Cooperative Institute for Marine and Atmospheric Studies

CIMAS

Second Annual Report

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I. EXECUTIVE SUMMARY

The Cooperative Institute for Marine and Atmospheric Studies (CIMAS) is a research institute hosted at the University of Miami (UM) in the Rosenstiel School of Marine and Atmospheric Science (RSMAS) and including at present 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 $19.67 M. Task I which includes not only Administration but also Research Infrastructure (ship-time, computing resource access etc.) and Education and Outreach was ca. $1.8M. The University of Miami contributed an additional $.25 M towards Administration. Task II, which supports CIMAS employees conducting closely collaborative research off- campus was ca. $ 10.5M.

Individual research project funding (Tasks III and IV) totaled ca. $7.29M. The largest portions were the research projects within Theme 3 (Sustained Ocean and Coastal Observations) which accounts for 60%. Themes 1, 2, 6 and 7(Climate Research and Impact, Tropical Weather Ecosystem Management and Protection and Restoration of Resources) accounts for 35%. The smallest portions were in Themes 4 and 5 (Ocean Modeling and Ecosystem Modeling & Forecasting) which together account for only 5%. 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 new 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 150 individuals at UM were directly provided salary support through CIMAS. Of these, 121 received over 50% of their support through CIMAS. Of the 121 research employees who received over 50% NOAA support, 77 worked at AOML, 29 at the SEFSC, 2 at RSMAS, 1 at NHC, 6 at the University of Puerto Rico, 1 at the University of

Virigin Islands and 5 in other locations. Thirty of these employees were Research Scientists including 2 part time former NOAA employees. The employees in the Research Associate and Research Scientist ranks have a diverse demographic profile. The population is 44% female leading to a 2% increase compared to last year. Foreign-born individuals make up 48% of the total. The largest foreign sub-groups are Hispanics (20%) and Asian and Pacific Islanders (11%). 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 40.5. 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 117 peer-reviewed publications and another 34 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. An effort was made to avoid projects highlighted in previous Annual Reports. 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

Investigation of the Movement of Adult Billfish in Potential Spawning Areas (continuous).
Analyses of electronic tagging data resulted in publication of a peer-reviewed paper describing the use of ocean heat content to estimate geolocation of PSAT monitored large pelagic fishes. This information provides improved accuracy over traditional SST models, and reveals the close associative behavior that these fish exhibit towards fronts and eddies. We have determined that areas of low dissolved oxygen in the eastern tropical Atlantic and Pacific Oceans plays a significant role in limiting the vertical movement and habitat use of billfishes and tunas. This in turn makes them extremely vulnerable to capture in surface fishing gears, causing concern for these already over-exploited stocks. In terms of time spent at temperature, billfishes seek out the warmest water available, and therefore spend most of their time in the warmer mixed surface layer. This also limits their vertical movement and increases vulnerability to surface fishing gears. Use of ocean heat content data to improve geolocation estimates reveals large pelagic predators are attracted to ocean fronts and eddies, around which prey species are known to aggregate.

Marine ‘Omics and eAUV Technology to Support Ecosystem Understanding and Fisheries Assessments
Unmanned, autonomous maritime systems are a critical need to aid dependence on expensive ship-based observing systems, providing an opportunity to increase spatio-temporal data coverage while reducing ship costs. However, AUV technology typically does not enable wet

sampling, which is required for the majority of biological information utilized to meet NOAA mandates. In April and May 2017, we field tested a prototype autonomous instrument that can search for oceanographic features and filter water remotely for molecular analysis in comparison to traditional sampling by CTD rosette with manual ship-board filtration. This prototype instrument can be deployed from dock or small boat, allowing rapid response, reduced ship-time costs, and increased sample coverage, which is important for NOAA modeling and forecast missions. The resulting genetic measurements can provide a sentinel of ecological status by measuring biodiversity, food web function, and harmful organisms, with information translated into improved understanding and prediction of fisheries productivity.

Ocean technology development: bottom drifter development

Our novel observation platform addresses the lack of instruments able to investigate near bottom environments. These environments are some of the most interesting and important zones for oceanographic dynamics, biological activity and mixing. Understanding the dynamics in this part of the ocean will aid climate predictions as well as fishery predictions and assessments of fish population and migration patterns. The program addresses the development of the observation platform as well as thoroughly tests of the code and instruments associated with it. It will further address the interaction between large-scale circulation on the shelf and canyons, bottom flow and turbulence and how events such as eddies and wind influence circulation and upwelling on the shelf. In addition, mechanisms that control vertical and lateral mixing as well as stratification, low oxygen and hypoxic zones are investigated. This will be addressed by deploying the platform in the plume of the Apalachicola River to determine Reynolds, and Richardson or Fraud numbers, evaluate mixing and relate the observations to external forcing of tides and winds. In addition the Drifter will allow us to investigate the role of shear across different layer interfaces. Until now it was not possible to investigate this in the near bottom environment, over a extended time period, nor was it possible to target different depths and layers easily. The new Coastal Bottom Drifter on the other hand will allow for a simple and easy way of investigating exactly this. This platform opens the door for targeted, long-term deployments to investigate coastal systems, which will lead to understand and predict the physical aspects, the role of carbon, and nutrients and better services and stewardship of the coastal environments.

Understanding spatiotemporal dynamics of Atlantic bluefin tuna spawning

Our work continues to improve the understanding of bluefin tuna spawning in the Atlantic. This species is overfished, and economically valuable, however recruitment processes are generally poorly known. Understanding where spawning occurs and what drives the timing of spawning is a critical issue. Our study links environmental data, field collections of larvae and laboratory studies to understand how spawning is influenced by the environment. The results from the study will facilitate better management of bluefin tuna and provide key insights into the potential impacts of climate change on the species.

Larval bluefin tuna ecology in the Gulf of Mexico and Caribbean

Our work continues to improve the understanding of larval bluefin tuna distribution and ecology in the Gulf of Mexico and western Atlantic. This is the first year of a two-year project funded by the NOAA RESTORE Act Science Program. Our team includes scientists from Scripps Institute of Oceanography, Florida State University, and the University of Hawaii at Manoa to examine

the "Effects of nitrogen sources and plankton food web dynamics on habitat quality for larval BFT." This species is overfished, and economically valuable, however recruitment processes are generally poorly known. Year class strength is likely to be determined during early life, and so quantification of environmental variability and planktonic food web effects on larval survival is critical. Our ongoing research project is the first to link larval distributions, feeding, growth and trophic interactions for the region. Results will facilitate better management of bluefin tuna, by enhancing knowledge of spawning behaviors and recruitment mechanisms.

Caribbean Reef Ecosystem Research, USVI Larval Distribution and Supply

This multi-year research focuses on understanding how larval fish populations in the U.S. Caribbean are organized, connected, and change over time. Many of the species which spawn in this region, such as snapper, grouper, and parrotfish, are important for local economies, as they are fished and exported or used for local food sources. Additionally, reef fish contribute to the tourism industry as a draw for SCUBA divers and snorkelers. Several protected areas have been established to try to improve the health of these species, however it is unknown what kind of impact these reserves have. This work combines the biology of larval fish distributions, abundances, and assemblages with physical oceanography in the region to provide insight to these questions. This project provides a significant time series of historical data, sampled over a time in which management policies were introduced and amended, allowing for the impact of these policies to potentially be observed.

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

Calibration and Evaluation of GEFS Ensemble Forecasts at Weeks 3-4

The revised RMM-r index monitors MJO evolution with improved amplitude in convection over the Maritime Continent and Western Pacific which is known of great importance to establish the teleconnection between the MJO and CONUS precipitation and temperature. It represents less skillful MJO predictions in GEFS due to less predictable OLR. This will help the MJO community with a focus on improving the MJO convection so as to improve its prediction. A new algorithm has been developed for tracking persistent high pressure systems including both conventional blocking anticyclones and persistent open ridges. It is being used to track the persistent high pressure systems in the GEFS reforecasts to investigate its predictability and prediction skills.

MJO is known to pose remote impact on the precipitation and temperature over the US. Our investigation of MJO prediction in week 2-4 is highly relevant to later prediction of flooding and drought especially in the Western US. The persistent high pressure systems are generally responsible for meteorological drought. Their predictability and prediction skills in the GEFS are being assessed for the first time. The results will provide useful guidance in predicting these systems and thus potential drought conditions.

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

This work supports efforts by NOAA to demonstrate and test a prototype small-UAS concept to collect observations within critical regions in a hurricane vortex that manned reconnaissance

aircraft can't otherwise sample due to safety restrictions. For this purpose, NOAA has successfully deployed two Coyote aircraft during its Hurricane Field Program in Hurricane Edouard (2014). Results here expand on the data collected in these missions by simulating Coyote observations in a hypothetical hurricane and considering scenarios that could not be realized during the actual Edouard flights due to various technical limitations encountered. Preliminary findings indicate that, when Coyote is flown at its specified technical capabilities, its observations have the potential to positively impact the model representation of the hurricane vortex structure even when conventional observations from manned reconnaissance aircraft are also utilized.

Airborne Doppler Wind Lidar

Direct measurements obtained by aircraft, such as NOAA's P-3 Orion Hurricane Hunters, are known to be vital in understanding and predicting tropical cyclones (TCs). However, several critical regions of hurricanes remain largely unobserved by these aircraft due to limitations of current airborne instrumentation. These data gaps are thought to inhibit improvements in hurricane forecasting. The Doppler Wind Lidar (DWL) provides an opportunity to fill these gaps in coverage by making complimentary measurements to those retrieved by the Tail Doppler Radar (TDR). In 2015 and 2016 a DWL was flown for the first time on the P-3 into various TCs, collecting wind profiles in the near surface and low/no precipitation regions. The data has been validated using other airborne observing systems and is ready to be used in both numerical models and by scientists to study new regions on the TC.

Global Observing System Simulation Experiments (OSSEs)

Observing System Simulation Experiments (OSSEs) can show us the impacts of potential new satellites before they are even built, and by working globally we can improve the realism of tropical-cyclone OSSEs by providing simulated observations, initial conditions, and boundary conditions, as is done operationally. A key component of global OSSEs involves making the observations and model skill realistic; if the observation/model skill is too good compared to real-world skill, the results are less credible. When our studies discovered that the NOAA/GFS model better produced better 5-day forecasts of the simulated environment (based on NASA/GMAO/GEOS5) than the real world, parameters were adjusted to bring the OSSE forecast skill more in line with real-world forecasts. Currently these improvements are currently being used to assess the impact of a five-satellite constellation (Geostationary Hyperspectral Sounders, or GeoHSS), in accordance with House Bill 353, which became law in April 2017. Initial tests with non-error-added observations showed significant improvements in global forecast skill, including improvements in hurricane track forecasting in some cases. Work using more accurate error-added observations is ongoing, and on track to finish in August 2016.

A Uniformly-High Resolution Nature Run for Hurricane OSSEs

This work addresses the issue of improving tropical cyclone track and intensity prediction. Due to the impact tropical cyclones have on society, it is of paramount importance to optimize their forecasts. OSSEs allow us to examine the potential benefits of using proposed observing systems' data for hurricane forecasts. Our 2 km nature run improves upon our current OSSE system by eliminating nests while retaining high resolution. Combined with other upgrades being developed for our OSSE system, we can provide stronger results regarding the benefits of proposed observing systems.

Improvement to the Tropical Cyclone Genesis Index (TCGI)

This work aims to improve and expand on TCGI, a model that predicts the likelihood of tropical cyclone formation in the 2-day and 5-day timeframes and provides real-time guidance to forecasters at NOAA NHC. TC genesis is not a well-understood stage of the TC lifecycle and is difficult to predict. Since NOAA NHC is tasked with predicting the likelihood of TC formation at the 2-day and 5-day time frames, the NOAA National Weather Service has identified the following hurricane forecaster priority: "*Guidance for tropical cyclone genesis at both the short-range (0-48 hours) and the medium-range (48-120 hours) that exhibits a high probability of detection and a low false alarm rate for, and/or provides probability of, genesis*". The improvement and expansion of TCGI attempts to address this scientific need and has direct implications for improving the prediction of TCs that form in the Atlantic and Pacific.

Impact of Aircraft Reconnaissance Observations on the Prediction of Tropical Cyclones

1) The broad scientific issue that our work addresses is evaluating observing system resources using OSSEs to determine their potential impact on hurricane prediction; 2) Our work is important to society because optimizing these resources can improve the numerical modeling of hurricanes and potentially allow for more accurate forecasts; 3) The specific issue addressed in our program is to improve tropical cyclone (TC) track and intensity forecasts while improving our understanding of the physical mechanisms that dictate a given TC's evolution; 4) We addressed these issues by creating a set of sensitivity studies that aim to optimize current airborne resources and software that is used in operational forecasting. In evaluating sensitivity results, we can investigate our knowledge gaps to form a better understanding of TCs.

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

(1)A combined set of SLOSH MEOW and MOM products for emergency planning and preparedness in Hispaniola countries to avoid loss of life due to storm surge flooding, and (2) a new methodology to develop a digital terrain model (DTM) using remotely-sensed data for current and future storm surge modeling and coastal inundation projects in Caribbean countries.

Ocean OSSE System Development and Applications for QOSAP

1) The overarching issue is to develop a model-based system to evaluate and optimize ocean observing systems and strategies for a broad range of ocean applications.

2) This project will provide methods to optimize the ocean observing system to reduce costs.

3) Specific scientific issues include understanding how ocean data assimilation reduces errors in ocean analyses and increases predictability time scales in ocean forecasts.

4) An ocean OSSE system was developed to address these issues.

5) The primary highlight is that we have designed and demonstrated the only ocean OSSE system that has been rigorously validated to prove that credible quantitative impact assessments of ocean observing systems are realized.

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

Western Boundary Time Series Project

The Western Boundary Time Series (WBTS) project maintains one of the longest time series of water mass and transport observations of key components of the global meridional MOC. Variations in the MOC have been shown in numerical climate models to be related to important societal quantities such as precipitation over the northern hemisphere, sea surface temperatures, and hurricane intensity. The WBTS project documents, through innovative uses of many different observational methods, the time variability of the warm upper and cold lower limbs of the MOC, which are carried, respectively, in the Florida Current and the Deep Western Boundary Current (DWBC). The project maintains daily observations of Florida Current and Deep Western Boundary Current transports as well as quarterly-to-annual ship sections to observe water property changes in both the Florida Straits and east of the Bahamas Islands.

In a recent study published in the Journal of Geophysical Research – Oceans (Domingues et al., 2016), seasonal changes in the Florida Current variability were attributed to remote signals originating in the open North Atlantic Ocean. Westward propagating sea height anomalies signals associated with seasonal timescales behave similarly to a theoretical first-mode Rossby wave. These wave-like features propagate westward at a fixed rate of roughly -4.6 km day-1 at 27°N, which indicates that it takes years to cross the basin. As these features arrive in the western boundary, they cause adjustments in the Florida Current transport by altering the sea surface and/or the main pycnocline depth, which changes the geostrophic flow. These geostrophic flow changes are crucial as they will be associated with sea level changes at both sides of the Florida Straits. Coherent sea level changes ranging between -10 cm and 10 cm are often observed along a large portion of the east U.S. coast during these events. Because these signals propagate approximately at a constant rate, knowledge of this mechanism may aid in producing improved seasonal forecasts of tidal range. It is expected that this research will provide value to regional efforts geared towards improving coastal resilience, and to stakeholders and coastal managers who deal with frequent flooding events (a too-common problem in South Florida).

Southwest Atlantic Meridional Overturning Circulation ("SAM") Project

NOAA and CIMAS have maintained a crucial long-term array measuring the western boundary components of the Meridional Overturning Circulation (MOC) in the South Atlantic near 34.5°S since 2009 via the 'Southwest Atlantic MOC', or 'SAM', project. With recent data collections on the western boundary by U.S., Argentina and Brazilian researchers and on the eastern boundary by French and South African scientists, a multi-year daily record of the trans-basin MOC has been achieved from a joint array of 20 moorings across the entire basin. A publication on this update is presently in preparation.

The Deep Western Boundary Current (DWBC) carries a major portion of the cold lower limb of the MOC at 34.5°S, and the 'Southwest Atlantic MOC', or 'SAM' array has been making crucial measurements of the DWBC transport since 2009. In a recent paper (Meinen et al. 2017), the SAM PIs described the variability of the DWBC over roughly six years. The observed variability is quite high, with peak-to-peak transport variations of nearly 140 Sv between a

southward flow of 89 Sv and a northward flow of 50 Sv. This study also showed that the largest variations in the DWBC transport were driven by Rossby Wave-like signals that propagated to the western boundary from the interior.

The covariability of SAMOC transport variations with SST fluctuations, observed during altimeter period (1993-2015) based on SAMOC estimates from altimeter and XBT measurements, motivated a recent study to reconstruct a century-long SAMOC transport index from 1870 to present using SST reanalysis products. The reconstructed transport index is highly correlated to the altimetry/XBT-based SAMOC transport time series during the period when it is available, and it provides a record much longer than any other SAMOC transport estimate. The results of this study (Lopez et al. 2017) show that the Inter-decadal Pacific Oscillation (IPO) is the leading mode of SAMOC-SST covariability, explaining approximately 85% of the observed variability, with the Atlantic Niño accounting for less than 10% of the variability. The reconstruction shows that SAMOC has recently shifted to an anomalous positive period, consistent with a recent positive shift of the IPO.

The GO-SHIP Repeat Hydrography Program

The purpose of this program is to quantify changes in storage and transport of heat, fresh water, carbon dioxide (CO_2), oxygen, nutrients, chlorofluorocarbon tracers and related parameters in the world oceans. 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. Our contribution to the program addresses changes in the carbon system in the ocean. We achieve this by reoccupying select transects of the oceans on a decadal frequency to determine long-term changes. This type of sustained, repeat hydrographical cruises are currently the only way to sample the deep oceans and quantify changes in storage and transport with adequate precision and accuracy.

Juvenile Sportfish Monitoring in Florida Bay, Everglades National Park

In Florida Bay, spotted seatrout populations are declining over time due to high salinities and a reduction in seagrass habitat. As part of the Comprehensive Everglades Restoration Project, restoring freshwater flow into Florida Bay is crucial in order to increase the area of optimal habitat for spotted seatrout and other commercially important sportfish. There is a significant correlation with juvenile spotted seatrout, salinity, temperature, and seagrass percent cover. In July 2015, there was an extreme hypersalinity event which killed extensive seagrass habitats, and resulted in low sportfish populations that year. In 2016, juvenile spotted seatrout populations in the bay were significantly higher than previous years since 2008. We hypothesize that this could be due to a combination of increased prey availability and higher turbidity from the bloom creating a false cover for seatrout in the absence of seagrass.

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

The Argo floats provide measurements of temperature and salinity to depths of 1000-2000 meters allowing a continuous monitoring of the state of the ocean. All data is made publicly available within hours after collection, for scientific use and assimilation into weather

forecasting and climate prediction models, which leads to improvements of such models. This program addresses the role of the ocean in climate modulation by collecting and processing temperature and salinity profiles globally that are used by the operational centers for weather and climate forecast. The data are also used by CIMAS employees to improve our understanding of the oceans and their influence on weather and climate.

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

Support of the National Coral Reef Management Assistantship Program

The goal of this project is to build coral reef management capacity in the seven US coral reef jurisdictions - American Samoa, CNMI, Florida, Guam, Hawaii, Puerto Rico and USVI. By building capacity, this project can have a positive impact on the coral reefs of each jurisdiction, which are valuable both economically and ecologically. The coral assistants' work plans address the NOAA CRCP national goals for climate change, land-based sources of pollution and fishing, as well as addressing 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. Each of the workplans encompass the threats to coral reefs on both a global and local scale. Both NOAA and the local jurisdiction defined the scope of work for each coral assistant, ensuring that the plans incorporate the NOAA CRCP goals. This project is significant to both NOAA and the local jurisdictions, as it provides additional capacity for addressing the priorities set by NOAA and the jurisdictional agencies for coral reef management.

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 inter alia 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, 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.
- Most recently (during this last project period) we also established an Ocean Modeling and OSSE Center (OMOC) in collaboration with AOML.

How CIMAS Carries Out Its Mission

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

- *By fostering, facilitating and implementing joint projects between regional university scientists and those employed by NOAA;*
- *By providing a mechanism for engaging undergraduate students, graduate students and post-doctoral fellows in this research;*
- *By arranging for visiting specialists to enhance the general effort in relevant research areas through short-term consultations and seminars or by arranging for their involvement in ongoing projects for longer time periods;*
- *By providing training for personnel in various areas of research in marine and atmospheric science.*

CIMAS enhances NOAA-university cooperation and thus promotes both the quality and attractiveness of the local NOAA facilities as a scientific working environment. It also serves to increase the breadth of university activity in research areas that are complementary to NOAA's mission.

The Link between CIMAS Research and NOAA Goals

CIMAS research and its scientific objectives have been guided by the general objectives of NOAA's scientific mission goals 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 IV as described below.

Research in CIMAS under this CA was also carried out under Tasks III and Task IV. 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 IV encompasses projects that support or complement the NOAA mission and are consistent with the CIMAS

Themes but are funded by other federal (non-NOAA), state or private funding sources. All funding provided by NOAA to 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 total of 155 persons were associated with CIMAS in various capacities. Of these, 121 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 this total who received over 50% NOAA support, 77 are located at AOML, 29 at the SEFSC, 2 at RSMAS, 1 at NHC. 5 work at distant NOAA facilities, 6 at UPR and 1 at UVI.

Table 1: CIMAS Research Personnel 2016 – 2017

Category	Number	BS	MS	Ph.D
Research Associate/Scientist	81	24	27	30
Part Time Research Associate/Scientist	6	2	1	3
Other Research Professional Category	4	1	2	
Postdoctoral Fellow	14			14
Research Support Staff	16			
Total (> 50% NOAA support)	**121**	**27**	**30**	**47**
Full Time Administrative Staff	5			
Task I Undergraduate Students	11			
Task I Graduate Students	13			
Visiting Scientist	5			
	77 - AOML 29 - SEFSC 2 - RSMAS 13 - (1) NHC, (6) UPR, (1) UVI (5) Other			
Obtained NOAA employment within the last year	0			

CIMAS Research Associates/Scientists are hired into a well-delineated series of categories that allow for professional advancement in the research ranks. There is a sequence of five positions targeted for advanced technical or scientific staff 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 14 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 “Division” 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 divisions (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 (http://cimas.rsmas.miami.edu/pdfs/pay-bands.pdf) and not only hiring new employees within these limits but raising the salary of legacy employees so 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 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 thirty eight 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 no employees were transitioned to Federal position.

