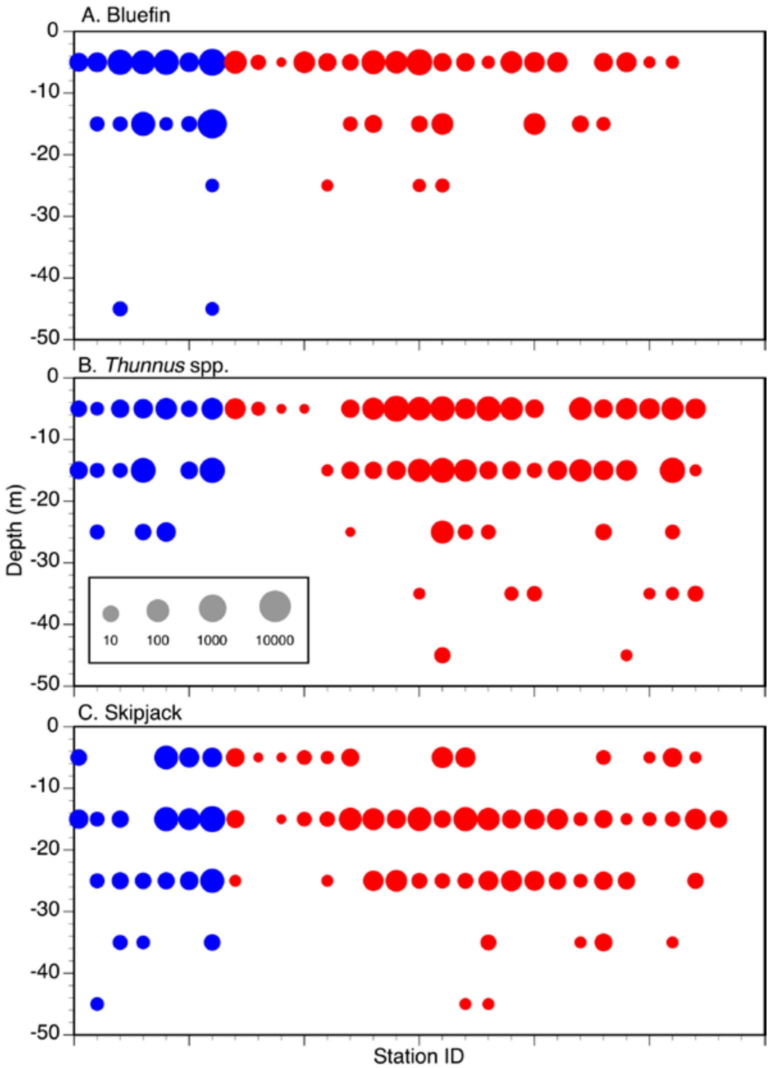

Figure 1: Vertical distribution of three different groups of tuna larvae.

Research Performance Measure: The research program is on schedule. This year's (NF1602) cruise was successfully completed on June 5, 2016; sample processing has started and sorting will begin shortly. Last year's cruise (NF1502) has been completely sorted and identification of larval bluefin tuna and other species of interest has been completed. For the trophodynamics sub-project, frozen samples of ichthyoplankton, mesozooplankton, microzooplankton and phytoplankton were shipped to the IEO laboratory in Malaga, Spain for processing. Otolith removal has been completed on the larval bluefin tuna from this shipment and is awaiting ageing. For the ageing sub-project, 138 larval bluefin tuna have been aged from the 2012 survey, and all larvae from 2013 and 2014 have also been aged. Lastly, 54 larval Skipjack tuna (*Katsuwonis pelamis*) have been aged for a multi-species comparison.

A New Zooplankton Community Index and Recruitment Model to Improve Understanding of the Stock-Recruit Relationship for Western Atlantic Bluefin Tuna

Project Personnel: L. Rasmuson, Y. Liu and A. Shiroza (UM/CIMAS)
NOAA Collabotrtors: M. Lauretta, J. Lamkin, T. Gerard, G. Zapfe and J. Lyczkowski-Shultz (NOAA/SEFSC); S K. Lee (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To develop an index for zooplankton communities in the Gulf of Mexico and relate the index to the recruitment of bluefin tuna

***Strategy*:** Count zooplankton to document zooplankton communities at selected, representative stations across the 34-year Gulf of Mexico time series. Use multivariate statistical techniques to derive one or more indices, which summarize spatiotemporal variability in the zooplankton community. Combine these indices with other physical and biological environmental variables in a predictive model of recruitment fluctuations for western stock bluefin tuna.

CIMAS Research Theme:

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

Link to NOAA Strategic Goals:

***Goal 1*:** Healthy Oceans – Marine fisheries, habitats, and biodiversity sustained within healthy and reproductive ecosystems

NOAA Funding Unit: NOAA FATE Program
NOAA Technical Contact: Matthew Lauretta

Research Summary:

Atlantic bluefin tuna (BFT) are distributed throughout the northern Atlantic Ocean. Despite various management measures, the western BFT stock is overfished. The most problematic knowledge gap for western BFT is the lack of understanding of the stock-recruitment relationship (SRR). The most recent assessment considers two potential forms of the SRR, resulting in two recruitment scenarios for the western Atlantic BFT stock: “low” and “high”. There is no evidence suggestion which recruitment scenario is better. Therefore, understanding the drivers of recruitment is critical in order to sustainably manage BFT.

In many pelagic fish species, recruitment is determined during early life history stages, i.e. eggs and larvae. Larval BFT are highly selective feeders, however feeding success is not related to ambient primary productivity levels but rather the abundance of specific planktonic prey and predator species. The zooplankton communities, which encompass larval fishes planktonic prey and predators, experience environmentally driven shifts. Environmentally driven shifts of zooplankton affect fisheries recruitment. As a result, decadal-scale time series of zooplankton composition are maintained in several US Large Marine Ecosystems. However, no such information currently exists for the GOM and therefore BFT.

In this project we use a 34-year time series to develop an index of zooplankton communities throughout the Gulf of Mexico. Preliminary analyses suggest fewer predators are present where BFT larvae were collected (Fig. 1).

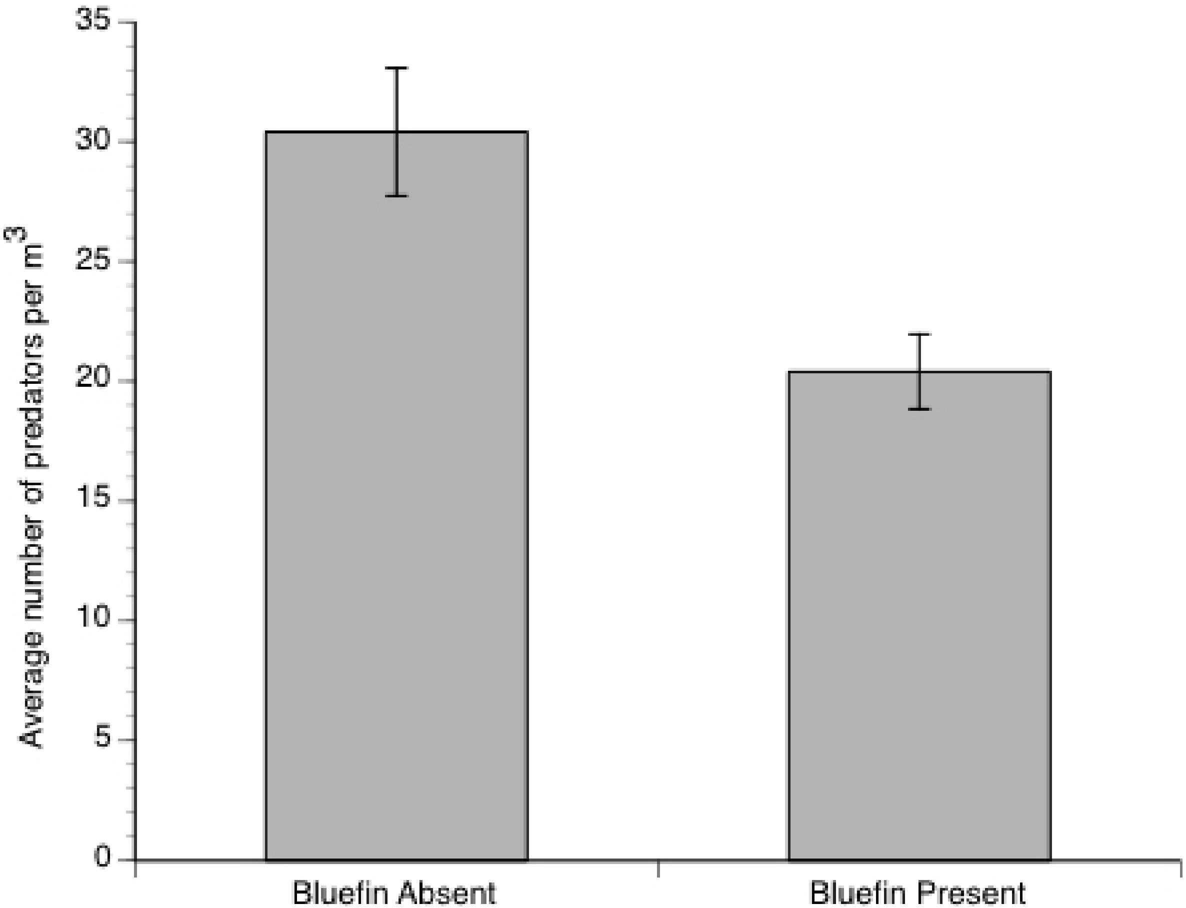

Figure 1: Mean number of predators at stations where bluefin were present and absent.

Research Performance Measure: The research program is on schedule. This year's focus has been selecting samples to count and counting the samples. To date 56 samples have been counted and preliminary analyses conducted.

Evaluation of Gulf of Mexico Oceanographic Observation Networks, Impact Assessment on Ecosystem Management and Recommendations

Project Personnel: M. Le Hénaff (UM/CIMAS); V. Kourafalou and H.-S. Kang (UM/RSMAS)
Other Collaborators: F. Muller-Karger and D. Otis (USF); L. McEachron (Florida Fish and Wildlife Conservation Commission)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To analyze the impact of current oceanographic observing systems in the Gulf of Mexico in terms of ecosystem management and provide recommendations on potential improvements.

***Strategy*:** To perform observing system experiments using coupled hydrodynamic-biogeochemical-ecosystem modeling.

CIMAS Research Theme:

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

Link to NOAA Strategic Goals:

***Goal 1*:** 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: NOAA RESTORE Act Science Program
NOAA Technical Contact: Julien Lartigue

Research Summary:

The ability of current observing systems of the Gulf of Mexico (GoM) to provide useful information to ecosystem managers is investigated using data assimilative modeling. The physical simulation is based on a high-resolution (2 km) configuration of the HYbrid COordinate Ocean Model (HYCOM) over the Gulf of Mexico (GoM) with 32 vertical levels and improved river representation based on realistic daily forcing for 15 major rivers in the US part of the GoM. The atmospheric forcing is from the NAVy Global Environmental Model (NAVGEM), and the simulation is nested into the operational global HYCOM run at the Naval Research Lab (NRL, Stennis Space Center). This GoM-HYCOM configuration, developed in the course ancillary projects, includes data-assimilative capacity, developed specifically for the hybrid vertical grid of HYCOM. We evaluated this GoM-HYCOM data assimilative simulation during the years 2014-2015, showing comparable to smaller levels of errors, compared with existing near-real time systems. This ensures that the physical model in our coupled simulations is capable to adequately represent the GoM large and meso-scale dynamical features. In parallel, the Carbon, Silicate, Nitrogen Ecosystem (CoSiNE) biogeochemical model has been coupled to HYCOM in the GoM, as part of an ancillary project, and is under evaluation. The coupled HYCOM-CoSiNE model will be used to perform Observing System Experiments during selected study periods.

The selected study periods considered for these experiments will include episodes of connectivity at the basin scale, which are first analyzed using remote sensing imagery. We have compiled a set of satellite imagery for the GoM and developed a tool to visualize images on a daily basis, in order to identify time periods when the LC interacts with the Yucatan Peninsula, or the Mississippi River plume, or both. Using ocean color and sea-surface temperature data from the Coastal Zone Color Scanner (CZCS), Sea-Viewing

Wide Field of View Sensor (SeaWiFS), and Moderate Resolution Imaging Spectrometer (MODIS), we created a catalog of images that illustrate two main phenomena: a) extension of the Mississippi River plume to the southeast into the Florida Keys region; and b) episodes when parcels of highly colored water extend north of the Yucatan Peninsula along the LC toward the Florida Straits. Figure 1 shows the remotely sensed Chl-a at four dates, which represent the two phenomena mentioned above. Figures 1A and 1B show examples of a high Chl-a filament extending north of the Yucatan Peninsula around the LC, while images 1C and 1D show filaments of high Chl-a extending from the northern GoM and the Mississippi region along the LC and toward the Florida Keys. We have continued the analysis of satellite imagery to extend it to the Florida Keys region, considering additional parameters such as turbidity, in support of the ecosystem modeling effort.

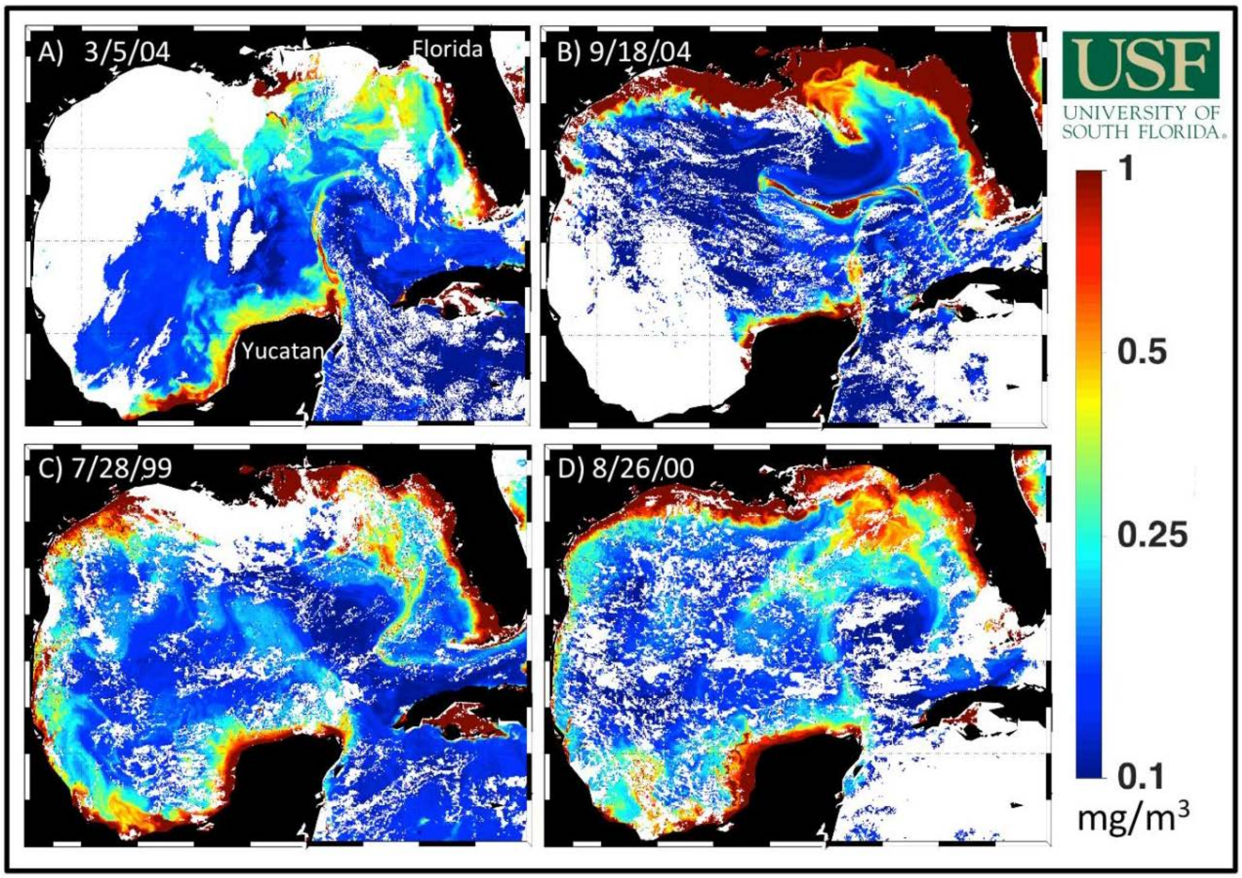

Figure 1: SeaWiFS and MODIS satellite estimates of Chl-a in the GoM. Figures 1A and 1B show highly colored water being advected northward from the Yucatan Peninsula. Figures 1C and 1D show the Mississippi River plume being entrained into the LC and advected toward the Florida Keys region.

In parallel of the hydrodynamic-biogeochemical modeling, we prepared the implementation of the ecosystem model Ecopath in the Florida Keys. We segregated reef fish survey data from 1994 to 2012 into 37 ecologically relevant trophic groups for the Florida Keys. We estimated diet composition, biomass, and other parameter estimates for each trophic group using related Caribbean and GoM based ecosystem models. We performed preliminary simulations using this Ecopath model configuration, which current work aims at improving by refining estimates of fishing mortality for high trophic groups.

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

High-Resolution Ocean-Biogeochemistry Modeling for the East and Gulf Coasts of the U.S. in Support of the Coastal Monitoring and Research Objectives of the NOAA OA Program

Project Personnel: Y. Liu, L. Barbero and R. van Hooidonk (UM/CIMAS)
NOAA Collaborators: R. Wanninkhof and S.-K. Lee (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To develop, validate and use a high-resolution regional ocean-biogeochemistry model (1) to fill the temporal ocean acidification data gap between the 5-yearly GOMECC cruise data; (2) to downscale the CMIP5 model projection of the carbon and biogeochemical parameters along the East and Gulf coasts of the U.S. for the 21st century, and (3) to optimize the observational strategy of the future GOMECC cruises.

***Strategy*:** To downscale global climate models to simulate carbon, physical and biogeochemical processes along the East and Gulf coasts of the U.S. for the recent decades (1979 - present day) and for the entire 21st century.

CIMAS Research Theme:

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

Link to NOAA Strategic Science Goals:

***Goal 4*:** Resilient Coastal Communities and Economies- *Resilient coastal communities that can adapt to the impacts of hazards and climate change* (*Primary*)

NOAA Funding Unit: NOAA/OAP
NOAA Technical Contact: Erica Ombres (erica.h.ombres@noaa.gov)

Research Summary:

Analysis of the data collected during the first (2007) and the second (2012) Gulf of Mexico and East Coast Carbon (GOMECC) cruises showed measurable temporal pH and aragonite saturation state (Ωar) changes along the eight major transects. However, it is challenging to determine how much of this temporal change between the two cruises was due to ocean acidification and how much is due to variability on seasonal to interannual scales. Therefore, in order to provide useful products for the ocean acidification (OA) research community and resource managers, it is important to filter out seasonal cycle and other variability from the multi-annual trend.

The newly released Modular Ocean Model version 5 (MOM5) coupled to the updated TOPAZ biogeochemical model (MOM-TOPAZ) was configured for the global ocean and used to simulate global ocean – biogeochemistry variability for the period of 1979-2014. The global MOM-TOPAZ covers the global ocean with a grid size of 360×200 on a tripolar grid with a longitudinal resolution of about 1.0° and a variable latitudinal resolution of approximately 0.3° near the equator. There are 50 vertical layers. To spin up the global model, the temperature and salinity fields were initialized based on hydrographic climatological fields obtained from the World Ocean Atlas (WOA). The biogeochemical tracers were initialized from WOA observations for NO_3, NH_4, PO_4, SiO_4, and O_2 and the GLobal Ocean Data Analysis Project (GLODAP; Key et al. 2004) for alkalinity and dissolved inorganic carbon (DIC). The model was integrated for 300 years using the ERA-Interim surface flux fields. During the spin-up run, the ERA-Interim surface flux fields between 1979 and 1996 were randomly selected for each model year.

During the 300-years spin-up run, the atmospheric CO_2 concentration was fixed to the pre-industrial level (286 ppm). After the first 300 years of spin-up run, the MOM-TOPAZ was further integrated for additional 121 years with the atmospheric CO_2 increasing from 286 ppm (1858 value) to 335 ppm (1978 value). Then, the MOM-TOPAZ was integrated from 1979 to 2014 using the real-time ERA-Interim surface flux fields with the observed atmospheric CO_2 concentrations.

Takahashi et al. (2014) calculated climatological mean monthly distributions of pH, total CO_2 concentration (TCO_2), total Alkalinity, pCO_2 and omega of Aragonite for the global surface ocean waters (excluding coastal areas), which were built upon the GLODAP, CARINA and LDEO database. Climatological distributions of pH, $TCO_2$2, total Alkalinity, pCO_2 and omega of Aragonite derived from the global MOM-TOPAZ simulation were compared with those from Takahashi (2014).

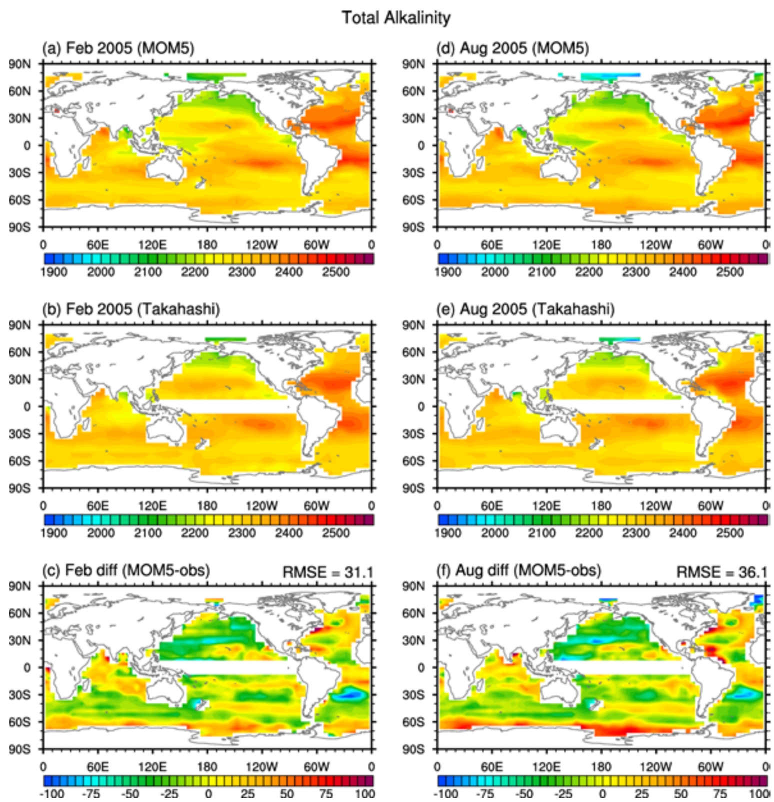

Figure 1: Total Alkalinity in February and August of 2005 derived from (Upper panels) the global MOM-TOPAZ simulation and (Mid panels) Takahashi, and (Bottom panel) the difference between the simulated and observation-based estimates. The unit is μEq Kg^{-1}.

As shown in Figure 1, the spatial pattern of simulated surface Alkalinity is realistic in both winter (February) and summer (August) months. In particular, the total Alkalinity is much higher in the Atlantic Ocean compared to other ocean basins due to the high surface salinity values. The global MOM-TOPAZ successfully simulated this characteristic very well. The globally averaged Root Mean Square Error (RMSE) is about 31 ~ 36 μEq Kg^{-1}, which is only about 1 ~ 2% of total Alkalinity values. However, the total Alkalinity is substantially overestimated in some regions especially the western tropical Atlantic and the Southern Ocean. The spatial pattern of the simulated and observation-based estimate of pCO_2 agrees well. In general, pCO_2 value is larger in cold regions with enhanced upwelling, especially in the equatorial Pacific cold tongue region. The global MOM-TOPAZ simulated this feature reasonably well. However, pCO_2 value in the equatorial Pacific is somewhat lower in the model simulation. It is quite possible that the 2004-2005 El Niño suppressed the upwelling of high DIC thermocline water to the surface, and thus reduced the equatorial Pacific pCO_2 value in the winter of 2005. Additionally, pCO_2 is too high in the subtropical regions of the North Pacific and North Atlantic during summer, suggesting that the summertime subtropical gyres may be too weak in both ocean basins. The spatial patterns and seasonal variations of pH, omega of Aragonite (Figure 2) and TCO_2 are also reasonably well simulated in the global MOM-TOPAZ in comparison to those estimated from observations (Takahashi, 2014). In general, the RMSE remains below 5% of the total.

In summary, our preliminary evaluation of the global MOM-TOPAZ simulation reveals that the carbon-related biogeochemical fields linked to ocean acidification are reasonably well simulated in the global MOM-TOPAZ. This suggests that the output from the global MOM-TOPAZ can be used to as initial and boundary conditions for the high-resolution regional ocean biogeochemistry model simulation of the East and Gulf coasts of the US. However, before we engage in the high-resolution simulation, we will further evaluate the global MOM-TOPAZ focusing on temporal variability of the key biogeochemical fields. In particular, long-term trends of the simulated pCO_2, pH and carbonate ion concentration are compared with direct observations in the North Atlantic and North Pacific Oceans, including Bermuda Atlantic Time-series Study (BATS, 31°40’N, 64°10’W; green) and Hydrostation S (32°10’, 64°30’W) from 1983 to present (updated from Bates, 2007), Hawaii Ocean Time-series (HOT) at Station ALOHA (A Long-term Oligotrophic Habitat Assessment; 22°45’N, 158°00’W) from 1988 to present and European Station for Time series in the Ocean (ESTOC, 29°10’N, 15°30’W; blue) from 1994 to present.

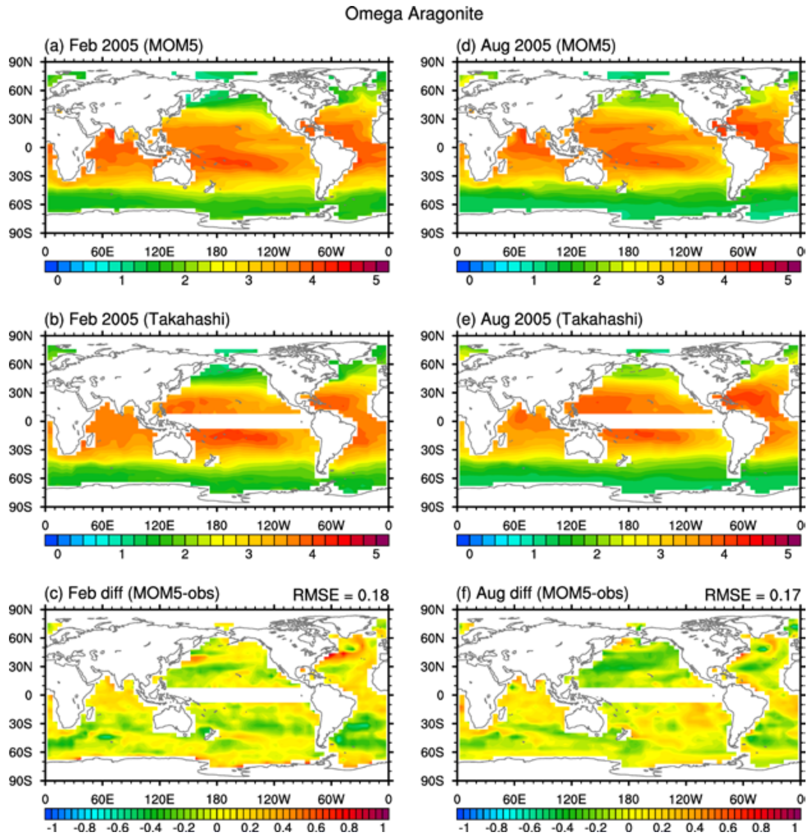

Figure 2: Surface aragonite saturation state in February and August of 2005 derived from (Upper panels) the global MOM-TOPAZ simulation and (Mid panels) Takahashi, and (Bottom panel) the difference between the simulated and observation-based estimates.

Research Performance Measure: We have met our primary objectives.


Courtesy of Daniel Benetti

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 Collaborators: J. Bohnsack (NOAA/SEFSC)
Other Collaborators: M. Feeley (NPS), A. Acosta(FWRI)

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 1**:** 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* (S*econdary*)

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, from Martin County to Key West, including the Dry Tortugas. This fisheries independent monitoring effort employs a spatially explicit, stratified random design enabling us to efficiently examine the effectiveness of management actions, as well as the impacts of fishing and other natural stressors, such as hurricanes, on the ecosystem. Specifically, this research allows us to quantitatively assess reef fish population changes, habitat associations, and ecosystem responses to fishing, management actions (including MPA zoning), and other human activities. This longitudinal monitoring 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, 208 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.

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: Divers conducted photo-documentation, RVC fish surveys, and habitat assessments at 208 sites in the SEFCRI region. NOAA SEFSC divers collaborated with the University of Miami and RSMAS, FKNMS, Florida Fish and Wildlife Department/FWRI, State of Florida, Nova Southeastern University, and the National Park Service (South Florida and Caribbean Network). In total, 932 dives were needed to complete the 2015 mission to monitor reef fish community composition, habitat composition, and abundance and size structure for more than 300 reef fish species on Florida's coral reef tract. Data are used to assess population and habitat trends (e.g., whether species are overfished), ecosystem responses to fisheries management actions, including determining the effectiveness of no-take MPAs and benthic community and coral demographics. All field related and QAQC milestones were met and objectives completed.

To further facilitate and promote the RVC dataset, in 2014, a custom R packages was developed and tested to calculate common metrics (i.e. fish density, occurrence, biomass and size structure). This package, designed in the open-source, statistical package R, retrieves analysis ready data from a NOAA server and computes common metrics for any species correctly based on the 2-stage approach. This year,

the R-package and an accompanying data sever went live and was distributed to all partners, collaborators and scientists.