Demographics of CIMAS Employees

The CIMAS population is 56% male, this represents a 2% decrease from las year. Foreign-born individuals make up 48% of the personnel; of these Hispanics make up 20% of the ranks; Asian and Pacific Islanders, 11%. Only 2% are African-Americans despite our efforts to expand this group's participation, this percentage remains the same. The population of CIMAS is relatively young with an average age of 40.5. 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 13 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 11 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 Outreach) 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. $21.0M 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
Year 2	1,839,999	10,530,402	5,114,605	1,385,366	792,923	19,663,295
TOTALS	**4,249,243**	**22,321,050**	**14,673,594**	**3,863,164**	**1,825,567**	**46,932,618**

The sources of that funding are shown in Table 2. The major source of NOAA funding continues to be OAR which provided 59% of the total. NMFS, NESDIS, NOS contributed at 23%, 15%, and 1% respectively. "Other" accounts for 5%, the source of funding include awards from NASA, NSF and private industry as well as sub-contractual awards from Florida International University, Purdue, University of Washington, Nature Conservancy, Florida Atlantic University, University of Wisconsin, SUNY to CIMAS investigators.

Table 2: Funding by Source

1 July 2016 - 30 June 2017		
Source	**Funding $M**	**% Total**
NESDIS	2.75	15%
NMFS	4.32	23%
NOS	0.24	1%
NWS	0.17	1%
OAR/AOML	9.62	50%
OAR/CPO	0.75	4%
OAR-Other	1.02	5%
GRAND TOTAL	**18.87**	**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 Division 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 and Task IV** encompass project-specific research funding at CIMAS. These Tasks provide support for research by university faculty, scientists and students. Task III encompasses activities that are funded by NOAA and may be carried out in cooperation with NOAA personnel in the local NOAA laboratories and elsewhere in the United States. Task III proposals may be submitted by UM or Partner University faculty and scientists or by CIMAS research scientist employees. Task IV includes projects supported by other (non-NOAA) funding sources. The approval of the Director (as the designate of the RSMAS Dean), is required for CIMAS employees to submit Task III or IV proposals. Their 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 IV 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 $10,125K per Partner University (40.5% 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 $ 1.84M, of which $0.21M was for the Administration component (that sum didn't include a 0.26M 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" 14% 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 26% of the total. Temporary Staff accounts for 12% 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 21% and student stipends another 7%.

Task I: General

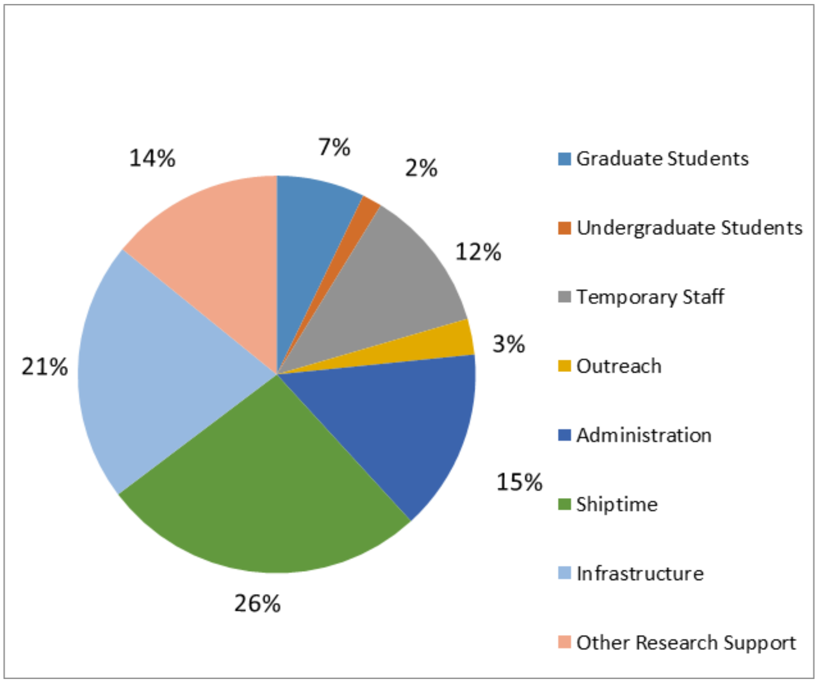

Figure 1: Distribution of Task 1 Funding

The funding provided for Task II employees totaled $10.5M over the past twelve months. The distribution of these funds by employee category is depicted in Figure 2.

Task II: Employees by Category

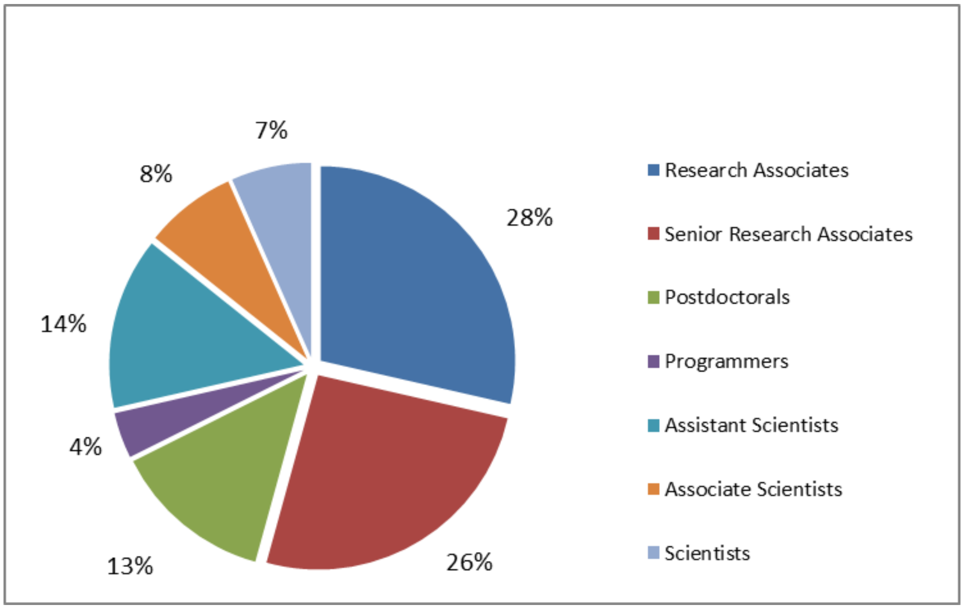

Figure 2: Distribution of Task 2: Funds by Employee Category

Funding By Theme

Project-specific research funding (Tasks III and IV) under the new CA totaled ca. $7.3M 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 60%. The smallest portion of funding was in Theme 5: Ecosystem Modeling and Forecasting – 2% and Theme 4: Ocean Modeling – 3%.

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

Research Funding by Theme

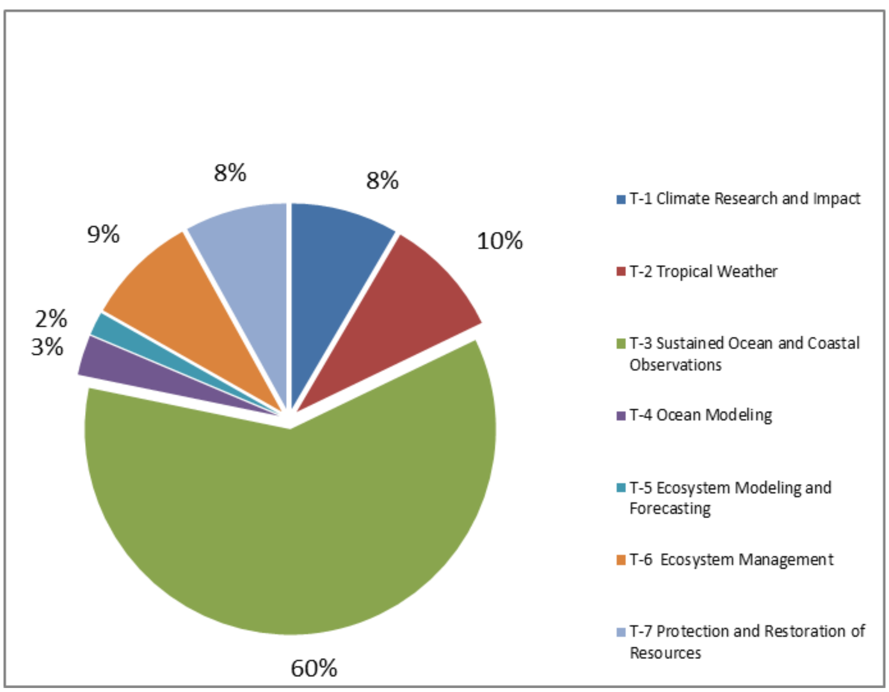

Figure 3: Percentage of Task 3 and Task 4 (Individual Research Project) funding per Theme

Table 3 below tabulates NOAA funding linked to CIMAS under the present Cooperative Agreement (CA). Marked with asterisk we indicate the 2 ongoing awards under the Disaster Relief Appropriation Act of 2013 related to Hurricane Sandy resulting in total for DRA funding of 6.8M. One project ended this reporting period.

Table 3: NOAA Projects with Individual Award Numbers

NOAA Award #	Principal Investigator	Award Period		Project Title
NA15NOS4510233	Babcock, E	09/01/15 - 08/31/17	$ 164,698	Ecosystem Modeling Efforts in the Gulf of Mexico: Current Status and Future Needs to Address Management and Restoration Activities
NA14OAR4830172*	Dunion, J	08/01/14 - 07/31/17	$ 1,249,008	Using NOAA UAS Assets and OSSE/DA Capabilities to Improve Sampling Strategies and Numerical Prediction of Tropical Cyclone Track, Intensity and Structure
NA15OAR4590201	Dunion, J	09/01/15 - 08/31/17	$ 46,789	Improvement to the Tropical Cyclone Genesis Index (TCGI)
NA12OAR4310083	Goes, M	08/01/12 - 07/31/16	$ 225,000	Toward Developing in a Seasonal Outlook for the Occurance of Major US Tornado Outbreaks
NA12OAR4310073	Kamenkovich, I	08/01/12 - 07/31/17	$ 408,500	Mesoscale Variability in the Gulf of Mexico and its Importance in Climate Extremes over North America
NA15NOS4510226	Lehenaff, M	09/01/15 - 08/31/17	$ 398,812	Evaluation of Gulf of Mexico oceanographic observation networks, impact assessment on ecosystem management and recommendation
NA14OAR4310193	Kirtman, B	08/01/14 - 07/31/17	$ 178,788	Developing Decision Support Tools for Understanding, Communicating and Adapting to the Impacts of Climate on the Sustainability of Coastal Ecosystem Services
NA16OAR4310149	Kirtman, B	07/01/16 - 06/30/18	$ 139,145	Sub-Seasonal Prediction with CCSM4
NA16OAR4310141	Kirtman, B	07/01/16 - 06/30/18	$ 149,126	Developing a Real-Time Multi-Model Sub-Seasonal Predictive Capability
NA17NMF4630010	Lirman, D	01/01/17 - 12/31/18	$ 521,920	Building Coastal Resilience Through Coral Reef Restoration
NA15OAR4590203	Nolan, D	09/01/15 - 08/31/18	$ 75,772	Guidance on Observational Understanding Over the Tropical Cyclone Lifecycle
NA11NOS4780045	Ortner, P	09/01/11 - 02/28/18	$ 4,518,662	2011 REPP-Understanding Coral Ecosystem Connectivity in the Gulf of Mexico-Pulley Ridge to the Florida Key
NA13OAR4310131	Perez, R	09/01/13 - 08/31/18	$ 222,723	South Atlantic Meridional Overturning Circulation: Pathways and Modes of Variability
NA14NWS4680028	Zhang, J	08/01/14 - 07/31/17	$ 389,332	Addressing Deficiencies in Forecasting Tropical Cyclone Rapid Intensification in HWRF
NA14OAR4830119*	Zhang, X	04/01/14 - 03/31/17	$ 1,035,877	CIMAS Contributions to OAR disaster Recovery Act Projects
*** Awards under the Disaster Relief Appropriation Act of 2013.**				

Funding distributed through CIMAS to the Partner Universities during the present reporting period was $.90M or 18% of Task III. The funding to the Partner Universities decreased by 15% compared to last reporting period. 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 IV projects encompass project-specific research funding at CIMAS under the direction of CIMAS researchers. These projects supported by other funding sourcesincluding 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 - 06/30/17	FIU	FPHL Model Operation & Maintenance & Model Upgrades
Annane, B	04/14/14 - 06/30/17	FIU	FPHLM Storm Surge & Flood Component Project
Annane, B	12/31/15 - 12/30/19	Purdue-U	Assimilation of GNSS-R Delay-Doppler MAPS into Hurricane Models
Barbero, L	07/01/14 - 06/30/17	FAU	Integration & Deployment of PCO2/PH Sensors on a ROV
Dunion, J	01/01/14 - 06/30/17	U of Wisconsin	An Observational and Numerical Investigation of Energy
Dunion, J	03/13/17 - 09/12/17	NASA	NASA Applied Sciences Program Support for an Applications Workshop on the Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats (TROPICS) Mission
Goes, M	09/15/15 - 08/31/18	NSF	The Interannual Variability of the Brazil Current
Harford, W	02/28/17 - 06/30/17	TNC	Red Abalone Management Strategy Evaluation
Perez, R	09/15/16 - 08/31/19	NSF	NSF Collaborative Research: Extratropical Triggering of ENSO Events Through the Trade-Wind Charging mechanism
Perez, R	04/18/14 - 04/17/18	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 Scale Sea level
Volkov, D	07/01/14 - 06/30/18	NASA	Investigating the Processes Contributing to the Salinity Differences Between Aquarius and In Situ Measurements
Zhang, J	07/03/14 - 07/02/18	U of W	Calculating tropical Cyclone Inflow and Boundary Layer Proce
Zhang, J	12/01/15 - 07/31/17	FIU-NOAA	Understanding the Impcat of Sub-Grid Scale Physics in HWRF
Zhang, J	03/15/15 - 02/28/18	SUNY-NSF	Mechanism of Intensity Change in Sheared Tropical Cyclone

Conclusion

In our funding summary we report only funding during the twelve months 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 IV projects see Table 4. To avoid unnecessarily burdening the responsible principal investigators of such Task III and all Task IV 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: Z. Barton, G. Berberian, S. Dolk, R. Domingues, R. Garcia, S. Garzoli, J. Hooper, M. Kersale, 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 possibly 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 measuring 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 chartered small boats. During the past year, the monitoring and data distribution systems for the Florida Current cable program have continued, providing Florida Current volume transports which are being made available in near real time via the web page http://www.aoml.noaa.gov/phod/floridacurrent (See Figure 1).

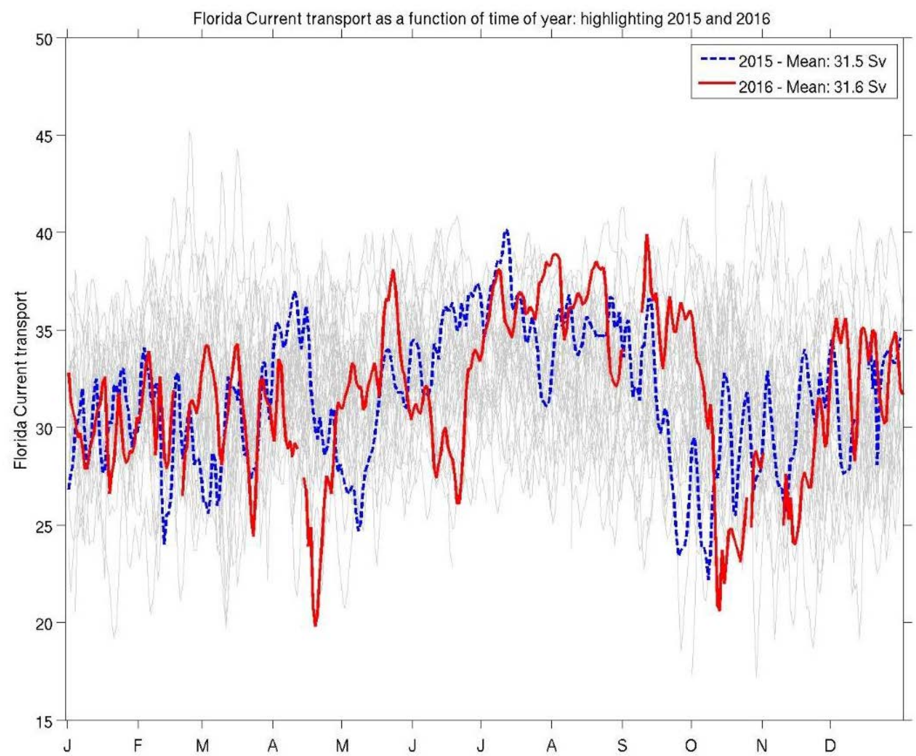

Figure 1: Volume transport of the Florida Current at 27ºN. The two most recent years are highlighted in color.

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 project, this program executes hydrographic cruises each year to monitor water mass changes along 26.5ºN east of Abaco Island in the Bahamas. These cruises often involve collaborations with scientists from RSMAS/University of Miami and/or from the National Oceanographic Centre, Southampton (NOCS), United Kingdom.

Several types of sustained Florida Current observations are obtained by the Western Boundary Time Series program, including a continuous record of the Florida Current transport using telephone cable measurements, as well as periodic ship-based full-depth data from CTDs, LADCP, dropsonde floats and XBTs at fixed stations across the Florida Straits at 27°N. The NOAA AOML led High Density XBT project provides complementary observations through the region roughly quarterly. Analysis of these observations can reveal important details about the variability of the Florida Current. For example, the seasonal variability of the Florida Current (Florida Current) transport is characterized by the presence of an annual cycle (representing roughly 8% of the total observed variance) with a peak-to-peak range of about 3 Sv, with a maximum northward transport in boreal summer. In a recent study published in the Journal of Geophysical Research – Oceans (Domingues et al., 2016), researchers with the University of Miami and at NOAA/AOML uncovered a mechanism through which signals originating in the open North Atlantic Ocean can significantly alias the average annual Florida Current variability. Specifically, this study and earlier work has shown that the seasonality displayed by the Florida Current transport record in any individual year can be very distinct from the average annual cycle (Figure 2a), with the Florida Current showing an apparently amplified annual cycle in some years, and apparent annual cycle phase shifts of as much as 90° in others years. In some years the record even shows an apparent semi-annual cycle. The recent Domingues et al. (2016) study shows that these apparent modulations of the Florida Current transport seasonality are largely caused by westward propagating sea height anomaly (SHA) signals that are formed in the eastern North Atlantic 4 to 7 years before they are observed at 27°N in the Florida Straits (Figure 2b). These westward propagating SHA signals behave approximately like first baroclinic mode Rossby waves. These propagating features can have crucial implications beyond changing the Florida Current transport alone. The integrated changes in the coastal sea-level between 25°N—42°N associated with these signals drive adjustments in the geostrophic transport of the Florida Current at 27°N, which can have implications for coastal sea level on the eastern U.S. seaboard.

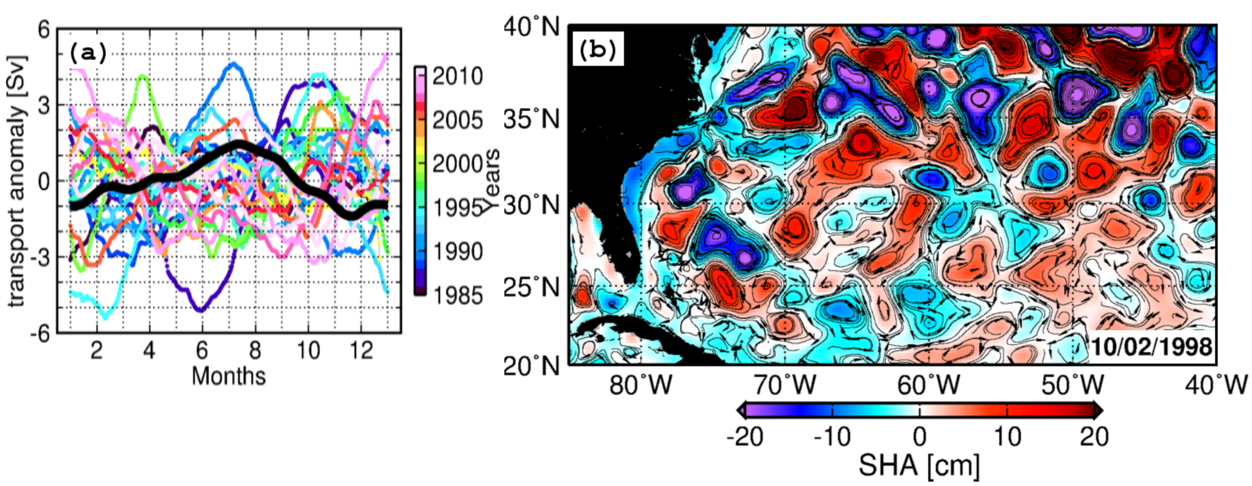

Figure 2: (a) Seasonality displayed by the Florida Current transport during 1983—2013, showing the annual cycle (thick black line) calculated as daily averages from the daily FC cable dataset from 1983—2013, and then smoothed using a 30-day running mean filter. (b) Satellite-altimetry SHA data for October 2, 1998 filtered for the 73-525 day seasonal band.

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 reports presenting the details of data collected as part of the WBTS project were completed during this period.

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Construction of an Agulhas Leakage Indicator

Project Personnel: F. Beron-Vera (UM/RSMAS)
NOAA Collaborators: G. Goni, S. Dong and C. Moes (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 and formation.

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 (Wang et al., 2016) the development of successive short-term coherent material loops that shield the rings' interior from mixing with the ambient fluid (Fig. 2). 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.

Further investigation led us to find that the generation of Agulhas rings tend to happen right after the emergence of strong cyclonic eddies. This led us to seek an index for the emergence of such strong cyclones which can allow us to anticipate the generation of Agulhas rings. According to McWilliams (1984) the emergence of coherent structures from quasigeostrophic turbulence is associated with a growth

of the kurtosis of vorticity. In agreement with this observation, we found evidence of a good correlation between the generation of strong cyclones and vorticity kurtosis strength (Fig. 3).

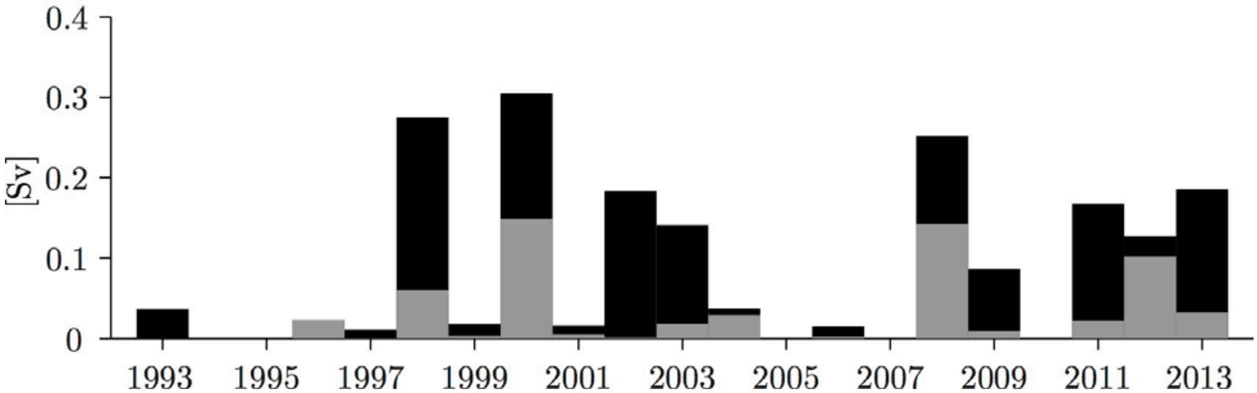

Figure 1: Annual average time series of transport across the South Atlantic produced by coherent material rings. Gray-shaded bar portions correspond to transport of Indian Ocean water trapped inside the rings.

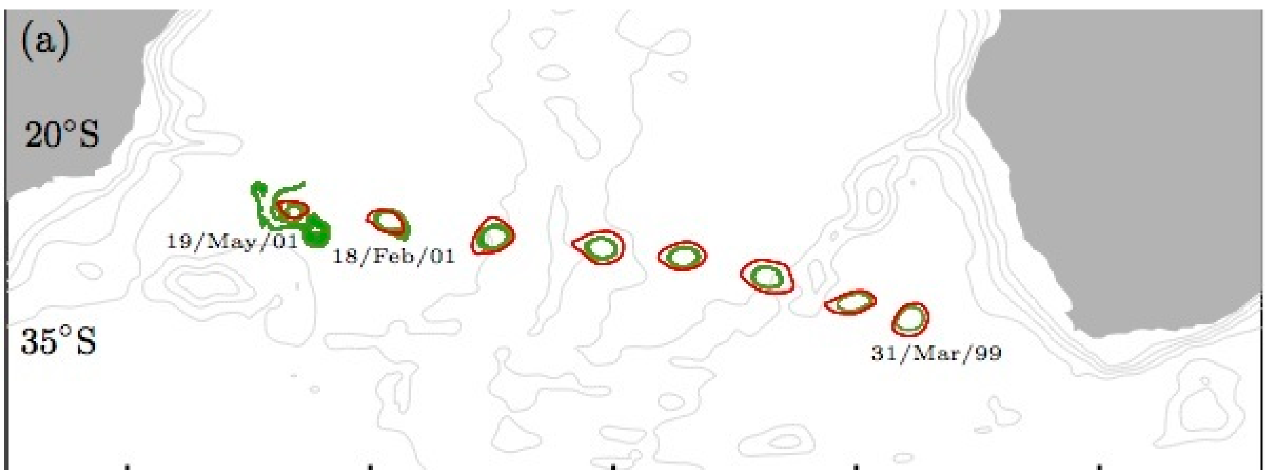

Figure 2: Short-term coherent material loops (red) that provide shielding to the fluid in their interior as this evolves under the altimetry-derived flow. The green curve is a material loop that is assessed to be coherent only up to 31 May 1999 using geodesic eddy detection on 31 March 1999. Beyond 31 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.

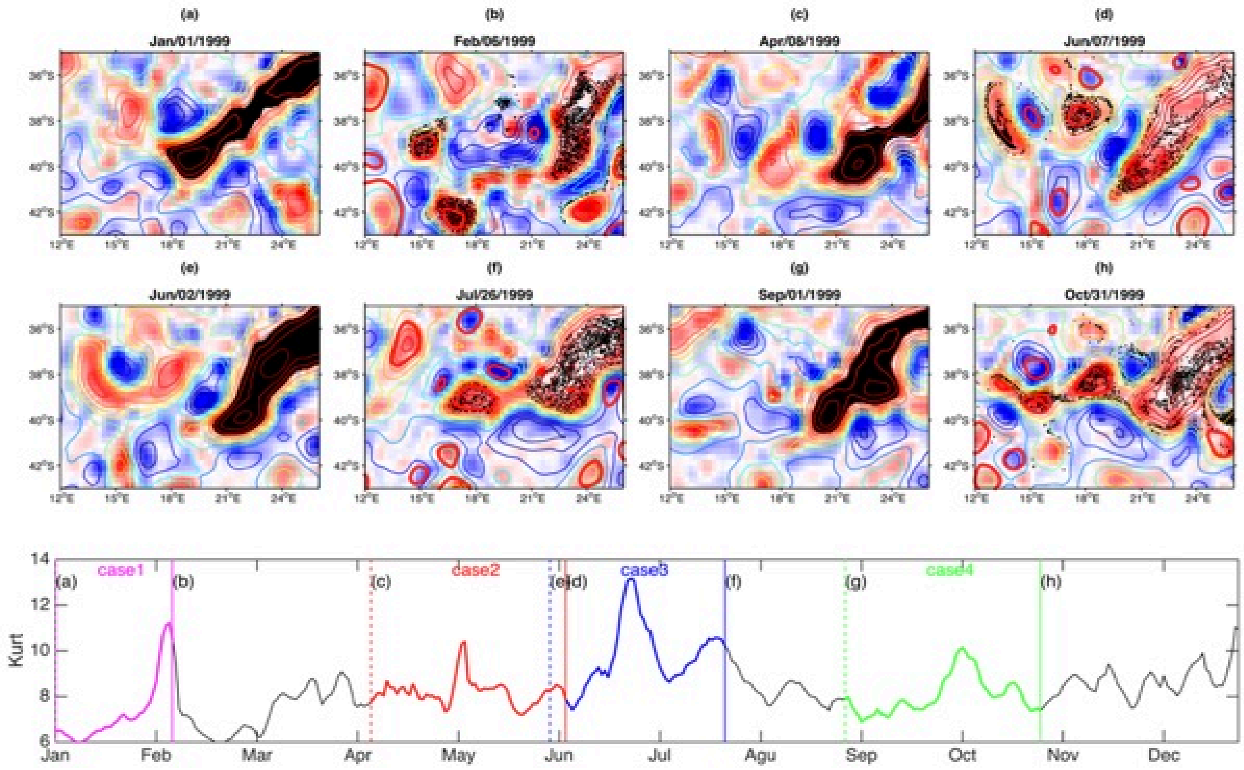

Figure 3: (top) Evolution of vorticity (red is anticyclonic while blue cyclonic) over 1999 with SSH contours (black) and coherent Lagrangian eddy boundaries (red) overlaid; dots are tracers initiated inside the Agulhas current. (bottom) Vorticity kurtosis as a function of time.

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. Vorticity kurtosis is identified as a potentially 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, RMS)
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:

The project has two key components. The first is to study the vertical profile of hurricane winds near the hub height of wind turbines. The second is to determine the return period of high hurricane winds at the hub height. This research is intended to be beneficial in determining the design conditions and risk for offshore wind turbines along the U.S. coast. However, due to budget cuts, funding for this project has been terminated. As a result, we have focused our efforts on completing the first component only.

Research Performance Measure: Significant progress has been made in analyzing some of the GPS dropsonde data, as previously reported. As mentioned above, this project has been terminated. The researchers are trying to complete the GPS dropsonde study on their own time and expense. Additional dropsonde data has been acquired and processed, and this should lead to more robust results. Publication of the results is anticipated in the near future.

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Global Drifter Program

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

Long Term Research Objectives and Strategy to Achieve Them:

Objectives**: :** To maintain a global 5x5 degree array of nearly 1300 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 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 nearly 1300 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 and the transitioning of the drifter array communication network from the Argos to the Iridium constellation of satellites - 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 ~1300 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.

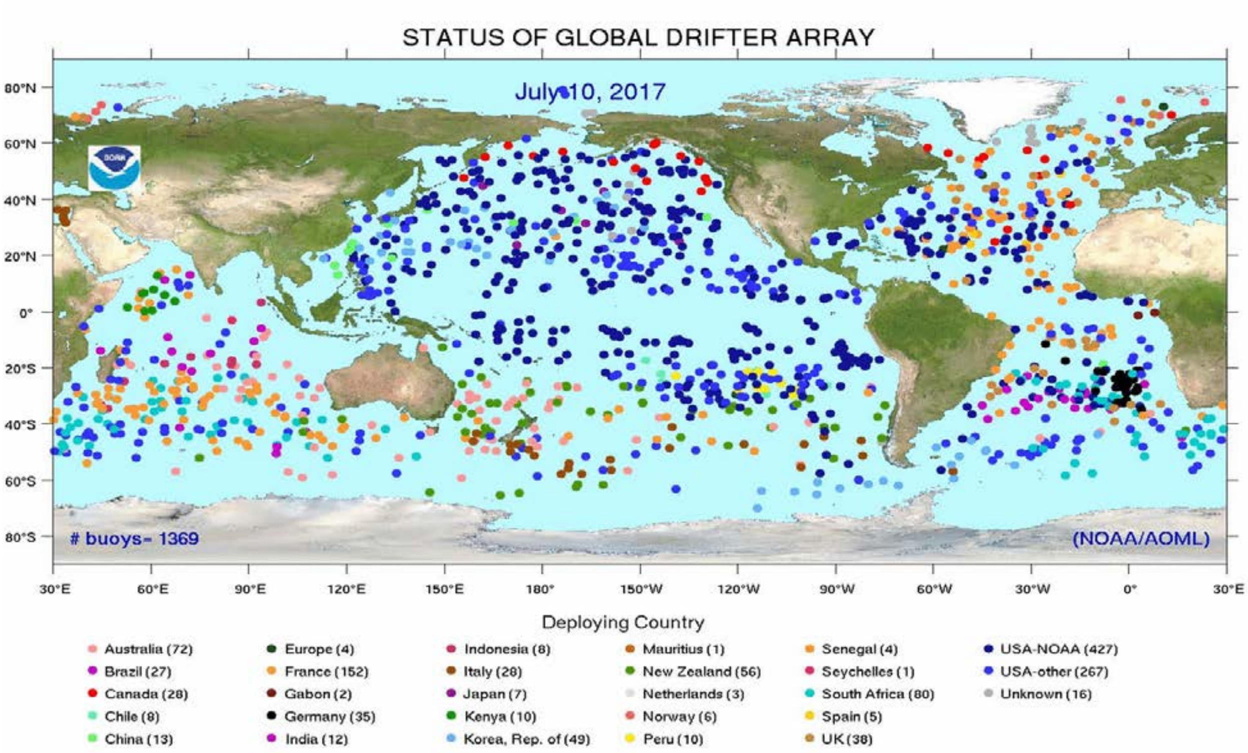

Figure 1: Status of the Global Drifter Array (updated weekly)

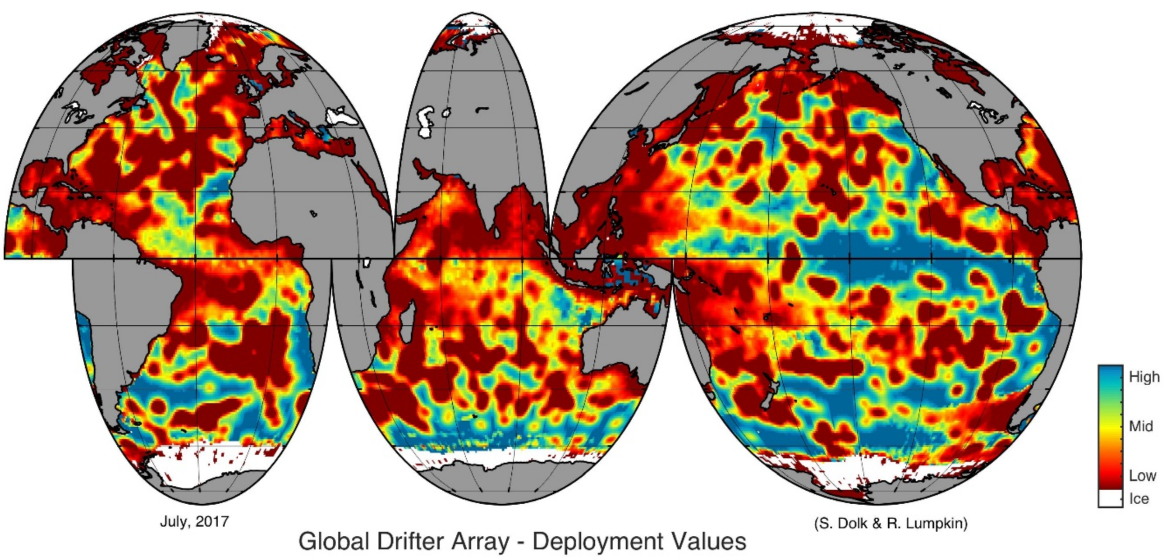

Figure 2: Deployment Value Map(s) (updated monthly)

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. An updated hourly global surface drifter dataset was generated this year by S. Elipot (UM/RSMAS), with collaboration from R. Lumpkin, R. C. Perez, and

other researchers (following a methodology designed in 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/hourly_data.php), and systematically updated.

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Coral Health and Monitoring Program (CHAMP)

Project Personnel: I. Enochs, R. van Hooidonk, P. Jones, X. Serrano, G. Kolodziej, L. Valentino, M. Jankulak, L. Gramer, M. Gidley, C. Aguilar, N. Amornthammarong and N. Putman (UM/CIMAS)

NOAA Collaborators: J. Hendee, D. Manzello, C. Kelble, C. Sinigalliano and J. Stamates (NOAA/AOML)

Other Collaborators: N. Traylor-Knowles (RSMAS), C. Hu and B. Barnes (USF), A. Soloviev and B. Walker (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 CO2 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 an international collaboration with the Caribbean Community Climate Change Centre (CCCCC) and with local communities in south Florida, to deploy coral reef and coastal monitoring stations and to collect, process, disseminate and archive their data. CHAMP has continued to make those data available in near real-time via the CHAMP Portal data query web site (http://www.coral.noaa.gov/champportal). In addition to the growing network of in situ data sources, the CHAMP Portal also continues to add sources of remotely-sensed data. Among these data sources are “foundation” sea surface temperature (SST) products from Remote Sensing Systems (www.remss.com), adjusted for diurnal warming to simulate temperatures closer to the depths where coral reefs are found. Such integrated data allows the CHAMP Portal to cover over 100 marine monitoring sites of interest, including coral reef sites in Cuban and other international waters, as well as NOAA National Marine Sanctuaries and other Marine Protected Areas in the tropical and sub-tropical waters of the U.S. and its territories. A report is currently in preparation characterizing the data-gathering and rigorous quality-control procedures applied to the raw in situ data from all CREWS stations. The report analyzes sea temperature variability and trends at the U.S. Caribbean CREWS stations, in terms of coincident in situ data on meteorology and light from the stations (Figure 1).

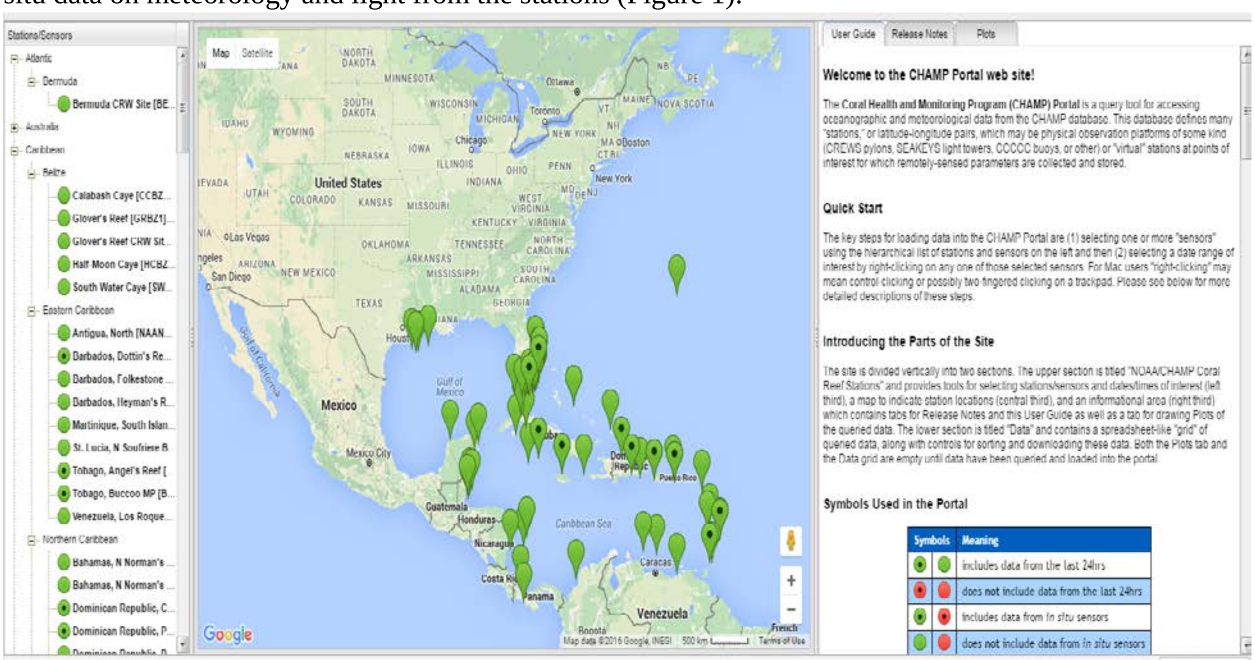


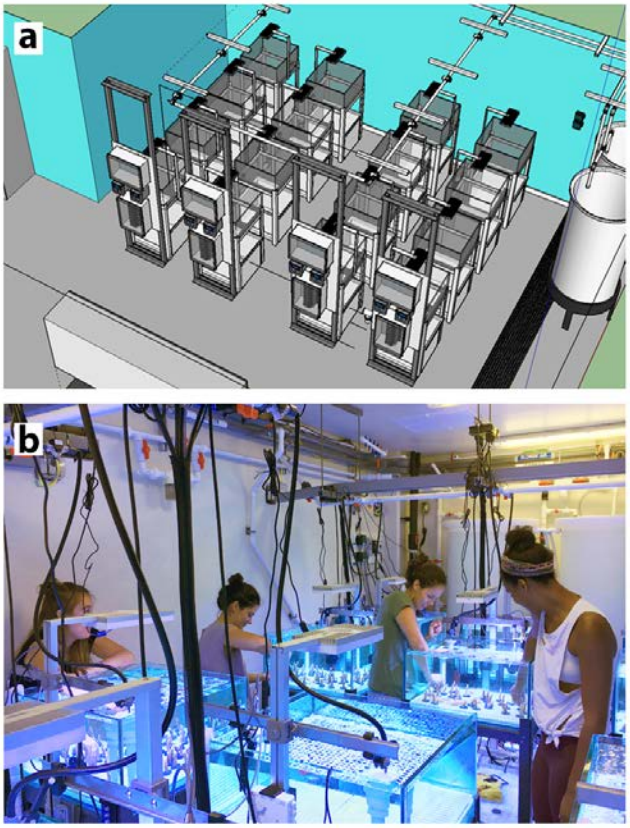
Figure 1: Annual distributions of hourly air (a) and near-bottom sea (b) temperatures from the automated CREWS/ICON reef monitoring station at La Parguera, Puerto Rico. (c) Screenshot from the CHAMP Program Web site, showing monitored reef sites and data access tools provided by the CHAMP Data Portal.

The ACCRETE (Acidification, Climate, and Coral Reef Ecosystems TEam) 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 group 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, Mike Jankulak, Paul Jones, 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 collected and deployed in the Florida Keys, St. Croix, and throughout Puerto Rico. These monitoring units included high-accuracy temperature loggers, as well as biodiversity, calcification, and bioerosion monitoring units.
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, Mike Jankulak, 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, collection and processing of calibration/validation water samples, as well as electronics replacement and servicing of the MAPCO2 mooring.

ACCRETE personnel conducted collaborative work at multiple sites experiencing unique pCO_2 conditions, using real-world gradients in carbonate chemistry to gain insights on ecological responses to future ocean acidification conditions. These collaborations included work in the Galapagos Islands, where upwelling in the southern Islands locally raises pCO2 and impacts reef permanence. In Papua New Guinea, they worked with scientists from the Australian Institute of Marine Science to explore undescribed volcanic CO_2 vents. In the Marianas Islands and New Caledonia, they worked with colleagues from NOAA CREP, as well as IRD and UTS, Sydney, respectfully, to carbonate chemistry and coral reef bioerosion. In the Florida Keys and across the Florida Reef Tract, ACCRETE continued ongoing work with Dr. Chris Kelble, and CIMAS scientist Lindsey Visser to analyze carbonate chemistry from water samples taken on the RSMAS ship, the RV Walton Smith.

This year saw the construction of a state-of-the-art Future Reef Lab (FRL) as part of the OAR-funded Coral ‘Omics initiative (Figure 2a). The facility is located at the University of Miami’s new MTLSS building and consists of 16 completely independent aquaria. Every tank in the FRL system is controlled by a central computer and graphical user interface (GUI) that runs custom software written in LabVIEW. Every minute, every tank logs pH, temperature, as well as CO_2, air, and water flow, along with several other system-wide parameters. In total, more than a 110 different measurements are recorded every minute (nearly 160,000 a day), allowing us to keep very detailed logs of what our corals are experiencing. Temperature and pH can be programmed with time dependent set points so that diel oscillations can be tested, rather than static treatment levels. CIMAS scientists were involved with all aspects of the build and design, from initial 3D CAD renderings, to plumbing and electrical, to software and control algorithm construction.



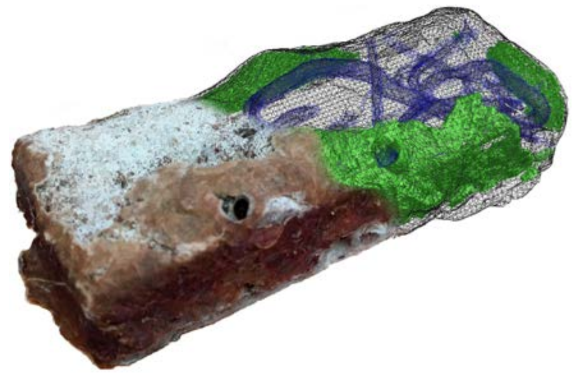


Figure 2: (a): The CIMAS Future Reef Lab. a, 3D CAD diagram showing tanks, plumbing, and electronics layout. **(b)** CIMAS employees and UM undergrad conducting an experiment on endangered *Acropora cervicornis*. From left: Kami Cohen, Lauren Valentino, Dr. Catalina Aguilar, and Madison Jackson.

Figure 2b: A composite of two images of the same piece of calcium carbonate material deployed in a reef environment for two years. On the left, the photograph shows external features and newly accreted crustose coralline algae (brownish-red). The image on the right is a micro-CT rendering showing the features of the same block as a transparent wire mesh, with newly calcified material depicted in green and internal worm holes in blue.