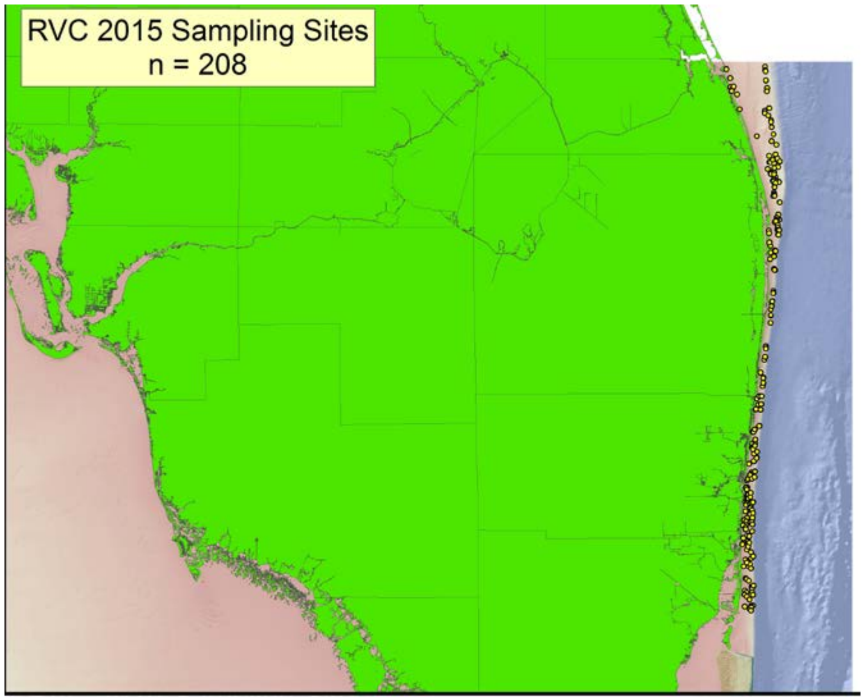

Figure 1: Sampling site locations for 2015 in the Florida domain.

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Gulf of Mexico Integrated Ecosystem Assessment

Project Personnel: G.S. Cook, A. Gruss, K.A. Kearney, W. Harford and C. Quenée (UM/CIMAS)
NOAA Collaborators: C.R. Kelble (NOAA/AOML); M. Karnauskas, M. Schirripa and M. McPherson (NOAA/SEFSC); M. Jepson (NOAA/SERO)
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 (*Secondary*)

Link to NOAA Strategic Goals:
***Goal 1*:** 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: Molly Baringer

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 nation's 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.

Since the GoM is a vast and complex large marine ecosystem we have taken a scaled approach to exploring how this social-ecological system is structured and how it functions. At smaller geographic scales we are working with multiple stakeholders to identify and develop ecosystem indicators for coastal south Florida. Leveraging existing partnerships within south Florida we have developed several county-level projects to develop the ecosystem-based management tools necessary to study the various sectors comprising the broader Gulf of Mexico. For example, building upon results from the Marine and Estuarine Goal Setting for South Florida (MARES) project we developed matrix-based approaches for understanding and ranking the various pressures impacting the south Florida coastal ecosystem (Cook et al 2014), and have developed a suite of indicators for beach ecosystems along the southeast Florida coast (Marshall et al 2014).

At the broader Gulf of Mexico scale we recently analyzed over 100 indicators representing physical, biological, and economic aspects of the GoM and using a Drivers-Pressures-State-Impact-Response (DPSIR) framework, identified an ecosystem-wide reorganization in the mid-1990s (Figure 1, Karnauskas

et al., 2015). Additional analyses showed a shift in composition of fishery landings in the GoM in the late 1970s that aligned with the advent of the Magnuson-Stevens Fishery Conservation and Management Act, and shifts in the mid-1960s and 1990s aligned temporally with changes in the Atlantic Multidecadal Oscillation (AMO; Figure 2). Based on this comprehensive analysis we provide recommendations on how resource managers can adjust to various climate regimes in the broader Gulf of Mexico.

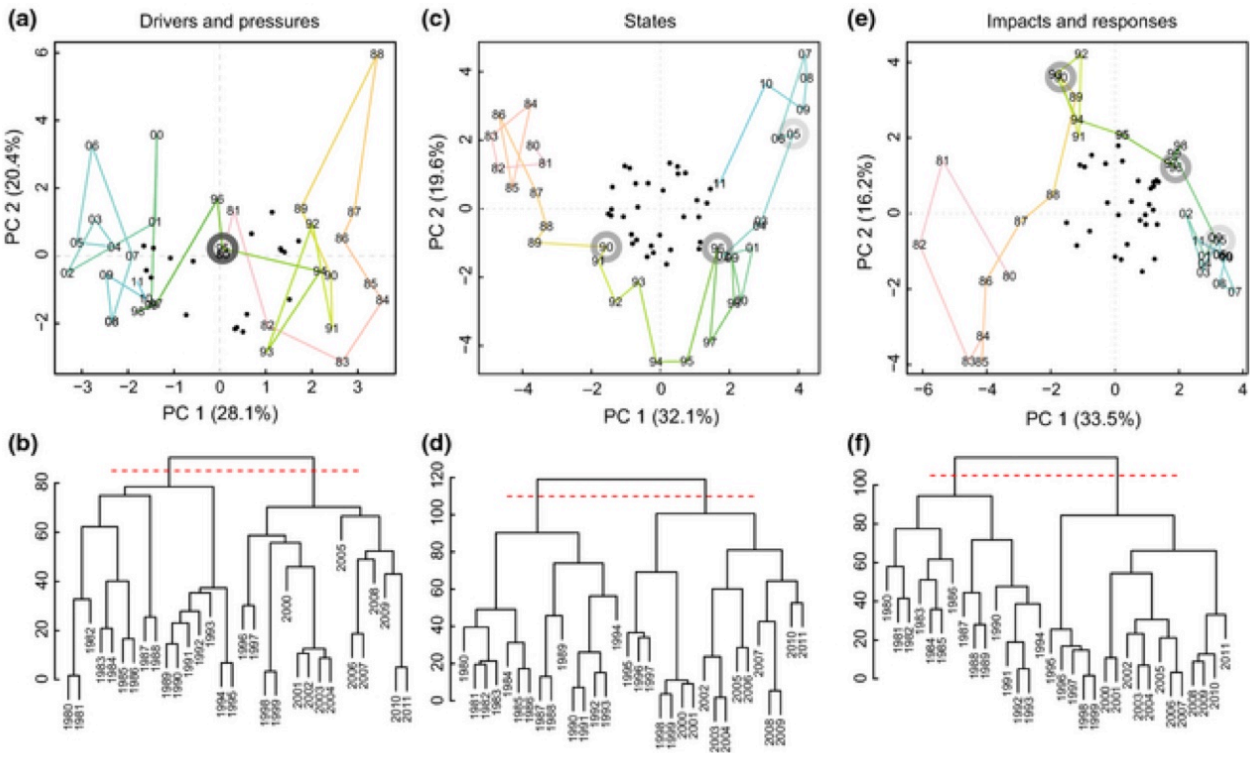


Figure 1: Multivariate analyses of three groups of ecosystem indicators: drivers and pressures (a, b), states (c, d), and impacts and responses (e, f). Top row (a, c, e): Yearly scores of first two principal components are plotted, based on principal components analysis (PCA) of ecosystem indicator values from 1980 to 2011. Segments are color-coded on a continuous scale to aid reader in the interpretation of change through time. Circles represent breaks in the first principal component (i.e. the first year of a new regime) as identified by the STARS algorithm; significance is denoted by darkness of circle color (darker lines = higher significance; all breaks $P < 0.01$). Small dots denote indicator loading on the first two axes. Bottom row (b, d, f): Chronological clustering analysis of ecosystem indicators from 1980 to 2011. Horizontal dotted lines denote the threshold for significance of breaks.

We used simulated management strategy evaluation to confront the effects of uncertain future occurrences of red tide-induced natural mortality on fishery harvests. The red tide dinoflagellate *Karenia brevis* episodically causes mortality to harvested fish stocks in the eastern Gulf of Mexico. Faced with the unpredictability of these natural mortality events, we evaluated whether and how precautionary harvest control rules (HCRs) or reactionary HCRs could lead to improvement in achieving fishery management objectives. Precautionary HCRs were those that reduced catches as an anticipatory means of mitigating possible future biomass declines, while reactionary HCRs relied on post-event responsiveness through catch adjustments to mitigate episodic natural mortality increases. We found that both precautionary and reactionary HCRs can lead to achievement of management objectives under sporadic and uncontrollable natural mortality increases. However, reactionary HCRs require timely management interventions and accurate assessment of fish stock status to produce benefits similar to those produced by precautionary HCRs. As ecosystem-based management becomes prominent in U.S. marine resource policy,

management strategy evaluation can contribute to integrated ecosystem assessment. Integrated ecosystem assessment follows a spectrum of approaches from fishery-focused models to holistically-focused assessments of cumulative pressures on ecosystem services. At one end of this spectrum, our single-species approach incorporates environmental interactions into decision-support tools for fishery management.

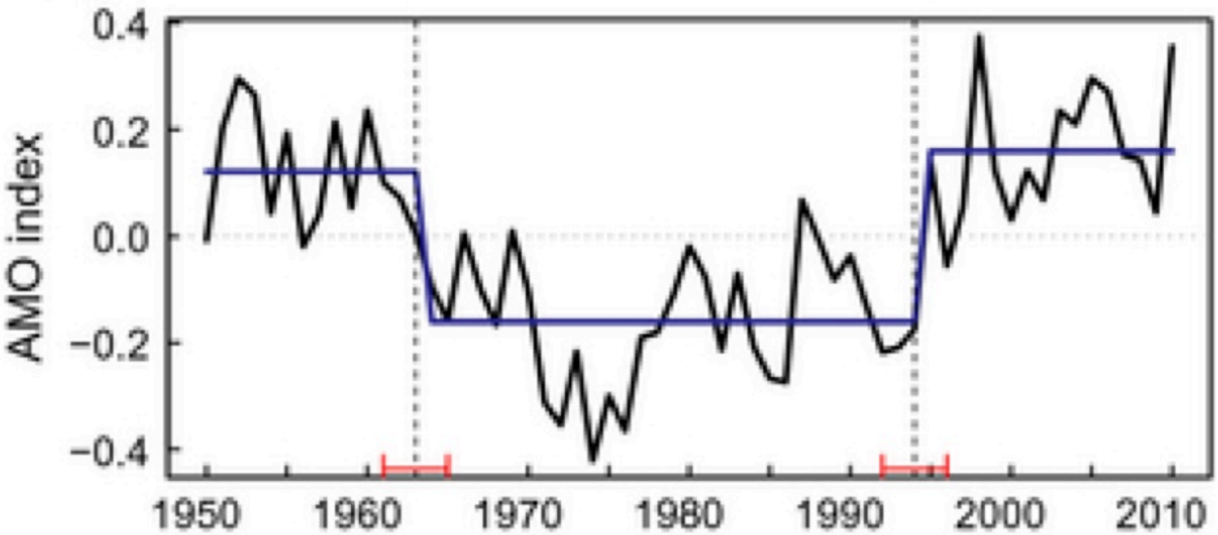


Figure 2: Time series of the Atlantic Multidecadal Oscillation (AMO), with significant breaks and their confidence intervals identified using a sequential F-test algorithm.

Through these projects we provide complementary frameworks for exploring and characterizing the various pressures threatening the sustainability of ecosystem services in coastal south Florida and the Gulf of Mexico large marine ecosystem. The results from these studies highlight the challenges we face at different spatial scales; at the local scale there are logistical challenges inherent to managing and mitigation planning for far-field pressures (e.g. climate change, sea level rise, etc.), while at the vast Gulf of Mexico scale understanding and disentangling the effects of climate drivers from those effects caused by a complex tapestry of interacting anthropogenic pressures can prove daunting without spatially and temporally comprehensive datasets.

Research Performance Measure: All major research objectives are being met and are on schedule. By leveraging the intellectual products created through various projects we have created a framework for identifying and characterizing indicators for assessing the health of the Gulf of Mexico ecosystem across spatial and temporal scales. Currently we are building upon these studies and applying these products in concert with ecosystem and network models along the west Florida Shelf to better understand how the broader Gulf of Mexico large marine ecosystem is structured and how it functions.

Caribbean Reef Ecosystem Research, USVI Larval Distribution and Supply

Project Personnel: E. Malca, L. Rasmuson, K. Shulzitski, S. Privoznik, K. Doering, A. Ender, A. Jugovich, A. Shiroza, J. Mostowy and A. Spera (UM/CIMAS)
NOAA Collaborators: J. Lamkin and T. Gerard (NOAA/SEFSC)

Long Term Research Objectives & Strategy to Achieve Them:

***Objectives*:** To provide essential information required for coral reef ecosystem assessment and a scientifically-based ecosystem approach to fisheries management in the Caribbean region.
***Strategy*:** To carry out large-scale larval and hydrographic surveys with complementary inshore larval collections to map the larval distribution, transport, and recruitment pathways.

CIMAS Research Theme:

***Theme 6*:** Ecosystem Management

Link to NOAA Strategic Goals:

***Goal 1*:** 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 fisheries oceanography research project combines the expertise of fisheries biology, oceanography, and local knowledge from managers to assess the long-term sustainability of coral reef fish populations in the Caribbean, focusing on the U.S. Virgin Islands. Surveys of water properties, currents, dispersal and transport of settlement-stage larvae provide data and a further understanding of the biological and physical processes that drive production on the Grammanik and Red Hind Banks. These sites are protected fisheries management areas established by the Caribbean Fisheries Management Council due to the presence of multi-species spawning aggregations for economically important coral reef fish. Additional surveys of inshore juvenile fishes yield an understanding of the spatial variation in the supply of settlement-stage fishes in coastal waters. This is a follow-up to a long-term interdisciplinary research project conducted in the following years: March 2007, March 2008, April 2009, February – March 2010, April – May 2011, followed by April 2015 and June 2016. Cruises utilized the NOAA Ship NANCY FOSTER to conduct biological and physical oceanographic surveys of the Virgin Islands' (VI) bank ecosystems and surrounding regional waters. In addition, inshore biological collections of 2007, 2008 and 2009 took place in St. Thomas using either light traps or seine nets in important nursery habitats targeting juvenile coral reef fishes.

Research Performance Measure: The research program is on schedule. This study requires a comprehensive understanding of regional larval transport, and overall larval recruitment in the study area. Data analyses are ongoing for all four cruises: 2007-2011, and 2015-2016. Oceanographic cruise data has been collected and processed for 2007-2011, and 2015. Biological collections from the 2015 cruise included the use of Neuston nets sampling subsurface waters and down to 10 meters depth, as well as stratified net sampling with a multiple opening and closing net environmental sampling system (MOCNESS). In addition, the taxonomic family identification has been completed for 2007, 2008, 2009, and 2010, with species of interest identified from 2011 and 2015. Ichthyoplankton sampling in 2015 yielded 121 samples (37 MOCNESS and 84 subsurface Neuston) from 85 stations. The most recent cruise was successfully completed as this report was submitted (07 – 17 June 2016), replicating collections at

some historical stations and adding additional sampling techniques. We completed a total of 74 stations, yielding 180 plankton samples (60 subsurface Neuston, 120 MOCNESS), of which sorting will soon begin, and 36 micro- and meso-zooplankton samples, which will be analyzed for stable isotopes.

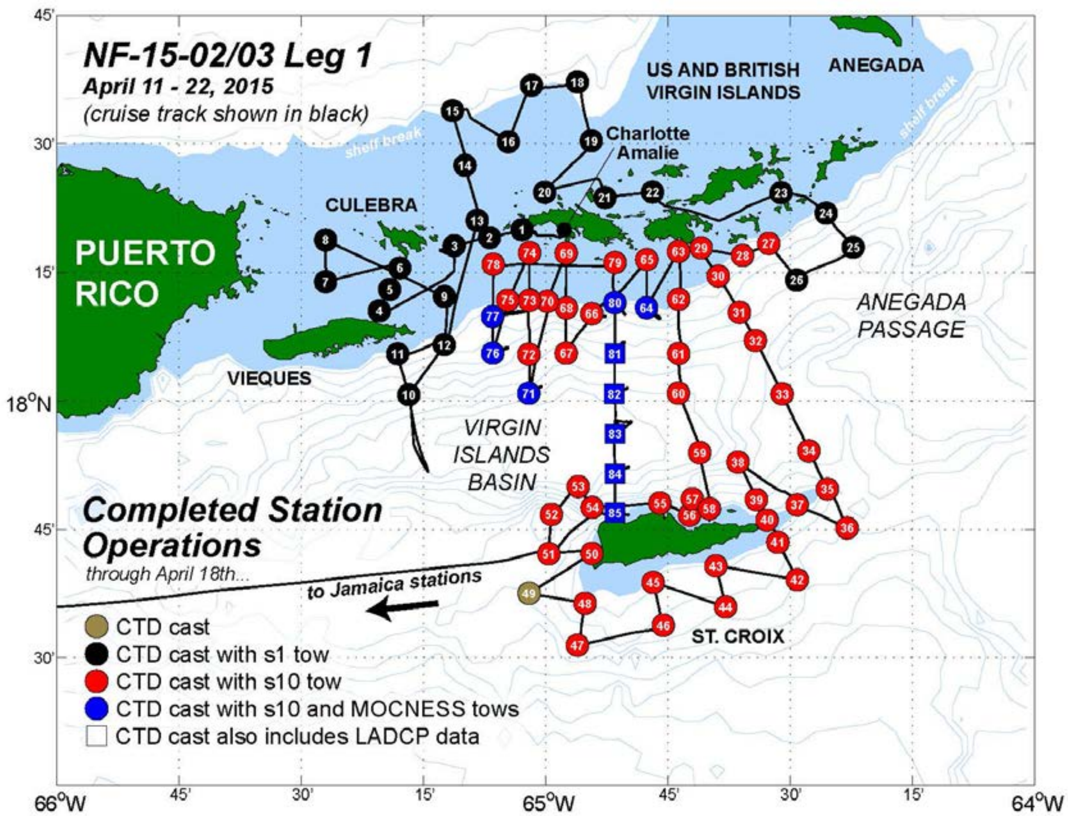


Figure 1: Cruise track showing collection gear and sampling locations in 2015.

Figure 2: Larvae collected on 2016 cruise and sorted live at sea; clockwise from top left: parrotfish (*Scarus* sp.), parrotfish (*Sparisoma* sp.), bluehead wrasse, snapper, squirrelfish, grouper.

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 Unified Data Processing system (UDP) and pelagic individual fish weight data for entry in the Pelagic Weigh-out Receipt (PWR) system, 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 1**:** 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).

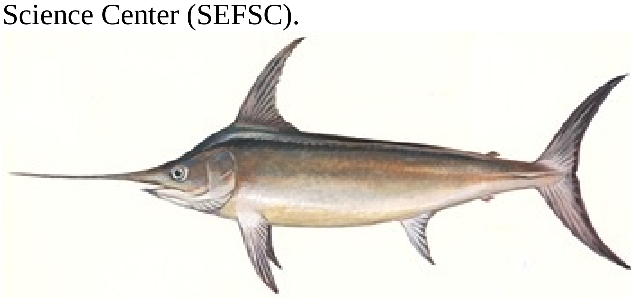


Figure 1: *Xiphias gladius*, the swordfish (www.safmc.net**).**

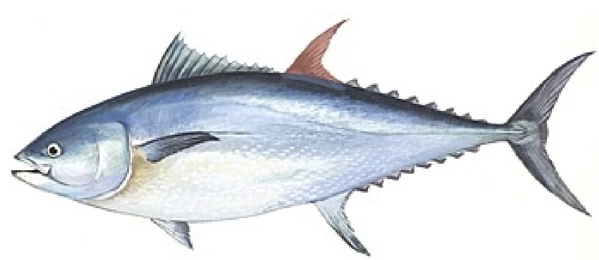


Figure 2: *Thunnus thynnus*, the Atlantic bluefin tuna (www.safmc.net**).**

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. A compliance audit which reconciles logbook data with dealer-reported data identifies delinquent or missing

logbook reports. The results of the audit have also been used by other scientists within NOAA to identify missing dealer reports. Additionally, the recent development and implementation of the Unified Data Processing (UDP) system has expanded validation of data and created a mechanism to provide feedback to permit holders about required logbook information. Pelagic individual fish weight data, previously held in the Domestic Longline System (DLS), is now processed within UDP to better integrate catch and effort data. This integration allows for automated reports used in annual ICCAT assessments, further streamlining the assessment process.

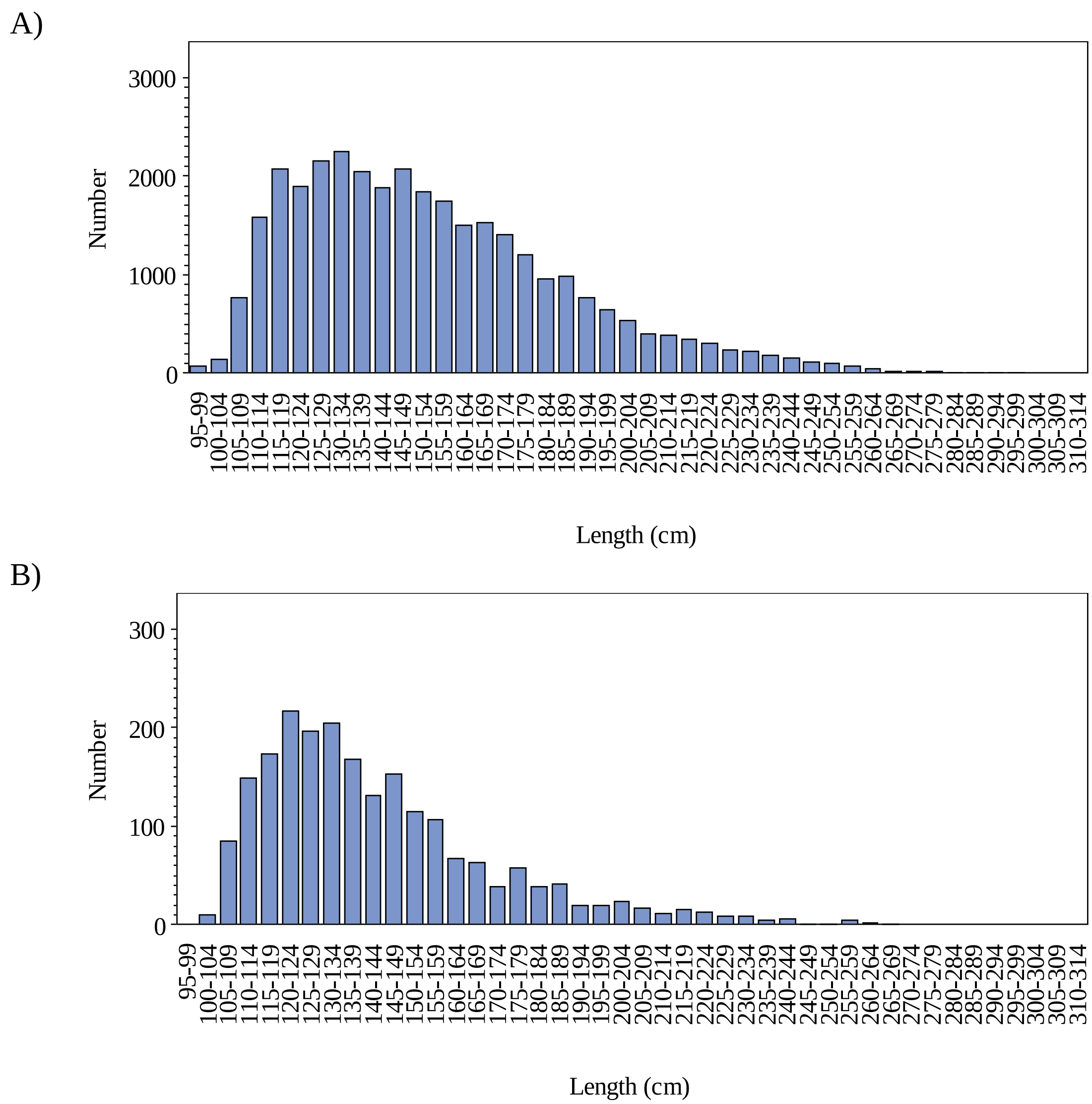


Figure 3: Length frequency (lower jaw fork length, in cm) of swordfish caught in commercial (A) longline and (B) hand gear fisheries obtained from catch as size (CAS) data reported to the Pelagic Longline program for 2014.

Research Performance Measure: One hundred twenty-nine validations designed to improve logbook data quality have been integrated into UDP. One hundred twenty vessels have been contacted about missing or invalid information submitted on logbooks for 429 distinct trips since 1 July 2015.

Annual Catch Limit (ACL) Monitoring Program

Project Personnel: A. Shideler (UM/CIMAS)
NOAA Collaborators: D. Gloeckner and M. Judge (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To improve electronic reporting compliance by federally permitted dealers; to prevent overfishing of federally managed fish species through use of annual catch limits (ACLs).

***Strategy*:** To compile all sources of dealer-reported data on federally managed fish species and allocate the landings to distinct quotas based on reported catch area and landing location; to use current and historical landings data to provide predictions on when the ACL will be met; to advise the Southeast Regional Office (SERO) on the current status of all South Atlantic and Gulf of Mexico managed stocks and provide recommended closure dates.

CIMAS Research Theme:

***Theme 6*:** Ecosystem Management

Link to NOAA Strategic Goals:

***Goal 1*:** 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 Magnuson-Stevens Reauthorization Act of 2006 mandates that federal fish stocks be managed through the implementation of annual catch limits (ACLs) and accountability measures (AM) to prevent and end overfishing. When an ACL is reached, an AM, such as a trip limit or season closure, goes into effect. NOAA Southeast Fisheries Science Center (SEFSC) and Southeast Regional Office (SERO) work with regional councils to manage over 70 federal fish stocks in the South Atlantic and Gulf of Mexico.

Federally permitted dealers are required to report either landings or "no activity" reports electronically each week. We apply reported landings towards an ACL based on species, gear, and location data included in the report. These reported landings are combined with estimated landings of missing and future reports to project when the ACL will be reached (Figure 1). We use several estimation methods incorporating current season and/or prior season landings to provide a range of closure dates (Figure 1). Average Landings per Day Current Year (ALPD_CY, average landings per day by dealer) and Fishery Prior Year Same Day Ratio (FPYSDR, the dealer-based landings on the same day of the prior season, adjusted by the ratio of the fishery's current season to the previous season), are generally the preferred estimation methods. We notify SERO within one week of when an ACL is expected to be reached so that the appropriate AM can be taken.

Accurate projection of ACL closure dates depends on complete, timely data submission from dealers. We contact dealers by email or letter when reports have not been received for a weekly period. While late reporting remains an issue (Figure 2), additional outreach measures and coordination with local partners should improve reporting in the future.

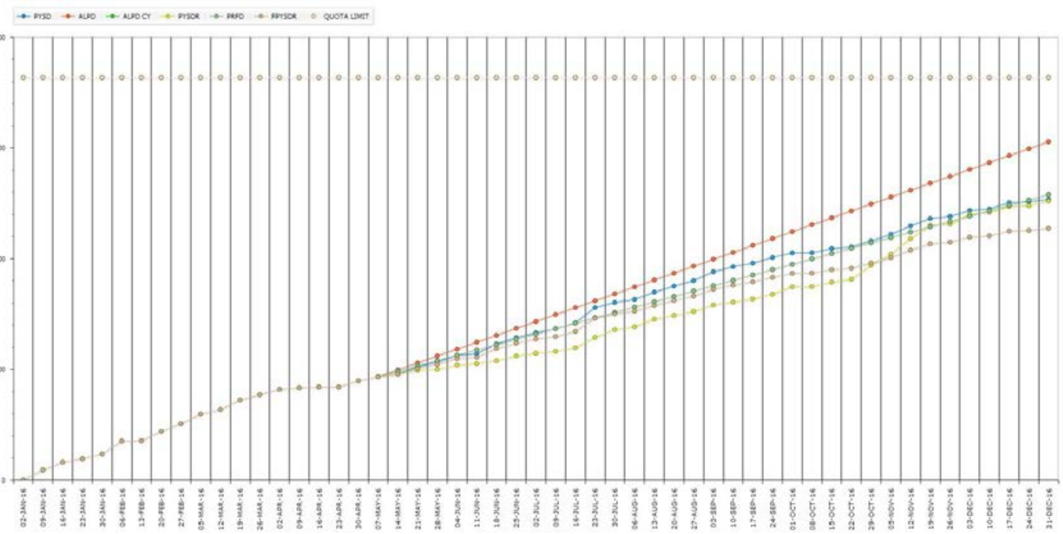
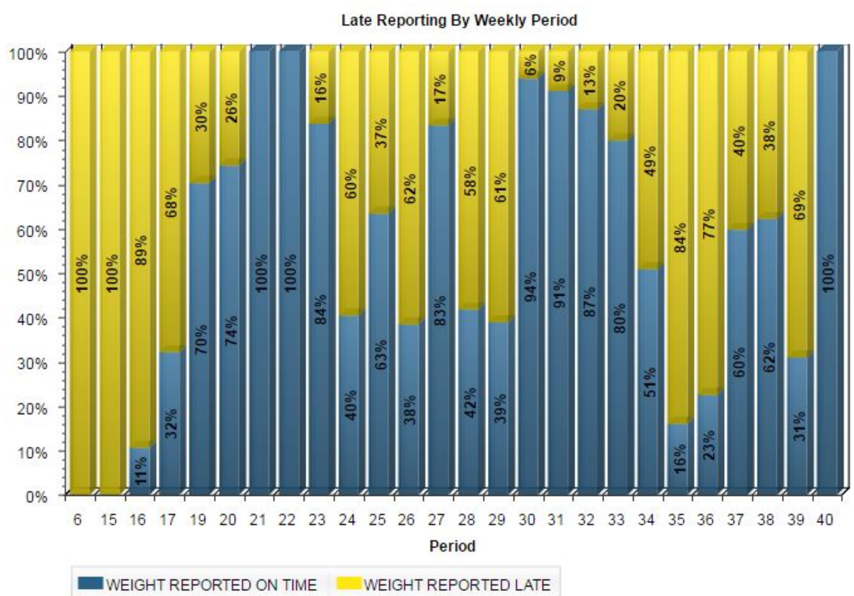


Figure 1: Landings of South Atlantic Porgies group through May 7, 2016, with projected landings using different estimation methods for dates after May 7, 2016. The horizontal dotted line represents the Annual Catch Limit (ACL). Estimation methods are: Prior Year Same Day (PYSD, blue symbol, the dealer-based landings on the same day of the season the prior season), Average Landings Per Day (ALPD, red symbol, the dealer-based average landings per day for the prior season), Average Landings Per Day Current Year (ALPD_CY, green symbol, the dealer-based average landings per day for the current season), Prior Year Same Day Ratio (PYSDR, yellow symbol, the dealer-based landings on the same day of the season the prior season adjusted by the ratio of the current year's landing to the previous year's landings), Fishery Prior Year Same Day Ratio (FPYSDR, tan symbol, the dealer-based landings on the same day of the prior season, adjusted by the ratio of the fishery's current season to the previous season).