CIMAS researcher Dr. Xaymara Serrano is currently working in collaboration with NOAA scientists Dr. Margaret Miller, Dr. Jim Hendee and Dr. Cheryl Woodley, as well as RSMAS professor Nikki Traylor-Knowles, in a project aimed at characterizing the transcriptomic basis of disease resistance in Acropora corals. This project is part of OCED 'omics initiative and will consist of quantifying various traits in the field through disease exposure/resistance assays using available *Acropora palmata/cervicornis* genotypes from various propagation nurseries in South Florida. The goal is to obtain a baseline characterization of genes that are responsible for disease susceptibility in these coral species. In 2016, Miller and colleagues developed a 7 day field contact-challenge assay where actively diseased fragments are used as inoculants (Figure 3A; methods described in Miller and Williams 2016). This protocol was implemented in a preliminary screening of 16 *A. cervicornis* and 6 *A. palmata* genotypes from two different coral nurseries in the upper and middle Florida Keys to get a spectrum of disease resistance present in these genotypes (Figure 3). Overall, results from this study are expected to help predict which Acropora phenotypes are more “resistant” to disease and whether these “resistant” phenotypes also display a higher reproductive capacity during the spawning period. In addition, results are expected to provide a disease “diagnostic tool” which may help improve out-planting and restoration success of these genotypes in the field.

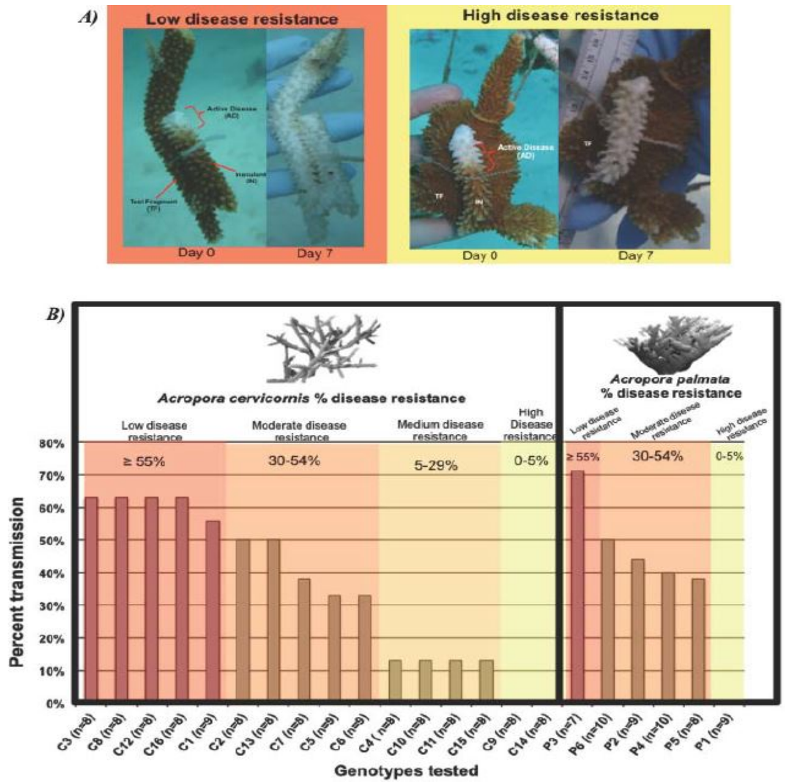


Figure 3: Spectrum of disease resistance in genotypes from Florida coral nurseries. A) An example of the field disease transmission assay to identify if there are resistant corals. B) The percentage of disease transmission in *A. cervicornis* and *A. palmata* genotypes from the Coral Reef Foundation (CRF) and Florida Wildlife Commission (FWC) nurseries. In *A. cervicornis*, few of the tested genotypes have high disease resistance, representing about 6% of the total corals tested (yellow bars).

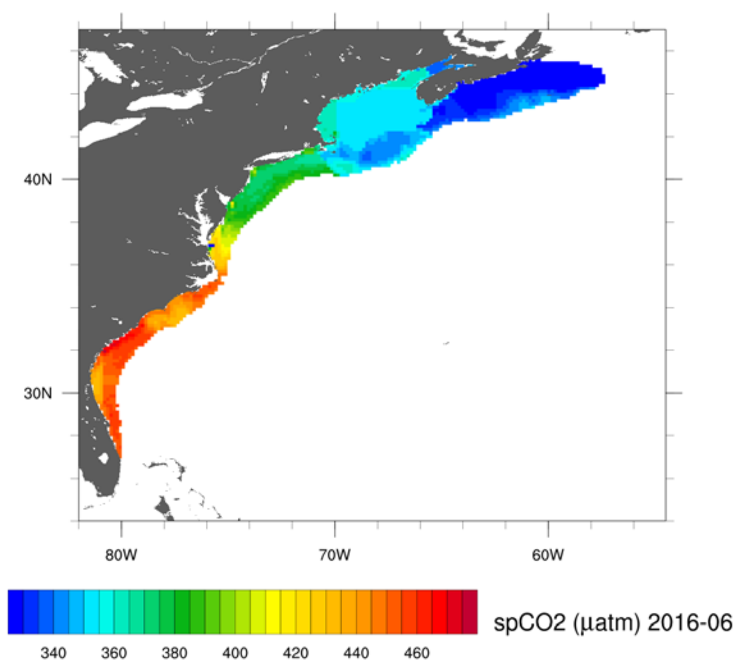


Figure 4: The computed surface partial pressure of CO2 near the US East coast in July 2016.

Serrano also collaborated with ACCRETE's team in their project "Elucidating the recipe of coral reef resilience in the Florida Keys", by providing the algal symbiont characterization of samples collected from the ESA-listed coral *Orbicella faveolata*. To analyze these samples, Serrano used quantitative PCR assays developed for the four main dominant symbiont clades found in Caribbean corals (A-D). This data will be included in a manuscript led by the ACCRETE's team summarizing the results from this study. In addition, this work led to the discovery of unique *O. faveolata* genotypes that are bleaching resistant in the Florida Keys which will be candidates for future ACCRETE field and laboratory experiments aimed at quantifying the heat tolerance of these genotypes.

Local-scale projections of coral reef futures and implications of the Paris Agreement:

In the past Dr. Ruben van Hooidonk produced climate model-resolution (~1x1°) projections of the timing of annual severe bleaching (ASB). 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, Dr. 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. 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. The results are published in Nature Scientific Reports and are shared as an easy to use Google Earth document on NOAA's Coral Reef Watch website (https://coralreefwatch.noaa.gov/climate/projections/downscaled_bleaching_4km/index.php) and the United Nations Environment Programme Live website (http://www.uneplive.org/theme/index/19#data).

Projections of bleaching in UNESCO World Heritage Sites with Coral Reefs:
Using the satellite data and the downscaled bleaching projections an analysis on the UNESCO's World Heritage Sites with coral reefs was performed. This is the first global scientific assessment of climate change impacts on World Heritage coral reefs. Soaring ocean temperatures in the past three years have subjected 21 of 29 World Heritage reefs to severe and/or repeated heat stress, and caused some of the worst bleaching ever observed at iconic sites like the Great Barrier Reef (Australia), Papahānaumokuākea (USA), the Lagoons of New Caledonia (France) and Aldabra Atoll (Seychelles). The analysis predicts that all 29 coral-containing World Heritage sites would cease to exist as functioning coral reef ecosystems by the end of this century under a business-as-usual emissions scenario.
http://whc.unesco.org/en/news/1676

Ocean Acidification Product Suite:
Dr. van Hooidonk constructed and improved a tool to monitor ocean acidification over the wider Caribbean and Gulf of Mexico. This tool utilizes satellite data and a data-assimilative hybrid model to map the components of the carbonate system of surface water. This effort represents an update to the experimental Ocean Acidification Product Suite (OAPS) developed by Coral Reef Watch (http://coralreefwatch.noaa.gov/satellite/oa/index.php). A similar effort is underway to monitor OA on the USA East coast, where algorithms are tailored to each of 5 specific regions.

In 2016-2017, CIMAS researcher Dr. Lew Gramer completed analysis and a final report on products from a NOAA CRCP-funded project to monitor turbidity over shallow reef waters. The project was in collaboration with Jack Stamates of NOAA, and Prof. Chuanmin Hu and Dr. Brian Barnes of University of South Florida, covering southeast Florida, American Samoa, and the Commonwealth of the Northern Mariana Islands (CNMI). These partners analyzed results of a novel algorithm to produce a proxy (Color Index or "CI") for "relative" in-water turbidity within shallow (<= 5 m) generally clear waters near shore, using ocean color data from the MODIS instruments aboard polar-orbiting satellites. The algorithm was applied to fifteen years of historical daily satellite overpasses at 250m spatial resolution in order to generate baselines from long-term time series, with forward processing continuing in near-real time (2002 – present). These satellite ocean color products were analyzed to characterize the source of turbidity plumes such as those related to the Port of Miami expansion dredging, and to assess their potential impact on coral reefs. A paper was submitted by USF partners to the journal Remote Sensing of Environment, also incorporating data from management actions of the South Florida Water Management District. For the final report, Gramer produced time series of relative turbidity and processed and analyzed high-resolution wave model products for multiple smaller Regions of Interest within the three jurisdictions. He used linear relationships between relative turbidity and modeled wave height seasonally in southeast

Florida and the major island of American Samoa, Tutuila, to control for the effect of wave action on coastal turbidity. Waves did not explain all significant events of relative turbidity at in these ROIs, nor was such a relationship apparent for any regions analyzed within the CNMI. The report further analyzed the spatial placement and timing of events within each region to show that the satellite products do in fact allow monitoring of in-water turbidity related to land-based sources of pollution (LBSP) over these three disparate shallow coral reef systems.

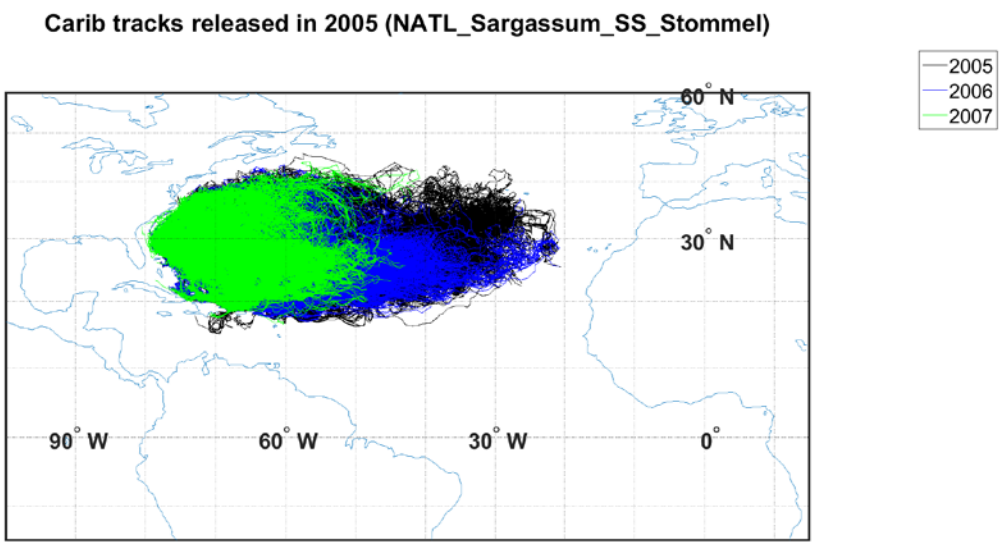
Gramer also completed final analysis and a report on a collaboration with NOAA scientists Tom Carsey(ret.) and Jack Stamates, Profs. Brian Walker and Alexander Soloviev of Nova Southeastern University, and Luke McEachron of Florida Fish and Wildlife Commission, to gather and analyze oceanographic data on upwelling in southeast Florida. Approximately seventeen (17) years of acoustic Doppler current profiler (ADCP) ocean current profiles, and sea temperature data at multiple sites, were analyzed for the region. The goal was to contribute information to the nutrient mass budget of the northern Florida reef tract, by quantifying nutrient fluxes associated with ocean upwelling. In a prior year, Gramer analyzed ship bottle and temperature data from depths of 20 to 360 m and found consistent linear relationships between temperature (T) below 24 °C and each of the three macronutrients, nitrogen, phosphorous, and silicates The final report characterizes total annual fluxes of heat, nitrate plus nitrite, soluble phosphate, and silicates, as well as along- and cross-shore patterns and interannual variability in these fluxes. Distributed across the length of the SE Florida shelf, total volume of upwelled water at the 30m isobath is of order 1 million m^3/year.

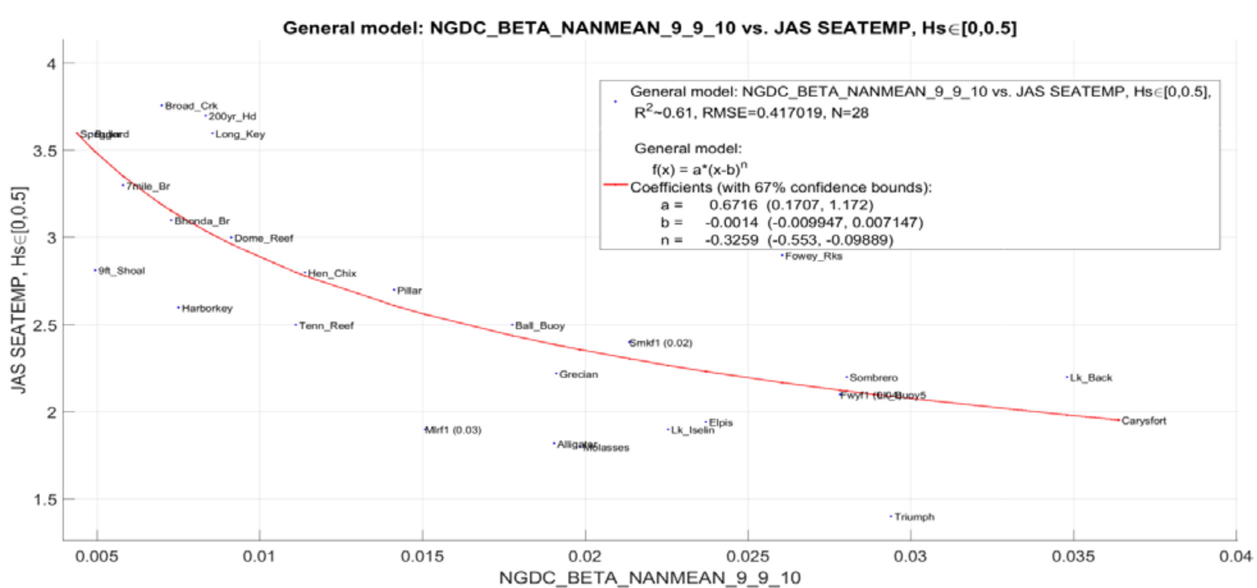
Analyses suggesting dynamical oceanographic mechanisms for the upwelling will be submitted for peer review in 2017-2018. These analyses and the final report show that summer upwelling occurs annually throughout the approximately 100 km length of the southeast Florida shelf from Miami-Dade to Martin Counties. For the upcoming paper, Gramer analyzed sea temperature and ocean currents data from a partner-maintained array of moorings at depths of 11 to 140 m in the central SE Florida shelf over two years, thirteen years of such data from the mooring at 11 m, as well as currents and temperature data from twelve other instrumented moorings on the shelf from 2002 to 2016. These data showed consistent episodic summer upwelling of water at initial temperatures from 10 to 23 °C, and that this cooler, nutrient-rich water mixes across the shelf at a predictable rate, reaching sites as shallow as 4 m inshore with final temperatures ranging from 21 to 28 °C. Analysis for the paper shows that these events are dependent on ocean stratification, as they do not occur during months when near-surface vertical-ocean mixing is most energetic, generally November through April. It further shows that the timing of many of these events can be explained by a variety of oceanographic processes other than direct air-sea flux, including sea surface wind stress (coastal Ekman flux divergence), and breaking (overtopping) on the sloping shelf topography of either internal waves or vortical instabilities of the Florida Current. This information is a significant contribution to knowledge of the coastal environment in Florida, and Gramer is working with regional managers in 2017-2018 to help directly inform their decisions related to the management of the reefs and related human uses.

Dr. Nathan Putman and Dr. Gramer undertook a project in 2016-2017, funded under the NOAA 'Omics Initiative. The project applies data from hydrodynamic model outputs for sea-surface currents, waves, and winds to numerical experiments in Lagrangian particle tracking. The goals of these experiments are to better understand the biogeography of two important, distinct classes of marine organisms: benthic corals in the Florida reef tract, and the pelagic species of the algal genus *Sargassum*. Outbreaks of coral disease have become a rapidly increasing threat to the hard coral communities in south Florida, and Putman and Gramer seek to use Lagrangian particle tracking to better quantify the patterns of connectivity that may transport both disease-resistant traits, and potentially pathogens, between these communities. In a separate effort, Putman and Gramer worked together with Drs. Gustavo Goni, Libby Johns, and Jim Hendee of NOAA to model "brown tides" of recent years (2010-2011, 2014-2015) – large mats of pelagic *Sargassum* coming ashore with significant economic and ecological impacts on regions of the Caribbean and Gulf of Mexico to "brown tides". They simulated the Lagrangian transport of pelagic *Sargassum* to the Caribbean and Gulf between 2000 and 2016, from regions of the north Atlantic subtropical gyre

where its historical distribution is known. Both modeled ocean currents, winds, and the interaction between them right at the sea surface – an effect called "Stommel shear" – were found to be important in reproducing observed *Sargassum* distribution and movement (Figure 5b). Both efforts – Florida coral connectivity and Sargassum biogeography – are expected to result in peer reviewed publications in 2017-2018.

Finally, in 2016-2017 Gramer began a collaboration with Drs. Xaymara Serrano, Maribeth Gidley, Chris Sinigalliano, and Prof. Chris Langdon. He analyzed multiyear records of *in situ* sea temperature from CREWS/ICON stations in the U.S. Caribbean and from partner-maintained moorings in the Florida Keys. These analyses compared sea temperature variability with meteorological measurements, remotely-sensed turbidity, modeled waves, and bathymetric site data – water depths, estimates of seafloor slope and bottom roughness, and predicted patterns of exposure to waves. The objective of this analysis is to characterize geographic differences in the benthic biological community at distinct reef sites (community species composition and richness, and genetic information on corals, their endosymbionts, and the accompanying microbiome), in terms of persistent features of their physical environment that may help to drive such differences. (Figure 5c).





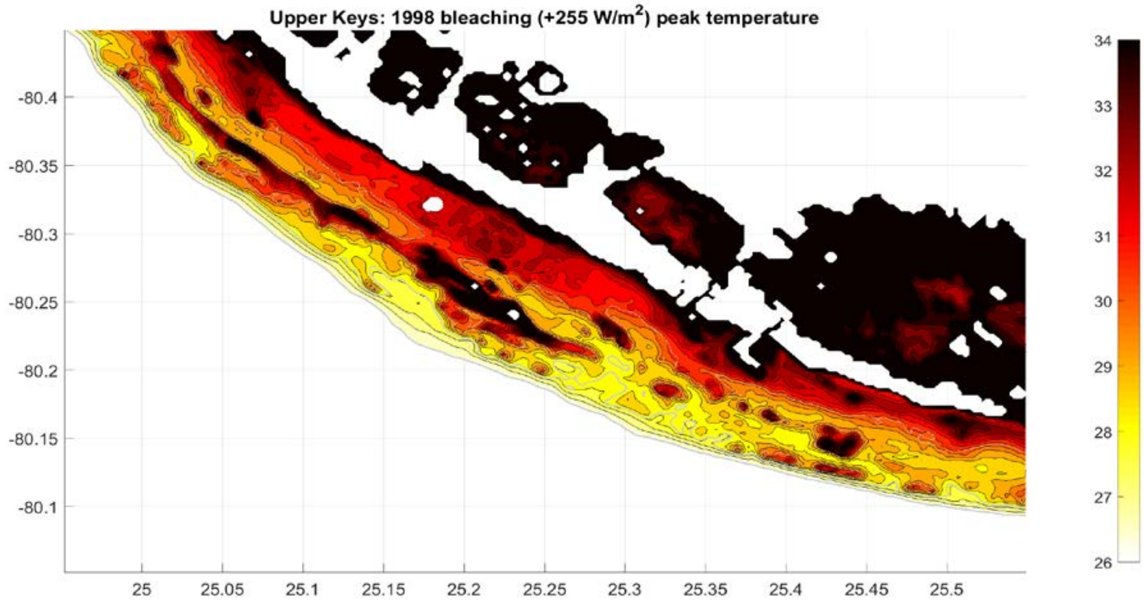


Figure 5a: Lagrangian particle tracking experiments showing the combined effects of modeled ocean surface currents and wind-driven surface water motion ("Stommel shear") on simulated pelagic *Sargassum* distributions during the years (b) 2010-2012. The latter period includes years when "brown tides" of *Sargassum* caused significant economic impacts coming ashore along coastlines of the Caribbean. Gulf of Mexico, and Florida. **Figure 5b, c:** Statistical analysis showing a relationship between summer-time (July-September) sea temperature variability at approximately 30 sites in the Florida Keys, and seafloor slope at those sites, consistent with predictions for an oceanographic process called horizontal convection. Maps of predicted sea temperature variability in the Florida Keys based on horizontal convection and air-sea flux during a warm summer in the Upper Keys when coral bleaching occurred

Dr. Amornthammarong has developed low-cost underwater temperature data logger for long-term monitoring shallow ocean waters (fig m1) that has an accuracy of +/-0.05 C, can remain submerged for over six months without a change of its AA batteries, and costs about $15 in parts. This low cost sensor (comparable with a commercial sensor at ~$130) has the potential to enable wide geographic coverage for acquiring long-term, high-accuracy data sets to better characterize the course of daily and seasonal temperature fluctuations. Currently, Dr. Amornthammarong has been granted a provisional patent for this technology. Temperature is an important factor to consider when assessing water quality. It influences several other parameters and can alter the physical and chemical properties of water. In addition, water temperature can affect the metabolic rates and biological activity of aquatic organisms. Some organisms, such as aquatic plants, flourish in warmer temperatures, while some fishes such as trout or salmon prefer colder streams. Water that is too warm is usually considered to be more dangerous to aquatic life than cold water. Water that is too cold will affect the biological processes and metabolic rates of aquatic organisms. The more and higher accuracy data, the more abnormal fluctuations can be detected and addressed.

As part of a citizen-science collaboration with local communities and county partners in Broward County led by AOML/Sea Grant scientist Pamela Fletcher, an array of these devices will be deployed on southeast Florida shelf in July, to observe gradients in sea temperature across and along shore and high-frequency variability, including possible summer upwelling. These data will be analyzed by NOAA-CREST Fellow Andrea Gomez beginning this Fall, in concert with Fletcher, AOML scientist Jack Stamates, and AOML/CIMAS scientist Lew Gramer. This project is part of a larger effort by AOML PI Jim Hendee's Coral Health and Monitoring Program (CHAMP) to understand sea temperature at the scales and depths where corals and other coastal benthic organisms exist. (Figure 6)

Figure 6: Picture of the low cost, long term, submersible temperature data loggers.