Research Performance Measure: Since 1 July 2015, 2402 emails or letters have been sent to 307 distinct dealers informing them of one or more periods of reporting non-compliance. In 2016, we advised for the closure of seven quotas based on projected landings meeting or exceeding the ACL.

Figure 2: Percent of weight reported by dealers on time (blue) versus late (yellow) by weekly reporting period for the King Mackerel Gulf of Mexico Annual Catch Limit (ACL).

Net Revenues of the Federal Fin-Fish Commercial Fisheries in the Gulf of Mexico

Project Personnel: E. Overstreet (UM/CIMAS)
NOAA Collaborators: C. Liese (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To develop and report net revenues of commercial fishing operations in the Gulf of Mexico reef fish (snappers and groupers) and coastal migratory pelagics (mackerels). A central gap in the Southeast's commercial fishery economic assessments are estimates of net revenues for federally-managed fin-fish fisheries; including Gulf of Mexico Reef Fish - Non-IFQ, Red Snapper IFQ, Grouper-Tilefish IFQ, and Coastal Migratory Pelagics. These fisheries include two catch share fisheries; and one non-catch share fishery (vermillion snapper) that are part of the national performance indicator project.

***Strategy*:** To ensure both statistical representativeness and meaningfulness/usefulness of the economic results, the already collected economic data needs to be analyzed/post-stratified to take into account: 1) the applicable sampling designs (the design changed over time); 2) the actual realized fishing activity each year (the designs incorporated historical fishing activity), and 3) it needs to be an iterative process. To clarify the latter, after adjusted confidence intervals for summary statistics for a given post-stratification are calculated, it is likely that we will need to circle back and adjust the stratification, i.e., further reduce the number of strata to increase sample size in each. Dimensions available for stratification include time and space; vessel/owner/permit characteristics; and annual and trip-level fishing activity, including gear, effort and catch by species. Statistical precision will tentatively require high levels of aggregation, while economic meaningfulness and usefulness for fishery management will tentatively argue for low levels of aggregation.

CIMAS Research Theme:

***Theme 6*:** Ecosystem Management

Link to NOAA Strategic Goals:

***Goal 1*:** 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:

With the departure of another contracted employee in June 2015, the contractor assumed additional duties relating to the management of two economic data collections. Validations have been created to clean the already collected economic data. These validations were also implemented in the database to ensure a higher quality of the economic data being reported to the coastal logbook database. The contractor is also working on creating automated reports which summarize various commercial fishery segments of the Gulf of Mexico and the South Atlantic; equations to estimate net revenues for these segments have been built and are being tuned.

The attached figures are examples of the output being generated by the one of the automated reports. Both figures are for estimated revenue of reef fish fisheries managed by the Gulf of Mexico Fishery Management Council (SOI).

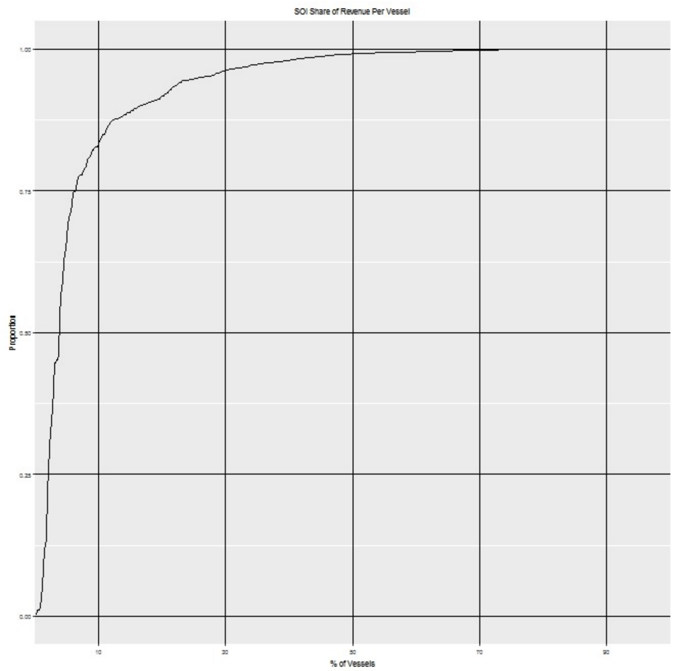


Figure 1: A graph showing the SOI share of estimated revenue per vessel. Vessels were arranged based on an increasing SOI share. Where the horizontal dashed line intersects the curve indicates the percent of vessels where the percent of SOI share was 50% or less.

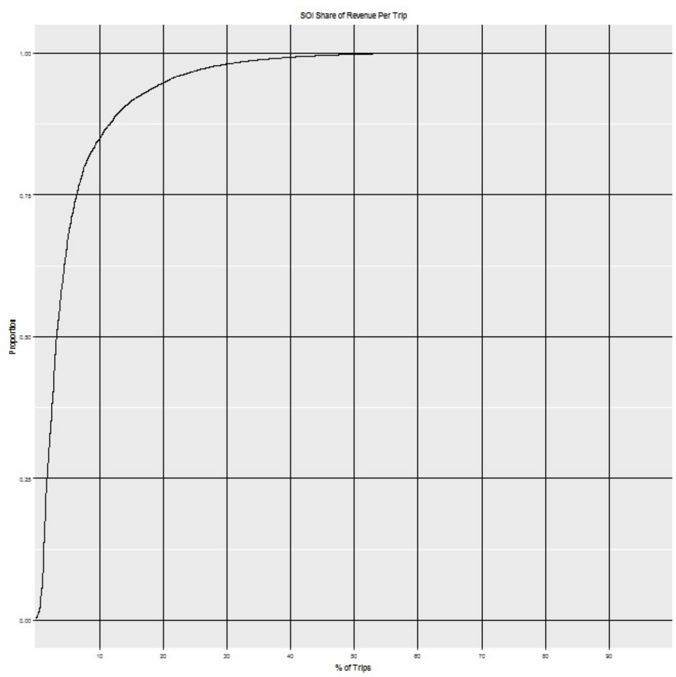


Figure 2: A graph showing the SOI share of estimated revenue per trip. Trips were arranged based on an increasing SOI share. Where the horizontal dashed line intersects the curve indicates the percent of trips where the percent of SOI share was 50% or less.

Research Performance Measure: Progress is being made toward economic analysis of economically and statistically meaningful sub-populations of the SE federal fin-fisheries (including at the trip- and annual/vessel-levels). The quality of the ongoing data collection has been significantly improved.

Population Estimates of Revenue and Trip Costs in the Gulf of Mexico and South Atlantic For-Hire Sector & Annual Economic Survey of Federal Gulf and South AtlanticShrimp Permit Holders

Project Personnel: A. Stemle (UM/CIMAS)
NOAA Collaborators: C. Liese (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** The For-Hire project is to develop and report population estimates of revenue and trip costs of For-Hire fishing operations in the Gulf of Mexico and South Atlantic. The Shrimp Economic Survey project is to collect up-to-date cost data for the Gulf and South Atlantic commercial shrimp fisheries in federal waters.

***Strategy*:** To implement both data collection projects as self-administered mail surveys to the Federal For-Hire and Commercial Shrimp permit holders of the Gulf of Mexico and South Atlantic.

CIMAS Research Theme:

***Theme 6*:** Ecosystem Management

Link to NOAA Strategic Goals:

***Goal 1*:** 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
Technical Contact: Theo Brainerd

Research Summary:

The For-Hire project began on August 20th, 2015. Project personnel have conducted outreach interviews with for-hire vessel owners, held two focus groups, and submitted PRA documents to receive approval from the Office of Management and Budget (OMB) to conduct the data collection. Project personnel have also designed survey instruments and sampling frames.

The Shrimp Economic Survey project began on January 12th 2015. Project personnel have been responsible for implementing the 2015 survey. This includes conducting mail-outs, data entry and validation, and telephone outreach to survey participants.

Research Performance Measure: The For-Hire project received OMB clearance on 03/01/2016 and the project is moving forward as scheduled. The first round of the Shrimp Economic Survey has been completed and being implemented on schedule.

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 quantitative ecologists 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 1*:** 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 under the "MRA Core Courses" heading in Section 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,

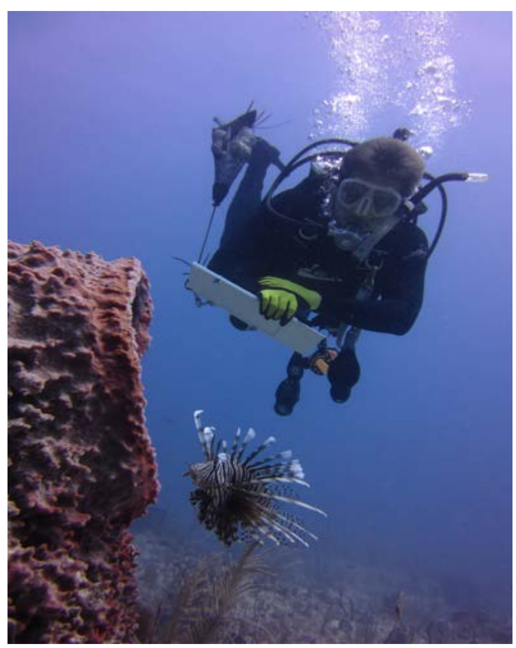


Figure 1: USF MRA faculty member Dr. Chris Stallings conducting a lionfish survey in Biscayne Bay, Florida.

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.

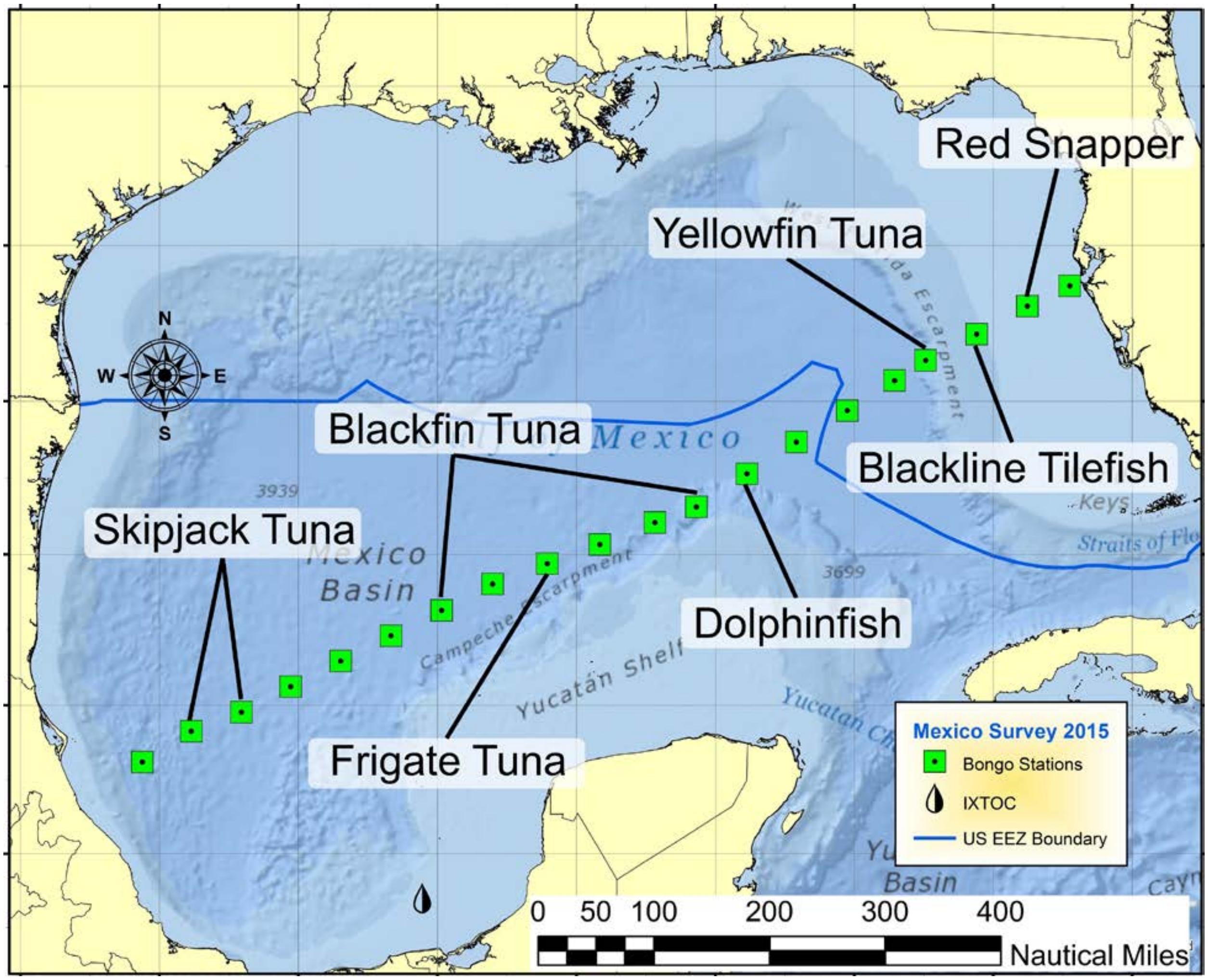


Figure 2: Selected fish-egg identifications based on DNA barcoding by USF MRA faculty Drs. Ernst Peebles and Mya Breitbart. This Fall, 2015, cross-Gulf transect took advantage of a return trip from MRA-related work in Mexico that was being conducted by USF MRA faculty member Dr. Steve Murawski. A total of 19 egg species have been identified from this series of 20 plankton samples.

There are currently 27 fulltime USF-CMS students participating in the MRA program, with 8 being Master's students and 19 being doctoral students. The present award provides fellowships for 5 of the 27 students; all 5 are doctoral students. The remaining 22 MRA students work as Graduate Assistants on research grants and compete for internal and external graduate fellowships.

Figure 3: Reef fish collected for fecundity analysis by USF MRA faculty and students (Ernst Peebles photo)

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. 4). MRA students currently represent >30% 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.

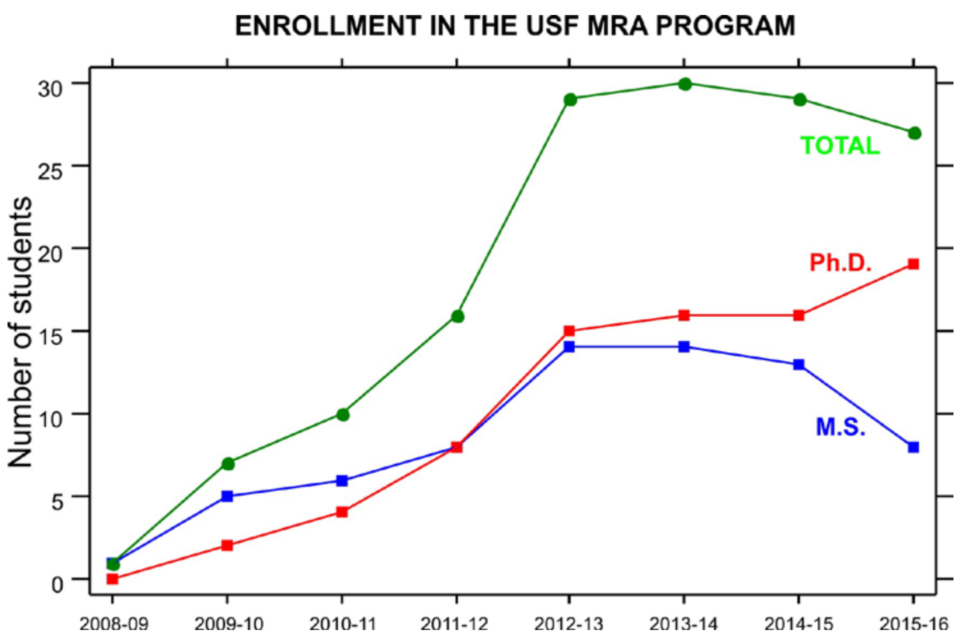


Figure 4: Enrollment in the USF-CMS Marine Resource Assessment (MRA) program by type of student and academic year.

Enrollment by professional fisheries scientists in MRA courses has exceeded expectations. Agency students have been associated with the following labs: (1) Florida FWC: Fish and Wildlife Research Institute, St. Petersburg, FL. (2) 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 are employed in the living-resource management field after graduation (63%) or pursue a doctoral degree (25%). 12% have left the field.

Testing a Gamma Likelihood Function to Replace Bias Corrected Log Likelihood Recruitment Estimation Function in Stock Synthesis

Project Personnel: E. Councill (UM/CIMAS)
NOAA Collaborators: C. Porch (NOAASEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To evaluate a potential method to eliminate the need to perform a bias adjustment procedure on recruitment deviation estimation in Stock Synthesis, an integrated fishery assessment model widely used to manage fish stocks in the US. Our goal is to determine if this extra step, in an already long complex process of determining stock status, is necessary or if it can be effectively eliminated, thereby reducing the workload of assessment scientists who use stock synthesis.

***Strategy*:** To create a simulation framework that tests how well our new method works versus the older more cumbersome method on a variety of assessed fish stocks and their archived Stock Synthesis data.

CIMAS Research Theme:

***Theme 6*:** Ecosystem Management

Link to NOAA Strategic Goals:

***Goal 1*:** Healthy Oceans **-** *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems*

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

Research Summary:

Our work endeavors to improve the efficiency of the process by which fishery management scientists assess the status of exploited fish stocks in the US by investigating the possibility of removing one extra step in the process of evaluating stock status. We will accomplish this by performance testing Stock Synthesis, an integrated fishery assessment model often used to determine stock status for US fisheries, with a new formulation aimed at removing an extra step in the process of generating accurate measures of stock status.

The project has just begun recently, but we have successfully created a simulation framework to test our methods against current standard methods, and we have created programs to extract the relevant output data needed to determine if our method is equally good as or more efficient than the current methods employed. Our simulation framework only works for one species at the moment, but we will expand it beyond this limited preliminary investigation in the coming months.

Our immediate goal is to complete our analysis of our preliminary output data, and, in the process, develop a set of metrics by which we can measure the efficiency and accuracy of our method against the standard procedures currently used. Once our methods are solidly created and implemented, we will expand our study to include a variety of exploited species that are routinely managed using Stock Synthesis to test whether our preliminary results hold across a variety of managed species.

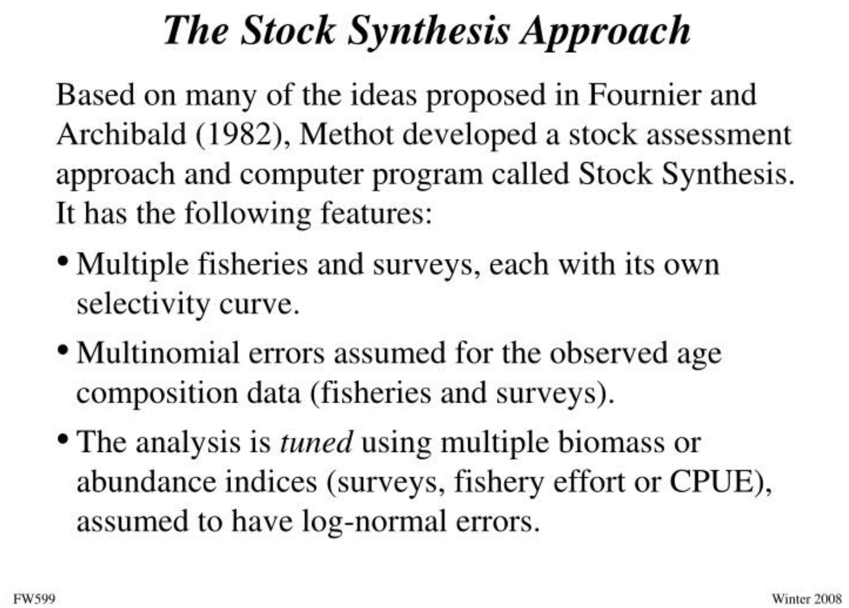


Figure 1: An outline of the method used by Stock Synthesis, the software program we are utilizing for this work.

Research Performance Measure: This project is in its early stage, but our primary objective is the publication of a robust and useful scientific paper that can provide useful guidance to other fishery scientists and, hopefully, help reduce the number of steps those scientists must take to achieve their objectives of providing indicators of stock status.

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

Project Personnel: D.E. Williams, A.J. Bright and R.E. Pausch (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, bleaching, etc.) impacting the remaining elkhorn (*Acropora palmata)* populations in the upper Florida Keys and determine the relative importance of each 'threat'. 3) To evaluate reef-scale changes in distribution and abundance of elkhorn and staghorn corals.

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) Reef-scale surveys to re-assess *Acropora* spp. population in areas surveyed in 2006. 3) Periodic assessments of other Caribbean *Acropora* spp. populations. 4) In 2014 and 2015, successive warm-stress-induced mass bleaching events were intensively characterized in the focal population

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

Link to NOAA Strategic Goals:
***Goal 1*:** 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 to compare its performance to other Caribbean locations. This is an on-going monitoring project entering its twelfth year of thrice yearly surveys in the upper Florida Keys and tenth 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). To evaluate larger scale changes in distribution of *Acropora cervicornis* and *A. palmata*, selected reef sites were surveyed by a snorkeler who marked locations of each *Acropora* spp. colony. Initial surveys were conducted in 2006, and selected sites were resurveyed at for comparison in 2014 and 2015.

During summer 2015, we observed bleaching among the upper Florida Keys *A. palmata* population for a 2nd consecutive year. Bleaching response varied between sites but was remarkably consistent with the response observed at these sites during the 2014 bleaching event. Temperature sensors deployed at each site documented daily average water temperatures that were slightly lower than 2014 however the duration of elevated/stressful temperatures (>31 °C) was longer in 2015 than 2014. Overall, we estimate that approximately one third of live tissue area of the focal *A. palmata* population was lost during each bleaching event (i.e. between our planned seasonal surveys in June and February of the following year), or 50% loss between spring 2014 (prior to 2014 bleaching) and spring 2016 (following both bleaching events). In 2005, the upper Florida Keys populations suffered similar losses associated with the 2005 hurricane season, and recovery was only minimal over the ~ decade prior to the recent bleaching events.

Based on low resolution reef-scale surveys, *A. palmata* showed a small but negative trend in density between 2006 and 2014. Over this same time period, *A. cervicornis* increased in density at sites where active population enhancement (by Coral Restoration Foundation) has occurred and decreased at sites where it has not. Both species decreased in density (regardless of restoration efforts) between 2014 and 2015 following the 2014 bleaching event.

While the Florida Keys reefs have experienced moderate bleaching events in the past decade, this is the first severe bleaching event to affect local *A. palmata* since the 1998 El Niño-associated bleaching event (Miller et al. 2002).

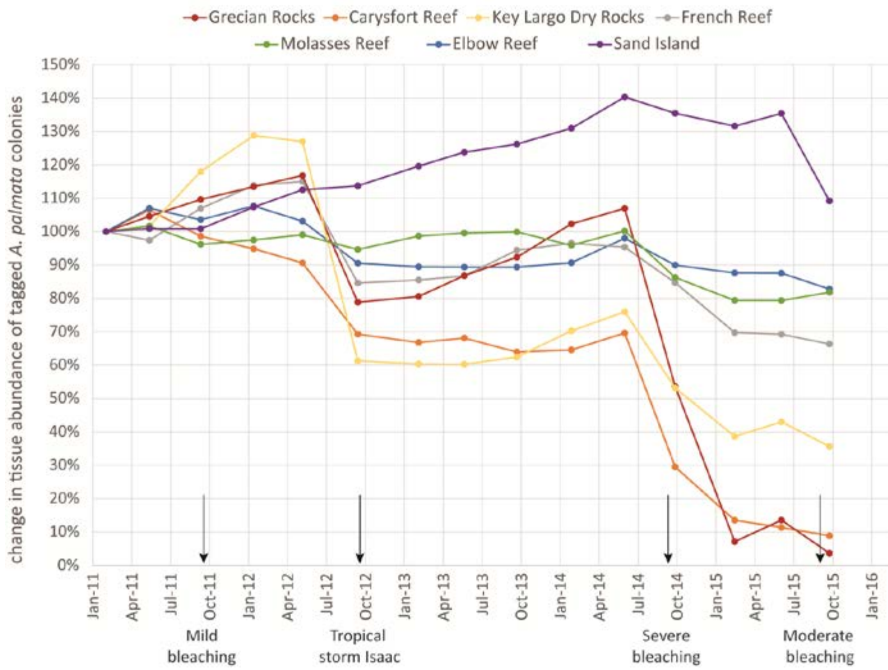

Figure 1: Relative change in live tissue abundance of tagged *Acropora palmata* colonies in upper Florida Keys monitoring plots expressed as a percentage of the 2010 abundance.

Research Performance Measure: All planned monitoring surveys of the Florida Keys sites were conducted as scheduled with two additional (unplanned) surveys conducted in the Florida Keys during fall 2015 to fully document the second bleaching event affecting the population. In 2015, 16 reef-scale surveys were conducted for comparison to 2014 and 2006 surveys. Manuscripts for both survey components are in prep for peer-reviewed publication.

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Support of the National Coral Reef Management Assistantship Program

Project Personnel: W. Wood-Derrer (NSU)
NOAA Collaborators: J. Tomczuk, D. Wusinich-Mendez and P. Maurin (NOAA/CRCP)
Other Collaborators: K. Koltes (US Department of the Interior Office of Insular Affairs)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives: To support NOAA's ecosystem approach to management in U.S. coral reef ecosystems by building local management capacity in U.S. coral jurisdictions.

Strategy: To meet the NOAA CRCP and jurisdiction's capacity needs, the program is structured to build coral reef management capacity at the local level, help fill identified capacity gaps, and meet management priority objectives in each jurisdiction, as well as the national objectives of the NOAA CRCP. As a fully-functioning program, with Coral Assistants in each jurisdiction, benefits to both the Coral Assistant, as well as the jurisdiction are being maximized with specific outcomes dependent on particular activities identified and chosen during work plan development between the NOAA CRCP, POCs and mentors. Coral Assistants are expected to work on NOAA CRCP national goals for climate change, land-based sources of pollution and fishing, as well as address local needs such as the development of management plans for marine managed areas, increased community involvement in

monitoring and response, climate change adaptation, and biological monitoring. The Coral Reef Management Assistantship Program meets one of the highest coral reef management needs in the U.S. jurisdictions and is an identified target issue for the NOAA CRCP and USCRTF—capacity building. Capacity building encompasses many different things, including coordination, strategic planning, and technical assistance. A cross-cutting theme across all jurisdictions, in terms of capacity building, is the need for additional professionals to do the work needed in the jurisdictions, on the jurisdictional level. This program fulfills this need by providing local management agencies a young professional with experience, expertise, or the capability to help fill an identified jurisdictional capacity gap. A NOAA CRCP primary objective is "address[ing] strategic coral reef management needs in a targeted, cost-effective and efficient manner on-the-ground and in-the-water" (CRCP Roadmap). The fellowship strives to assist both the NOAA CRCP and jurisdictions in meeting this need.

CIMAS Research Theme:

***Theme 6*: ** Ecosystem Management

Link to NOAA Strategic Goals:

***Goal 1*:** 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/CRCP

NOAA Technical Contact: John Tomczuk

Research Summary:

In the last year, NSU has hired the seven coral management assistants for all seven jurisdictions – American Samoa, CNMI, Florida, Guam, Hawaii, Puerto Rico and USVI. Working with NOAA and the local POCs in the jurisdictions, the final assistants were chosen from a pool over 530 applicants. In January 2016, the fellows relocated to their jurisdictions (where applicable) and started working at their respective agency in mid-January.

All seven coral assistants, their direct supervisors and NOAA staff met for a training orientation at NSU in Ft. Lauderdale, FL, where they worked with meeting facilitator Kevin Doyle, to develop their work plans and receive professional development training.

In March 2016, all fellows had finalized their work plans and are currently working on their projects in their jurisdictions. NSU and NOAA staff have monthly check-in calls with the seven coral assistants, which at times also include the local agency POC/supervisor. All seven are also planning their professional development training for 2016. Over half will attend the International Coral Reef Symposium in June 2016.

Research Performance Measure: All goals were met for the program this year. All seven positions were filled with qualified applicants and included local applicants for some jurisdictions. As of this report, all seven fellows are working successfully in their respective local jurisdictional agency and continue to have regular contact via scheduled calls with NSU and NOAA. There is also interaction on a regular basis with NOAA CRCP jurisdictional liaisons.

The following is a two-pager with images of the seven coral assistants and a brief bio for each.

2016–2017 NATIONAL CORAL REEF MANAGEMENT FELLOWS

NSU
NOVA SOUTHEASTERN UNIVERSITY
Halmos College of Natural Sciences and Oceanography

The National Coral Reef Management Fellowship Program is a partnership between Nova Southeastern University's National Coral Reef Institute, NOAA's Coral Reef Conservation Program, the U.S. Department of Interior Office of Insular Affairs, and the U.S. Coral Reef All Islands Committee.

The program recruits Coral Reef Management Fellows for the seven U.S. coral reef jurisdictions (American Samoa, the Commonwealth of the Northern Mariana Islands, Florida, Guam, Hawaii, Puerto Rico, and the U.S. Virgin Islands) to address current capacity gaps and to build longer-term capacity in these locations. This is done by placing highly qualified individuals whose education and work experience meet each jurisdiction's specific coral reef management needs. The program's goal is to develop a thriving collaborative fellowship program that builds excellent next-generation leaders and capacity for effective local coral reef ecosystem management.

American Samoa • Sabrina Woofter

Sabrina Woofter is from Jacksonville, Florida. She received her B.A. in Anthropology from the University of North Florida and her M.A. in Environmental Studies from the University of North Carolina—Wilmington.

As the fellow for American Samoa, Woofter is working with local communities and governmental agencies to improve the health of the area's coral reef ecosystems through the Coral Reef Advisory Group. Her project is focused on improving stormwater understanding and implementing best management practices in local communities to combat land-based sources of pollution. She also aims to improve climate change resilience by increasing local community awareness through the development of community resilience plans and the translation of outreach and education materials about climate change into the Samoan language.

Guam • Whitney Hoot

Originally from Annapolis, Maryland, Whitney Hoot holds a B.A. in Sociology and Environmental Science from Barnard College, Columbia University, and an M.S. in Sustainable Development and Conservation Biology from the University of Maryland—College Park.

During the fellowship, she is working on crafting an island-wide reef resilience strategy for Guam that incorporates extensive stakeholder feedback to create a new framework for coral reef management among the island's natural resource agencies. Additionally, she is coordinating the island's coral reef response team and developing standard operating procedures to address acute reef impacts—such as vessel groundings, oil spills, coral disease outbreaks, and bleaching events.

05-055-16MCP

Puerto Rico • Mariana C. León-Pérez

Born and raised in Puerto Rico, Mariana C. León-Pérez has a B.S. in Environmental Sciences from the Metropolitan University in San Juan and an M.S. in Biological Oceanography from the University of Puerto Rico—Mayagüez.

As Puerto Rico's fellow, León-Pérez is working under the Puerto Rico Coral Reef Conservation and Management Program (PRCRMP) at the Department of Natural and Environmental Resources. Her efforts are centered on conducting an assessment of PRCRMP's Coral Reef Monitoring Program and providing recommendations on the current state and future needs of coral reef conservation and management in Puerto Rico. Additionally, she is developing a GIS database of Puerto Rico's coral reef monitoring data.

U.S. Virgin Islands • Hilary Lohmann

From Summit, New Jersey, Hilary Lohmann has B.A. degrees in both Animal Behavior and Spanish from Bucknell University and an M.A. in Marine Affairs from the University of Rhode Island.

In St. Croix, Lohmann is working with the Department of Parks and Natural Resources to expand the economic and outreach capacity of the East End Marine Park. She is also working to revive Friends of the East End Marine Park to promote responsible recreation through fund-raising, citizen science, and local partnerships. Her fellowship plan assists in building a foundation to help the Friends thrive, with better organization and engagement on conservation activities long into the future.

Commonwealth of the Northern Mariana Islands (CNMI) • Autumn Poisson

Autumn Poisson is a Michigan native. She has a B.S. in Environmental Science with a minor in Mathematics and an M.S. in Conservation Ecology. Both are from the University of Michigan.

As the fellow in the CNMI, Poisson is working on the Luta/Talakhaya Revegetation Project, located on the island of Rota. The overall goal of her project is to improve the health of the Talakhaya watershed, including its streams and adjacent coral reef habitat, from land-based sources of pollution. Her main activities include planting grasses and trees in the watershed, as well as assisting with monitoring of the stream and coastal water quality on Rota.

Hawaii • Cameron Ka'ilikea Shayler

Cameron Ka'ilikea Shayler is a Native Hawaiian from the *ahupua'a* of He'ēia in the *moku* of Ko'olaupoko on the island of O'ahu. He received his B.S. in Marine Science from the University of Hawai'i—Hilo.

Shayler's fellowship is stationed in the Division of Aquatic Resources (DAR) at the Department of Land and Natural Resources in Honolulu. He is assisting the Community-Based Subsistence Fishing Area (CBSFA) program by supporting the establishment of post-designation procedures for recently designated CBSFA communities, as well as developing a community-based monitoring program that falls in line with DAR's monitoring program.

Florida • Kelly Montenero

Originally from Wisconsin, Kelly Montenero received her B.S. in Conservation Biology from the University of Wisconsin and her M.S. in Marine Affairs and Policy from University of Miami's Rosenstiel School of Marine and Atmospheric Science.

Montenero is working with the Florida Department of Environmental Protection (FDEP) Coral Reef Conservation Program in Miami, where she is responsible for coordinating the Southeast Florida Action Network, a citizen science marine incident reporting and response program. She will also lead the development and implementation of a community engagement strategy to increase public awareness of reef resources and manage logistics for a reef tract water quality monitoring project that is being coordinated between FDEP and NOAA.

Assessment of Hydro-Ecological Changes in Nearshore Areas of Biscayne Bay Based on Spatial and Temporal Changes in Distribution of Epiphytic Diatoms

Project Personnel: Anna Wachnicka (FIU)
NOAA Collaborators: J. Browder (NOAA/SEFSC); C. Kelble and L. Visser (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Theme:

***Objectives*:** Long term goals of this study are to: 1) investigate mechanisms of algal blooms in coastal areas of Biscayne Bay; 2) develop water quality base algal bloom prediction models. The Major objective of the FY2016 study was to: assess hydro-ecological conditions in nearshore areas of Biscayne Bay based on spatial and temporal distribution of epiphytic diatoms at 47 IBBEAM sites. Specific goals of this FY 2016 part of the larger project were to: (1) Enumerate and statistically analyze epiphytic diatoms collected from the 47 IBBEAM sites during the 2015 Wet Season sampling event and (2) Collect epiphytic samples during the 2016 Dry Season sampling event, deliver the samples to the Southeast Environmental Research Center's Nutrient Lab for nutrient analysis, and preserve epiphytic samples for the future diatom analysis.

***Strategy*:** These goals of the FY2016 study were accomplished by: (1) describing spatial and temporal patterns of epiphytic diatom assemblages at 47 IBBEAM locations (2) identifying indicator taxa that are indicative of specific zones and physicochemical settings along the Biscayne Bay shore; and (3) developing and improving previously developed diatom-based prediction models for the most important water quality parameters and habitats.

CIMAS Research Theme:

***Theme 6*:** Ecosystem Management
***Theme 7*:** Protection of Restoration of Resources

Link to NOAA Strategic Science Goals:

***Goal 1*:** 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: SEFSC/Ecosystems
NOAA Technical Contact: Theo Brainerd

Project Summary:

In this study we characterized spatial differences in algal communities and water quality at 47 locations in nearshore areas of Biscayne Bay, which are part of the Integrated Biscayne Bay Ecological Assessment and Monitoring program (IBBEAM) and additional 23 locations along the E-W transect from the mouth to the most inland location in the major drainage canals that could be reached by a boat (Figs. 1 and 2). These locations are most likely to experience significant changes in freshwater quantity and quality as a result of the Biscayne Bay Coastal Wetlands Project (BBCWP), which is part of CERP.

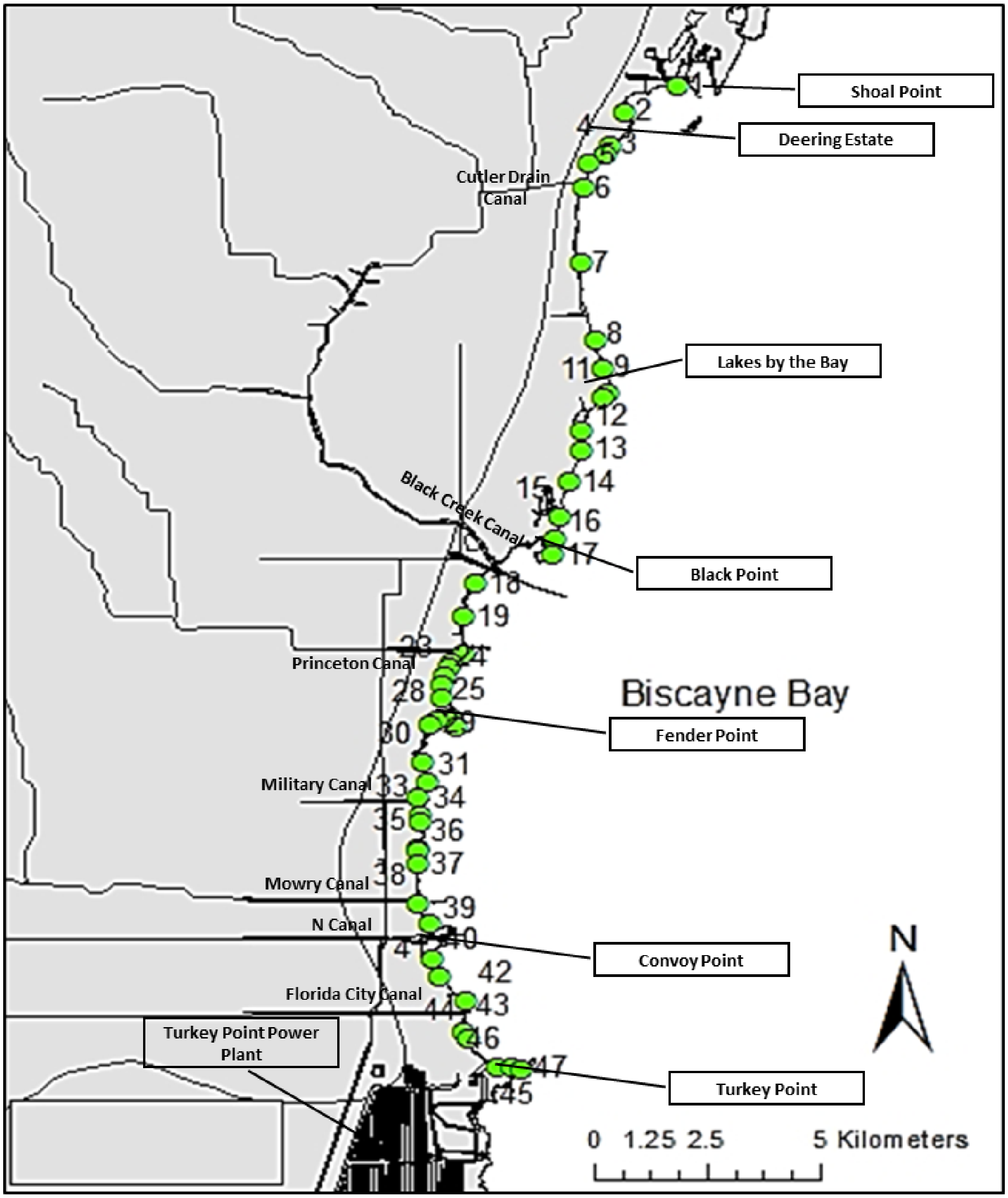


Figure 1: Map showing epiphyte sampling locations in Biscayne Bay (Florida, U.S.A.).

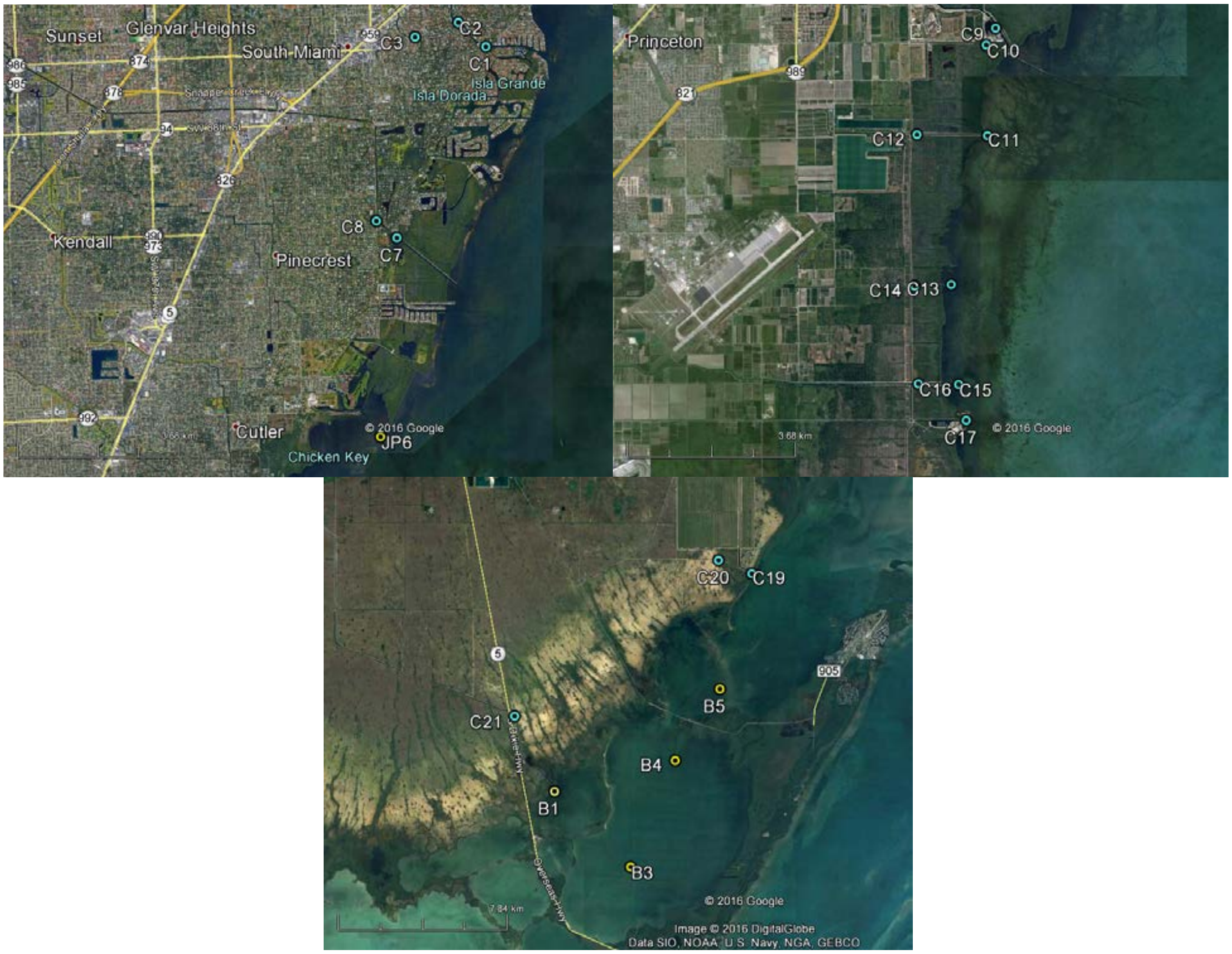


Figure 2: Map showing phytoplankton sampling locations in Biscayne Bay (Florida, U.S.A.). Coral Gables Canal (C1,C2,C3,C4); Snapper Creek Canal (C7,C8); Cutler Channel (C9,C10); Princeton Canal (C11,C12); Military Canal (C13, C14); Mowry Canal (C15, C16); Convey Point (C17); Deering Estate (J6); Canal S of Turkey Point (C19, C20); C-111 Canal (B1, C21); Barnes Sound (B3, B4); Card Sound (B5).

The following have been learned from the study:

Epiphyte Sampling Locations

Water quality measurements revealed that Si, PO_4 and NO_2 were elevated in central part of the bay compared to northern and southern parts of the bay. In general, sites located south of Convoy Point had lower concentration of nutrients in water and epiphytes compared to other areas of the bay (Fig. 3, Table 1).

Sites were divided into four major clusters based on differences in water quality conditions (Fig. 4). Clusters 1 & 2 grouped sites located south of Princeton Canal, while Clusters 3 & 4 grouped sites located north of Princeton Canal. However, this general division of sites should be treated with caution, since the aforementioned clusters also contained several sites from other areas.

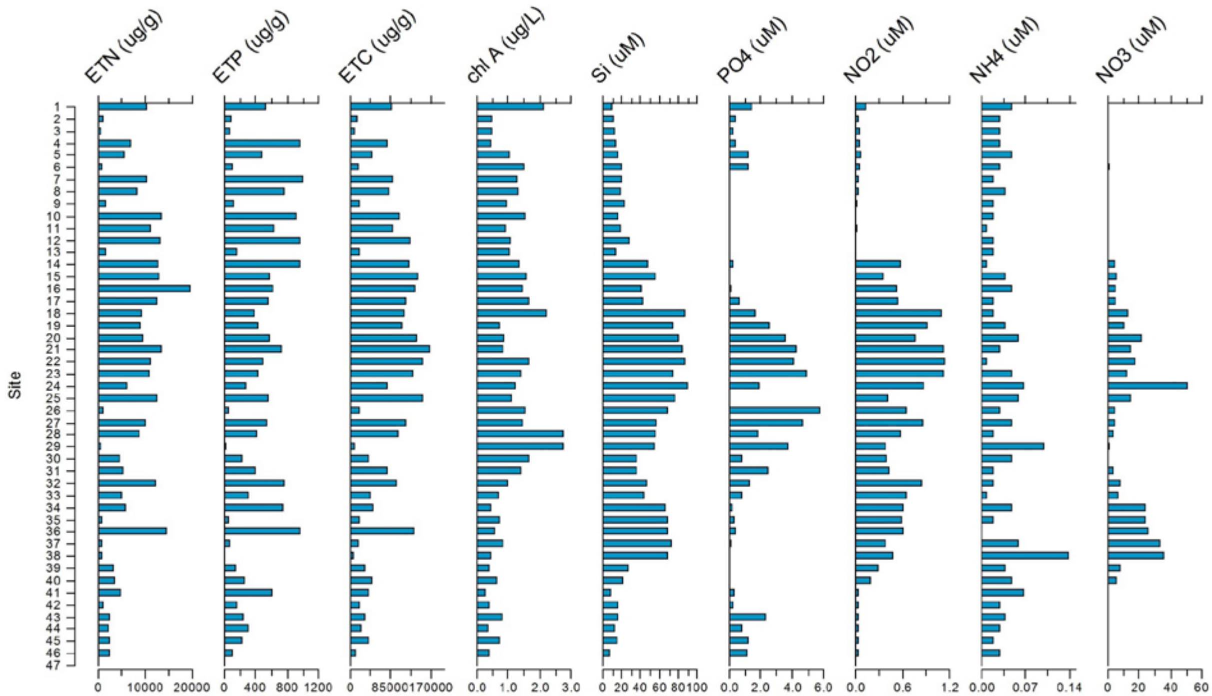


Figure 3: Changes in water quality and chlorophyll *a* concentration in epiphytic and water samples collected from IBBEAM locations.

Table 1: Minimum, maximum, average and standard deviation values of water quality variables recorded during the dry season 2016 sampling event at IBBEAM sites. Abbreviations: ETN = epiphyte total nitrogen, ETP = epiphyte total phosphorus, ETC = epiphyte total carbon, silica (Si), nitrite (NO_2), nitrate (NO_3), ammonium (NH_4), phosphate (PO_4) and chlorophyll *a*.

	N	Minimum	Maximum	Mean	Std. Deviation
ETN	46	734.90	19773.50	7095.1783	4992.70902
ETC	46	7375.60	169785.80	73636.0283	50030.11285
ETP	46	18.07	1014.44	445.4977	302.43273
Si	46	7.60	90.40	42.7891	26.96122
NO2	46	.00	1.16	.4048	.36713
NO3	46	.08	50.97	8.5043	11.34640
PO4	46	.00	5.85	1.2941	1.57011
NH4	46	.00	.14	.0372	.02491
chl_a	46	0	3	1.13	.602
Valid N (listwise)	46				

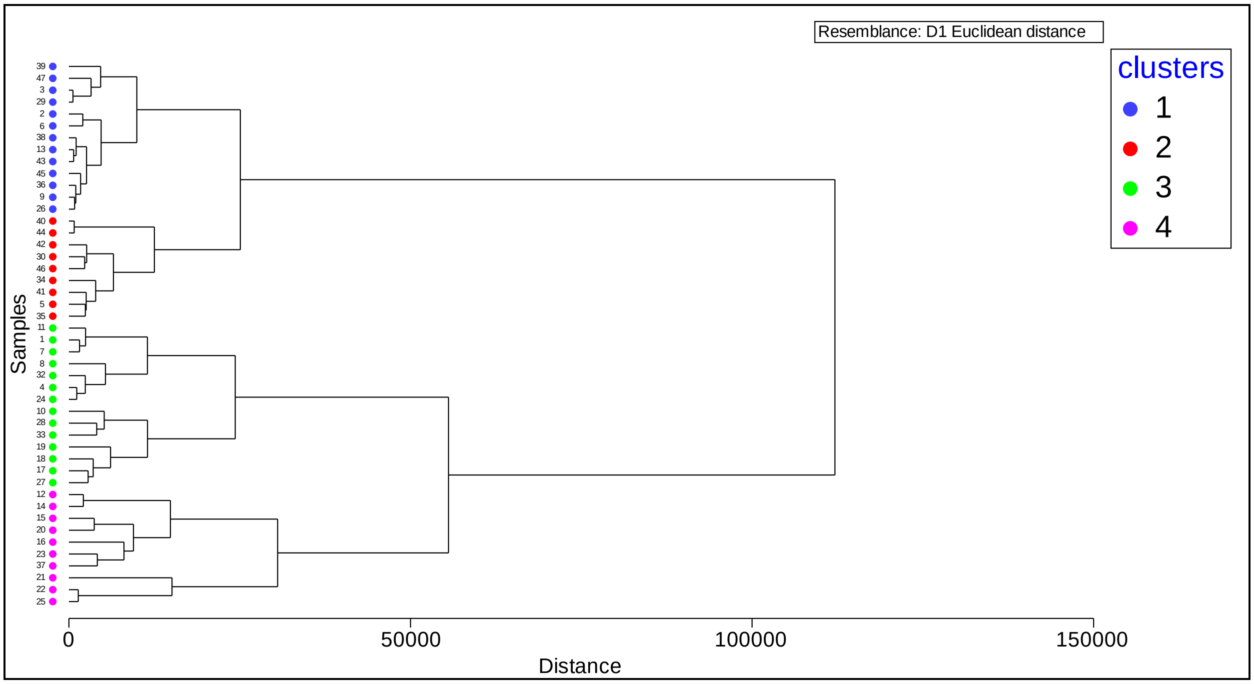


Figure 4: Difference among IBBEAM sites based on differences in water quality in dry season 2016.

ANOVA revealed that there were statistically significant differences among clusters in terms of ETN, ETC, ETP ($p<0.05$). Post Hoc Tukey test further revealed that cluster 1 and 2 were significantly different from cluster 4 in terms of Si concentration ($p<0.05$); clusters 1 and 4 were significantly different from each other in terms of NO2 concentration; and clusters 2 and 3 were significantly different from each other in terms of chlorophyll a concentration ($p<0.05$). There were no significant differences among clusters in terms of NO3, NH4 and PO4. (Fig. 5).

ANOSIM revealed that there were also significant differences in species composition among the clusters. Significant differences in epiphytic diatom assemblage structure (species composition and abundance) were detected among northern, central and southern parts of the bay. However, just like in case of water quality studies, some overlaps between clusters have also been observed (Fig. 6).

BIO-ENV analysis revealed that salinity was the most influential variable structuring epiphytic diatom assemblages along the Biscayne Bay coast. This variable explained more than 35% of variation in their structure ($\rho w = 0.354$).

Two significant shifts in assemblage similarity between consecutive sites along the coast were detected by STAR analysis. The largest restructuring of epiphytic diatom communities occures between Black Point Canal and Princeton Canal and the second largest shift was detected south of Convoy Point. The magnitude of changes in the structure of epipytic communities between consecutive sites along the coast was the largerest north of Black Point Canal (Fig. 6).

The initial results of chemotaxonomic analysis of 10 phytoplanktonic samples (the analysis are ongoing) revealed that fucoxantin was the most abundant in the samples. Microscopic examination of the samples indicated that the most common components of the microalgal community were diatoms. Hence, we interpreted fucoxanthin concentration to primarily represent diatom abundance, though a few dinoflagellate cysts were also noted at two of the locations (Fig. 7).

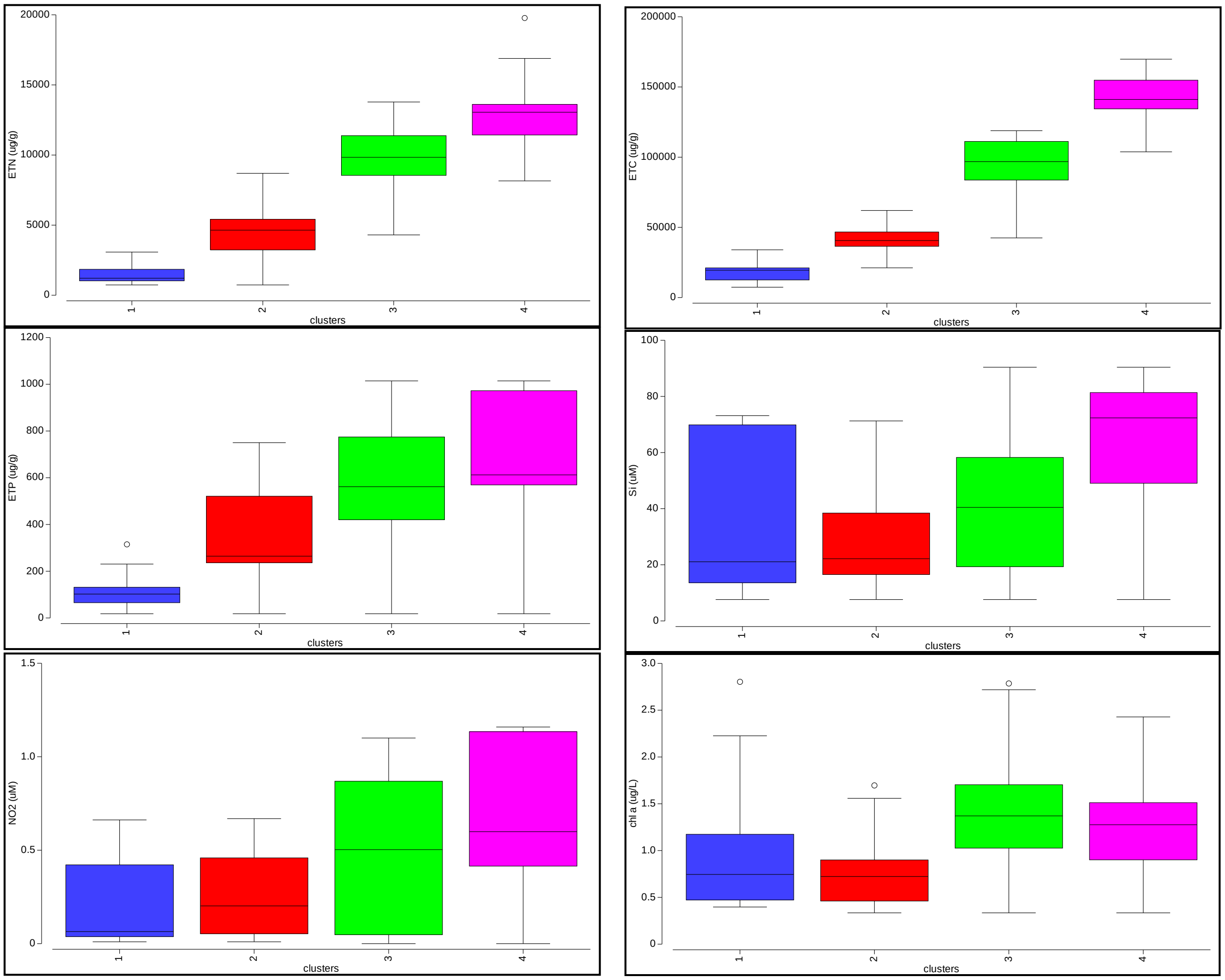


Figure 5: Box plots of total nitrogen, total carbon, total phosphorus in epiphytes (ETN, ETC, ETP); total silica concentration in water (Si) among dry season 2016 clusters of IBBEAM sites; and box plots of Nitrite (NO_2) and chlorophyll *a* in water samples along dry season 2016 cluster of IBBEM sites.

Phytoplankton Sampling Locations

Water quality measurements revealed that Cutler Channel, Princeton Canal and Mowry Canal had significantly lower salinity and higher NH_4, NO_3, Si and chlorophyll *a* concentration compared to other canals (Fig. 8, Table 2). The near 0ppt values in these canals implies that freshwater was being released from the canals during the sample collection.

Based on water quality, these sites could be divided into 4 major clusters: **CLUSTER 1:** Cutler Channel (C9, C10), Princeton Canal (C11,C12); **CLUSTER 2:** Snapper Creek Canal (C7,C8), Card Sound (B5), Mowry Canal (C15, C16), Coral Gables Canal (C3); **CLUSTER 3:** Canal (B1, C21); Barnes Sound (B3, B4), Canal S of Turkey Point (C19, C20), Convey Point (C17), C-111 (B1, C21), Deering Estate (J6); **CLUSTER 4:** Coral Gables Canal (C1,C2,C4); Military Canal (C13, C14). (Fig. 9).