Another aspect of CHAMP this past year has been to conduct coral ecosystem microbiome/holobiont studies to better understand coral ecosystem biodiversity, function, and health status. Drs Gidley and Sinigalliano, supported by Ben VanDine and Paul Jones, are addressing the issue 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, physical, and biological oceanographic data. The community composition, biodiversity, and interactions of the coral algal symbiont populations in the coral holobiont and of the microbial community populations in the coral microbiome have been implicated as major drivers influencing coral resiliency to environmental stress. AOML, in cooperation with CIMAS, has developed a pilot Coral Genomic Observing Network (CGON) for reefs in Southern Florida. These coral ecosystem genomic observations are integrated into a number of NOAA programs, including the Coral Reef Conservation Program (CRCP), the Coral Health and Monitoring Program (CHAMP), the AOML 'Omics Initiative, and the NOAA Marine Biodiversity Observation Network (MBON) program. This research is characterizing coral microbiome community metagenomic structures and biodiversity by Next-Generation-Sequencing (NGS) and measuring land-based microbial contaminant exposure of reefs by molecular microbial source tracking (MST) for corals, near-coral sediments, and water column communities that may influence coral reef status. This CGON research is conducted by CIMAS personnel and by collaborators from NOAA, from Nova Southeastern University (NSU), and from the University of Minnesota Biotechnology Institute. This past year, as part of the CHAMP research, we have concluded a CRCP project investigating LBSP influences on coral microbiomes of reefs offshore of Broward and Miami-Dade Counties using both NGS and MST approaches (Figure 7). We have published the NGS part of this work (Staley et al., 2017), and are currently preparing the MST portion for publication. A similar study has also been initiated for the Florida Keys National Marine Sanctuary (FKNMS).

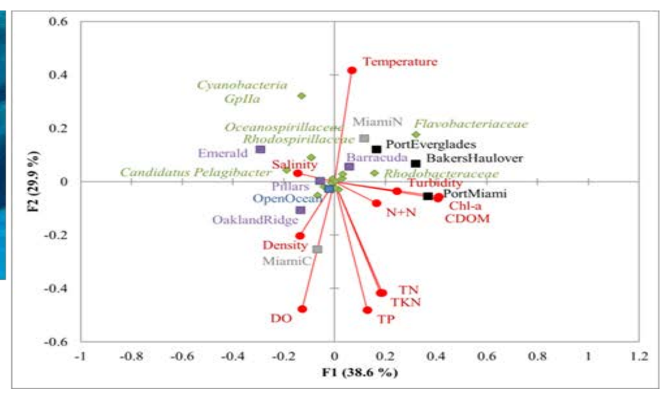


Figure 7: (left): Diver collects coral tissue by syringe biopsy for coral microbiome analysis; (right): Redundancy analysis relating physicochemical parameters, sample site locations, and distributions of the 15 most abundant bacterial families among water samples collected from SE Florida Reef Tract

Research Performance Measure: The CHAMP project addressed and met the defined objectives during 2016-2017 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.

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Southwest Atlantic Meridional Overturning Circulation ("SAM") Project

Project Personnel: R. Garcia, S. Garzoli and R. Perez (UM/CIMAS)
NOAA Collaborators: S. Dong, C. Meinen, P. Peña, 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/OOMD
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

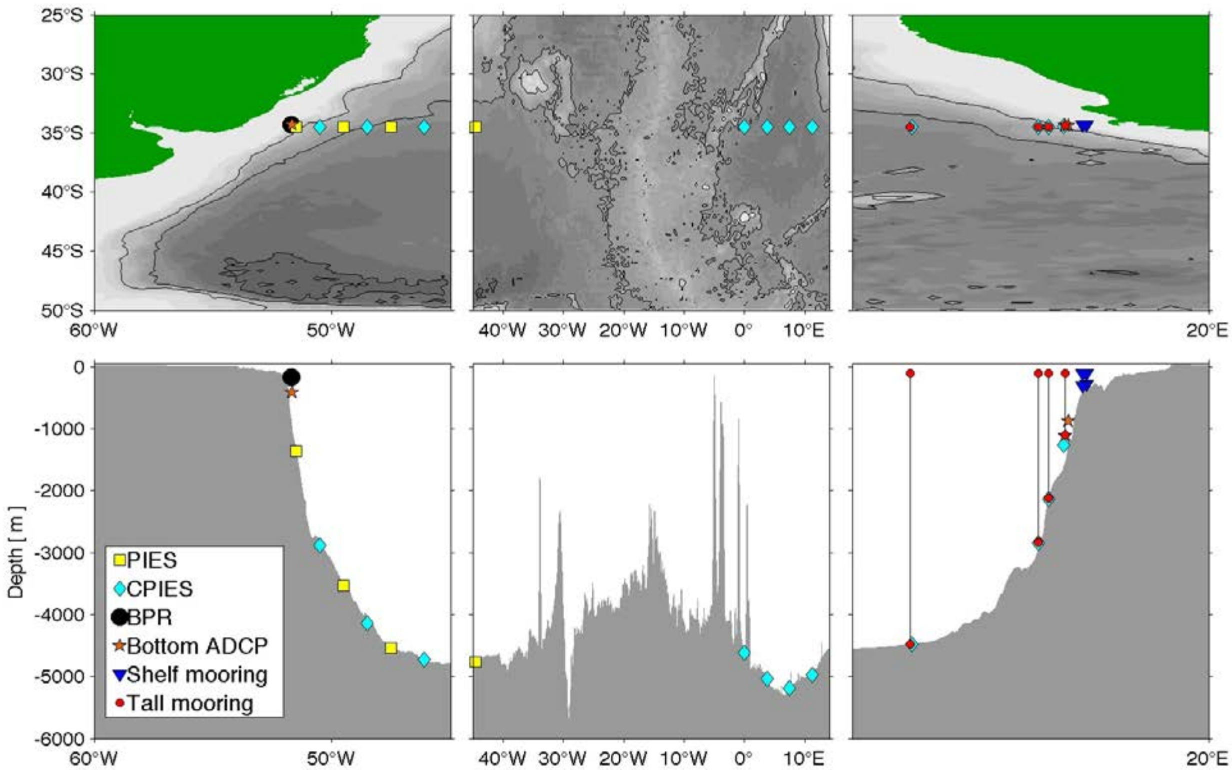

Figure 1: Map indicating the location (top panel) and the vertical distribution (bottom panel) of the four NOAA PIES making up the SAM array at 34.5°S; also shown are the Brazilian CPIES deployed in December 2012, the Brazilian coastal moorings deployed in December 2013, the French CPIES deployed in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

South Africa along 34.5°S (Figure 1). With nine moorings on the western side of the basin (in December 2013) and fourteen moorings on the eastern side of the basin (in September 2014), this trans-basin array ("SAMBA") has achieved a new milestone of collecting multi-year daily trans-basin MOC measurements. Note, the number of total moorings deployed has varied since 2013-2014 depending on the timing and success of recovery/redeployment missions. Efforts now are focused on mid-deployment data retrievals, instrument recovery and redeployment, and obtaining funds for future augmentations to the array.

Research Performance Measure: Ship time issues in 2015 had resulted in only limited PIES (pressure equipped inverted echo sounder) data being available during that year. In October 2016, two years worth of data were collected and processed after a successful cruise. Project PIs led and/or participated in a peer-reviewed paper on the DWBC variability at 34.5°S that was published this year (Meinen et al. 2017). Project PIs are collaborating with international researchers on future manuscripts describing the variability of the Brazil Current and the DWBC along 34.5°S using data from the SAM

PIES and Brazilian CPIES (PIES with a current meter 50 m above seafloor), 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 AMOC volume transport from the combined international observed arrays along 34.5°S, and from comparisons between these time series and numerical models. Results from several analyses were presented at the Ocean Observing and Monitoring Division (OOMD) Community Workshop in Silver Spring, MD in May 2017 and at the US AMOC Science Team meeting in Santa Fe, NM in May 2017.

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Interannual-to Decadal Variability of the South Atlantic MOC

Project Personnel: A. Gronholz (UM/CIMAS); B. Kirtman (UM/RSMAS/CIMAS)
NOAA Collaborators: S. Dong, S.-K Lee, G. Goni and M. Baringer (NOAA/AOML); M. Harrison (NOAA/GFDL)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To better understand the South Atlantic Meridional Overturning Circulation (SAMOC) variability and to explore the impact of mesoscale eddies on SAMOC variability on interannual to decadal time scales.

Strategy: To use a combination of analysis of CMIP5 models and ocean model experiments to study decadal variability of the SAMOC in CMIP5 models, to explore the role of mesoscale eddies on decadal variability of the SAMOC and to quantify the relationship between the Southern Hemisphere westerlies and the SAMOC.

CIMAS Research Theme:

***Theme 1*:** Climate Research and Impact *(Primary)*
Theme 4: Ocean Modeling *(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: NOAA/OAR/CPO
NOAA Technical Contact: Sandy Lucas

Research Summary:

The importance of the Meridional Overturning Circulation (MOC) derives from its role in transporting oceanic properties, in particular the oceanic heat. The conventional view is that the MOC and the associated Atlantic Meridional Heat Transport (MHT) are largely modulated by deep convection activity in the high-latitude sinking regions in the North Atlantic. However, recent studies have suggested the possibility of the southern origin of the Atlantic MHT anomalies. These studies have used General Circulation Models (GCMs) to demonstrate co-variability between the South Atlantic MOC (SAMOC) and the Southern Hemisphere westerlies at interannual to longer time scales. However, it has been pointed out that the sensitivity of the SAMOC to the changes in the Southern Hemisphere westerlies depends critically on the representation of mesoscale eddies in those models. Indeed, in the South Atlantic, eddy heat transport contributes significantly to the MHT and accounts for a considerable portion of the MHT variance. The observation-based estimates of MHT in the South Atlantic have a wide range of values, which, to some extent, is due to the misrepresentation of the eddy heat transport. Therefore, understanding the variability of the MOC/MHT in the South Atlantic on various time scales and the role of eddies in the South Atlantic are essential ingredients toward achieving decadal predictability of the

Atlantic MOC and its impact on climate. Therefore, in order to better understand the variability of the MOC/MHT in the South Atlantic, we explore the impact of resolving eddies in an ocean GCM on interannual-to-decadal variability of the simulated SAMOC and quantify the relationship between the Southern Hemisphere westerlies and the SAMOC.

For the proposed high-resolution ocean model experiments, a computer account at GAEA has been set up, where the proposed ocean model experiments will be performed in collaboration with Matthew Harrison (GFDL). So far, we configured the Modular Ocean Model (MOM) version 5 and version 6, developed at GFDL, and conducted several test case simulations for MOM5 and MOM6 to test general provided ocean-only and coupled ocean-sea ice simulations.

In collaboration with Ben Kirtman (UM/CIMAS), we have downloaded the eddy-resolving *Community Climate System Model version 4 (CCSM4) simulation carried out at UM/RSMAS.* In an effort to explore the impact of resolving eddies in numerical models on representation of the SAMOC, we analyzed the outputs from the eddy resolving CCSM4 and non-eddy resolving (i.e., eddy-parameterized) Community Earth System Model version 1 (CESM1) as shown in Figure 1. By the use of temperature, salinity and sea surface height fields of CCSM4 dataset, we are currently conducting our first investigations regarding eddy pathways into and across the South Atlantic.

Additionally, we set up and are currently testing a two-level quasi-geostrophic model to explore the Agulhas leakage variability in response to the changes in global overturning circulation and Southern Hemisphere westerlies. The two-layer QG model fully resolves mesoscale eddies and is much faster to run compared to primitive equations models. Thus, we started to perform different experiments using this model to answer some of the scientific questions of this project.

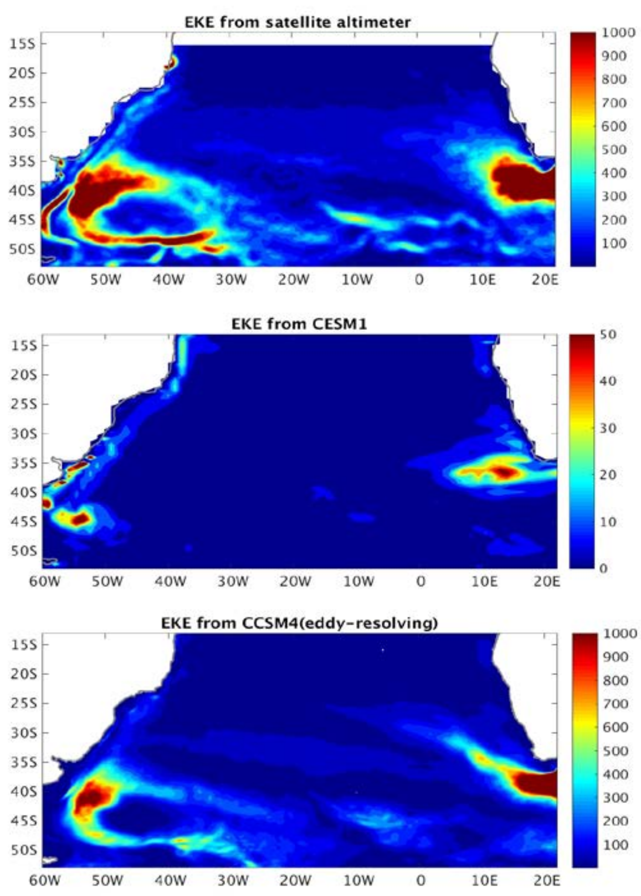

Figure 1: Time-mean eddy kinetic energy (EKE) at the ocean surface computed from the geostrophic velocity of satellite altimetry (top), non-eddy permitting model CESM1 (middle), and the eddy-resolving model CCSM4 (bottom). Units are $cm^2\ s^{-2}$. Note that a different color scale is used for CESM1 due to its low values.

Research Performance Measure: For the first 9-month of the project, our work follow the initial work plan, no significant deviations from what we proposed. However, due to the time needed for the search of postdoctoral researcher, our planned work is delayed.

2016 National Coral Reef Monitoring Plan

Project Personnel: K. Kilfoyle and R. Spieler (NSU)
NOAA Collaborators: M. Johnson, L. Grove and J. Kimball (NOAA/SEFSC)
Other Collaborators: S. Smith (UM/RSMAS); J. Blondeau (UM/CIMAS)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** The overarching goal of the National Coral Reef Monitoring Plan (NCRMP), in the broadest sense, is to provide a "consistent flow of information to assess and report the status and trends of environmental conditions, living reef resources, and the people and processes that interact with coral reef ecosystems in Federal and U.S. territorial waters (i.e., Florida, U.S. Virgin Islands, and Puerto Rico)". This is aligned with NOAA's strategic plan of 1) improved understanding of ecosystems to inform resource management actions, 2) recovered and healthy marine and coastal species, and 3) healthy habitats that sustain resilient and thriving marine resources and communities. The specific goal for this project is to collect benthic monitoring data from the Southeast Florida Coral Reef Initiative (SEFCRI) region, including coral reef and hardbottom habitats from Martin, Palm Beach, Broward, and northern Dade Counties, for use in a full assessment of coral reef health and trends along the entire Florida Reef Tract (SEFCRI, FL Keys, and Dry Tortugas). This project is complimentary to the Southeast Florida Fishery-Independent Baseline Assessment project (SEFCRI RVC), with both projects incorporating the same statistically robust, habitat-based, tiered protocol and sophisticated allocation and randomization procedures to assess coral reef fish and benthic resources in the southeast Florida coral reef segment.

***Strateg*y:** The NCRMP SEFCRI Benthic Sampling project contains 3 primary tasks: 1) completion of NCRMP benthic surveys in the SEFCRI region, 2) completion of data entry and initial quality control (data proofing) for all surveys, 3) and assisting NOAA-SEFSC and/or RSMAS staff with final Florida report writing. NSU will conduct the 2016 NCRMP biological benthic surveys (LPI and Demo protocols) according to pre-determined survey design. NSU will enter NCRMP data into the NOAA NCRMP database and assist with report completion pertaining to the SEFCRI region data.

CIMAS Research Themes

***Theme 1*:** Climate Research and Impact (*Primary*)
Theme 3: Sustained Ocean and Coastal Observations (*Secondary*)
***Theme 6*:** Ecosystem Management (*Tertiary*)
***Theme 7*:** Protection and Restoration of Resources *(Quaternary)*

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

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

Research Summary:

From August through early November 2016 NSU conducted standardized surveys of benthic community structure, topographic complexity (Figure 1) and stony coral demographics (Figure 2) over the course of 194 individual dives at 97 sampling stations throughout the SEFCRI region (Figures 3 through 6). Classroom and in-water methodology training was provided by NOAA-SEFSC support staff and visiting NOAA staff affiliated with the National Coral Reef Monitoring Program. All project oversight, logistical

coordination, data collection, and data entry was provided by NSU. The Florida Fish and Wildlife Conservation Commission (FWC) – Tequesta Laboratory assisted with one day of vessel support for sampling several sites in the far northern portion of the survey domain near St. Lucie inlet (i.e., Martin County). All other sites were surveyed from NSU vessels.

In December 2016, all data entry was completed and proofed for errors by each individual survey diver. This was immediately followed by a rigorous quality assurance/quality control procedure with assistance from NOAA-SEFSC support staff. Following that, in early 2017, the process of creating an analysis-ready dataset was initiated, and completed in the spring. Full data analysis and reporting is beyond the scope of this project, but the dataset is currently being analyzed by NOAA scientists and NSU personnel remain available to assist in a supporting role during the analysis.

Figure 1: Survey diver conducting a line point-intercept (LPI) survey along transect line.

Figure 2: Survey diver conducting a coral demographic survey along transect line.

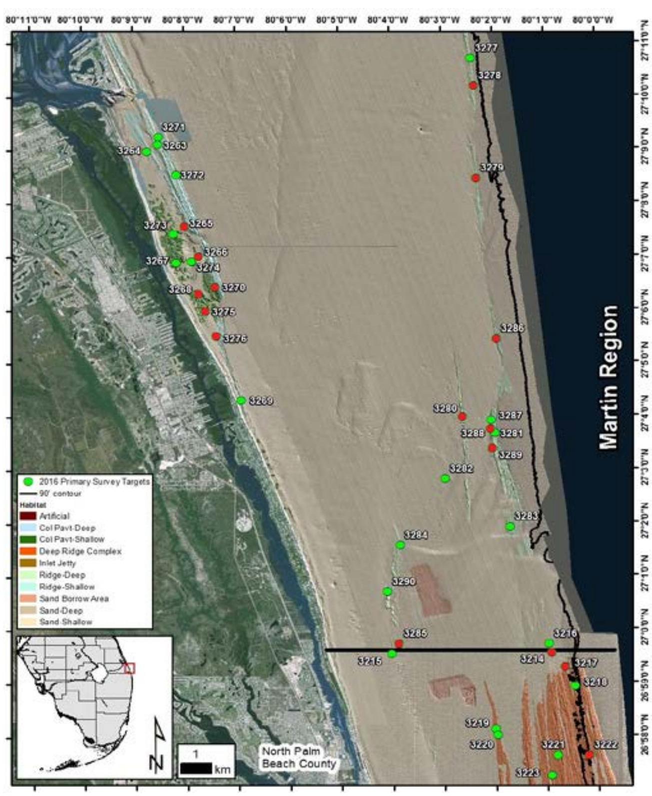

Figure 3: SEFCRI region 2016 survey targets for the Martin subregion. Green dots indicate location of RVC fish surveys. Red dots indicate the location of RVC fish + NCRMP benthic surveys.

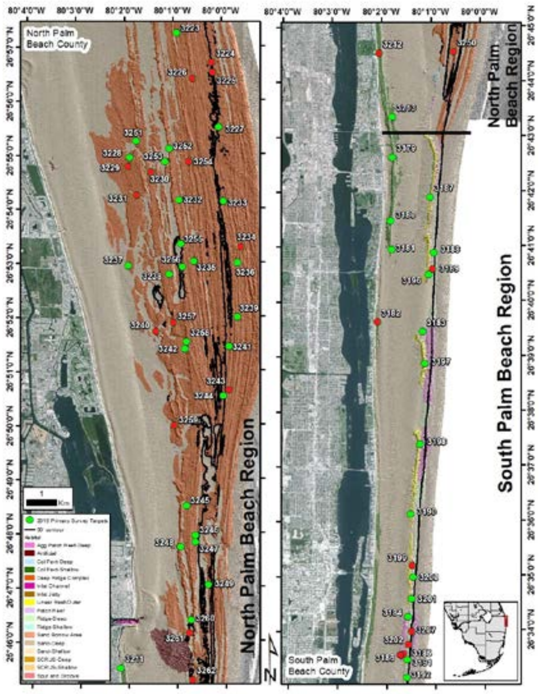

Figure 4: SEFCRI region 2016 survey targets for the North Palm Beach subregion. Green dots indicate location of RVC fish surveys. Red dots indicate the location of RVC fish + NCRMP benthic surveys.

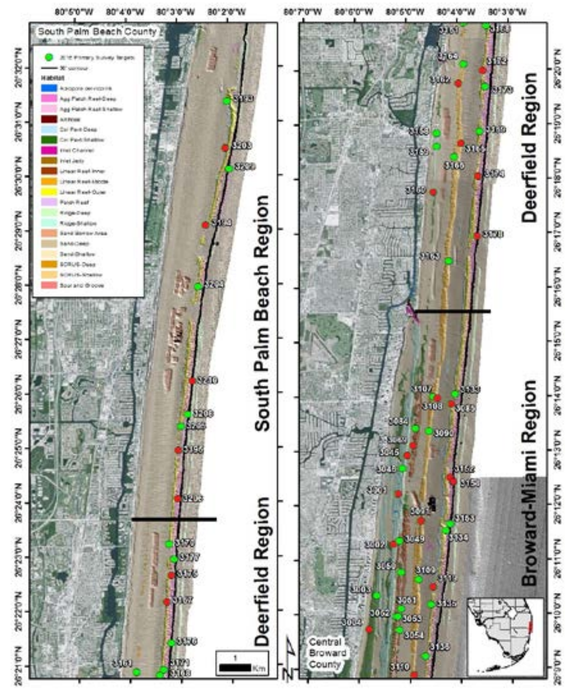

Figure 5: SEFCRI region 2016 survey targets for the South Palm Beach subregion. Green dots indicate location of RVC fish surveys. Red dots indicate the location of RVC fish + NCRMP benthic surveys.