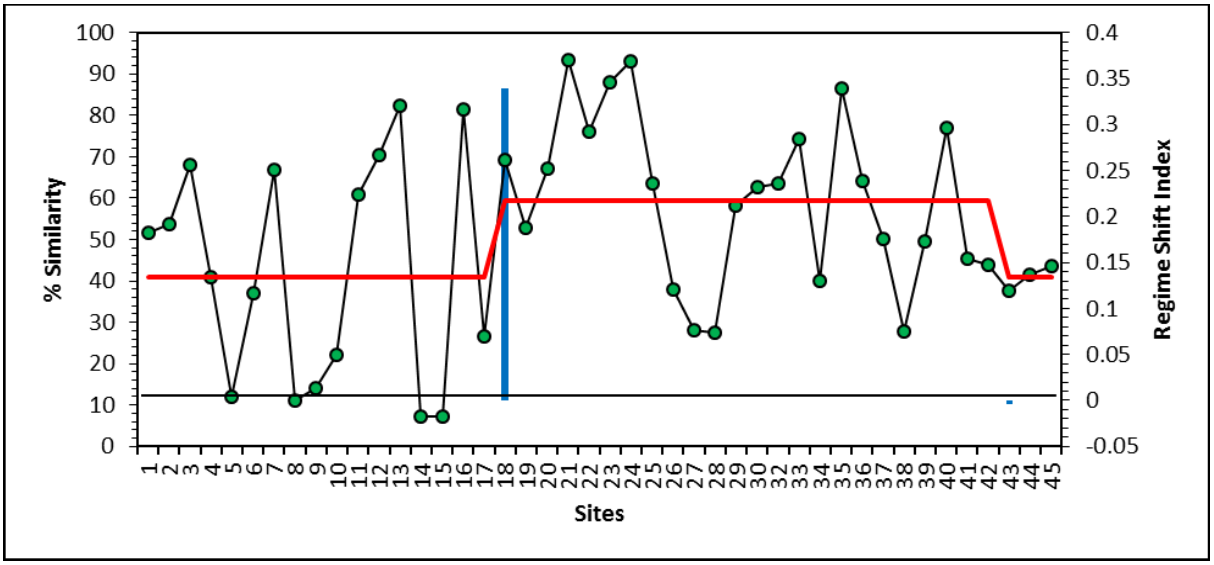


Figure 6: Shifts in % similarity between consecutive sites along the N-S transect. Breaks in the red line represent locations of significant shifts in the structure ($p<0.05$) detected by STAR analysis.

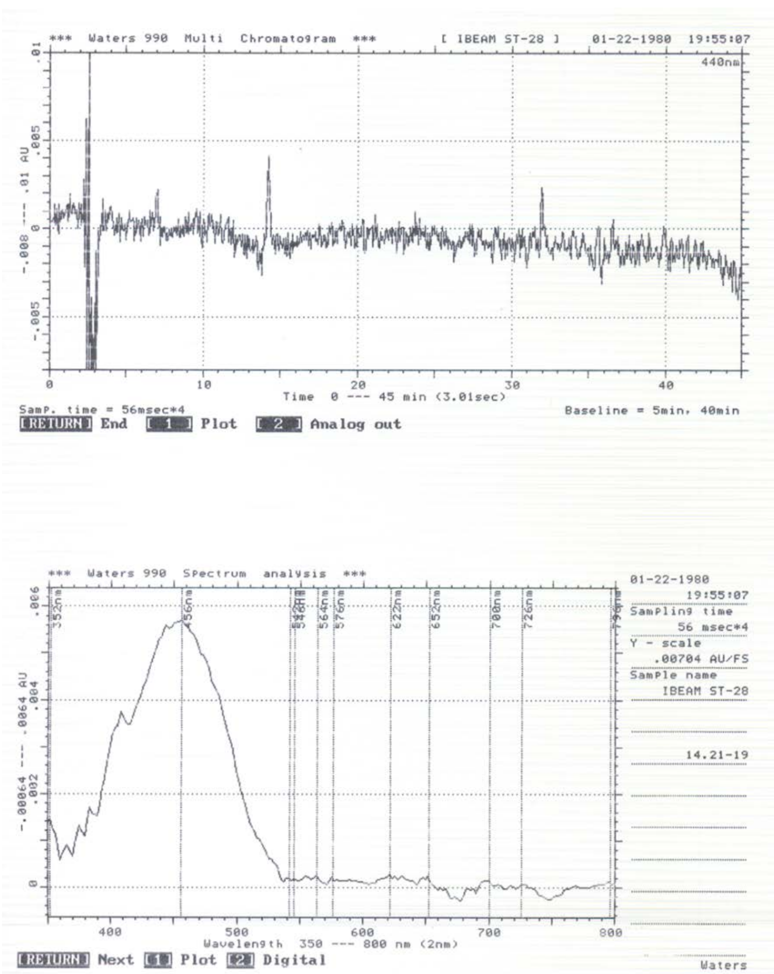


Figure 7: Initial results of chemotaxonomic analysis which are currently being run on the samples. Highest pick indicated high abundance of fucoxanthin pigment.

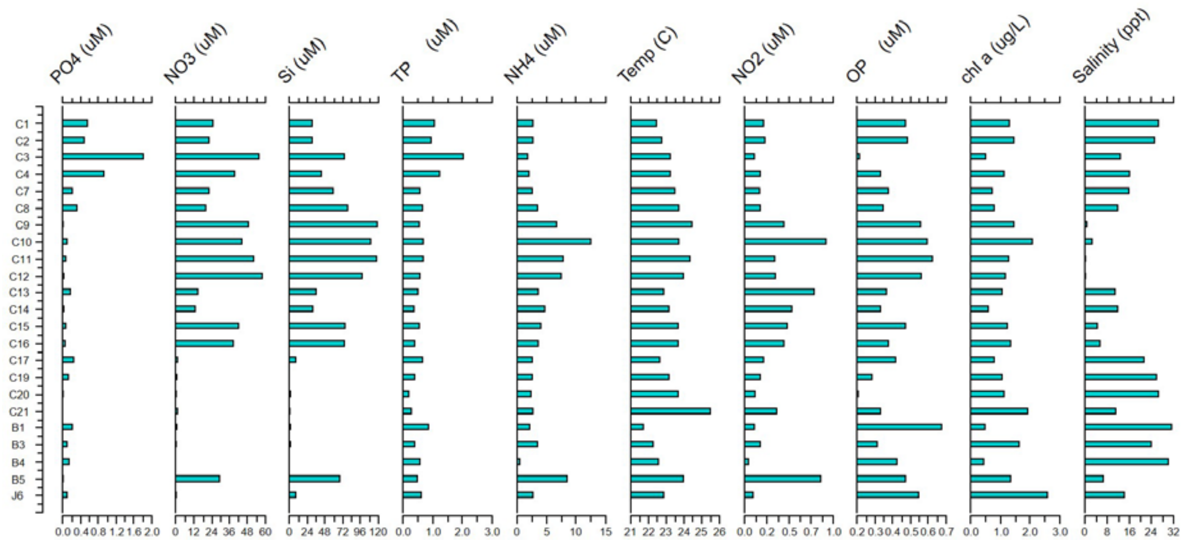


Figure 8: Changes in water quality and chlorophyll a concentration in water samples collected from: Coral Gables Canal (C1,C2,C3,C4); Snapper Creek Canal (C7,C8); Cutler Channel (C9,C10); Princeton Canal (C11,C12); Military Canal (C13, C14); Mowry Canal (C15, C16); Convey Point (C17); Canal S of Turkey Point (C19, C20); C-111 Canal (B1, C21); Barnes Sound (B3, B4); Card Sound (B5); Deering Estate (J6).

Table 2: Minimum, maximum, average and standard deviation values of water quality variables recorded during the dry season 2016 sampling event at phytoplankton sampling sites. Abbreviations: salinity (sal), temperature (temp), silica (Si), nitrite (NO_2), nitrate (NO_3), ammonium (NH_4), phosphate (PO_4), total phosphorus (TP), organic phosphorus (OP) and chlorophyll *a*.

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
sal	23	.30	31.80	15.0391	10.01207
temp	23	21.80	25.50	23.3957	.81491
Si	23	.00	119.50	47.5087	41.12888
NO_2	23	.06	.89	.3270	.23607
NO_3	23	.19	58.84	23.6839	20.69272
NH_4	23	.75	12.69	4.2404	2.76186
PO_4	23	.00	1.82	.2683	.40277
TP	23	.23	2.05	.6983	.38047
OP	23	0	1	.43	.127
chl_*a*	23	.46	2.61	1.2232	.52521
Valid N (listwise)	23				

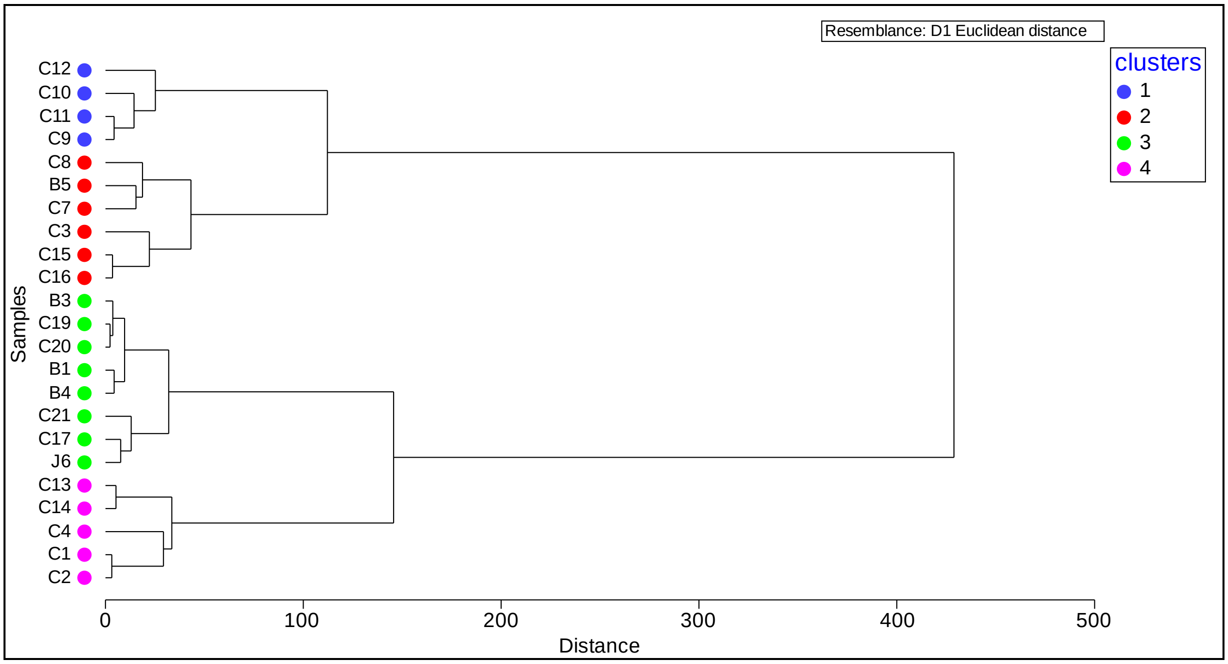


Figure 9: Difference among phytoplankton sites based on differences in water quality in dry season 2016. **CLUSTER 1:** Cutler Channel (C9, C10), Princeton Canal (C11, C12); **CLUSTER 2:** Snapper Creek Canal (C7, C8), Card Sound (B5), Mowry Canal (C15, C16), Coral Gables Canal (C3)**; CLUSTER 3:** Canal (B1, C21); Barnes Sound (B3, B4), Canal S of Turkey Point (C19, C20), Convey Point (C17), C-111 (B1, C21) Deering Estate (J6); **CLUSTER 4:** Coral Gables Canal (C1, C2, C4); Military Canal (C13, C14).

ANOVA revealed that there were significant differences among the clusters in terms of salinity, Si, NO_3, NH_4, and OP ($p<0.05$). Furthermore, Post Hoc Tukey test revealed that salinity differed significantly only between clusters 1 vs. 3 and 4, and 2 and 4; silica was significantly at all clusters; NO_3 was not significantly different between clusters 2 and 4; NH_4 was not significantly different between clusters 2 and 3 and 4; and OP was only different between clusters 1 and 2. (Fig. 10).

Chemotaxonomic analysis of phytoplanktonic samples from these locations are currently being done for these sites and the results will be delivered in the next progress report, once the PI receives the results.

Research Performance Measure: All research objectives have been accomplished by this study. Some tasks are still being completed in the labs. This tasks include analysis of algal pigments in samples collected during the study. The delays are due to the lab moving to the new the location and recalibration of all their equipment. The complete results of this task will be attached in the next progress report.

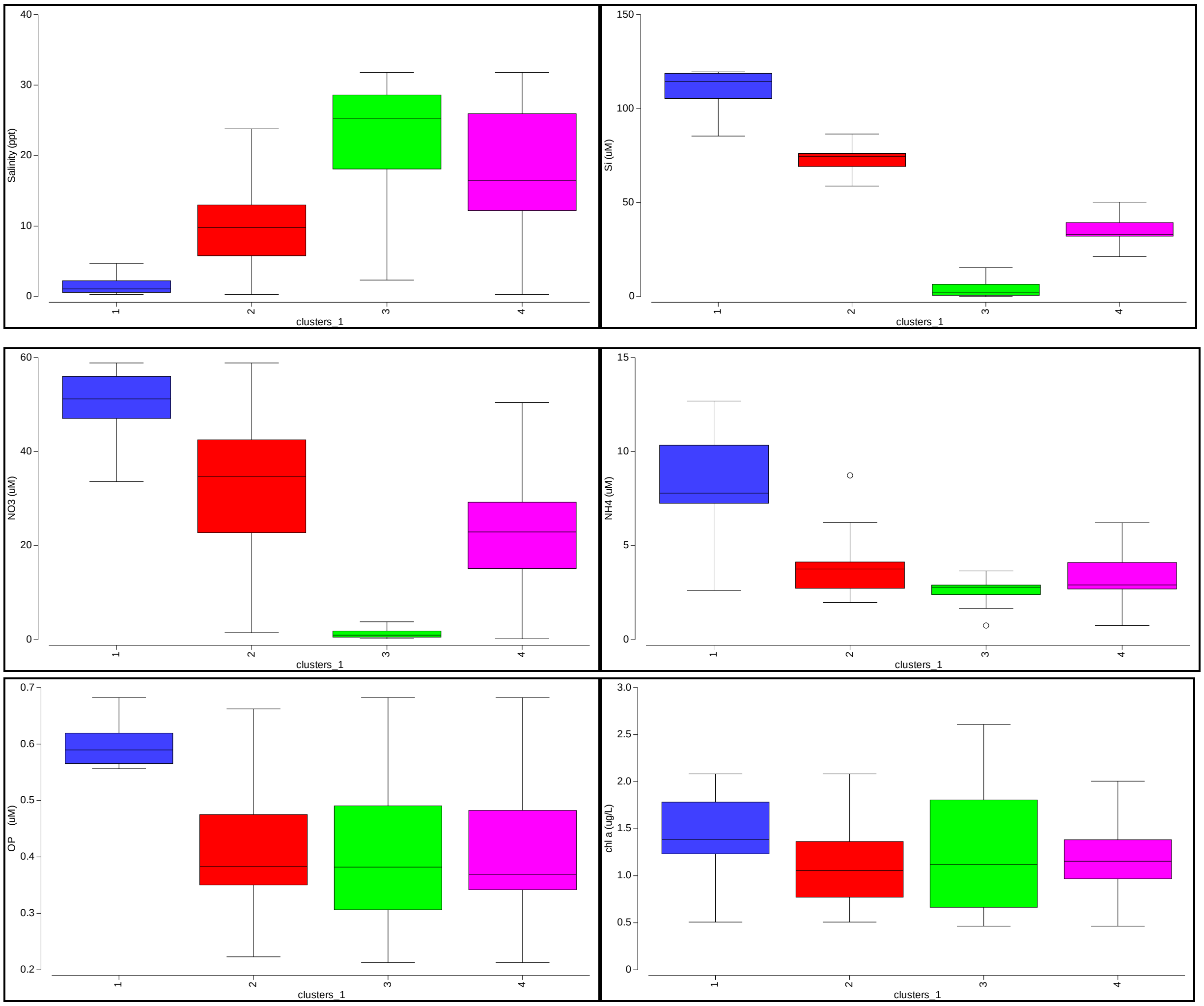


Figure 10: Box plots of salinity, total silica (Si), nitrate (NO_3), ammonium (NH_4), in water samples among dry season 2016 clusters of phytoplankton sites. (Bottom panels) Box plots of organic phosphate (OP) and chlorophyll $_a$ in water samples among dry season 2016 clusters of phytoplankton sites.

RESEARCH REPORTS

THEME 7: Protection and Restoration of Resources

Marine Mammal Research and Stranding Response

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

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** 1) To assist during Natural Resource Damage Assessment (NRDA) studies associated with the Deepwater Horizon (DWH) Oil Spill in the Gulf of Mexico. 2) To support the investigation of the Northern Gulf of Mexico Marine Mammal Unusual Mortality Event (UME). 3) To assist the Southeast Fisheries Science Center (SEFSC)'s Protected Resources and Biodiversity Division in research and management of protected cetacean species under the Marine Mammal Protection Act (MMPA). 4) To support the Marine Mammal Health and Stranding Response Program (MMHSRP) and ensure data quality in compliance with the Data Quality Act.

***Strategy*:** 1) To collect, analyze and manage data for the NRDA injury and restoration assessments associated with the DWH Oil Spill in the Gulf of Mexico and writing of scientific reports. 2) To perform data management, auditing and handling of evidentiary images in response to the investigation of the Marine Mammal UME in the northern Gulf of Mexico. 3) To assist in project planning and field work during cetacean surveys onboard NOAA research vessels (small and large), management of data and samples collected and writing of scientific reports. 4) To respond and coordinate response actions during cetacean strandings dead or alive in the US Southeast Region. 5) To validate historical stranding data working with the SEFSC staff and stranding network members to implement effective data auditing and correction.

CIMAS Research Theme:

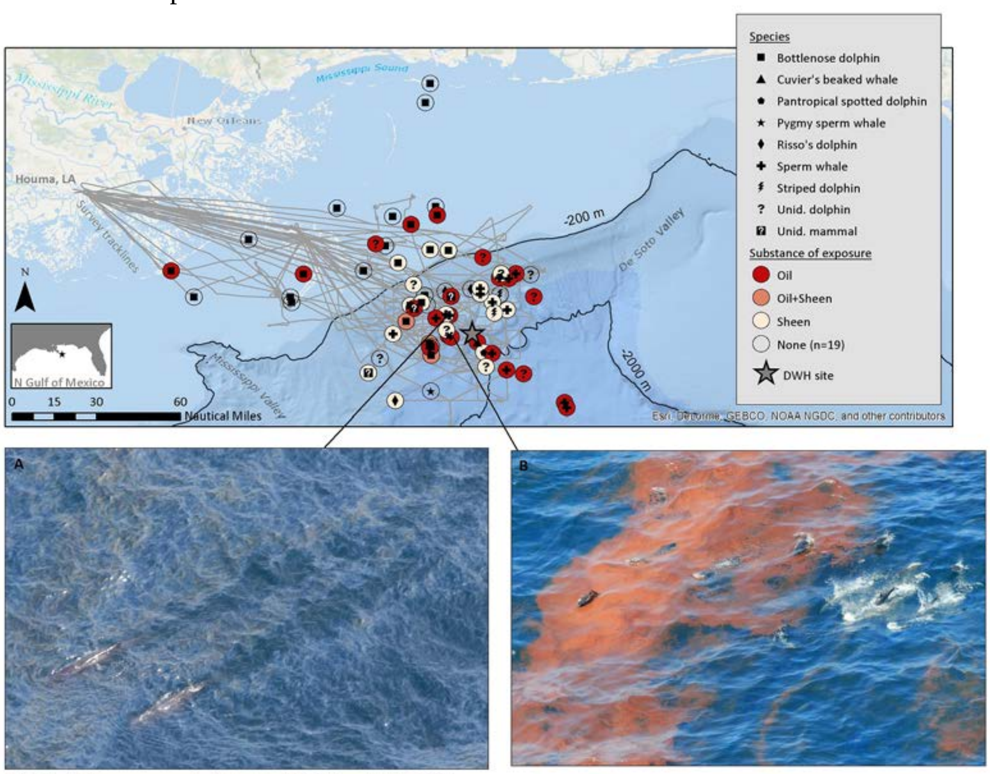
***Theme 7*:** Protection and Restoration of Resources

Link to NOAA Strategic Goals:

***Goal 1*:** 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:
After the pre-assessment phase in which, time sensitive data was collected during and immediately following the DWH oil spill, injury assessment studies were implemented to determine whether natural resource injuries have or might result from the spill. A comprehensive restoration plan for the Gulf was developed (Programmatic Damage Assessment and Restoration Plan-PDARP), which included several documents outlining potential impacts of the DWH oil spill on natural resources in the Gulf. Dias produced and co-authored two technical reports in support of the PDARP: 1- Evidence of marine mammals' direct exposure to petroleum products during the Deepwater Horizon Oil Spill in the Gulf of Mexico, and 2- Distribution and Abundance of Cetaceans in the Northern Gulf of Mexico. The first report documented several cetacean species swimming through oil and with oil on their bodies by means of photographs and field observations collected during NOAA/NRDA projects (Figure 1). In the latter report, aerial and ship-based survey data over a 20-year span indicated the distribution, abundance and density of whales and dolphins in the Gulf of Mexico.



NOAA activities were conducted under MMPA Permit 779-1633.

Figure 1: Marine mammal sightings in the presence or absence of petroleum products and survey tracklines during the Helicopter Survey. A: sperm whales swimming through oil, 28 April 2010, photo by NOAA; B: striped dolphins swimming through oil, 29 April 2010, photo by NOAA. (Unid. -unidentified).

In addition to writing reports related to the DWH oil spill, Dias participated in the 2015 Southeast Fisheries Science Center (SEFSC) research cruise on board the *NOAA Ship Gordon Gunter*. This survey was conducted along the continental shelf and shelf-break waters in the northeastern Gulf, with the main objectives to: 1- collect biopsy samples of bottlenose (*Tursiops truncatus*) and Atlantic spotted (*Stenella*

frontalis) dolphins and, 2- deploy acoustics tags on Bryde's whales (*Balaenoptera edeni*). During this cruise, Dias worked as the data and sample manager and also assisted in writing scientific reports.

Dias also participated in the long-term monitoring of bottlenose dolphins (*T. truncatus*) in Biscayne Bay as a photographer. Off-season Dias assisted in project planning and scientific permit renewal.

Research Performance Measure: all objectives were completed on time. 1) Managed data and wrote two technical reports for the Offshore Marine Mammal Injury Assessment under the NRDA PDARP (see publications below). 2) Worked as a marine mammal observer and managed data and samples collected during the 2015 SEFSC research cruise in the Gulf of Mexico. During this project, more than 3,500 km of survey effort were performed, 332 cetacean sightings recorded, 222 biopsy samples collected and one acoustic tag deployed. 3) Assisted with North Atlantic Right Whale (*Eubalaena glacialis*) satellite tagging attempt in northern Florida. 4) Audited the Introduction to Geographic Information System (GIS) class at RSMAS during one semester. 5) Assisted in project planning and development for the Biscayne Bay Photo-ID project also working as a photographer during two field seasons. 6) Managed evidentiary images (photographs) of stranded cetaceans from the Northern Gulf of Mexico Marine Mammal UME and associated legal deliverables, totaling nearly 300 GB of data. 7) Validated historical stranding records. 8) Trainings accomplished: 24-hour Hazardous Waste Operations and Emergency Response (HAZWOPER); Department of Transportation/ International Air Transport Association Hazardous Material Shipping (DOT/IATA).

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Natural Resource Damage Assessment Plankton Processing

Project Personnel: S. Privoznik, A. Ender, A. Jugovich, K. Doering, E. Keister, T. Morrell, A. Shiroza and J. Mostowy (UM/CIMAS)
NOAA Collaborators: J. Lamkin and Trika Gerard (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To assist the NOAA Natural Resource Damage Assessment process relative to the Deep Water Horizon BP oil spill incident.
***Strategy*:** To analyze plankton samples through measurement of sample displacement volume, removal of fish eggs, fish larvae, and debris, and the identification of larval fish removed.

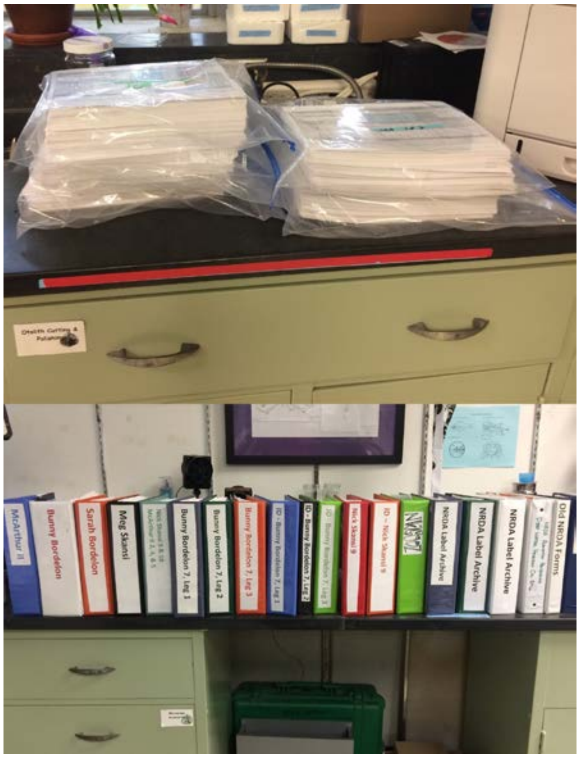
CIMAS Research Theme:
***Theme 7*:** Protection and Restoration of Resources

Link to NOAA Strategic Goals:
***Goal 1*:** 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 FORCES (Fisheries Oceanography for Recruitment, Climate, and Ecosystem Science) laboratory at the NOAA/NMFS Southeast Fisheries Science Center, Miami Lab is assisting in the analysis and larval identification 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.



Research Performance Measure: The large volume of samples generated in response to the DWH was divided into prioritized Tiers among the multiple institutions to facilitate processing and data acquisition. The SEFSC Miami Lab has processed a total of 1,970 samples. To date, plankton samples from nine prioritized categories or "tiers" (Tiers 1A, B and C, Tiers 2A, B, and C, Tiers 3A and D, and Tier 4C) have been sorted. This includes samples from eight cruises carried out using the research vessels McArthur II, Bunny Bordelon, Sarah Bordelon, Meg Skansi, and Nick Skansi. The Miami Lab expanded its operation to include larval identification, and has identified 117,419 larval fish, from 612 samples, to the lowest possible taxonomic levels. 100% of sorted and identified samples at NOAA SEFSC Miami Lab have been entered into the online database shared by the NRDA labs. 100% of samples sorted and identified have been labeled and sent to the DWH Plankton Assessment Archive.

Figure 1: Upon completion of the multi-year plankton processing project, the necessary sample archiving resulted in hundreds of Chain of Custody forms (top) and dozens of binders of datasheets and forms (bottom).

Figure 2: The FORCES Lab was pleased to share their contribution to the DWH Damage Assessment with NOAA deputy administrator VADM Brown in March 2016.

Fisheries Trip Matching System (FTM)

Project Personnel: S. Aguilar (UM/CIMAS)
NOAA Collaborators: D. Gloeckner, S. Turner and J. Hall (NOAA/SEFSC)
Other Collaborators: C. Bumpus and O. Rodriguez (Jamison Professional Services)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** Develop a system that matches commercial fishing trips reported through various data collection programs including logbooks, IFQ and trip tickets. The main objective is to match trips and identify differences in an effort to increase the quality control on these data that are used for resource management and scientific analyses.

***Strategy*:** Data sets may have different identifiers for vessel or dealer. A key task will be creating a function that determines if two vessels/dealers with different identifiers/names may be the same. This will require building a bridge between the identifiers in each system. Additionally, catches are sometimes reported using codes that identify different taxonomic levels (ITIS, GENUS, FAMILY) or use an invalid species name. We are going to incorporate GENUS code comparisons to account for some of the differences between databases. We are also creating new reports that show the possible matching trips, which will help the scientific staff to determine if the trip is a match or not.

CIMAS Research Theme:

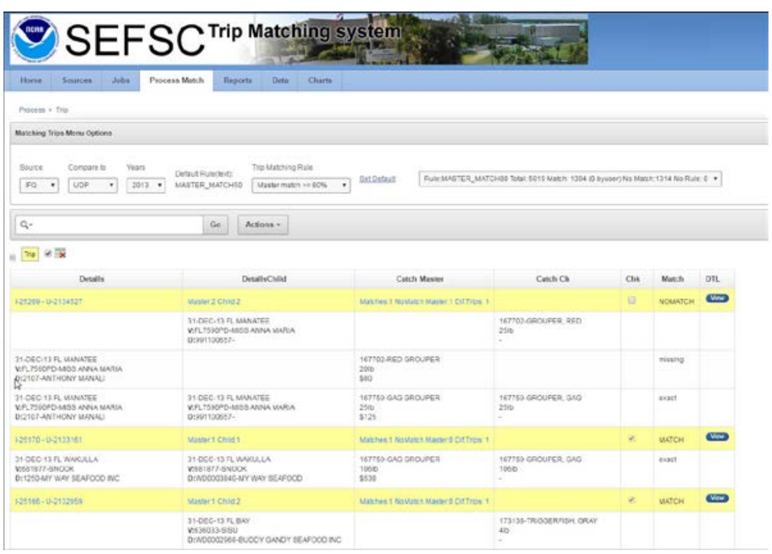
***Theme 7*:** Protection and Restoration of Resources

Link to NOAA Strategic Goals:

***Goal 1*:** 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: FTM project: The system was developed in Oracle-Application Express (APEX). The main goal is to create a system to identify matching trips compared across multiple databases using the existing variables or creating new variables and new reports in APEX.



Research Performance Measure: FTM: Currently working on creating routines to increase the precision of matching trips.