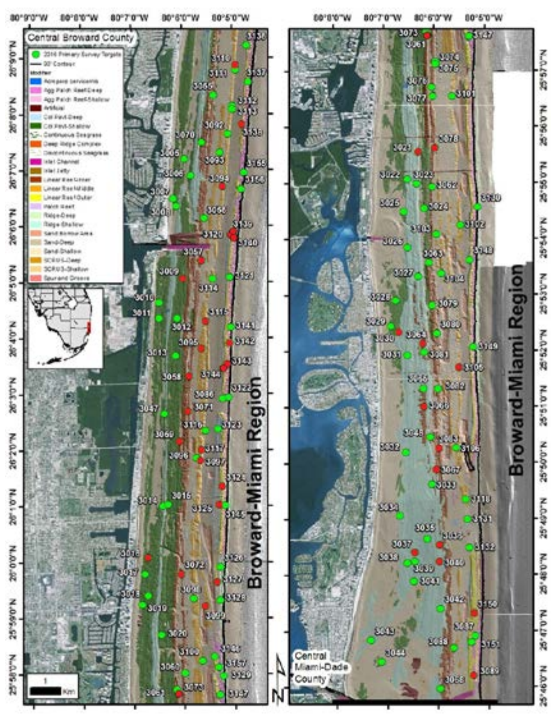

Figure 6: SEFCRI region 2016 survey targets for the Broward-Miami subregion. Green dots indicate location of RVC fish surveys. Red dots indicate the location of RVC fish + NCRMP benthic surveys.

Research Performance Measure: The sample allocation was based on NSU completing benthic surveys at an estimated 100 sites throughout the entire SEFCRI survey domain, and utilized a subset of the survey sites allocated for the Southeast Florida Fishery-Independent Baseline Assessment: Year 5 project (SEFCRI RVC). The total number of survey targets by county are as follows: Martin (15), Palm Beach (32), Broward (40), and Dade (13). NSU completed surveys at 97 out of 100 sites, entered the data, and thoroughly cross checked the data for quality control/quality assurance. All field-related and QAQC milestones were met and primary objectives completed.

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Collaboration with NOAA on PFSST

Project Personnel: K. Kilpatrick, P. Minnett, S. Walsh and E. Williams (UM/RSMAS/CIMAS)
NOAA Collaborators: S. Baker-Yeboah and K. Casey (NESDIS/NCEI)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To complete the final transition of the AVHRR Pathfinder SST Climate data from the research environment to full operations at NOAA.
***Strategy*:** Provide training and analytical software scripts to NOAA related to calibration and validation of AVHRR SST products, and verify the successful transition of all PFSST activities to NOAA operations.

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

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

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

Research Summary:
The 35 year record of global AVHRR Pathfinder sea surface temperature (PFSST) is one of the signature and most widely used products in NOAA's Climate Record Data stewardship program (CDR), with a very broad user base both within NOAA, university research groups, and internationally, including through the Group on High Resolution Sea Surface Temperature. The PFSST product was originally developed by researchers at the University of Miami/RSMAS and, as part of NOAA's Research to Operations program (R2O), the software and production was migrated over a several year period to be the responsibility the CDR program. We have now completed and verified the final phase of this transition to NOAA operations.

This year's activities focused on training NOAA personnel within the CDR program to become skilled in the use of analytical methods and tools to validate and maintain the accuracy of the Pathfinder SST CDR time series. Scripts and access to data sets needed by NOAA to continue the generation of the matchup database of collocated Level-1 and Level-2 satellite measurements with *in situ* SST data were also provided. Training and software provided by UM researchers to use the matchup database for coefficient

estimation to optimize the atmospheric correction algorithm, diagnostic analyses, and methods for uncertainty estimation.

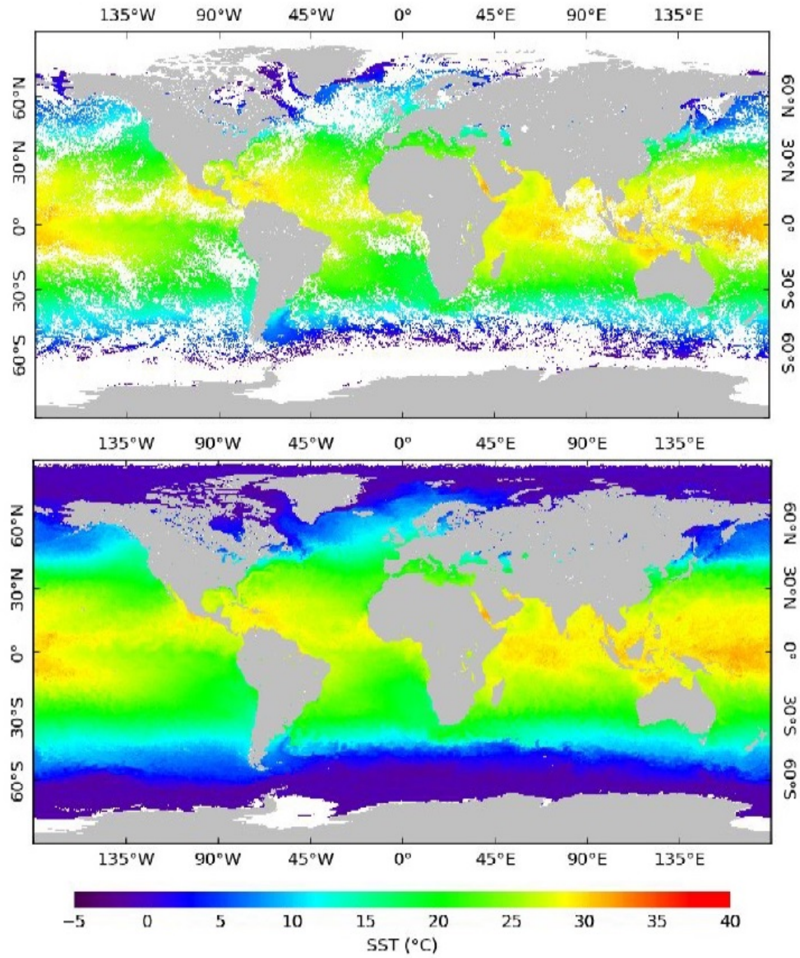

Figure 1: Newly generated V5.3 Pathfinder SST 7-day climatology (top) and gap-filled field (bottom) used, for example, to calculate thermal stress anomalies and degree heating days in the Coral Reef Temperature Anomaly Database (CoRTAD).

Research Performance Measure: All analytical software was successfully transitioned to the NCEI CDR group. Training was completed. The PFSST V5.3 data set for the period 1981 through 2016 was validated by NOAA/NCEI CDR group. It was released in September 2016.

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

Project Personnel: B. Kirtman (UM/RSMAS/CIMAS)

Long Term Research Objectives and Strategy to Achieve Them:

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

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

The recent US National Academies "Assessment of Intraseasonal to Interannual Climate Prediction and Predictability" (NRC 2010[1]) was unequivocal in recommending the need for the development of a US NMME operational predictive capability. Indeed, the national effort is required to meet the specific tailored regional prediction and decision support needs of the emerging National Climate Service. The challenge is to meet this national need without diluting existing model development activities at the major centers and ensure that the forecast products continue to improve and be of societal value.

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

CIMAS Research Theme:

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

Link to NOAA Strategic Goals:

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

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

[1] http://www.nap.edu/catalog.php?record_id=12878

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

Research Summary:

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).
- We are in the process of developing, in collaboration with NCEI, the dissemination of real-time daily data of limited fields.

b. Seasonal Forecasting of Winds, Waves and Currents in the North Pacific

The ability to accurately forecast beyond 'weather' time-scales (up to seven days) offers socio-economic value by effective managing and planning against changes in weather and climate. An improved assessment and understanding of the upcoming environmental conditions beyond one month (seasonal time-scale) can allow decision makers to reduce costs and increase safety. One example of this is seasonal forecasting of tropical cyclones. The re-insurance industry uses this data as a means of risk management by estimating financial losses occurred by landfalling tropical cyclones over a season. In addition, this data is used for preparedness for residents and businesses of coastal and near-coastal regions.

Vessel routing is an important industry where seasonal forecasting can help to reduce fuel costs and improve vessel stability for voyages lasting more than a few weeks. To the authors knowledge this has yet to be implemented. Optimal ship routes depend on environmental conditions such as weather, ocean waves and ocean currents. The vessel route is also influenced by the vessel's characteristics such as hull design and propulsion efficiency; however, these are outside the scope of this study. Beyond weather time-scales, voyage planners will use climatology: the average of all previous years. Climatology is the bench-mark to beat for a successful seasonal forecast. One of the longest seafaring journey is across the Pacific from Singapore to San Diego (almost 15,000 km). This journey was undertaken by the US Navy's Littoral Combat Ship (LCS 3) Fort Worth at the end of Summer 2016 which took approximately one month. This paper explores the skill of forecasting environmental conditions for the North Pacific on seasonal time-scales to assess the benefit such a system would provide to voyage planners.

In terms of seasonal forecasting of the environmental conditions which are important for vessel routing (surface wind, surface currents and waves) there has been little research. Seasonal forecasting of surface wind have been investigated in terms of extremes such as tropical cyclones in the Western North Pacific and East Pacific and extratropical cyclones, however seasonal forecasting of extremes still has challenges (Slater *et al*., 2016). While forecasting extremes months ahead is important, the vessel will ultimately avoid heavy weather (and therefore the entire distribution of the field is needed. An assessment of seasonal forecasting of ocean currents has yet to be complete with most research focusing on the short-

term forecasting. For ocean waves, Lopez & Kirtman (2016) noted that the boreal summer significant wave height is predictable in the Western North Pacific region up to five months ahead. This skill improved during El Niño years via a strengthening of the northwest Pacific subtropical high. Other studies have looked at the climatology of waves in the North Pacific.

The purpose of work reported here is to determine the predictability of environmental conditions in the North Pacific for vessel routing between Singapore and San Diego. Fig 1b, for example, shows the monthly climatology of wind speed, current speed and significant wave height along the great circle between Singapore and San Diego shown as the black line in Fig. 1a. Wind speed and current speed are used here instead of the U and V components as to not offer preference of the direction of travel between the two locations. Wind speed and significant wave height have large seasonality with higher values in the winter month associated with extratropical cyclones and lower values in the Summer months. July is the calmest month across the North Pacific. The surface current speed has less seasonality and the lowest values are in the Spring. It would be ideal to transport a vessel in July as it would have the least amount of route deviation due to inclement weather. Therefore, we focus on forecasting July in this study.

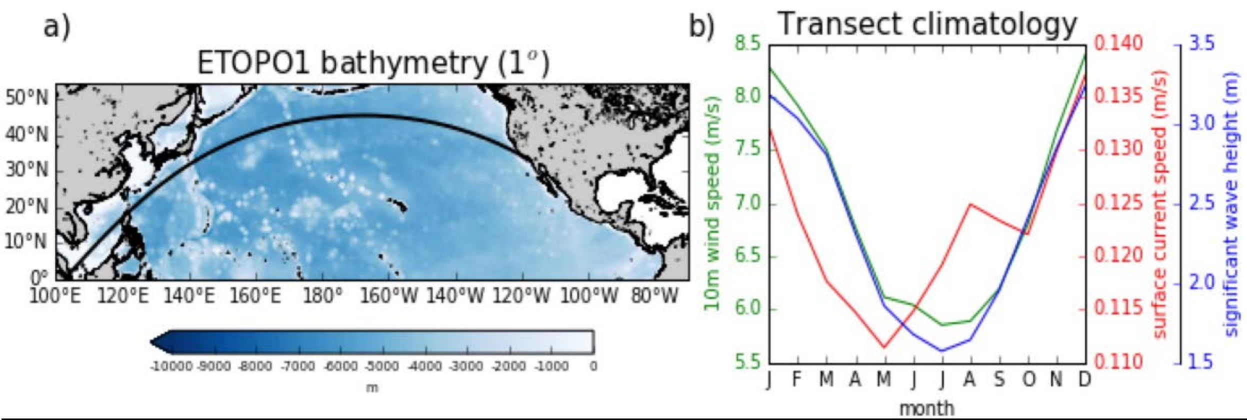

Figure 1: a) Bathymetry of North Pacific from ETOPO1 at 1° spatial resolution. The black line is the great circle between Singapore and San Diego (transect). b) Transect monthly climatology (January to December) for 10m wind speed (green; ERA-Interim); significant wave height (blue; ERA-Interim) and ocean surface current speed (red; ORAP5).

Figure 2 shows spatial maps of the skill metrics presented in section 2.7 for CCSM4 compared to ERA-Interim. For the deterministic skill metrics, there is skill throughout most of the tropics. The largest anomaly correlation results are in the tropical central Pacific and southern South China Sea (Fig 2a). The anomaly correlation coefficient becomes weaker in the extratropics (north of 30°N) but some areas remain statistically significant at the 95-percentile level. For the RMSE (Fig. 2b) the largest sources of error are in the South China Sea, south of Japan and in the north-east North Pacific. The ensemble spread (Fig. 2c) shows a clear divide between the north west - as the location of the subtropical atmospheric jet varies – and the south-east which has little variability between model ensembles. The blue colors of saturation RMSE in Fig. 2d show where the forecast error is smaller than internal variability. The region around 10°N, 160°E-140°W shows the highest level of skill. In the track of the vessel crossing (black line) the model is skillful below ~30°N. For the probabilistic skill metrics, the RPSS (Fig. 2e) shows the region in the central North Pacific has more skill than a climatological forecast however, further into the extratropics the RPSS is noisier. The positive normalized ROC area under the curve in Fig. 2f shows a similar pattern to positive RPSS.

July H_s is shown to be skillfully forecast with a one-month lead time for the Western North Pacific and south of Hawaii (Fig 3). The anomaly correlation is statistically significant in both these regions (Fig 3a) along with low values for the saturation RMSE (Fig 3b). CCSM4-WW3 is also able to predict the significant height wave in other regions such as south of Aleutian Islands and in the eastern North Pacific

shown by the positive RPSS (Fig. 3e). The RPSS corroborates the regions which have good deterministic skill and the forecasts can be seen to be better than climatology. Interestingly, there is more skill in the higher latitudes for H_s then there is for wind speed (see Fig 3e and Fig 2e). These results are reported in Bell and Kirtman (2017).

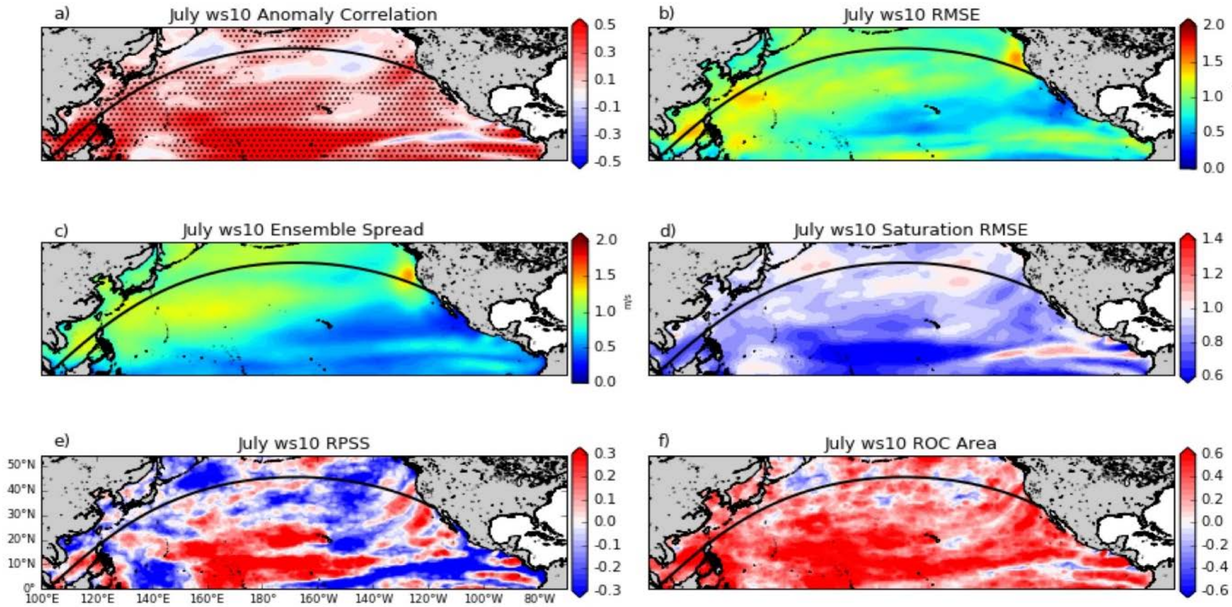

Figure 2: CCSM4 skill of simulating July 10m wind speed compared to ERA-Interim using July initial condition. a) Anomaly correlation; b) Root Mean Square Error; c) Ensemble spread; d) Saturation Root Mean Square Error; e) Rank Probability Skill Score and f) Normalized Relative Operating Characteristic Area. The stippling on the anomaly correlation shows areas where the correlation coefficient is significantly different from zero at the 95-percentile level.

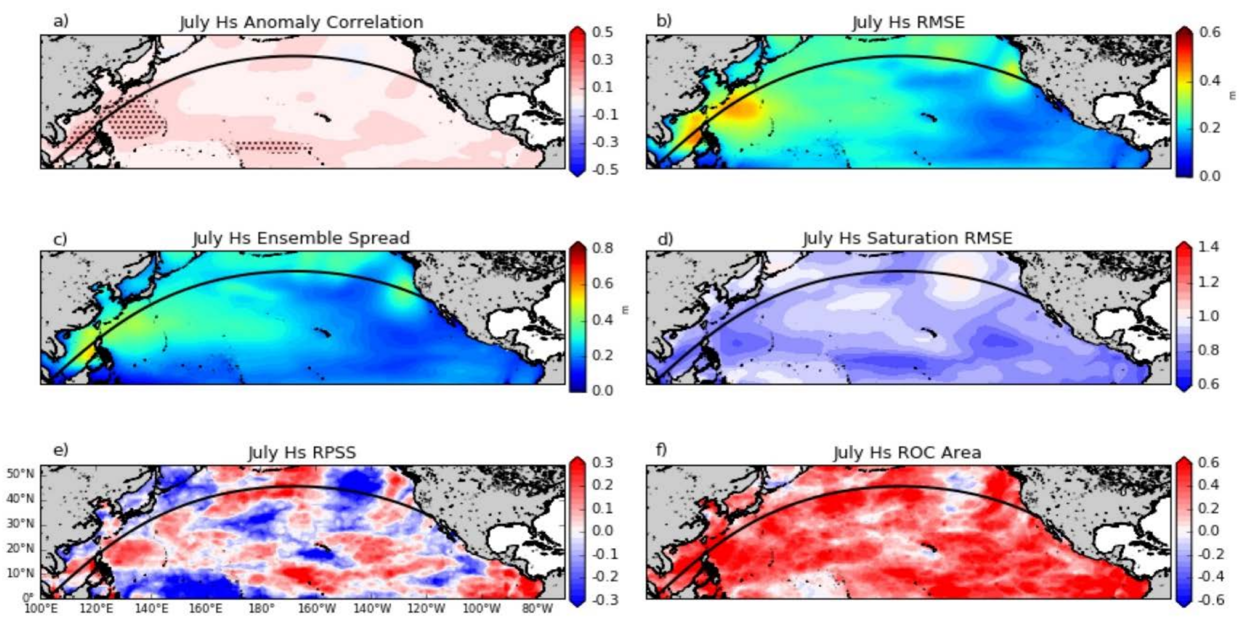

Figure 3: CCSM4-WW3 skill of simulating July significant wave height (H_s) compared to ERA-Interim using July initial condition. a) Anomaly correlation; b) Root Mean Square Error; c) Ensemble spread; d) Saturation Root Mean Square Error; e) Rank Probability Skill Score and f) Normalized Relative Operating Characteristic Area. The stippling on the anomaly correlation shows areas where the correlation coefficient is significantly different from zero at the 95-percentile level.

c. CGCM and AGCM Seasonal Climate Predictions – A Study in CCSM4

Seasonal climate predictions are comprised of model simulations of the near-term climate for approximately a year in the future. These predictions are based on known, present conditions, and simulate anticipated near-term climate information for the upcoming months and seasons. On the seasonal timescale, sea-surface temperatures (SSTs) are a very important element, as predictions are predominantly influenced by slowly evolving surface boundary conditions including, but not limited to, SSTs. We focus on the role of the ocean in seasonal climate predictions of North American land-based precipitation and temperature. We aim to study the relative importance of errors in SSTs (observed versus forecasted) and differences in ocean-atmosphere coupling in predictions made with a coupled general circulation model (CGCM) compared to an atmospheric general circulation model (AGCM). This study considers CGCM and AGCM prediction methods using the Community Climate System Model version 4.0 (CCSM4), of which fully coupled hindcasts are included in the North American Multi-Model Ensemble (NMME) (Kirtman et al. 2014).

Due to the importance of SSTs and potential influence of SST errors, one of our main considerations is the influence of SST errors on hindcast skill and predictability in CCSM4. Foreknowledge or skillful predictions of SST anomalies (SSTAs) can add to predictability or prediction skill in regions with strong associations. For example, SSTAs such as those associated with the El Niño Southern Oscillation (ENSO), can stimulate atmospheric teleconnections that impact North American climate variability. Using historical CMIP5 models, In some regions, such as the southeastern US, prediction skill is highly sensitive to changes in SST, and skill can suffer due to errors in predicted SSTs (Infanti and Kirtman 2015).

A second motivation for this manuscript is the differences in ocean-atmosphere coupling in CGCM versus AGCM predictions. The focus here is on large-scale fields affecting North American climate variability. Wintertime North American climate variability is largely and principally influenced by the tropical Pacific (through ENSO variations). However, other studies have suggested that mid-latitude SSTs may play a role, particularly on seasonal timescales, such as the linkage of the North Pacific ocean and geopotential height over North America, or the Pacific North American (PNA) pattern. The use of a AGCM can lead to inconsistencies in surface energy fluxes, and thus inaccuracies in simulated climate variability. However, CGCMs are not without their deficiencies. They can also produce un-realistic air-sea fluxes due to biases in SSTs or winds. Ocean-atmosphere coupling, or lack of ocean-atmosphere coupling in the case of an AGCM prediction, may have some bearing on model performance and therefore prediction skill due to atmospheric feedbacks on SSTs and any resulting changes in global circulation. It is therefore important to characterize the ocean-atmosphere coupling (or lack of), and the influence on skill and predictability in a prediction setting.