Figure 1: FTM Trip Matching Report**.**

Coastal Fisheries Logbook Program

Project Personnel: J. Diaz (UM/CIMAS)
NOAA Collaborators: D. Gloeckner, M. Judge, 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 7*:** Protection and Restoration of Resources

Link to NOAA Strategic Goals:

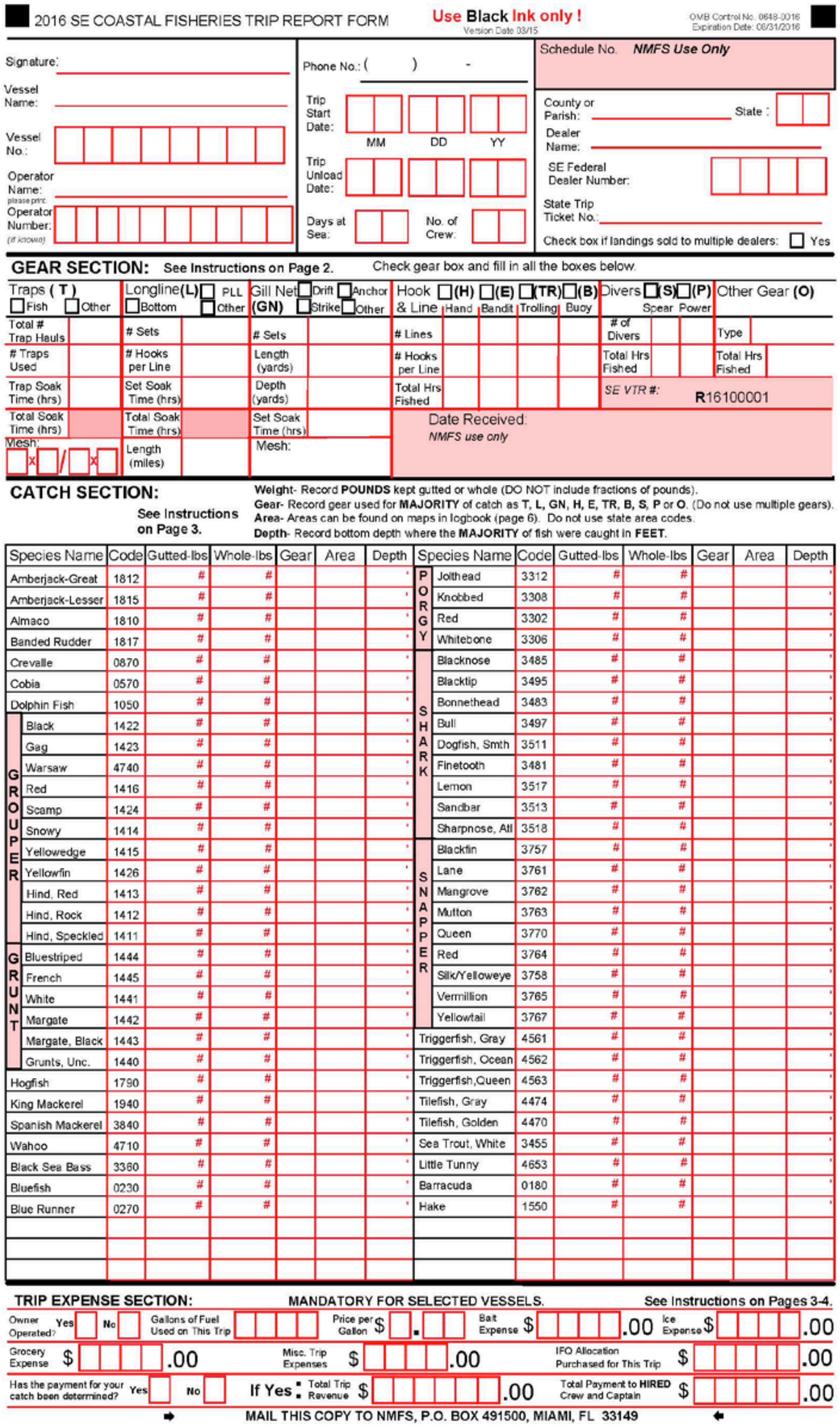
***Goal 1*:** Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems*

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.



2016 SE COASTAL FISHERIES TRIP REPORT FORM — **Use Black Ink only !** — Version Date 03/15 — OMB Control No. 0648-0016 Expiration Date: 08/31/2016

Signature: ____ Phone No.: ( ) -

Schedule No. *NMFS Use Only*

Vessel Name: ____

Trip Start Date: MM DD YY

County or Parish: ____ State:

Vessel No.: ____

Dealer Name: ____

Trip Unload Date:

SE Federal Dealer Number:

Operator Name: (please print) ____

Operator Number: (if known) ____

Days at Sea: ____ No. of Crew: ____

State Trip Ticket No.: ____

Check box if landings sold to multiple dealers: ☐ Yes

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

Traps (T) ☐Fish ☐Other		Longline(L) ☐PLL ☐Bottom ☐Other		Gill Net (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		SE VTR #:		R16100001	
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** kept 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 6). Do not use state area codes.
Depth- Record bottom depth where the **MAJORITY** of fish were caught in **FEET.**

Group	Species Name	Code	Gutted-lbs	Whole-lbs	Gear	Area	Depth	Group	Species Name	Code	Gutted-lbs	Whole-lbs	Gear	Area	Depth
	Amberjack-Great	1812	#	#				PORGY	Jolthead	3312	#	#			
	Amberjack-Lesser	1815	#	#				PORGY	Knobbed	3308	#	#			
	Almaco	1810	#	#				PORGY	Red	3302	#	#			
	Banded Rudder	1817	#	#				PORGY	Whitebone	3306	#	#			
	Crevalle	0870	#	#				SHARK	Blacknose	3485	#	#			
	Cobia	0570	#	#				SHARK	Blacktip	3495	#	#			
	Dolphin Fish	1050	#	#				SHARK	Bonnethead	3483	#	#			
GROUPER	Black	1422	#	#				SHARK	Bull	3497	#	#			
GROUPER	Gag	1423	#	#				SHARK	Dogfish, Smth	3511	#	#			
GROUPER	Warsaw	4740	#	#				SHARK	Finetooth	3481	#	#			
GROUPER	Red	1416	#	#				SHARK	Lemon	3517	#	#			
GROUPER	Scamp	1424	#	#				SHARK	Sandbar	3513	#	#			
GROUPER	Snowy	1414	#	#				SHARK	Sharpnose, Atl	3518	#	#			
GROUPER	Yellowedge	1415	#	#				SNAPPER	Blackfin	3757	#	#			
GROUPER	Yellowfin	1426	#	#				SNAPPER	Lane	3761	#	#			
GROUPER	Hind, Red	1413	#	#				SNAPPER	Mangrove	3762	#	#			
GROUPER	Hind, Rock	1412	#	#				SNAPPER	Mutton	3763	#	#			
GROUPER	Hind, Speckled	1411	#	#				SNAPPER	Queen	3770	#	#			
GRUNT	Bluestriped	1444	#	#				SNAPPER	Red	3764	#	#			
GRUNT	French	1445	#	#				SNAPPER	Silk/Yelloweye	3758	#	#			
GRUNT	White	1441	#	#				SNAPPER	Vermillion	3765	#	#			
GRUNT	Margate	1442	#	#				SNAPPER	Yellowtail	3767	#	#			
GRUNT	Margate, Black	1443	#	#					Triggerfish, Gray	4561	#	#			
GRUNT	Grunts, Unc.	1440	#	#					Triggerfish, Ocean	4562	#	#			
	Hogfish	1790	#	#					Triggerfish,Queen	4563	#	#			
	King Mackerel	1940	#	#					Tilefish, Gray	4474	#	#			
	Spanish Mackerel	3840	#	#					Tilefish, Golden	4470	#	#			
	Wahoo	4710	#	#					Sea Trout, White	3455	#	#			
	Black Sea Bass	3360	#	#					Little Tunny	4653	#	#			
	Bluefish	0230	#	#					Barracuda	0180	#	#			
	Blue Runner	0270	#	#					Hake	1550	#	#			

TRIP EXPENSE 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.

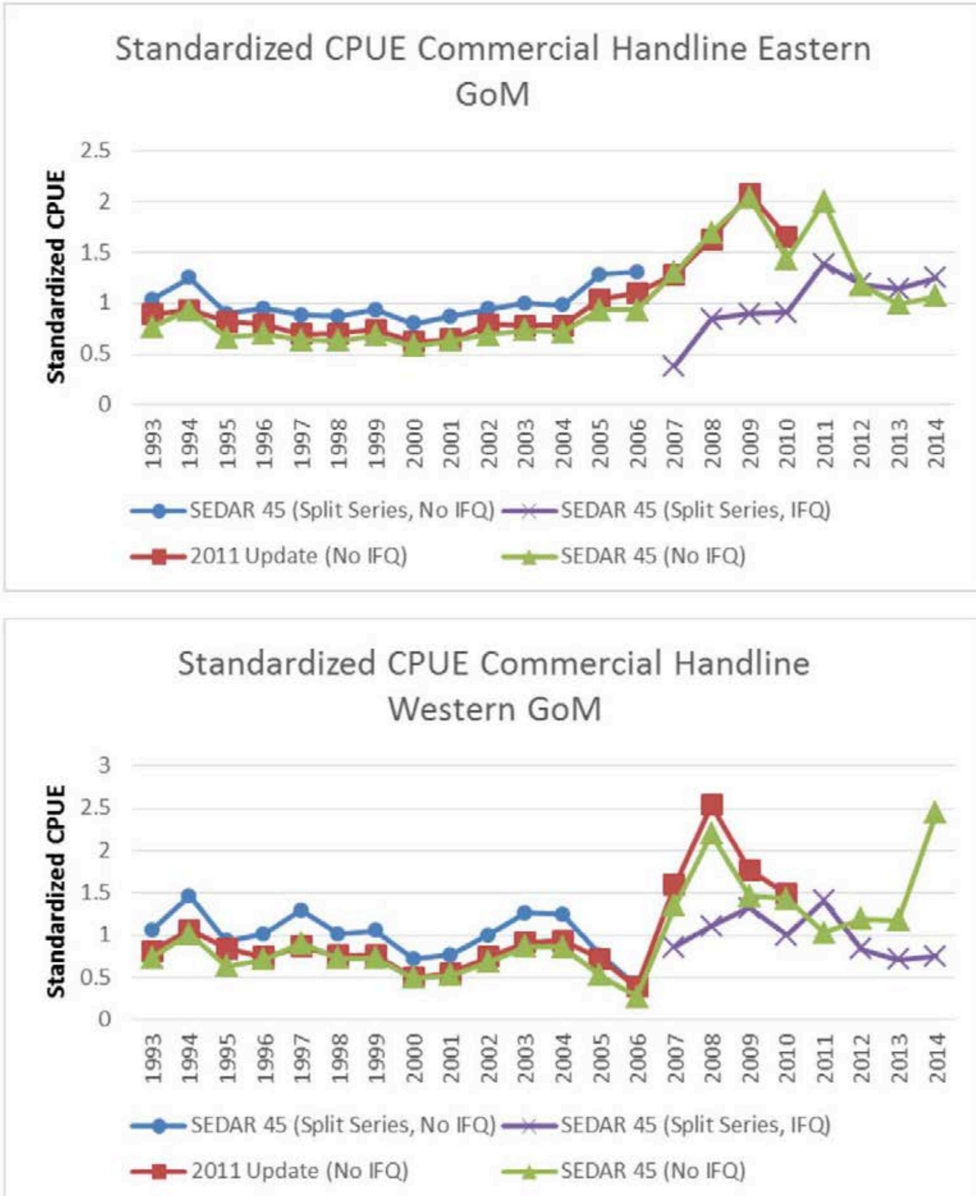


Figure 2: The recent SEDAR45 utilized a standardized commercial logbook catch per unit effort in the U.S. Gulf of Mexico. Figure 2 shows the standardized catch-per-unit effort (CPUE) for the commercial handline fishery in the eastern (top panel) and western (bottom panel) Gulf of Mexico. In the 2011 update (red lines) no factor was included in the standardization process to account for the implementations of red snapper IFQs in 2007. Given that red snapper IFQs may impact vermilion snapper CPUE (due to potential changes in targeting behavior), it was deemed inappropriate to continue to ignore the IFQ variable. To account for red snapper IFQs, the commercial CPUE indices were truncated in 2006 (blue lines) assuming no IFQ variable and a new timeseries was begun in 2007 (purple lines) with the IFQ variable included. The non-truncated timeseries with no IFQ variable (green lines) is shown for comparison to the 2011 update indices. The truncated timeseries with no IFQ show similar patterns to the 2011 update, while the new IFQ timeseries, not surprisingly, show different trends from the 2011 update. Since 2007, the western stock has been relatively stable, whereas the eastern stock has shown a generally increasing trend that has leveled off over the last three years. All indices are normalized to their mean.

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 (Contractor)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** Contribute with conservation efforts towards the northern right whale by educating and improving the awareness of mariners on the plight of the right whale.

***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. Complying vessels are provided with a return message containing information about how to reduce the risk of ship strikes with whales, which includes the location of latest whale sightings.

CIMAS Research Theme:

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

Link to NOAA Strategic Goals:

***Goal 1*:** Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems*

NOAA Funding Unit: NMFS/OPR/MMSTCD and USCG
NOAA Technical Contact: Molly Baringer

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 U.S Coast Guard (USCG) upon entering two designated report areas (Figure 1).

In 2013, the National Marine Fisheries Service (NMFS) and the USCG opted for transitioning the system to an in-house government facility because of certain I/T security requirements. The new version of the MSR, fully developed and hosted by AOML/PhOD, became operational on April 1st, 2014. Since it became operational, the system hosted at AOML has received and processed more than **8,300** reports. All vessels reporting to the MSR were provided with a response message containing information on how to avoid collisions with whales, speed limit requirements, and the location of latest whale sightings.

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.

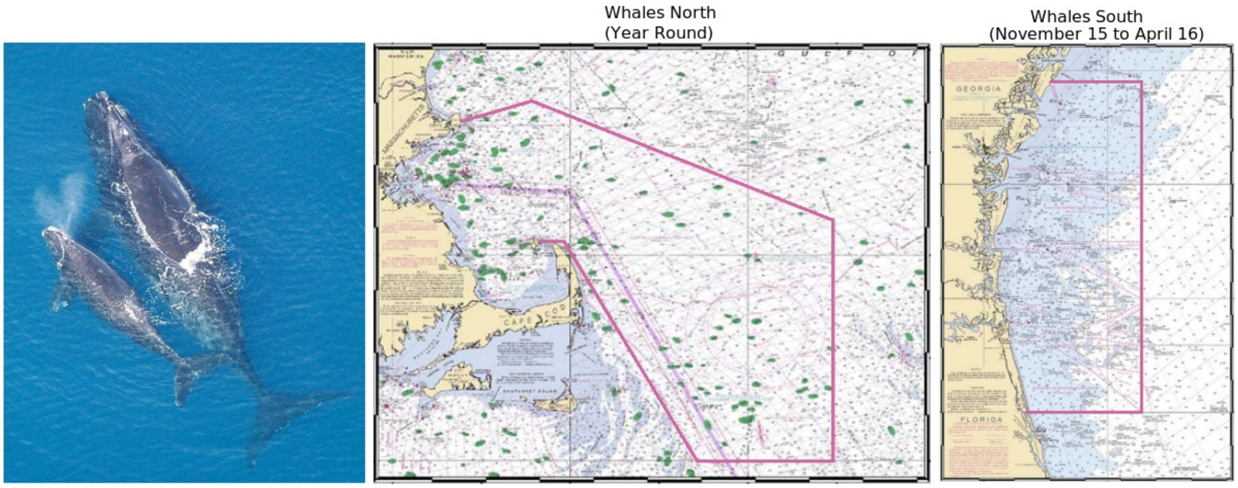


Figure 1: (left) North Atlantic right whale with calf. The (center) Whales North and (right) Whales South reporting areas along the east coast of United States within the Mandatory Ship Reporting system. The reporting requirements for each area are emphasized above the maps.

Research Performance Measure: All planned goals were met during this year. During the period between July 1, 2015 and June 30, 2016, the MSR hosted at AOML has received and processed more than 3,500 reports. Ships reporting to the MSR were provided with an automated response message containing information on how to avoid collisions with whales, including the location of the latest whale sightings.

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Coral Restoration and Recovery

Project Personnel: R.E. Pausch, A.J. Bright and D.E. Williams (UM/CIMAS)
NOAA Collaborators: M.W. Miller (NOAA/SEFSC)
Other Collaborators: Coral Restoration Foundation, Mote Marine Lab

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 under the Endangered Species Act.

***Strategy*:** To undertake observational and experimental studies to evaluate factors affecting and potentially enhancing coral success, especially of early life stages and cultured/restocked colonies.

CIMAS Research Theme:

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

Link to NOAA Strategic Goals:

***Goal 1*:** 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, especially those under protection as threatened species. The first component involves studies related to spawning, larval and post-settlement ecology of broadcast-spawning coral species (particularly *Acropora* spp. and *Orbicella faveolata*). During the current project year, we completed a second year of intensive genet-specific spawning observations for *O. faveolata* at Horseshoe reef. Eight of 28 genets under observation failed to spawn over the 6 expected nights (August 6-8 and September 3-5). We also completed focused experiments documenting larval duration, survivorship, and competency curves over time for these two species. Overall, *A. palmata* shows peak settlement at day 8-9 following spawning, at which time approximately 75% of the larval cohort remained alive. For *O. faveolata*, settlement response is well-developed earlier, by day 4-5, though only about 50-60% of *O. faveolata* fertilized embryos survived this long. As part of a collaborative effort with Mote Tropical Marine Research Lab, we had unprecedented success this year in culturing post-settlement *O. faveolata*, with over 8000 polyps (recruits) thriving at the Mote facility into spring 2016 (Fig 1). This provides opportunity to experiment with using these larval recruits for reef population enhancement in the coming year.

Figure 1: *Orbicella faveolata* recruits settled from larvae in Aug 2015 and cultured in collaboration with Mote Tropical Research Lab. An unprecedented 8000 recruits of this threatened species are thriving in lab culture over six months. (Photo credit: C. Page).

We implemented a new experiment under another project component evaluating aspects of outplant design for cultured fragments of elkhorn coral (*A. palmata*). This experiment, initiated in May 2015, was designed to compare the performance of four different genetic individuals across distinct habitat types (fore-reef versus patch reef; three sites each). Preliminary results of this experiment provide definitive evidence that the four genetic individuals tested show marked variation in their thermal bleaching tolerance during the high temperature stress experienced during summer 2015 (Fig 2). This is important knowledge on a climate-resilience trait for this keystone reef-building coral.

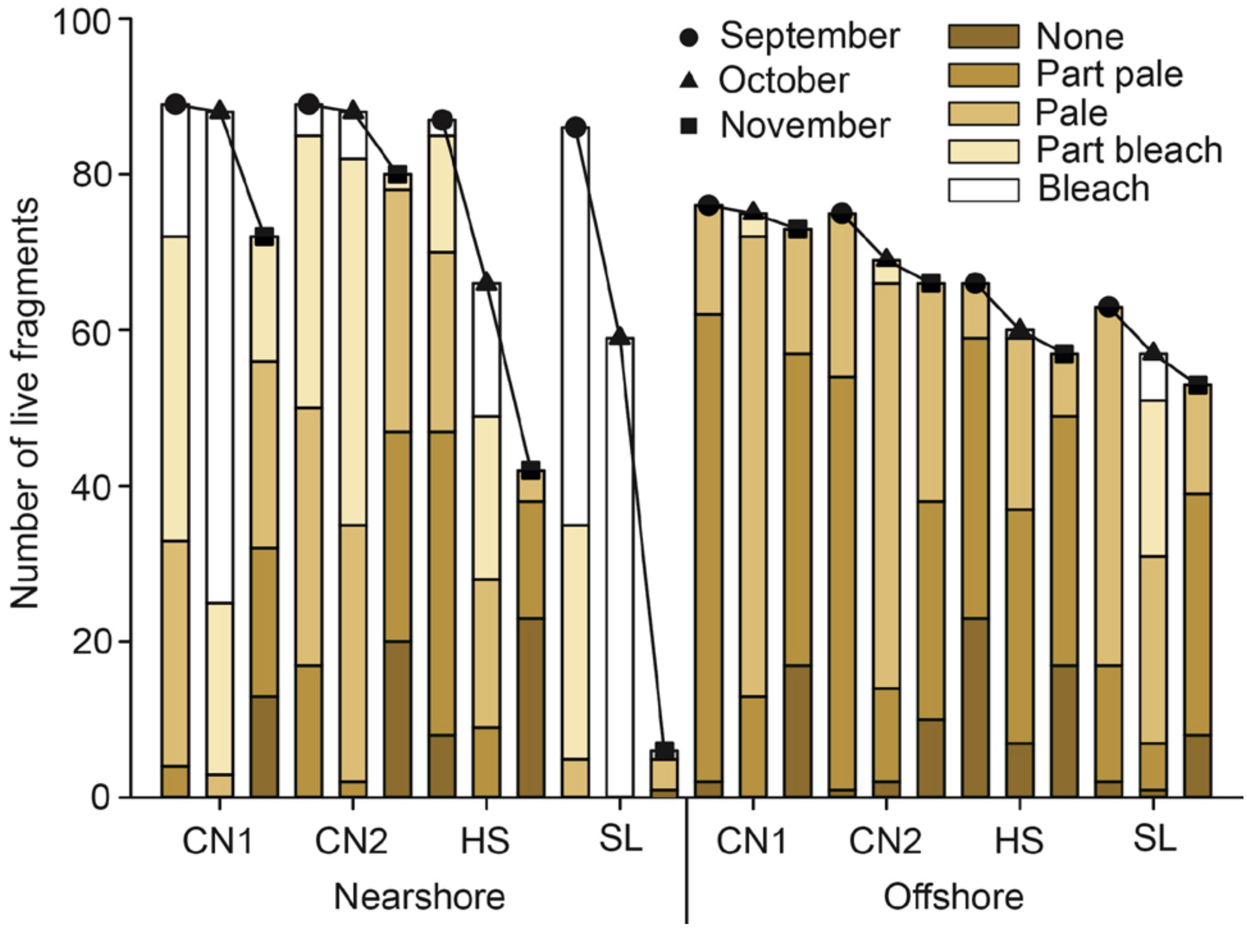


Figure 2: Bleaching score composition of *Acropora palmata* outplanted fragments in Sept, Oct. and Nov 2015. Fragment genotype and habitat treatments are shown on the x-axis. Bleaching was substantially worse in the nearshore patch reef (compared to offshore reef) habitat. Also, the SL genotype showed much higher bleaching susceptibility in both habitats than the other three genotypes, which translated into high mortality in the patch reef habitat.

Research Performance Measure: Intensive field work is involved with each project component. We were successful in implementing the second *A. palmata* outplant experiment as planned (May 2015) and were successful in performing spawning and larval experiments in Aug-Sept 2015.

Quantitative Tools to Study Individual to Population-Level Implications of Marine Animal Movement

Project Personnel: N. Putman (UM/CIMAS)
NOAA Collaborators: P. Richards (NOAA/SEFSC); G. Goni (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To develop quantitative approaches for modeling movement of protected species, integration of population processes with oceanographic models, and development of tools that can be utilized for management of these resources.

***Strategy*:** To link behavioral data from telemetry studies to oceanographic processes through comparison with ocean circulation model output and simulate population level processes driven by demographic parameters, organism behavior, and environmental conditions.

CIMAS Research Theme:

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

Link to NOAA Strategic Goals:

***Goal 1*:** Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems* (*Primary*)

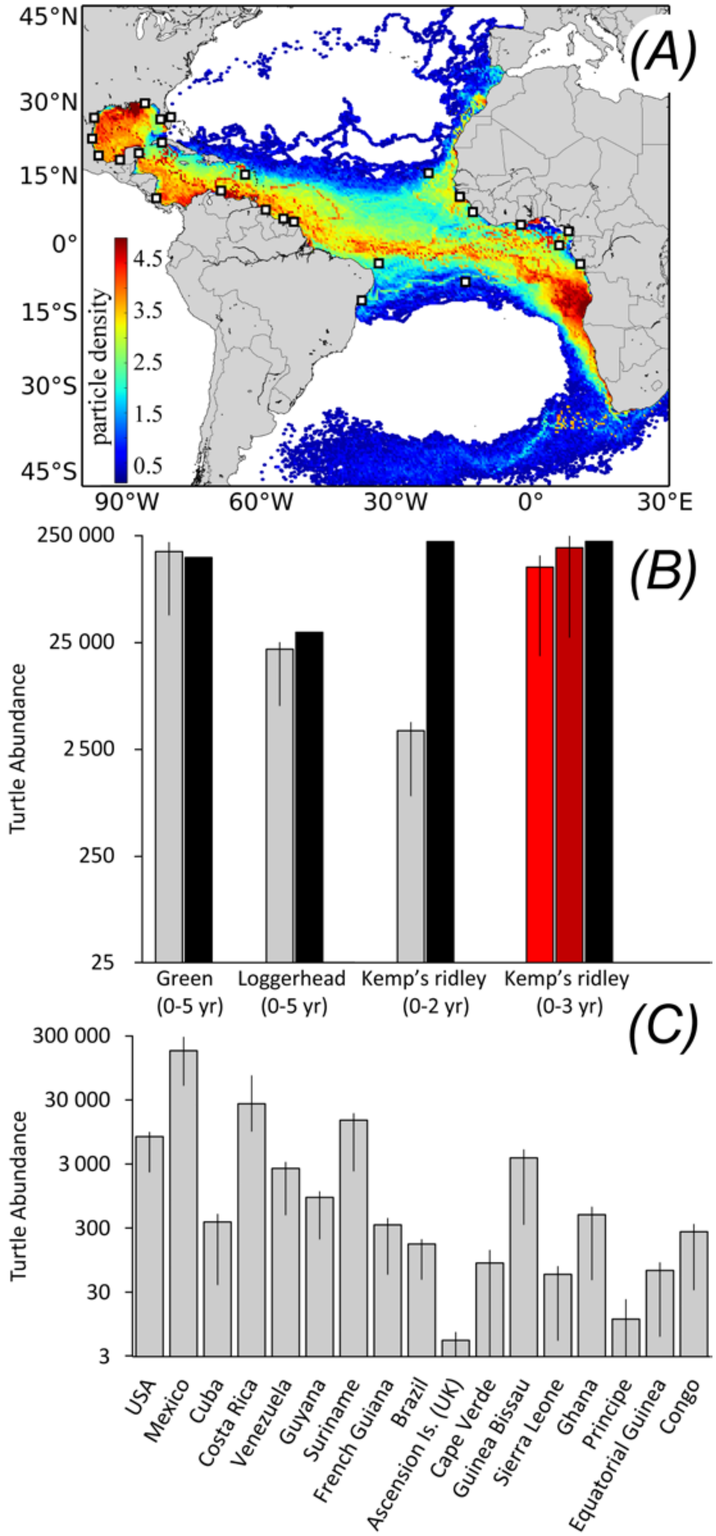
***Goal 3*:** Climate Adaptation and Mitigation - *An informed society anticipating and responding to climate and its impacts* (*Secondary*)

NOAA Funding Unit: NMFS/SEFSC; OAR/AOML
NOAA Technical Contact: Theo Brainerd; Molly Baringer

Research Summary:

The project began with CIMAS on March 2, 2015 as a continuation of work began with the National Research Council: *A "movement ecology" approach to predicting the oceanic distribution of sea turtles*. To date we have developed novel ways to mechanistically predict the movement, distribution, and abundance of juvenile sea turtles using lab and field-based information on swimming behavior, demographic parameters, and ocean circulation model output. These predictions are being further refined as we develop new ways to extract turtle behavior from tracking data through paired releases with surface-drifters and subsequently subtracting modeled ocean velocity from track velocity. We are currently working to apply this work to specific areas of interest and a variety of other taxa – ranging from cnidarians to fishes. At the beginning of April his project transitioned from being housed at the SEFSC (under the mentorship of Dr. Paul Richards) to AOML (under the mentorship of Dr. Gustavo Goni).

Research Performance Measure: Research performance is measured in terms of peer-reviewed publications produced. A manuscript showing how demographic information can be layered into models of physical transport to estimate abundance of juvenile turtles at the site of the DWH spill was published in *Biology Letters*. Other publications include identifying physical transport mechanisms that influence the genetic population structure of sea turtle foraging grounds and sensory basis by which turtles can re-locate small oceanic islands for nesting.



We investigated the extent that the 2010 Deepwater Horizon oil spill potentially affected oceanic-stage sea turtles from populations across the Atlantic. (A) Within an ocean circulation model, particles were backtracked from the Gulf of Mexico spill site to determine the probability of young turtles arriving to this area from major nesting beaches (white squares). Abundance of turtles in the vicinity of the oil spill was derived by forward-tracking particles from focal beaches and integrating population size, oceanic-stage duration, and stage-specific survival rates. (B) Simulations indicated that as many as 213,248 green (Chelonia mydas), 24,646 loggerhead (Caretta caretta), and 243,804 Kemp's ridley (Lepidochelys kempii) turtles were likely within the spill site (grey bars). These predictions compared favorably to estimates from in-water observations recently made available to the public (black bars). Though our initial predictions for Kemp's ridley were substantially lower than in-water estimates, better agreement was obtained with modifications to mimic behavior of young Kemp's ridley turtles in the northern Gulf (red bars). (C) Simulations predicted 75.2% (71.9-76.3%) of turtles came from Mexico, 14.8% (11-18%) from Costa Rica, 5.9% (4.8-7.9%) from countries in northern South America, 3.4% (2.4-3.5%) from the United States, and 1.6% (0.6-2.0%) from west African countries. Thus, the spill's impacts may extend far beyond the current focus on the northern Gulf of Mexico.

Marine Mammal Genetics Research

Project Personnel: C.G. Sprehn (UM/CIMAS)
NOAA Collaborators: P.E. Rosel (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** 1) To assist the Southeast Fisheries Science Center (SEFSC)'s Marine Mammal Molecular Genetics Laboratory (MMMGL) in research related to the characterization and assessment of Gulf of Mexico (GOMx) and western North Atlantic bottlenose dolphins (*Tursiops truncatus*) and other marine mammal populations. 2) To support the investigation of the 2013 Mid-Atlantic UME. 3) To support general lab functionality and data and sample management.