We have focused on a comparison of predictions and simulations in CCSM4 and the role of the ocean in prediction skill and predictability. We provide a comparison of fully coupled predictions versus prescribed SST predictions, and of forecasted versus observed SSTs. Our intent is to determine the relative importance of ocean-atmosphere coupling and SST errors for prediction skill and predictability of precipitation and 2-meter temperature. Prediction skill and predictability are examined through deterministic (anomaly correlation) and probabilistic (RPSS) methods for precipitation and 2-meter temperature. We identify 3 main conclusions from this work related to prediction skill and predictability of 2-meter temperature and precipitation in CCSM4:

1. Prediction skill (predictability) is not significantly influenced (very weakly influenced) by ocean-atmosphere coupling when the same SSTs are used, except for the western Pacific
2. Prediction skill and predictability are significantly and robustly influenced by errors in SSTs when comparing simulations with forecasted versus observed SSTs
3. Comparatively, errors in SSTs lead to more significant and robust differences in prediction skill and predictability versus inconsistencies in ocean-atmosphere coupling

These results are reported in Infanti and Kirtman (2017).

Research Performance Measure: The project has been extended until July 2018, key performance measures are continued operational CCSM4 prediction, and prediction and predictability research with CCSM4.

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The Southward Returning Pathways of the AMOC and Their Impacts on Global Sea Surface Temperature

Project Personnel: M. Goes (UM/CIMAS)
NOAA Collaborators: S.-K. Lee (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives**:* The main working hypothesis of this project is to study the AMOC and its relationship with the global SST. The main objectives are 1) to diagnose the meridional heat transport and its link to model SST biases; 2) Exploring AMOC southward returning flow pathways and sources of the shallow returning flow of the AMOC; 3) To investigate the relationship of North and South Atlantic water masses associated with the AMOC.

***Strategy*:** 1) to perform quantitative analysis to test the above hypothesis using available observations, CMIP5 model outputs, and ocean and sea-ice model experiments; 2) to perform and analyze "robust diagnostic" simulations of the AMOC, where the sensitivity of the model to the relaxed thermohaline properties are investigated. 3) to analyze the effect of different ocean model parameter choices on the AMOC and heat transport, and link to the SST biases/changes in the North Atlantic.

CIMAS Research Theme:

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

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: CVP; OAR/CPO
NOAA Technical Contact: Sandy Lucas

Research Summary:

The Atlantic Meridional Overturning Circulation (AMOC) transports the upper warm water northward and the deep cold water southward in the Atlantic, and is a key component of the global energy balance. A recent study showed that climate models with weaker AMOC are associated with colder upper ocean temperature biases in the North Atlantic. However, in many of the climate models that participate the Coupled Model Inter-comparison Project Phase 5 (CMIP5), the amplitudes of the AMOC agree very well with or are even larger than the observed value of about 18 Sv at 26.5N; but, they still show cold upper ocean temperature biases in the North Atlantic. This suggests that the AMOC strength may not be the only factor that determines the meridional ocean heat transport. A common symptom in these models is that the returning flow of the AMOC at depth is too shallow. A shallow returning flow would carry excessive heat southward; thus the net northward heat transport by the AMOC would be weaker than the observed.

1 Meridional ocean heat transport and Antarctic sea-ice trends

Although this task is not explicitly listed in the proposed tasks, the PIs have found that the

meridional ocean heat transport in the Atlantic sector is closely linked to the sea-ice trends over the Weddell Sea. Therefore, we further explored to what extent and through what mechanisms the recent sea-ice trends over the Weddell Sea are affected by meridional ocean heat transport.
We used the ocean component of the NCAR CESM1 model coupled to Community Icea Model v.4 to investigate the recent sea-ice trends in the Weddell Sea and its link to the meridional heat transport in the South Atlantic. This model was spunup for 400 years using adjusted CORE2 (period 1948-1978) and MERRA (period 1979-2014) atmospheric forcings. The historical and reference simulations will be utilized to carry out other proposed modeling tasks.

Since late 1978, Antarctic sea-ice extent in the Atlantic has expanded persistently over the Weddell Sea in warm seasons, but retreated in cold seasons, while an almost opposite trend has occurred in the East Pacific over the Amundsen and Bellingshausen Seas (Figures 1a and b). By using a surface-forced ocean and sea-ice coupled model that reasonably reproduces the observed sea-ice trends around West Antarctica (Figures 1c and d), here we show that regional wind-driven ocean dynamics played a key role in driving these trends.
In the Atlantic, the poleward shifting SH westerlies in the region strengthened the northern branch of the Weddell Gyre, which in turn increased the meridional thermal gradient across it as constrained by the thermal wind balance (Figure 2).
As summarized in Figure 3, ocean heat budget analysis (not shown) further suggests that the strengthened northern branch of the Weddell Gyre acted as a barrier against the poleward ocean heat transport, and thus produced anomalous heat divergence within the Weddell Gyre and anomalous heat convergence north of the gyre. The associated cooling within the Weddell Gyre and the warming north of the gyre contributed to the expansion of sea ice in warm seasons and the retreat in cold seasons, respectively. The leading EOFs of the detrended Antarctic sea-ice variability (i.e., interannual variability) also show spatially and seasonally contrasting sea-ice variations around West Antarctica.

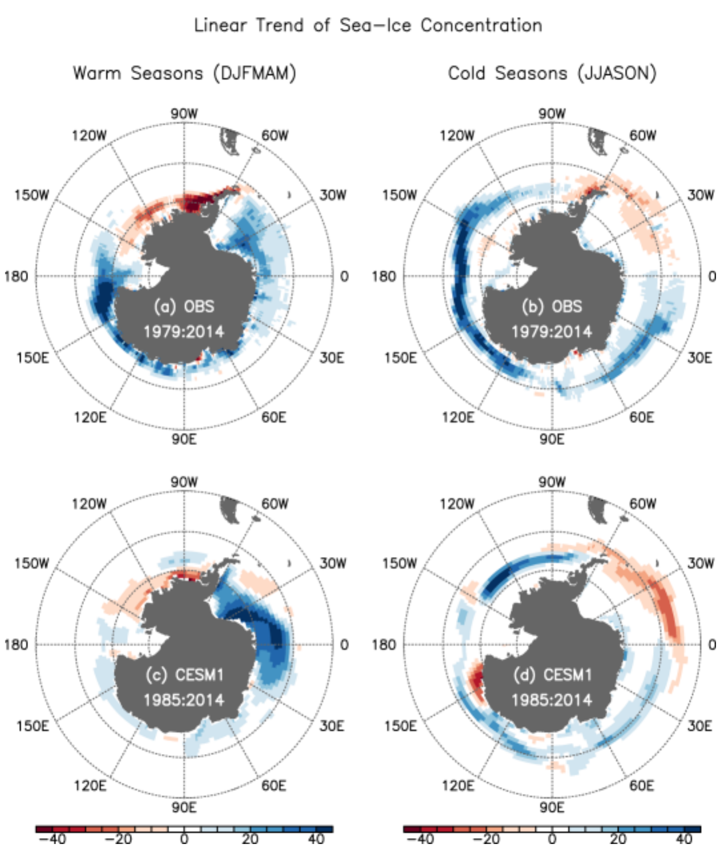

Figure 1: Linear trends of Antarctic sea-ice concentration during (a,c) the warm (December –May and (b,d) cold (June - November) seasons, obtained from (a,b) the Hadley Center sea-ice and sea surface temperature data sets over the period of 1979 - 2014 and (c,d) the CESM1 historical simulation over the period of 1985 - 2014. The first six years of the model results were excluded to prevent any potential model drift in the beginning of the control simulation from affecting the modeled sea-ice trend. The units are % in 35 years.

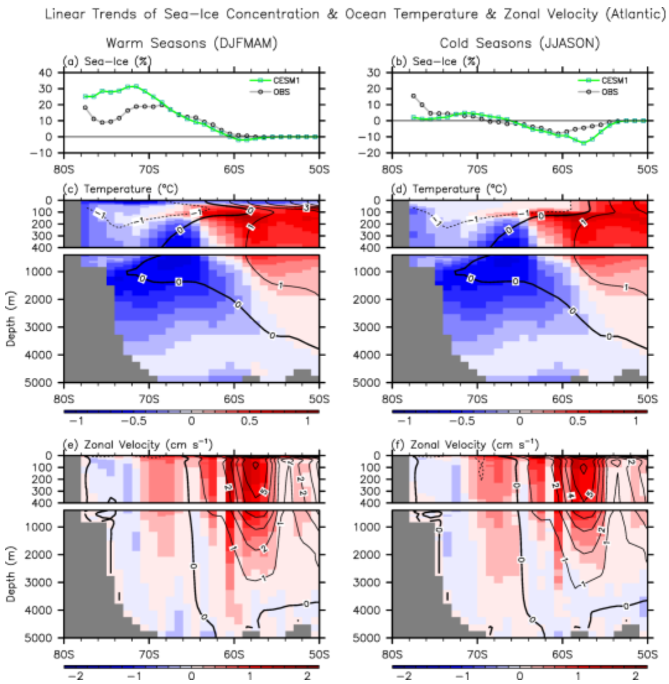

Figure 2: Linear trends of (a,b) Antarctic sea-ice concentration, (c,d) ocean temperatures, and (e,f) zonal velocity averaged in the Atlantic sector (60°W - 0°) for (a,c,e) the warm and (b,d,e) cold seasons over the period of 1985 - 2014, obtained from the CESM1 historical simulation. Observed linear trends of Antarctic sea-ice fraction over the period of 1979 - 2014 averaged in the Atlantic sector are also shown in (a,b). The black lines in (c,d) and (e,f) indicate the climatological temperatures and zonal velocity, respectively. The units are % in 35 years for sea-ice concentration, °C in 35 years for ocean temperature and cm s -1 in 35 years for zonal velocity.

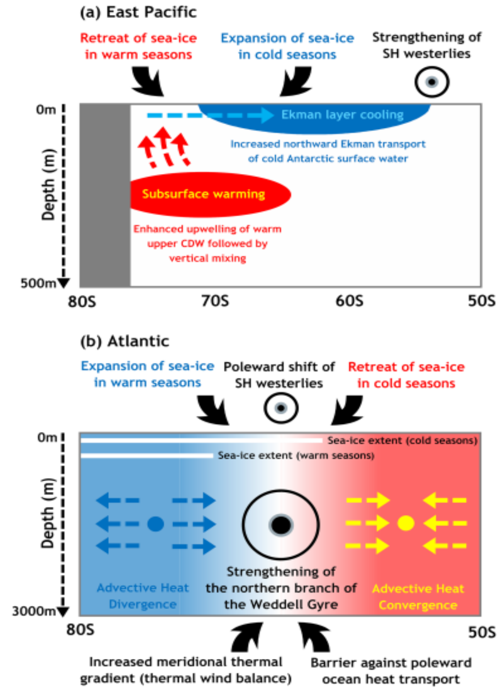

Figure 3: Sketch of the physical mechanisms that link the wind-driven ocean dynamics & the Antarctic sea-ice trends in the Atlantic sector.

2 Role of African dust in the weakening of AMOC during Heinrich events

Increased ice discharge in the North Atlantic is thought to cause a weakening, or collapse, of the AMOC during Heinrich events. Paleoclimate records indicate these periods were marked by severe tropical aridity and dustiness. Although the driver of these events is still under debate, strong freshwater input (~1 Sv) is necessary for climate models to simulate the magnitude, geographical extent, and abruptness of these events, indicating that they may be missing feedbacks. We hypothesize the dust-climate feedback is one such feedback that has not been previously considered. Here, we analyze the role of dust-climate feedbacks on the AMOC by parameterizing the dust radiative effects in an intermediate complexity model, and consider uncertainties due to wind stress forcing and the amounts of atmospheric dust loading and freshwater hosing. We simulate both stable and unstable AMOC regimes by changing the prescribed wind stress forcing. In the unstable regime, additional dust loading during Heinrich events cools and freshens the North Atlantic and abruptly reduces the AMOC by 20% relative to a control simulation. In the stable regime, however, additional dust forcing alone does not alter the AMOC strength. This study shows that including both freshwater and dust forcing results in a cooling of the subtropical North Atlantic more comparable to proxy records than with freshwater forcing alone. We conclude that dust-climate feedbacks may provide an amplification to Heinrich cooling by further weakening AMOC and increasing North Atlantic sea ice coverage. This work is under revision in Paleoceanography.

Research Performance Measure: All research goals were met during this year with respect to the investigation of the AMOC and meridional heat transport effects in the modeled North Atlantic sea surface temperature biases. During the project report period, the PIs of this project have engaged in the following list of activities and subjects:
1) Surface-forced ocean and sea-ice coupled CESM1: spinup and historical simulations
2) Meridional ocean heat transport and Antarctic sea-ice trends
3) Role of African dust in the weakening of AMOC during Heinrich events

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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 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
NOAA Technical Contact: Molly Baringer

Research Summary:

Using observations, atmospheric reanalysis products, and surface-forced and coupled models, we found that low-frequency variability of the SAMOC is tightly associated with the leading EOF of SSH in the South Atlantic Ocean. This EOF mode was described as a dipole in SSH with alternating sign north/south of 20°S and is strongly modulated by multi-decadal variability in the Pacific Ocean, namely the IPO.
The positive phase of the IPO is characterized by SST pattern that forces cyclonic and anti-cyclonic atmospheric Rossby waves extending from the tropical Pacific towards the South Atlantic. These Rossby waves have source regions that extend from the central Pacific southeastward towards the South American coast. This causes enhanced atmospheric blocking frequency west and east of the Drake Passage consequently shifting the westerlies equatorward towards the South Atlantic. This in turn produces a northward Ekman transport, modulating the strength of the subtropical gyre in the South Atlantic (Fig. 1c). This mechanism is verified by analyzing altimetry data as well as an ocean general circulation model forced with different atmospheric reanalysis data and a fully coupled model. The SSH dipole is associated with positive (negative) wind stress curl north (south) of 40°S due to northward shift of the westerlies over the Atlantic (Fig. 1a and b).

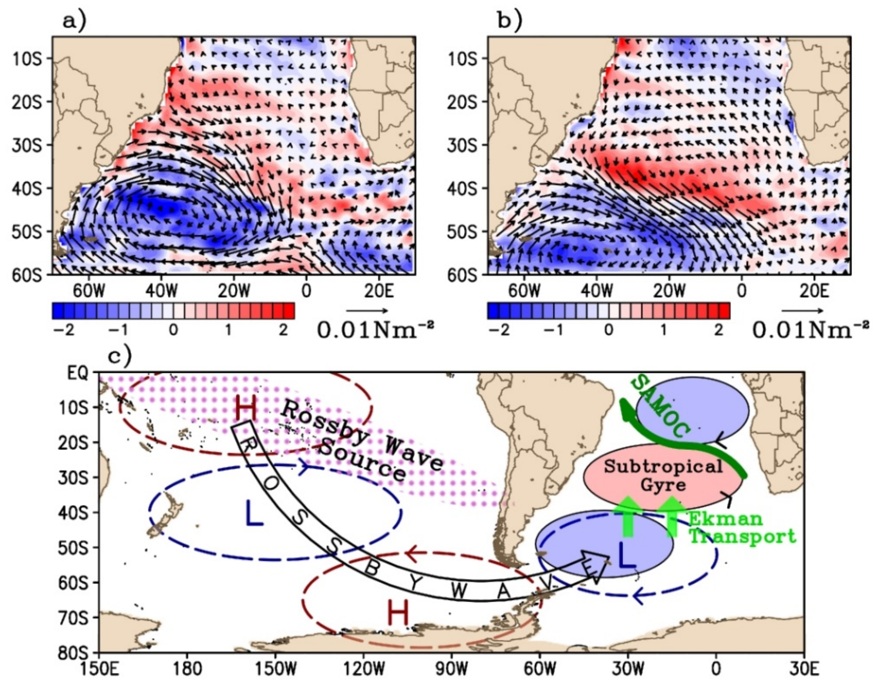

Figure 1: (a) Regression of SSH PC1 with surface wind stress (vector) and wind stress curl times Coriolis parameter (color) from altimetry data. (b) Same as (a) but for 20 Century Reanalysis. (c) Schematic diagram of the influence of the IPO on South Atlantic SSH and SAMOC variabilities. Heating anomaly in the atmosphere associated with the positive IPO generates Rossby wave source region extending from the tropical western Pacific toward South America (pink hatching). This generates a stationary wave pattern extending from the source region poleward around the southern tip of South America (labeled H and L for anticyclone and cyclone, respectively). This circulation produces anomalous westerlies in the South Atlantic between 30°S and 40°S, enhancing the northward Ekman transport, which in turn enhances the subtropical gyre circulation and northward SAMOC (dark green arrow).

This mechanism suggests that central Pacific SST anomalies associated with the IPO generate atmospheric Rossby waves to the Southern Hemisphere. Rossby wave generation associated with the IPO is not just confined to the tropical central Pacific; significant wave source is also present over the South Pacific Convergence Zone. The meridional propagation of wave energy flux into the South Atlantic is possible due to reduced subtropical jet in austral summer.

The relationship between the IPO and SAMOC motivated the reconstruction of a century-long South Atlantic Meridional Overturning Circulation (SAMOC) index (Fig. 2). The reconstruction is possible due to its covariability with sea surface temperature (SST). A singular value decomposition (SVD) method is applied to the correlation matrix of SST and SAMOC. The SVD is performed on the trained period (1993-present) for which Expendable Bathythermographs (XBT) and satellite altimetry observations are available. The joint modes obtained are used in the reconstruction of a monthly SAMOC timeseries from 1870 to present. The reconstructed index is highly correlated to the observational-based SAMOC timeseries during the trained period and provides a long historical estimate (Fig. 2). As described earlier, the IPO is the leading mode of SAMOC-SST covariability, explaining ~85% with the Atlantic Niño accounting for less than 10%. The reconstruction shows that SAMOC has recently shifted to an anomalous positive period, consistent with a recent positive shift of the IPO.

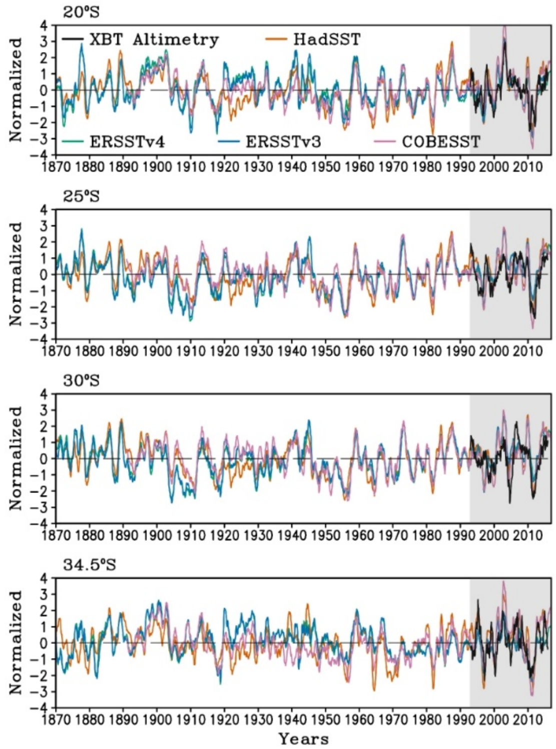

Figure 2: SAMOC time series obtained from altimetry (black) and those reconstructed from SST and SAMOC joint variability using different SST products (color). All time series were normalized by their standard deviation. The trained period is highlighted by a grey box.

Research Performance Measure: The research objectives were met based on the primary objective: to quantify the SAMOC flow pathways and its influence on global climate and extreme weather. The potential impact of the SAMOC on climate and extreme weather events demonstrates the importance of understanding and monitoring the SAMOC variability in the South Atlantic.

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Calibration and Evaluation of GEFS Ensemble Forecasts at Weeks 3-4 (SUNY)

Project Personnel: P. Liu (State University of New York at Stony Brook); B. Kirtman (UM/RSMAS/CIMAS)
NOAA Collaborators: Y. Zhu (EMC); Q. Zhang (CPC)
Other Collaborators: W. Hu, B. He and R. Sukhdeo (State University of New York at Stony Brook)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** Improve week 3-4 predictions in the NOAA GEFS
***Strategy*:** To decompose the GEFS predictions into leading EOF modes before calibration and prediction

CIMAS Research Theme:

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

Link to NOAA Strategic Goals:

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

NOAA Funding Unit: NWS/STI NGGPS Program
NOAA Technical Contact: Cristopher Hedge and Frederick Toepfer

Research Summary:

The Global Ensemble Forecast System (GEFS), core of NOAA's operational forecast suite, has extended the lead time of operational forecasts guidance to day 30. Calibrating and evaluating the ensemble forecasts of the upgraded GEFS at the new ranges is an important step towards developing the NGGPS.

We propose to continue the previously funded project for another year majorly to extend the investigation to the new ensemble forecasts at weeks 3-4. We will use the principal component analysis to first decompose the ensemble forecasts and observations into uncorrelated modes. Thresholds based on the explained variance can be established to differentiate signal and noise components. Reconstructed signals will then be calibrated and verified by existing metrics with necessary modifications for the longer lead times. This approach is being tested to apply to the GEFS forecasts at weeks 1-2 and we propose to continue the application to the new forecasts at weeks 3-4. We will test two New Approaches: 1) estimate the predictability of MJO at weeks 2-4 using our revised Real-Time Multivariate MJO (RMM) index; 2) identify atmospheric blocking episodes for their intensity, gravitational center, impacting region, and duration to improve their forecasts at weeks 2-4 using our newly developed object tracking algorithm. We propose to 1) use a small part of this year to complete the implementation of the above approaches to calibrate and evaluate the GEFS forecasts at weeks 1-2; 2) continue to test the approaches in the new forecast guidance at weeks 3-4; and 3) make a transition of the approaches to operational forecasts at weeks 3-4.

Research Performance Measure: We are estimating the MJO predictability in the GEFS V2 reforecasts using the revised RMM-r index. We are identifying atmospheric blocking episodes as well as persistent open ridges for their intensity, location, impact area and duration. Their frequency distributions are shown in Figure 1 as the average between 40-60°N.

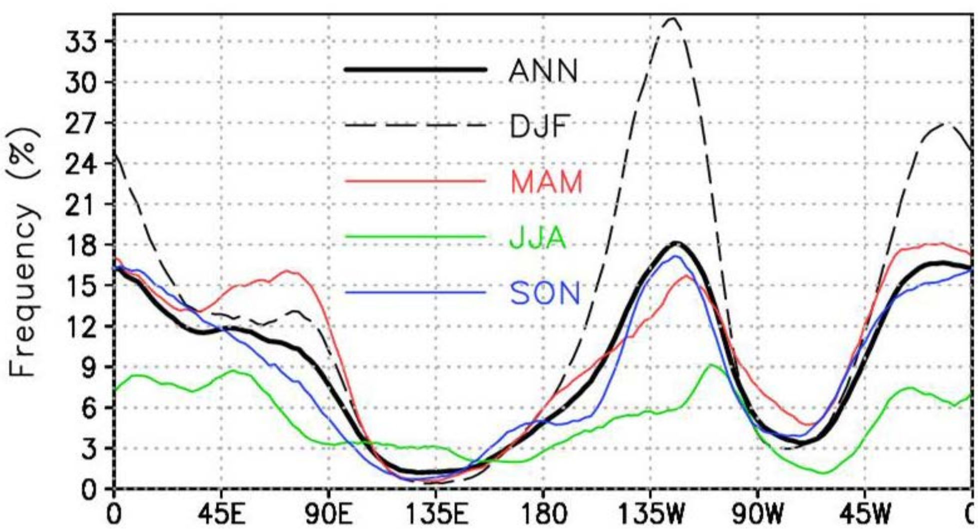

Figure 1: Annual frequency distribution for the impact grid points of the tracked PMZ events be-tween 1979-2015 for annual (solid black), seasonal DJF (black dashed), MAM (red), JJA (green), and SON (blue) averaged between 40°, 50°, and 60°N.