***Strategy*:** 1) To analyze biopsies collected in shelf waters of the northern GOMx in 2015. 2) To genotype selected animals of known stock and compare animals involved in the 2013 Mid-Atlantic unusual mortality event (UME) to identify source stocks. 3) To organize and archive received samples and manage their associated data in a comprehensive database. 4) To assist with general laboratory upkeep.

CIMAS Research Theme:

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

Link to NOAA Strategic Goals:

***Goal 1*:** 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 SEFSC is responsible for assessing the status of marine mammal stocks in the GOMx and U.S. waters of the western North Atlantic. Detecting changes in marine mammal populations can help indicate changes in overall ecosystem health and therefore inform wide scale conservation actions. Genetic data collected from biopsies provides a basis to examine stock structure. Past work has shown that current stocks may not accurately represent biological populations. More biologically accurate stock delineations can increase the efficacy of conservation and management efforts.

In 2015, a total of 222 biopsies were collected during a ship-board survey in shelf waters of the northern GOMx. The majority of biopsied animals were bottlenose dolphins and Atlantic spotted dolphins, but some unknown and miscellaneous marine mammals were also collected. We are in the process of extracting genomic DNA, determining sex, and generating genetic data through mitochondrial DNA control region sequencing for each biopsied animal. These data will contribute to the long-term archival data set used to evaluate population structure and demographics, help inform stock assignments of bottlenose dolphins in the GOMx, and assess anthropogenic and environmental impacts to inform conservation strategies.

I have also been organizing samples and their associated data for archival storage. I was responsible for quality assurance and database management for over 750 samples. I was similarly responsible for intake and subsequent processing of any samples received from collaborators throughout the Southeast region on a continuous basis.

Figures 1: Common bottlenose dolphin surfacing. Taken under NMFS SEFSC MMPA Permit No 779-1633.

Research Performance Measure: all objectives were completed on time or are ongoing. 1) Processing samples (including DNA extraction, sexing, and mtDNA sequencing) from the 2015 Gunter cruise. 2) Assisting with the completion of genotyping samples to identify stock assignments for animals associated with the 2013 Mid-Atlantic UME. 3) Organizing and verifying data entry for samples in archival storage and database management for tissue samples. 4) Helping maintain stocks of laboratory reagents. 5) Trainings accomplished: Globally Harmonizes System of Classification and Labeling of Chemicals; Hazard Communication Standard; Safety, Environmental, and Sustainability Awareness; NOAA IT Security Awareness.

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Evaluation of Methods of Incorporating Oceanographic Indicators into Indices of Abundance for Stock Assessment

Project Personnel: F.C. Forrestal (UM/CIMAS)
NOAA Collaborators: M. Schirripa (NOAA/SEFSC); S.-K. Lee (NOAA/AOML)
Other Collaborators: P. Goodyear (Independent Scientist)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To determine how best to incorporate environmental variables into the stock assessment process for pelagic fish stocks.

***Strategy*:** To use a longline CPUE (catch per unit effort) simulator (LLSIM) to simulate known data for testing a suite of hypotheses concerning how best to incorporate environmental variables.

CIMAS Research Theme:

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

Link to NOAA Strategic Goals:

***Goal 1*:** 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:

It is now a generally accepted fact that variation in the planet's climate and its effects on the world's oceans is increasing. For marine fish, specifically those of the highly migratory nature, this increased climate variation has led to changes in distribution, migratory patterns, and susceptibility to various fishing gears. Many of these changes have created situations where there is no historic analog to the current climatic and biological conditions. These changes become especially problematic when they manifest themselves through the fishery dependent indices of abundance (such as catch-per-unit-effort, or CPUE) used to assess the status of the stocks, such as is done routinely by the International Commission for the Conservation of Atlantic Tuna (ICCAT).

One of the key aspects of CPUE interpretation is the catchability factor, usually denoted by *q*. The *q* parameter denotes the extent in which the population at large is available to the gear from which the CPUE is derived. CPUE is a function of both stock abundance and the *q* of the fishing gear; however, these two factors are many often times convoluted. For example, the population size of the stock could remain relatively stable year-to-year, but changes in other time dependent functions, (e.g. species distribution, gear configuration, species targeting) can result in changes in *q* that will in turn result in variations in the estimated CPUE, despite the constant stock size. In this way, time varying *q* is especially troublesome.

The NOAA/NMFS Ecosystem Based Fisheries Management Policy sees "advancing our understanding of ecosystem process" as the foundation guiding principle towards best to incorporate environmental variables into the stock assessment process. Specifically, to conduct science to understand ecosystem processes, drivers, and threats which include oceanographic features and other environmental factors.

Previously, the ICCAT Working Group on Methods recommended the use of simulated data sets with known values of underlying population trends to test the robustness of CPUE standardization methods. Dr. Philip Goodyear developed a longline CPUE data simulator (LLSIM) to meet this requirement to simulate known data for testing a variety of hypotheses. Data describing the physical environment within the modeled region are used to predict fish abundances using a habitat suitability model (HSM). This approach is in common use for predicting habitat quality from habitat suitability indices (HSI) based on ecological niche theory. Applications to billfish species include the identification of potential new fishing grounds and forecasts the effects of climate change. This project applies HSM to address issues important to stock assessment.

The objective of this project is to arrive at "best practices" recommendations for how best to incorporate environmental variables into the stock assessment process. While the study will be designed around catchability of Atlantic swordfish, the results will be able to provide much more universal guidance on the handling and use of environmental data. Dr. Michael Schirripa has a lead role in developing and conducting the ICCAT Atlantic swordfish assessment. Dr. Francesca Forrestal has experience with ecosystem modeling and is conducting the analyses in this project. Dr. Philip Goodyear built the Longline simulator used in this project and Dr. Sang-Ki Lee provides the environmental data used in this project.

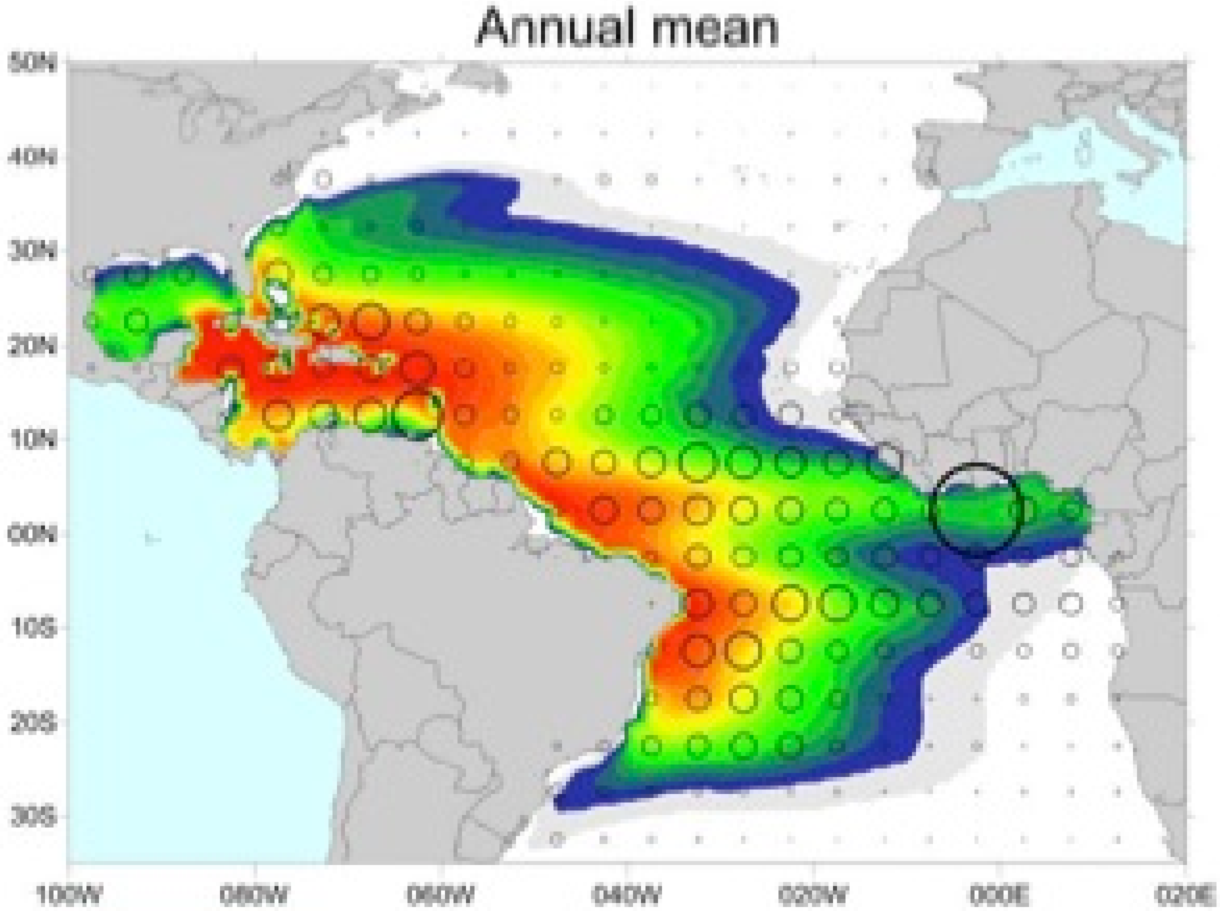


Figure 1: Isopleths of HSM-predicted areal distribution of blue marlin habitat averaged over all months and the 1956-2012 total blue marlin catch on longlines by 5° by 5° latitude-longitude bins (circles). The contour scale depicts the ratio of the abundance summed over depth at the geographic position to the average maximum abundance. The area of each circle is proportional to the catch in that bin. The catch data are from the CATDIST data files maintained by ICCAT.

Research Performance Measure: The research program is on schedule.

Marine Mammal Research

Project Personnel: J. Wicker (UM/CIMAS),
NOAA Collaborators: L. Garrison, A. Martinez, J. Contillo and J. Litz (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.

***Strategy*:** 1) To perform field work and data management during marine mammal sampling efforts in the Gulf of Mexico and Atlantic Ocean. 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. 2) To support the West Florida Bottlenose dolphin Cruise by collecting biopsy samples, photographic data, acoustic data and visual data. 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:

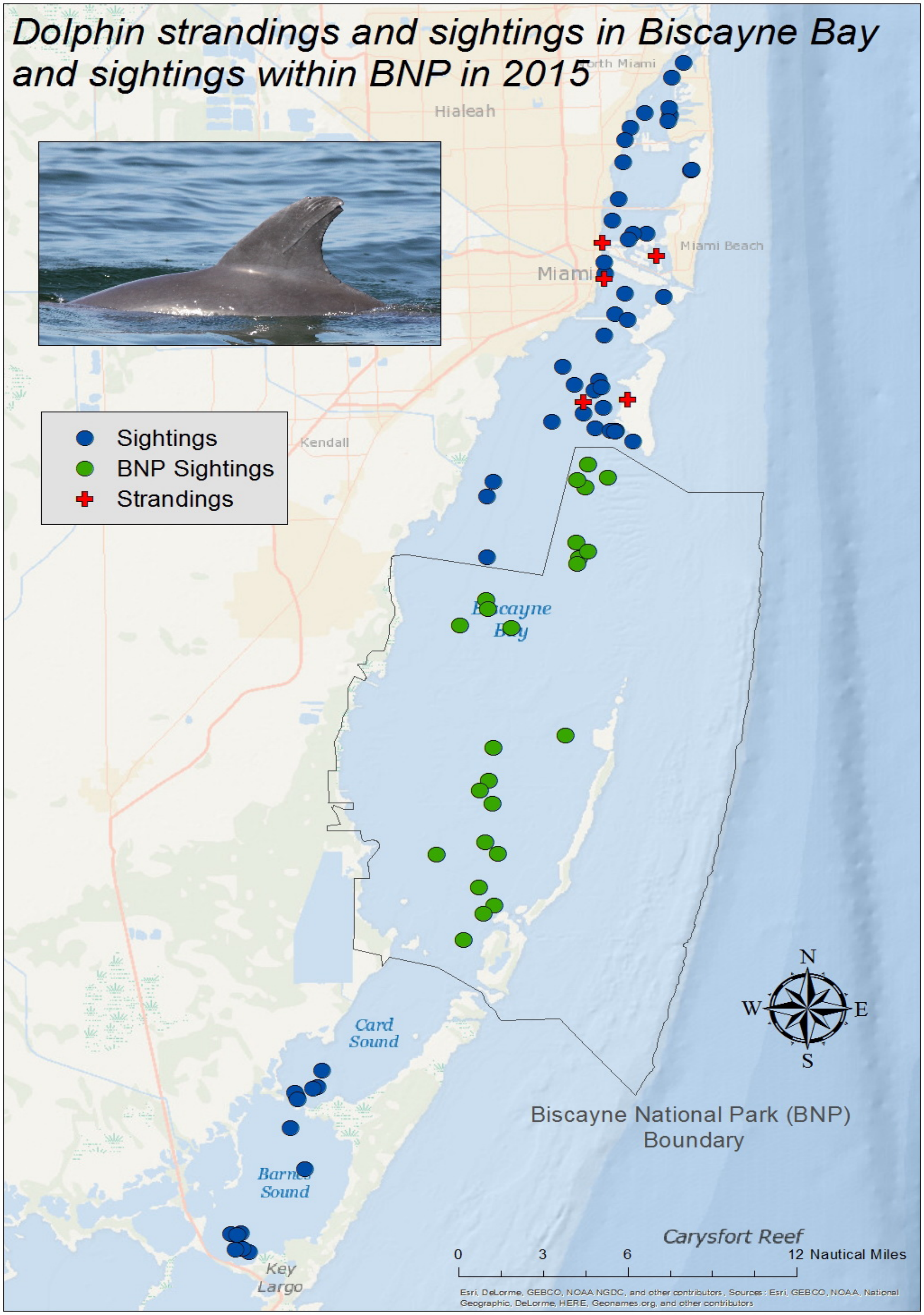
***Goal 3*:** Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems*

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 332 marine mammal sightings, 222 biopsy samples, and 3,500 (km) of visual survey effort. The summer 2015 West Florida Bottlenose dolphin Cruise assessed the abundance, habitat and spatial distribution of Bottlenose/Atlantic spotted dolphins through visual and passive acoustic monitoring, and biopsy sampling.

Research Performance Measure: all objectives were completed on time. 1) 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. 2) Served as a small boat coxswain/FPC onboard NOAA ship Gordon Gunter during the marine mammal large vessel survey during the summer of 2015. 3) Assisted in the development of cruise plans and lead survey teams while in the field. 4) Maintained and verified data quality, interacting with principal investigators to effectively execute scientific methodology during the cruises. 5) Managed and updated the Biscayne Bay Photo ID Database and continued to import historical data into FinBase database. 6) Assist in NOAA small boat field work through SE United States.


Dolphin strandings and sightings in Biscayne Bay and sightings within BNP in 2015
North Miami
Hialeah
Miami Beach
Miami
Kendall
Sightings
BNP Sightings
Strandings
Biscayne Bay
Card Sound
Barnes Sound
Key Largo
N
W
E
S
Biscayne National Park (BNP) Boundary
Carysfort Reef
0
3
6
12 Nautical Miles
Esri, DeLorme, GEBCO, NOAA NGDC, and other contributors, Sources: Esri, GEBCO, NOAA, National Geographic, DeLorme, HERE, Geonames.org, and other contributors

VII. EDUCATION AND OUTREACH

CIMAS research has, since its inception, worked hard in integrating its core science activities with the educational enterprise through the RSMAS graduate academic program. After the expansion of CIMAS to additional University partners, CIMAS has expended this link to other academic programs in other Partner Universities. The major example of this expansion 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. "Florida FWC" refers to employees of the Florida Fish and Wildlife Conservation Commission. USF MRA students supported by NOAA-sponsored fellowships under the present award are identified by a double asterisk (**); these fellowships first became available during Fall 2011.

MRA Core Courses
Fish Biology, taught Spring 2009 (course was taught prior to present award as part of the MRA program) 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)

This course was taught for the fourth time during Fall 2015 by Christopher Stallings and Ernst Peebles of USF-CMS. (8 students and one visiting-scientist auditor – 0% agency)
USF students: Krista Abbott, Kristie Armas, Megan Hepner, Alexander Ilich, Brianna Michaud, Tess Rivenbark, Kelly Vasbinder, Julie Vecchio
Florida FWC students: none
NOAA students: none

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

This course was taught for the third time during Fall 2014 by Cameron Ainsworth of USF-CMS (8 students, including 5 agency employees - 63% agency)
USF students: Joseph Curtis, Brianna Michaud, Kara Wall
Florida FWC students: Oscar Ayala, Brittany Combs, Benjamin Kurth, Claire Crowley
NOAA students: Katie Davis (NMFS SERO, St. Petersburg)

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

This course was taught for the third time during Spring 2015 by David Jones of USF-CMS (8 students, including 1 agency employee - 13% agency)

USF students: Steven Douglas, Michelle Hoffman, Kimberly Lyons, Jason Richardson, Shaojie Sun, KaraWall, Mengqui Wang
Florida FWC students: none
NOAA students: Katie Davis (NMFS SERO, St. Petersburg)

This course was taught for the fourth time during Spring 2016 by David Jones of USF-CMS (6 students; 0 agency employees)

USF students: Kate Dubickas, Christian Gfatter, Brianna Michaud, Kelly Vasbinder, Julie Vecchio, Elizabeth Simpson
Florida FWC students: none
NOAA students: none

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

This course was taught for the third time during Spring 2015 by Kendra Daly and Mark Luther of USF-CMS (8 students, including 1 agency employee - 13% agency)

USF students: Oscar Ayala, Kate Dubickas, Megan Hepner, Selena Johnson, Michelle Michaud, Ann Sager, Elizabeth Simpson
Florida FWC students: none
NOAA students: Katie Davis

MRA Elective Courses

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

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

This course was taught for the second time during Spring 2016 by Cam Ainsworth of USF-CMS (8 students, including 3 agency employees – 38% agency).

USF students: Elizabeth Simpson, Brianna Michaud, Kaitlyn Colna, Kelly Vasbinder, Melissa Rohal
Florida FWC students: Brittany Combs, Ben Kurth
NOAA students: Walter Ingram (audited)

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.

Special Topics in Biometry, taught Fall 2014 by David Jones of USF-CMS (11 students, including 2 agency employees - 18% agency)

USF students: Sean Beckwith, Dinorah Chacin, Marcy Cockrell, Joseph Curtis, Brock Houston, Abdiel Laureano-Rosario, Tasha Snow, Kara Wall, Mengqui Wang
Florida FWC students: Benjamin Prueitt
NOAA students: Katie Davis (NMFS SERO, St. Petersburg)

This course was taught for the second time during Fall 2015 by David Jones of USF-CMS (8 students, including 3 agency employees – 38% agency)

USF students: Erin Cuyler, Christian Gfatter, Kate Dubickas, Brianna Michaud, Jen Granneman
Florida FWC students: Brittany Combs, Mike Murphy
NOAA student: Nic Alvarado

MRA Graduates (All Years)

Claire Crowley (M.S., Spring 2012); employed by FWC FWRI
Catherine (Bruger) Hayslip (M.S., Fall 2013); left the field
Beverly Sauls (M.S., Fall 2013); employed by FWC FWRI
Sky Williams (M.S., Fall 2013); North Pacific Groundfish Observer at Saltwater Inc.
Alisha Gray (M.S., Spring 2014); employed by FWC FWRI
Mary Janine Vara (M.S., Spring 2014); employed by NMFS SERO
Brittany Hall (M.S., Summer 2014); employed by FWC FWRI
Holly Rolls (Ph.D., Summer 2014); left the field
Dinorah Chacin (M.S., Summer 2014); continuing in MRA program as Ph.D. student
Susan Snyder (M.S., Fall 2014); continuing in MRA program as Ph.D. student
Sennai Habtes (Ph.D., Fall 2014); employed as assistant professor at the University of the Virgin Islands
Elizabeth Herdter (M.S., Fall 2014); continuing in MRA program as Ph.D. student
Sarah Grasty (M.S., Fall 2014); continuing in MRA program as Ph.D. student
Brock Houston (M.S., Summer 2015, employed as sales engineer at YSI Instruments)
Sheri Huelster (M.S., Summer 2015, employed as project scientist at Cardno)
Orian Tzadik (Ph.D., Fall 2015, employed by FWC FWRI)

RESEARCH HIGHLIGHTS – MRA FELLOWSHIP RECIPIENTS:

During the past year, five doctoral students were supported by fellowships under the present award. Below are highlights of each of the student's doctoral research projects.

Marcy Cockrell (advisor: Dr. Steve Murawski): Development of a decision-support framework for implementing marine protected areas on the West Florida Shelf.

Marcy has been working on a project jointly funded by NOAA and the National Science Foundation to understand choice behavior of where and when to fish and what species to target.

This research has used accumulated satellite tracking data (>28 million position records) of reef-fish fishing vessels in the Gulf of Mexico. Data analyzed to date indicate significant spatial patterning and a significant habitual component to areas fished. Working with economists from the University of California, Davis, the research will include economic models of fisher's choice as well as the development of metrics of the degree of entropy in spatial fishing patterns. The attached figure provides spatial information for the number of site locations visited by one minute of latitude and longitude for the second half of 2009.

Michael Drexler (advisor: Dr. Cameron Ainsworth): An Atlantis model for the Gulf of Mexico (Atlantis-GoM):

Ecosystem-based management strategies for the Gulf of Mexico are being developed in support of NOAA's Integrated Ecosystem Assessment (IEA) Program. Integrating ecosystem considerations into fisheries management is a current scientific and policy priority for our NMFS partners. While the goals of the IEA process are broad and may be reached through a myriad of management strategies, Marine Protected Areas (MPAs) have the potential to impact multiple desired management outcomes.

For his research, Mike will continue to develop the Atlantis-GOM ecosystem model, incorporating all of the best information available through a network of federal and state collaborators. In addition, he has developed sub-models that estimate adult abundance across the entire GoM via habitat modeling and long-term population connectivity based on physical transport. These models will be incorporated into the larger Atlantis-GoM model and used to perform a spatially based management strategy evaluation, testing the expanded use of MPAs throughout the GoM and their connectivity across multiple species. The results from these simulations will improve our understanding of how spatially based fisheries management strategies affect ecosystems and provide strategic management advice regarding MPAs in the GoM.

Mike has completed one manuscript that examines altered larval dispersal patterns resulting from exposure to oil from the Deepwater Horizon event, and another that details results for an individual-based-model of larval transport in the Gulf of Mexico. He has recently taken a full-time job at the Ocean Conservancy, but continues to make good progress on his dissertation.

Joshua Kilborn (Co-advisors: Dr. David Naar and Dr. Ernst Peebles): Projecting longline CPUE using SEAMAP trawl catch composition and dynamic environmental factors.

Joshua is developing new multivariate techniques to identify statistically distinct communities of groundfishes on the West Florida Shelf (WFS), as represented by the Southeast Area Monitoring and Assessment (SEAMAP) summer groundfish trawl surveys (2010-2013). Discrete community types are being examined for stability in space and time and are being associated with environmental parameters. A second, independently collected dataset, produced by National Marine Fisheries Service longline sampling in the summer months of 2010-2012, is being examined as well to identify spatiotemporal correlations between high catch-per-unit-effort (CPUE) for longline catch and the previously identified groundfish community/environment types. The goal of the project is to produce a predictive model that can forecast likely

distributional changes in longline-associated species based on the SEAMAP trawl data and dynamic environmental variables. The model predictions can be used to increase the efficiency of future index surveys and to inform managers of the effects of changing biotic and abiotic conditions on the WFS.

Orian Tzadik (advisor: Dr. Christopher Stallings): Non-lethal alternatives to otoliths for application to juvenile groupers. Dr. Tzadik graduated in Fall 2015 and is now employed at FWC FWRI.

Ori is developing new, non-lethal approaches to retrospective analysis of individual fish life histories, including the history of such characteristics as movement and shifts in trophic position. This project is currently being applied to the Goliath Grouper other species of management concern in the Gulf of Mexico. More information on his project can be found at http://www.juvenile-grouper-project.com/index.php?subject=articles&page=7

Amy Wallace (advisor: Dr. Ernst Peebles): New methods for reconstructing site fidelity, movement, and trophic histories for predatory fishes in the Gulf of Mexico.

This project has developed new, stable-isotope-based method for reconstructing lifetime site fidelity and trophic position histories of individual fish using eye lenses as conservative isotope recorders (manuscript submitted). The first chapter of her dissertation was published in *PloS One* during 2014 – it is the first publication ever to address fish eye lenses and lifetime isotopic records. Additional efforts are underway to provide information that will improve the power and accuracy of the method.

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 and the success of this program in serving the needs of NOAA has been highlighted in previous CIMAS annual reports. In 2014, RSMAS was restructured into a departmentalized school. New Ph.D. and MS degrees within the five new departments are 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 and Marine Biology and Fisheries will continue to remain a strength of the RSMAS program. Currently there are close to 200 students enrolled in the RSMAS PhD and MSc programs, 80% of whom are in the Ph.D. programs.

In addition to the involvement of CIMAS in the formal RSMAS graduate curriculum, CIMAS also funds and coordinates specialized training activities of interest to NOAA and CIMAS scientists and local students. Often a national or international expert is invited to cover a methodological topic of special relevance to NOAA science. In the last year CIMAS has supported 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 training and teaching of graduate level courses 4) promoting Post-doc opportunities associated with NOAA labs and 5) funding students to participate in professional experiences along with NOAA scientists attending fish stock assessment meetings associated with the US fishery council process and ICCAT. Note that only those joining the NOAA associated workforce that are CIMAS employees (as scientists or post-docs) appear in our annual report. Another aspect of the connection with UM through CIMAS is that CIMAS employees working at the adjacent laboratories are eligible for tuition remission. Many have obtained M.S. degrees during their employment period and a smaller number have graduated from (and are currently enrolled in) the RSMAS Ph.D. programs. Tuition waivers are not provided to UM employees for terminal degrees (Ph.D., J.D., M.D.) but a few CIMAS employees have even received a waiver exempting them from all tuition requirements for their Ph.D. work. In all these cases, their thesis or dissertation work overlaps and complements their primary CIMAS duties.

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. Most of the MPS tracks are relevant to NOAA. Examples include: computational meteorology and oceanography, exploration science, fisheries management and conservation, marine aquaculture, tropical marine ecosystem management, marine conservation, coastal zone management and weather forecasting. This program now has an enrollment of about 150 students and some of these students complete their internships in NOAA labs or collaborate with NOAA scientists, in some cases supported by CIMAS funds in other cases directly funded by NOAA.

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 2015, more than 120 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 ongoing research collaboration 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 RJ Dunlap Marine Conservation Program. The RJ Dunlap 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. Beth Babcock, the UM P.I. of the Living Marine Resources Cooperative Science Center (LMRCSC) and of the collaboration of Dr. David Die CIMAS Associate Director who serves as UM representative in the LMRCSC science committee. This center is aligned with NMFS and therefore has as its 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, CIMAS supports the activities of the LMRCSC by funding part of the research and studies of the LMRCSC students who are housed at RSMAS. Moreover, the participation of US Caribbean universities in CIMAS benefits the LMRCSC by enhancing the recruitment of a diverse student body. Currently the program funds two PhD students and funded an additional MSc student earlier in the 2015 academice year.

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

CIMAS sponsored five climate education workshops covering the basics of climate in terms of understanding how greenhouse gases affect global climate, sea level rise, sea-ice concentration and thickness, land ice cover and the Earth's albedo. Elements of ecosystem science were also covered. The workshops included a total 133 attendees and also showcased how CIMAS science contributes to understanding climate variability and change. The workshop attendees were polled to assess how the training contributed to their understanding of climate - across all the workshops 68% of the participants felt "empowered to learn more avout climate change."

In addition, CIMAS projects have their own specific outreach components, listed in the section below according to project names:

Western Boundary Time Series Project

- C. Meinen was interviewed over the phone by a reporter for Science magazine on the latest updates to the Meridional Overturning Circulation ("MOC") arrays in the Atlantic on Tuesday, April 26th, 2016.

Hurricane Risk to U.S. Offshore Renewable Energy Facilities

- Department of Energy Webinar on Offshore Wind Energy: Characterizing Hurricane MET-Ocean conditions for design of offshore wind farms, Jan. 15. Dr. Mark Powell was one of three presenters.
- Dr. Mark Powell conducted a review of the IEC international standard for relevance to Hurricane Design conditions. March 2015.

Developing Decision Support Tools for Understanding, Communicating, and Adapting to the Impacts of Climate on the Sustainability of Coastal Ecosystem Services

- G. Cook - 2015 Review Panel for NOAA Ernest F. Hollings and Educational Partnership Program Undergraduate Scholarship Programs.
- Co-PI Kelble's related project work received coverage in the Miami Herald, Local & State section, on Monday May 4th. The article, entitled *Dry Winter, slow Glades progress put Florida Bay at risk*, written by Jenny Staletovich of the Herald, and includes quotes from Kelble concerning the impact of climate on precipitation and how elevated salinity in Taylor Slough (which flows into our central study region, Florida Bay) was due to an unseasonably dry winter, and how that can have downstream effects on the biotic components of our central sub-region.
- Project personnel conducted three separate Expert Opinion Polling sessions throughout South Florida, engaging managers and stakeholders to better the conceptual models that had been devised.

Coral Health and Monitoring Program (CHAMP)

- A study by Enochs and colleagues was covered in the popular media by The Miami Herald, Bradenton Herald, Environmental Monitor, Gizmodo.com, IFLScience.com, Climate Wire, Yahoo News, TorontoStar.com, ScienceDaily.com, among others.
- Media coverage of Xaymara Serrano's *Porites astreoides* paper published in 2016:
  UM Press release:
  http://www.rsmas.miami.edu/news-events/press-releases/2016/um-researchers-found-shallow-water-corals-in-florida-are-not-related-to-the/
  WLRN radio interview:
  http://wlrn.org/post/floridas-coral-getting-help-hundreds-miles-away
- Ruben van Hooidonk gave a presentation "the importance of coral reef conservation" at a TEDx event organized by the Dutch consulate, September 23, 2015.

Global Drifter Program

- In conjunction with the Adopt A Drifter Program, S. Dolk participated in numerous educational outreach programs, working with middle schools around the world to deploy and track drifting buoys. Through these efforts, students learn about the impacts of ocean currents and how this information is used to track marine debris, spilled oil, fish larva, etc.
- S. Dolk mentored 2 high school students, from MAST Academy, for summer internships during the summer of 2015.
- R. Perez participated in several K-12 outreach events at UM/RSMAS, NOAA/AOML and local schools including My Brothers Keeper in March 2016, and co-mentored a NOAA Hollings scholar during the summer of 2015.
- R. Perez, E. Valdes, R. Lumpkin, and M. Pazos participated in Bring Your Child to Work Day.

Southwest Atlantic Meridional Overturning Circulation ("SAM") Project

- C. Meinen was interviewed over the phone by a reporter for Science magazine on the latest updates to the Meridional Overturning Circulation ("MOC") arrays in the Atlantic on Tuesday, April 26th, 2016.
- S. Garzoli and R. Perez are involved in the MPOWIR (Mentoring Physical Oceanography Women to Increase Retention) organization.

Global Assessment of Looping Drifter Trajectories

- Beron-Vera completed a research/teaching leave at Instituto Tecnologico de Aeronautica (ITA), Sao Jose dos Campos, Brazil, 5–29 August 2015 (E. Rempel and A. Chian hosts) where he imparted lectures on inertial transport in the ocean.

Investigations of the Performance of the Basin-Scale HWRF

- Ghassan Alaka was involved with the following events:
  My Brother's Keeper National Lab Week (March 4, 2016)
  Introduction to Weather Lecturer (July 23, 2015)
  AOML Open House (May 14, 2015)
  Member of the Greater Miami AMS Chapter

Reanalysis of the Atlantic Basin Tropical Cyclone Database in the Modern Era

- Delgado, S., 2015: Reanálisis de HURDAD, VIII Congreso Cubano de Meteorología, Havana, Cuba (Talk given 2 Dec. 2015).
- Delgado, S., 2016: Reanalysis of the 1951-1959 Atlantic hurricane seasons, American Meteorological Society, San Juan, PR (Talk given 19 April 2016).
- Landsea, C.W., and Delgado, S., 2016: Hurricanes of Extraordinary Size: 1956's Greta, 1962's Ella, and 2012's Sandy, American Meteorological Society, San Juan, PR (Talk given 19 April 2016).
- Mock, C.J., Landsea, C.W., and Delgado, S., 2016: The Atlantic Hurricane Seasons of 1837 and 1838, American Meteorological Society, San Juan, PR (Talk given 19 April 2016).

- Moses, B., 2016: Re-Analysis of the 1964 Atlantic Hurricane Season, American Meteorological Society, San Juan, PR (Poster presented 21 April 2016).

Improvement to the Tropical Cyclone Genesis Index (TCGI)

- J. Dunion - Guest Speaker, Roosevelt School, Worcester, MA (March 2016)

Development of the Basin-Scale HWRF Modeling System

- Xuejin Zhang participated in the City of Pembroke Pines Charter School Career Day.

The GO-SHIP Repeat Hydrography Program

- D. Pierrot, R. Wanninkhof, and C. Langdon are actively involved in the international coordination and data quality control of efforts such as GO-SHIP repeat hydrography.
- J.-Z. Zhang is actively involved in the Joint IOC-ICES Study Group on Nutrient Standards (SGONS)

Sustained and Targeted Ocean Observations for Improving Atlantic Tropical Cyclone Intensity and Hurricane Seasonal Forecasts

- Website: http://www.aoml.noaa.gov/phod/goos/gliders/:
  Users can obtain more information about the project, and access real-time data and other information from the glider's mission, such as the last reported location of the gliders and the latest observations collected.
- Project video: http://www.aoml.noaa.gov/phod/videos/load.php?varid=gliders_2014
  A video targeting the general public providing general information about the project.

PIRATA Northeast Extension

- G. Foltz and R. Perez mentored a Hollings Undergraduate Scholar, Allyson Rugg, from May 26, 2015 to July 27, 2015.

Surface water partial pressure of CO_2 (pCO_2) measurements from ships

- D. Pierrot, L. Barbero and K. Sullivan participated in the AOML Open house in May 2015 where a station was set up to explain the CO_2 system in the ocean to students from local schools, boy and girl scouts and the general audience.

Ocean OSSE Development for Quantitative Observing System Assessment

- Weekly updated maps (7-day forecasts) for Sea Surface Height (SSH), Sea Surface Temperature (SST), temperature at 50m and surface currents are made publicly available at: http://coastalmodeling.rsmas.miami.edu/Models/View/FORECAST_GULF_OF_MEXICO_high_resolution

Evaluation of Management Strategies for Fisheries Ecosystems

- E.A. Babcock teaches a UM undergraduate course on Fisheries and Conservation Biology of the Galapagos. 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.

Caribbean Sea and Gulf of Mexico Bluefin Tuna Research

- Undergraduate students, Justin Suca and Alina Spera, from the University of Miami's RSMAS participated in the project in research cruises, sample and laboratory processing. The students provided valuable research support in the early life history unit laboratory in various projects and facilitated technical assistance while having the opportunity for hands-on learning
- Websites with educational information regarding the project and research survey:
  http://nfchroniclesnoaa.blogspot.com/
  http://www.aoml.noaa.gov/keynotes/keynotes_0415_nancyfostercruise.html
- During port visits, multiple "open house" activities took place in Miami, FL, and Cozumel, Mexico with overall 100 people touring the research vessel and its facilities.
- In Havana, Cuba the Nancy Foster hosted a delegation from the US Embassy where the ambassador learned about our ongoing research in Cuba.

Caribbean Reef Ecosystem Research, USVI Larval Distribution and Supply

- This research project and preliminary results have been shared with local managers including the University of the Virgin Islands and the Virgin Islands Department of Planning and Natural Resources Department of Fish and Wildlife. This project has had participation (both at sea and in the laboratory) of graduate students from the University of Miami and from the University of the Virgin Islands since 2007.
- In 2016, graduate students from the University of Virgin Islands, University of Puerto Rico-Mayaguez, and Florida A&M University also participated in the sampling effort, as well as managers from the National Authority for Maritime Affairs (ANAMAR) in the Dominican Republic and faculty at the University of the Virgin Islands. Also, an open house was carried out aboard the Nancy Foster for University of the Virgin Islands graduate students on 7 June 2016 to demonstrate laboratory and research capabilities while in port in St. Thomas, USVI.
- During these cruises, an informal blog was updated with educational information regarding the project and research survey: http://nfchroniclesnoaa.blogspot.com/

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

- http://www.marine.usf.edu/students/degree-requirements/marine-resource-assessment
- http://www.marine.usf.edu/ainsworthecology/
- http://www.marine.usf.edu/fishecology/

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

- Poster presentation "Ecology and recovery of *Acropora palmata*: ecosystem architect and climate sentinel" for 2016 NOAA SEFSC Ecosystem Science Review.

Support of the National Coral Reef Management Assistantship Program

- **American Samoa:** To date, outreach has been limited to speaking with villagers in the field when scouting rain garden sites or water sampling. There is structured outreach planned for later in 2016.
- **CNMI:** The CNMI Assistant presented at Environmental Expo at Sinapalu Elementary School in Rota
- **Florida:** The Florida Assistant has participated in many outreach activities with FL DEP, including, CRCP Outreach booth at the Miami Boat Show and the Green Planet Festival in February and the Blue Wild expo in April, speaking to the public about coral resources in Southeast Florida, species ID, and ways they can help protect coral.
  She also presented on the Southeast Florida Action Network (SEAFAN) and how citizens can make reports of marine incidents at the Dive In Lectures Series at NSU in March, to Gulliver Prep High School's SCUBA club and FAU Spearfishing Club in April and the IB Biology classes at Carrollton High School in May.
- **Guam:** Guam assistant organized *Eyes of the Reef* training on April 28th; 22 participants attended. During this 2-hour classroom-based training, community volunteers of all ages learn how to identify and report reef impacts - such as coral bleaching, disease, and invasive species - that they encounter while swimming, snorkeling, or diving on Guam's reefs. She revised the existing training materials and publicized the event through newspapers and social media. A second training is scheduled for May 17th.

  She also hosted the Coral Bleaching Symposium on May 19th. During the outreach component, from 8:30-1:30pm, participants learned about climate change and coral bleaching; the historical impacts of coral bleaching on Guam and anticipated future impacts; reef resilience; and Guam's coral reef response team and bleaching response team. Participants included representatives from local government, community organizations, business associations, dive operators, and educators.
- **Hawaii:** In partnership with Hawaii's Department of Land and Natural Resources (DLNR)outer island branches, the Hawaii assistant interviewed 162 people regarding the Community-Based Subsistence Fishing Area (CBSFA) post designation procedure and informed them more about the CBSFA.
- **Puerto Rico:** Together with NOAA, the PR coral assistant is preparing a "user friendly" document about the Coral Reef Monitoring Program of DNER, which will be disseminated to the general public.
- **USVI**: The USVI assistant participated in 6 field days for 2nd and 4th graders, hosted by other environmental groups, running activities on seashells and 'leave paradise in its place' aka things to take from a beach (rubbish) and things to leave (anything natural)

She is helping at EEMP's EcoCamp this summer, 15 high school students for 5 weeks learning about marine science, management, conservation and running the Sandwatch program on beach monitoring (erosion/accretion, SLR, shoreline vegetation, etc)

She wrote a feature article in the bi-monthly local magazine about lionfish (http://www.stcroixthisweek.com/articles/conserving-our-coral-reefs-on-earth-day-and-lionfish-awareness.html) and now has a “Friends Group” column for the year to discuss different themes (bleaching, turtle etiquette, Friends programs, etc)

Presented on the radio to discuss environmental stewardship, EEMP and the Friends group (https://www.youtube.com/watch?v=cxzNsPz2CTU&feature=youtu.be)

She’s working with the local dive club to support the park; divers volunteer their own time, gear, and boat and we get stuff done for free (eg check out derelict boats, lionfish infestation status, debris removal, etc). She’s also working on an existing turtle monitoring program in at least four East End beaches: to run August-October with volunteer patrols/monitors, which are mostly adult volunteers.

Mandatory Ship Reporting System

- The Mandatory Ship Reporting system website: https://www.rightwhalesmsr.aoml.noaa.gov/
- News item about the Mandatory Ship Reporting system at AOML’s Physical Oceanography Division website: http://www.aoml.noaa.gov/phod/news/load.php?pFullStory=20140416_20140515_MSR.html
- Article about the Mandatory Ship Reporting system at AOML’s Newsletter, issue of March-April 2014: http://www.aoml.noaa.gov/keynotes/PDF-Files/Mar-Apr14.pdf
- Detailed information about the Mandatory Ship Reporting system at the NMFS website: http://www.nmfs.noaa.gov/pr/shipstrike/msr.htm
- Detailed information about the Mandatory Ship Reporting system at AOML/PhOD website: http://www.aoml.noaa.gov/phod/research/ecosystems/msr/

Coral Restoration and Recovery

- This project served as the internship project for NOAA Hollings Scholar, Michael Connelly.
- D. Williams and M. Miller presented research results to managers and staff of Florida Keys National Marine Sanctuary, 28 Sept 2015.
- Research results were summarized at the SEFSC Ecosystem Science Review, March 2016.

VIII. CIMAS FELLOWS AND EXECUTIVE ADVISORY BOARD

The Fellows provide guidance to the Director on matters concerning the ongoing activities and future direction of CIMAS. Fellows-related matters are now addressed and implemented by means of email exchanges, and except one annual in-person meeting, all meetings are conducted as teleconferences via GOTOMEETING.

COUNCIL OF FELLOWS

FELLOWS	AFFILIATION
Dr. John Baldwin	**Florida Atlantic University**
Dr. Manhar Dhanak	Florida Atlantic University
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Dr. Tristan Fiedler	**Florida Institute of Technology**
Dr. Kevin Johnson	Florida Institute of Technology
Dr. William T. Anderson	**Florida International University**
Dr. James Fourqurean	Florida International University
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. Karl E. Havens	**University of Florida**
Dr. Thomas S. Bianchi	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. David Letson	University of Miami/RSMAS
Dr. Sharan Majumdar	University of Miami/RSMAS
Dr. Richard Appeldoorn	**University of Puerto Rico**
Dr. Gary Mitchum	**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. Benjamin Kirtman, Director	UM/CIMAS

***Ex Officio*:**

Dr. David Die, Associate Director	UM/CIMAS

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. Richard Nemeth	University of the Virgin Islands
Dr. Roni Avissar	UM/RSMAS Dean

***Ex Officio* Members**

Dr. Candice Jongsma	NOAA CI Program Office
Dr. Benjamin Kirtman	UM/CIMAS
Dr. David Die	UM/CIMAS

IX. AWARDS AND HONORS

Coral Health and Monitoring Program (CHAMP)

- Ian Enochs received the CIMAS Outstanding Scientific Performance Award (2015).
- Xaymara Serrano awarded a Ford Foundation Doctoral Fellowship (2015).
- Ruben van Hooidonk received the Sustainability Award from the Netherland America Foundation and Royal Dutch Airlines (KLM).

Using NOAA UAS Assets and OSSE/DA Capabilities to Improve Sampling Strategies and Numerical Prediction of Tropical Cyclone Track, Intensity, and Structure

- J. Dunion, Co-Recipient: 2015 American Meteorological Society Special Award to the University of Wisconsin-CIMSS Tropical Cyclone Group for "*providing the weather community with valuable tropical cyclone-related satellite information and derived products for over two decades*."
- NASA Group Achievement Award (2016): NASA Severe Storms Sentinel (HS3) Project.

Sustained and Targeted Ocean Observations for Improving Atlantic Tropical Cyclone Intensity and Hurricane Seasonal Forecasts

- Gustavo Goni, Francis Bringas, George Halliwell, Richard Bouchard (NWS) were awarded the **NOAA Bronze Medal Award** for the rapid and successful implementation of an array of underwater gliders geared towards Caribbean Sea and Tropical Atlantic hurricane research and forecasts.

Developing the Operational Calibration/Validation Components for VIIRS SST Retrievals

- Peter Minnett was a recipient of the University of Miami, 2015-2016 Provost's Award for Scholarly Activity.

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

- Claire Crowley **–** William Hogarth Marine Mammal Fellowship (USF CMS)
- Lindsey Dornberger **–** Garrels Memorial Fellowship in Marine Science (USF CMS)

X. POSTDOCTORAL FELLOWS AND GRADUATE STUDENTS

CIMAS-Supported Postdoctoral Fellows and Graduate Students

Postdoctoral Fellows

Alaka, Ghassan
Chen Leighton, Hua
Christopohersen Hui
Council, Elizabeth
Dong, Jili
Forrestal, Francesca
Gruss, Arnaud
Harford, William
Jones, Paul
Kearney, Kelly
Liu, Yanyun
Lopez, Hosmay
Majumder, Sudip
Putman, Nathan
Rasmuson, Lief
Serrano, Xaymara

Graduate Students
Task I

Adams, Molly
Drury, Crawford
Hariharan, S.
Hoenig, Daniel
Jensen, Brittany
Komisarjevsky, Nicholas
Pontes, Emma
Pritchard, Edward
Sculley. Michelle
Zink, Ian

Task III
Employees

Domingues, Ricardo
Gramer, Lewis J.
Jugovich, Amelia

Other Participants in CIMAS Projects

Postdoctoral Fellows
Barnes, Brian
Combes, Vincent
Infanti, Johnna

Graduate Students
Bouck, David
Chacin, Dinorah
Cortezi, Matheus
Crowley, Claire
Dean, Cayla W.
Denson, LaTreese
Dornberger, Lindsey
Duke, Mara.
Ferrá-Elias. Angela
Grasty, Sarah
Gray, Alisha
Gravinese, Philip
Groves. Caroline
Habtes, Sennai
Hall, Brittany
Hayslip, Catherine
Helms, Charles
Herdter, Elizabeth
Houston, Brock
Huelster, Sheri
Infanti, Johnna
Kelly, Elizabeth
Kotkowski, Rachel
Larson, Sarah
Li, Yen Ling.
Olinger, Lauren
Perryman, Holly A.
Pomales, Luis
Rolls, Holly
Rudzin, Johnna
Sauls, Beverly
Snyder, Susan
Sun, Shaojie
Tzadik, Orian
Valla, Daniel
Vara, Mary Janine
Williams, Sky

XI. RESEARCH STAFF

Aguilar, Sandra	Senior Research Associate III
Aichinger Dias, Laura	Research Associate III
Aksoy, Altug	Associate Scientist
Alaka, Ghassan	Postdoctoral Associate
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 II
Berberian, George	Research Associate II (PT)
Blondeau, Jeremiah	Senior Research Associate II
Bright, Allan	Senior Research Associate I
Bucci, Lisa	Senior Research Associate I
Carlton, Renee	Research Associate II
Chen, Hua	Postdoctoral Associate
Christophersen, Hui	Postdoctoral Associate
Christophersen, Johnathan	Research Associate II
Cook, Geoffrey	Assistant Scientist
Councill, Elizabeth	Postdoctoral Associate
Dahl, Brittany	Research Associate I
Delgado, Javier	Senior Research Associate II
Delgado, Sandy	Research Associate II
Diaz, Jose E.	Research Associate III
Diaz, Steven	Senior Research Associate I
Dolk, Shaun	Senior Research Associate I
Domingues, Ricardo	Research Associate III
Dong, Jili	Postdoctoral Associate
Dong, Shenfu	Associate Scientist
Dunion, Jason	Senior Research Associate III
Ender, Alexandra	Research Associate I
Enochs, Ian	Associate Scientist
Festa, John	Senior Research Associate III (PT)

Forrestal, Francesca	Postdoctoral Associate
Forteza, Elizabeth	Research Associate III
Gall, Robert	Scientist (PT)
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.	Assistant Scientist
Gruss, Arnaud	Postdoctoral Associate
Halliwell, Vicki	Senior Research Associate III
Halsall, Patrick	Research Associate II
Harford, William	Assistant Scientist
Hoffman, Ross	Scientist (PT)
Hoolihan, John	Scientist
Hooper, James	Senior Research Associate I
Jankulak, Michael L.	Systems Administrator
Jones, Paul	Postdoctoral Associate
Jugovich, Amelia	Research Associate I
Klotz, Bradley	Senior Research Associate II
Kolodziej, Graham	Research Associate II
Le Henaff, Matthieu	Assistant Scientist
Lee, Sang-Ki	Scientist
Liu, Yanyun	Postdoctoral Associate
Lopez, Hosmay	Postdoctoral Associate
Majumder, Sudip	Postdoctoral Associate
Malca, Estrella	Senior Research Associate I
Mehari, Michael	Senior Research Associate I
Nair Jayalekshmi	Research Associate III
Otero, Sonia	Senior Research Associate II
Overstreet, Elizabeth	Senior Research Associate II
Pausch, Rachel	Research Associate I
Perez, Renellys	Associate Scientist
Phillips, Nicole	Postdoctoral Associate

Pierrot, Denis P.	Associate Scientist
Privoznik, Sarah	Research Associate II
Putman, Nathan	Postdoctoral Associate
Quenee, Charline	Research Associate I
Rasmuson, Leif	Postdoctoral Associate
Rawson, Grant T.	Research Associate III
Roddy, Robert	Research Associate III (PT)
Ryan, Kelly	Sr. Research Associate II
Sabina, Reyna	Research Associate III (PT)
Sagarese, Skyler	Postdoctoral Associate
Sellwood, Kathryn J.	Research Associate III
Serrano, Xaymara	Postdoctoral Associate
Sevilla, Thomas	Electrical Engineer
Shideler, Allison	Senior Research Associate II
Shiroza, Akihiro	Senior Research Associate I
Shulzitski, Kathryn	Assistant Scientist
Sprehn, Charlotte	Senior Research Associate I
St. Fleur, Russell	Programmer, Intermediate
Stemle, Adam	Research Associate II
Stevens, Sabrina	Senior Research Associate I
Sullivan, Kevin F.	Senior Research Associate III
Teare, Paul	Research Associate II
Valdes, Erik	Research Associate III
Valentino, Lauren	Senior Research Associate I
van Hooidonk, Ruben	Assistant Scientist
Visser, Lindsey	Research Associate III
Volkov, Denis	Associate Scientist
Wicker, Jesse A.	Research Associate III
Williams, Dana E.	Associate Scientist
Zhang, Jun	Associate Scientist
Zhang, Xuejin	Associate Scientist

XII. VISITING SCIENTISTS

Dr. Nancy Maynard – October 1, 2012 (to continue through June 2017)
NASA Emeritus
NASA Goddard Space Flight Center
Greenbelt, MD

Dr. Tom Carruthers –November 2 – 6, 2015
University of British Columbia
Fisheries Centre Aquatic Ecosystems Research Laboratory (AERL)
Vancouver, BC, Canada
2 – 6 November, 2015 – "*Participate in NOAA SEDAR Data Limited Assessment Workshop*"

Dr. Julian Heming – March 14 – 17, 2016
UK Met Office
Fitzroy Road
Exeter Devon, United Kingdom
17 March, 2016 – "*Tropical Cyclone Predictions from the Met Office Global Model: A Brief History and Recent Developments*"

Dr. Dusanka Zupanski – March 28, 2016
Zupanski Consulting, LLC
Fort Collins, CO
28 March, 2016 – "*Theoretically Advanced, Yet Computationally Efficient Data Assimilation and Forecasting Method"*

Dr. Brad Beechler – March 29, 2016
Vaisala, Inc.
Boulder, CO
29 March, 2016 – "*Object-Based Data Assimilation: Strategies and Technologies"*

Dr. Jason Sippel – March 30, 2016
NCEP/EMC
College Park, MD
30 March, 2016 – "*The Challenges in Developing the Operational HWRD FA System: What I've Learned After 1.5 Years at EMC*"

Prof. U.C. Mohanty – June 6 – 10, 2016
School of Earth Ocean and Climate Sciences
Indian Institute of Technology Bhubaneswar
A2-708, Toshali Bhawan, Satya Nagar
Bhubaneswar-751007, Odisha, India
7 June, 2016 – "*Recent Developments in the Prediction of Tropical Cyclones in the North Indian Ocean*"

XIII. PUBLICATIONS

Table 1: Publication Record 2015-2016 for Cooperative Agreement NA15OAR4320064

	Institute Lead Author	NOAA Lead Author	Other Lead Author
	2015-2016	2015-2016	2015-2016
Peer Reviewed	50	13	42
Non-Peer Reviewed	20	4	3

Refereed Journal Articles

Abarca, S.F., M.T. Montgomery, S.A. Braun, and J.P. Dunion (2016), On the secondary eyewall formation of Hurricane Edouard (2014), *Mon. Wea. Rev*., (in press), doi:10.1175/MWR-D-15-0421.1 2016.

Adam T.C., M. Kelley, B.I. Ruttenberg, and D.E. Burkepile (2016), Groups of roving midnight parrotfish (Scarus coelestinus) prey on sergeant major damselfish (Abudefduf saxatilis) nests, *Marine Biodiversity*, 1-2, doi: 10.1007/s12526-016-0475-4.

Ainsworth, C.H., (2016), British Columbia marine fisheries catch reconstruction: 1873 to 2011, *BC Studies*, 188, 81-90.

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Bakker, D.C.E., B. Pfeil, C.S. Landa, N. Metzl, K.M. O'Brien, A. Olsen, K. Smith, C. Cosca, S. Harasawa, S.D. Jones, S.-I. Nakaoka, Y. Nojiri, U. Schuster, T. Steinhoff, C. Sweeney, T. Takahashi, B. Tilbrook, C. Wada, R. Wanninkhof, S.R. Alin, C.F. Balestrini, L. Barbero, N.R. Bates, A.A. Bianchi, F. Bonou, J. Boutin, Y. Bozec, E.F. Burger, W.-J. Cai, R.D. Castle, L. Chen, M. Chierici, K. Currie, W. Evans, C. Featherstone, R.A. Feely, A. Fransson, C. Goyet, N. Greenwood, L. Gregor, S. Hankin, N.J. Hardman-Mountford, J. Harlay, J. Hauck, M. Hoppema, M.P. Humphreys, C.W. Hunt, B. Huss, J.S.P. Ibanhez, T. Johannessen, R. Keeling, V. Kitidis, A. Kortzinger, A. Kozyr, E. Krasakopoulou, A. Kuwata, P. Landschutzer, S.K. Lauvset, N. Lefevre, C. Lo Monaco, A. Manke, J.T. Mathis, L. Merlivat, F.J. Millero, P.M.S. Monteiro, D.R. Munro, A. Murata, T. Newberger, A.M. Omar, T. Ono, K. Paterson, D. Pearce, D. Pierrot, L.L. Robbins, S. Saito, J. Salisbury, R. Schlitzer,

B. Schneider, R. Schweitzer, R. Sieger, I. Skjelvan, K.F. Sullivan, S.C. Sutherland, A.J. Sutton, K. Tadokoro, M. Telszewski, M. Tuma, S.M.A.C. Van Heuven, D. Vandemark, B. Ward, A.J. Watson, and S. Xu (2016), A multi-decade record of high-quality fCO_2 data in version 3 of the Surface Ocean CO_2 Atlas (SOCAT), *Earth Syst. Sci. Data Discussions*, 1-55, doi: 10.5194/essd-2016-15.

Baringer, M.O., W.E. Johns, W.R. Hobbs, S. Garzoli, S. Dong, and J. Willis (2015), Global Oceans: Meridional oceanic heat transport in the Atlantic Ocean [in "State of the Climate in 2014"], *Bull. Amer. Meteor. Soc.*, 96, 7, S78-S80.

Baringer, M.O., W.E. Johns, W.R. Hobbs, S. Garzoli, S. Dong, and J. Willis (2015), Global oceans: Meridional oceanic heat transport in the Atlantic Ocean, In State of the Climate in 2014, J. Blunden and D.S. Arndt (eds.), *Bull. Amer. Meteor. Soc.*, 96, 7, S81-S82.

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Baringer, M.O., G. McCarthy, J. Willis, D.A. Smeed, D. Rayner, W.E. Johns, C.S. Meinen, M. Lankhorst, U. Send, S.A. Cunningham, and T.O. Kanzow (2015), Global Oceans: Meridional overturning circulation observations in the North Atlantic Ocean [in "State of the Climate in 2014"], *Bull. Amer. Meteor. Soc.*, 96, 7, S81-S82.

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Bright A.J., M.W. Miller, and A.S. Bourque (2016), Tracking growth and survival of rescued boulder corals, *Restoration Ecology*, 24, 4, 456-462, doi: 10.1111/rec.12348.

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Cheng, L., J. Abraham, G. Goni, T. Boyer, S. Wijffels, R. Cowley, V. Gouretski, F. Reseghetti, S. Kizu, S. Dong, F. Bringas, M. Goes, L. Houpert, J. Sprintall, and J. Zhu (2015), XBT Science: assessment of instrumental biases and errors, *Bull. Amer. Meteor. Soc*., doi:10.1175/BAMS-D-15-00031.1.

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Domingues, R., G. Goni, F. Bringas, B. Muhling, D. Lindo-Atichati, and J. Walter (2016), Variability of preferred environmental conditions for Atlantic bluefin tuna (Thunnus thynnus) larvae in the Gulf of Mexico during 1993-2011, *Fisheries Oceanography*, 25, 3, 320-336, doi:10.1111/fog.12152.

Dong, S., G. Goni, and F. Bringas (2015), Temporal variability of the South Atlantic Meridional Overturning Circulation between 20°S and 35°S, *Geophys. Res. Lett*., 42, 7655-7662, doi: 10.1002/2015GL065603.

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Fanning, K.A., R.T. Masserini, Jr., J. Walsh, R. Wanninkhof, K. Sullivan, J.I. Virmani, C.A. Heil (2015), An ammonium enrichment event in the surface ocean: Wind forcing, potential ramifications, *Mar. Chem*., 174, 26-34, doi:10.1016/j.marchem.2015.03.018.

Feely, R.A., R. Wanninkhof, B. Carter, J.T. Mathis, and C.L. Sabine (2015), Global ocean carbon cycle, In State of the Climate in 2014, Global Oceans, *Bull. Am. Meteorol. Soc*., 96, 7, S87–S90.

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Folmer, M.J., R.W. Pasken, G. Chen, J.P. Dunion, and J. Halverson (2016), Modeling studies on the formation of Hurricane Helene: the impact of GPS dropwindsondes from the NAMMA 2006 field campaign, *Meteor. Atmos. Phys*., 128, doi: 10.1007/s00703-016-0452-2.

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Garzoli, S. L., S. Dong, R. Fine, C.S. Meinen, R.C. Perez, C. Schmid, E. van Sebille, and Q. Yao (2015), The fate of the Deep Western Boundary Current in the South Atlantic, *Deep Sea Research*, I, 103, 125-136, doi: 10.1016/j.dsr.2015.05.008.

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Infanti, J.M., and B.P. Kirtman (2015), North American rainfall and temperature prediction response to the diversity of ENSO, *Climate Dynamics*, 46, 9, 3007-3023, doi: 10.1007/s00382-015-2749-0.

Johnson, D.W., M.R. Christie, C.D. Stallings, T.J. Pusack, and M.A. Hixon (2015), Using post-settlement demography to estimate pre-settlement larval survivorship, a coral-reef fish example, *Oecologia*, 179, 3, 729-739, doi: 10.1007/s00442-015-3368-5.

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