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 Atlantic Ocean.

***Strategy*:** To implement a methodology to obtain three-dimensional velocity fields from Argo observations and satellite altimetry and to use these fields to calculate volume and heat transports.

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: David Legler

Research Summary:

Using observations from Argo, satellite sea surface height and NCEP reanalysis wind fields we constructed a monthly three dimensional velocity product for the entire Atlantic Ocean, except for the tropical regions. Initially, the data set was limited to the South Atlantic and covered the years 2000 to 2014. We used this data set to estimate MOC and MHT at the four latitudes (20S, 25S, 30S and, 35S). Time series of MOC at 30S and 35S are in good agreement with that from the Expendable bathythermograph transects at these latitudes.

In addition, we updated the MOC time series and computed meridional freshwater transport for the southern latitudes. We extended velocity product to cover the years 1993 to 2015. In a separate study we use the expanded velocity product to study the variability of the boundary currents in the south Atlantic. The climatology of the velocity fields show realistic circulation patterns both in the eastern and the western boundaries. Volume transport of the Brazil and the Benguela Currents are in good agreement when compared with the previous estimates (Figure 1), considering the fact that previous estimates were mostly based on synoptic surveys.

In terms of variability, the transport of the Brazil current exhibits, annual cycles at three different latitudes 24S, 35S, and 38S. Amplitudes of the annual cycle are weak when compared with a numerical ocean model at 24S, 35S. The time series this transport at 24S (Figure 2) shows strong interannual variability that is well correlated with the southern annular mode index. At the eastern boundary Agulhas eddies dominate the variability of the Benguela Current. We are currently analyzing MOC and MHT at multiple latitudes in the North Atlantic based the extended version to derive time series.

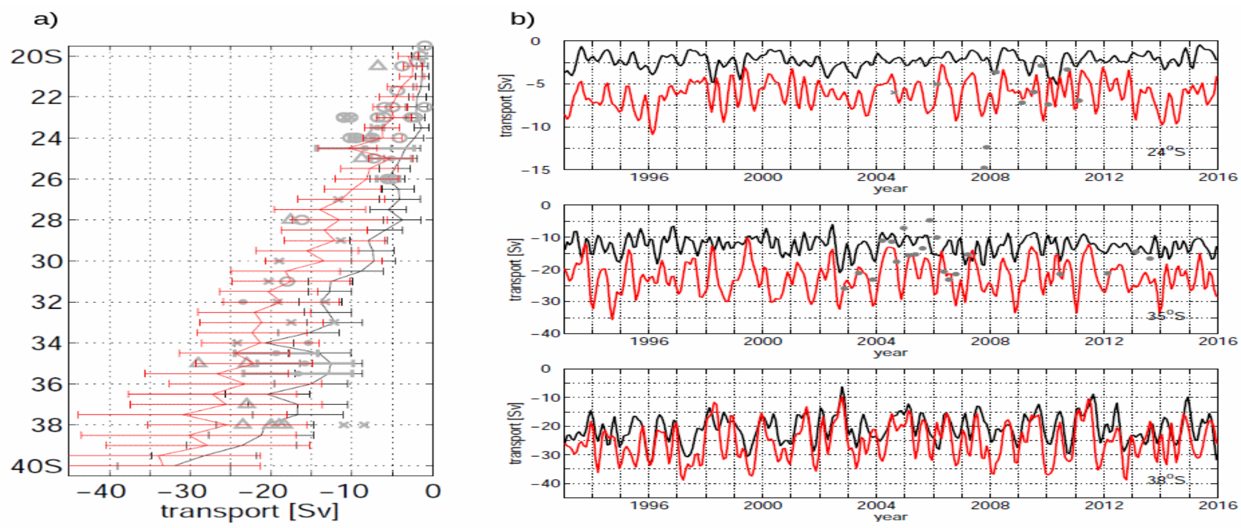

Figure 1: (a) Climatological mean of the meridional transports of the Brazil Current as a function of latitude from observations (black, grey) and HYCOM (red). The black line with error bars shows the mean from Argo & SSH for a layer thickness of 400 m north of 27S and 800 m elsewhere. Gray symbols with or without error bars are from previous studies (see Figure 1 for references). The symbols indicate if the integration depth is less than 800 m (circles), 800 m (crosses and dots) or greater than 800 m (triangles). Gray error bars are shown if the estimate is from several transects or a time series. Gray dots are based on velocity transects derived by Garzoli et al. (2013) for the purpose of estimating the Meridional Overturning Circulation transports in the South Atlantic. The red line represents the mean with error bars as derived from a combination of the HYCOM reanalysis (1993-2012) and the HYCOM analysis (2013-2015). All error bars indicate the standard deviation associated with the mean.

(b) Time series of the meridional transports in the Brazil Current at 24S, 35S and 38S from Argo & SSH (black) and HYCOM (red). The depth range is 0 to 400 m at 24S and 0 to 800 m at the other latitudes. The time series were smoothed with a second order
Butterworth filter (2 month low pass). Gray dots are based on transport estimates by Garzoli et al. (2013). Gray crosses indicate estimates from other previous studies.

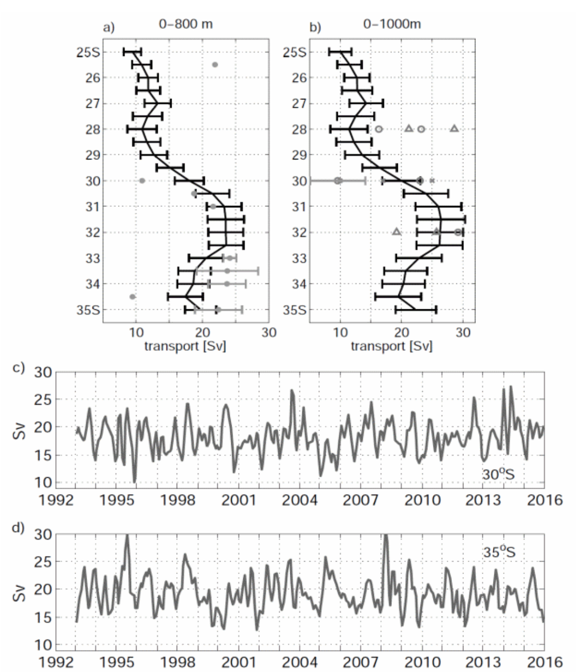

Figure 2: Latitude dependence of climatological mean of the meridional transport in the Benguela Current (between 3E and the eastern boundary) in the upper 800 m (a) and 1000 m (b). Gray dots are based on velocity transects derived by Garzoli et al. (2013) for the purpose of estimating the MOC transports in the South Atlantic. Other gray symbols are based on transport estimates from three studies: Garzoli and Gordon (1996), Clement and Gordon (1995), and Stramma and Peterson (1989). Gray triangles (circles) indicate that the western integration limit was the Greenwich Meridian (the western edge of the Benguela Current). All other gray symbols represent estimates based on a western integration limit at 3E. Gray error bars are shown where an estimate was derived from multiple transects or a time series. The vertical integration limits for Stramma and Peterson (1989) (shown in b) range from 940 m to 1180 m, with the largest values used at 32S and the smaller ones in 23S to 24S, and they derived each transport for two different reference levels as well as two different western integration limits. All error bars represent standard deviations.
(c, d) Time series of meridional transport of the Benguela Current in the upper 800 m at 30S and 35S.

Research Performance Measure: Relate actual accomplishments to the original objectives. Explain slippages if objectives were not met.

1) The main objective was to estimate the meridional volume and heat transport at different latitudes both in the north and the south Atlantic using observations and data from data assimilation models; and,
2) To prepare manuscripts based on these results.

The meridional volume and heat transports were derived at different latitudes for the north and the south Atlantic. The data set has been extended to 1993-2015 from the initial version covering 2000-2014. With an earlier version of this data set, and data assimilation models meridional volume (MOC) and heat transport (MHT) time series were estimated at four different latitudes (20S, 25S, 30S, and 35S) in the South Atlantic. The results of this research have been published in JGR Oceans. The new extended data sets are used to update and calculate time series of MOC, MHT and freshwater transport as well as to analyze the variability of the boundary currents in the south Atlantic. Two manuscripts based on the results on boundary currents have been submitted to the Journal of Ocean Sciences. Results on the new estimates were also presented in US AMOC Science Team Meeting in Santa Fe, NM in May, 2017 and CLIVAR Open Science Conference in Qingdao, China, in September 2016.

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Expanding NIDIS Drought Early Warning System in the Southeast

Project Personnel: C. 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

Research Summary:

Tasks 1 through 4 of this project have not been completed and no funds were spent on them. This decision was made between the first PI and NIDIS.

Global Assessment of Looping Drifter Trajectories

Project Personnel: M. Olascoaga and F. 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 a tendency so far overlooked of drogued and undrogued drifters to accumulate distinctly over the subtropical gyres, with undrogued drifters accumulating in the same areas where 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. This is done by using a newly proposed Maxey-Riley equation which models the submerged (surfaced) drifter portion as a sphere of the fractional volume that is submerged (surfaced).

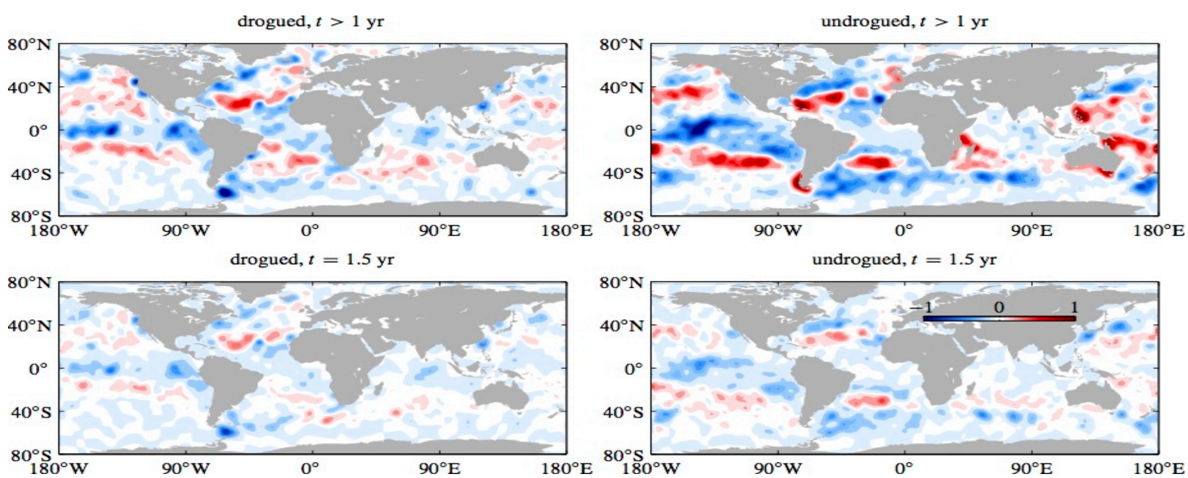

Figure 1: Expressed as a signed number per degree squared, density difference with respect to initial locations of (left column) drogued and (right column) undrogued drifters from the NOAA Global Drifter Program over 1979–2015 after at (top row) least 1 year or exactly (bottom row) 1.5 years past the time at deployment for drogued drifters or the location where a drifter loses the drogue.

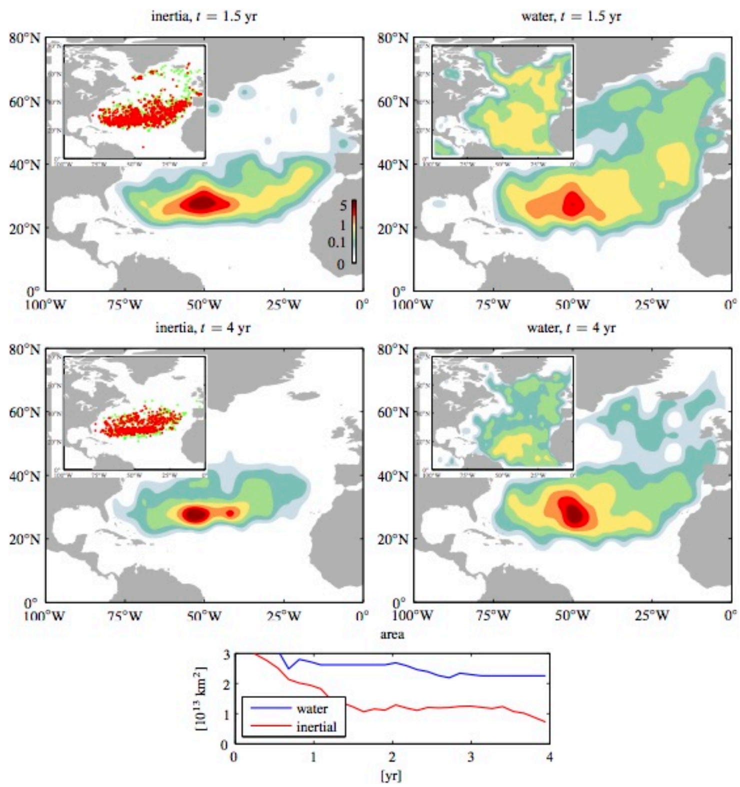

Figure 2: Density of particles after (top row) 1.5 and 4 (middle row) years of integration of the (left column) inertial (i.e., reduced slow-manifold Maxey-Riley) equation and of (right column) advection by water velocity normalized by density in the initially uniform distribution of particles. Insets in Figure 2 (left column) show final positions of inertial particles (red) and particles obeying the full Maxey-Riley equation (2) (green). Insets in Figure 2 (right column) show normalized density for particles advected by velocity derived geostrophically from sea surface height. (bottom) As function of time, area of the region where normalized particle density is higher than 1% for inertial (red) and water (blue) particles. Water velocity is given by surface ocean velocity from the 1/12° Global HYCOM+NCOM Ocean Reanalysis, from which sea-surface height is also taken. The air velocity corresponds to the wind velocity from the NCEP/CFSR reanalysis used to construct the wind stress that forces the model.

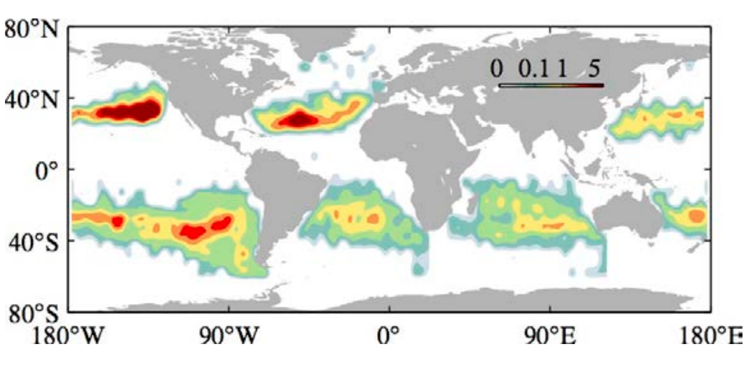

Figure 3: Expressed as number per degree squared, density of particles after 1.5 yr of integration of the inertial equation (5) normalized by density in the initially uniform distribution of particles over each global ocean basin. Water velocity is given by surface ocean velocity from the 1/12° Global HYCOM+NCOM Ocean Reanalysis. The air velocity corresponds to the wind velocity from the NCEP/CFSR reanalysis used to construct the wind stress that forces the model.

Research Performance Measure: The objectives of the project have been reached with respect to data analysis and comparison with the Maxey-Riley theory. Two peer-reviewed papers has been published, one in *Chaos* (Beron-Vera et al., 2015) and another one in *Geophys. Res. Lett.* (Beron-Vera et al., 2016).

Autonomous Marine Sampling Technology Testbed: Integrating advanced biomedical sensor technologies with advances in drop probe

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

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To develop and test biogeochemical sensors based on biomedical microtechnologies that can be adapted to oceanographic sampling needs in the context of the overall OceanScope program.

***Strategy*:** A fully collaborative multiyear team effort building upon ongoing highly successful research projects. Ortner and Rossby (assisted by OceanScope ocean carbon cycle investigators) would provide leadership, coordination and field test opportunities on OceanScope test-beds. AOML/PhOD would provide field test opportunities upon AOML gliders (see http://www.aoml.noaa.gov/phod/goos/gliders/observations.php). Meldrum *et al.* would optimize and develop sensors. Goes *et al.* would work with Johnson *et al.* and RSMAS Mar.Tech.Grp. To optimize autolaunchers for OceanScope purposes, improve XBT performance and ultimately integrate biomedical sensors into both/either XBTs and/or XCTDs.). Sensor performance would be evaluated with standard trials and compared against lowered instruments (e.g. CTDs with oxygen, pH and fluorescence probes) following protocols previously applied within international oceanographic and climate science communities.

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 (Primary)*

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

NOAA Funding Unit: OAR/PMEL
NOAA Technical Contact: Chris Sabine

Research Summary:

The results obtained show that the fluorescence emission of the pH sensor is specific to the pH, and does not react to temperature, pressure, and salinity. The variation of the measured emission is within the standard deviation of the measurement (~0.217). **Figure 1** shows the results in the three-dimensional pressure-temperature-salinity domain. The emission levels of the pH sensor are color coded for each dot. The color levels are shown in the color bar. Because the emission intensity had very small changes throughout the experiment, the colors of all dots appear to be the same. Similar results have been obtained with the Oxygen sensor and in both cases sensitivity is within the specifications set by AOML/OCE for climate quality biogeochemical data. On the other hand, response times achieved to data need to be improved more than an an order of magnitude for deployment on rapidly moving platforms (e.g. drop probes at 6m/sec).

Expendable bathythermograph (XBT) data provides one of the longest available records of 3 upper ocean temperature. However, temperature and depth biases in XBT data adversely affect 4 estimates of long-term trends of ocean heat content, and to a lesser extent of volume and heat transport 5 in the ocean. Several corrections have been proposed to overcome historical biases in XBT data, which rely on

constantly monitoring these biases. The results obtained show that the use of individual thermistor calibration in XBT probes is the most effective method to decrease the thermal bias, improving the mean thermal bias to less than 12 0.02°C, and its tolerance from 0.1°C to 0.03°C.

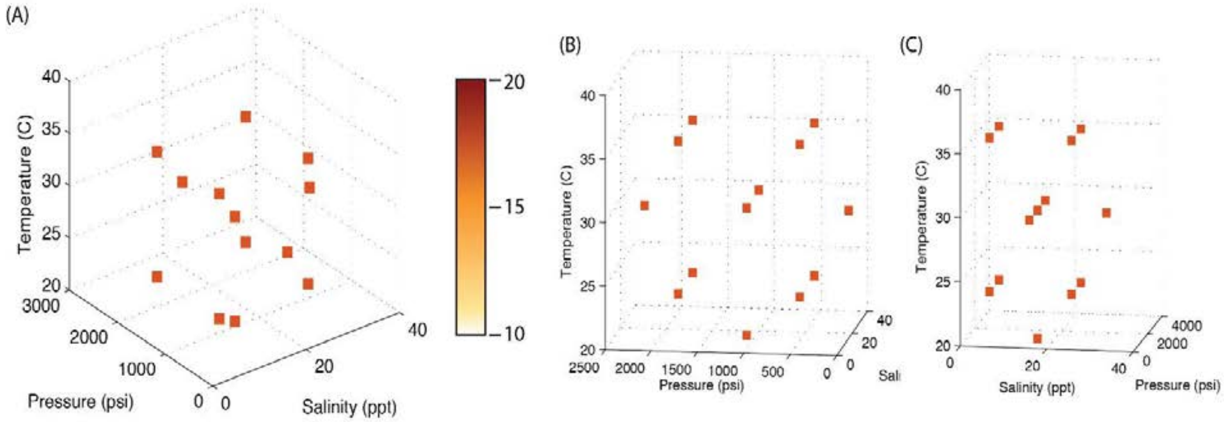

Figure 1: The distribution of the test points from the Central composite design. (A) An isometric view of the P-T-Salinity domain. The colors of the test points indicate the emission intensity (scale shown in the color bar on the right). (B) Same as (A) but emphasis on the P-T planes. (C) Same as (A) but emphasis on the Salinity-T planes.

Research Performance Measure: We have achieved (or demonstrated the feasibility of achieving) a drop probe compatible package (low power, small size, sufficent sensitivity etc.) in all respects excepting response time. Response time can we believe be drastically improved by increasing the surface area of the sensors through surface roughing and porous materials. We are working on doing with additional funding provided by an OceanScope grant from RCCL and a CIOERT subaward. Unfortunately, LMS is no longer interested adding pressure sensors to their commercially available XBTs. That project objective has been terminated. We continue to work with AOML to adapt their XBT autolauncher for use unattended on commercial ships and plan to deploy the first such unit this coming winter after a drydock of Adventure of the Seas in Grand Bahama.

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Deployment of dual-sensor SVP-S drifters in the equatorial Pacific

Project Personnel: D. Volkov (UM/CIMAS)
NOAA Collaborators: S. Dong, G. Goni, R. Lumpkin and G. Foltz (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To study the near-surface salinity structure in the equatorial Pacific Ocean in great detail and to link the satellite observations of sea surface salinity with all the oceanic and atmospheric processes that control its variability.

***Strategy*:** To deploy dual-sensor Lagrangian drifters, specifically designed to measure temperature and salinity near the surface (~0.2 m) and at 5 m depth, during SPURS-2 field campaign led by NASA.

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 (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:

In order to study the near-surface salinity structure in great detail and to link the satellite observations of sea surface salinity (SSS) with all the oceanic and atmospheric processes that control its variability, the National Aeronautics and Space AdministraPon (NASA) initiated two field campaigns within the framework of Salinity Processes in the Upper-Ocean Regional Study (SPURS) project (http://spurs.jpl.nasa.gov/). The first campaign, SPURS-1, took place in the evaporation-dominated subtropical North Atlantic Ocean in 2012-2013. The second campaign, SPURS-2, was planned to become the opposite of SPURS-1 and focused on a 3×3° domain in the Inter-Tropical Convergence Zone (ITCZ) in the eastern equatorial Pacific (123.5-126.5°W and 8.5-11.5°N), where the near-surface salinity is strongly dominated by precipitation (Figure 1). The first SPURS-2 cruise took place in Aug- Sep 2016 on board R/V "Roger Revelle", during which a complex multi-instrument oceanographic survey was conducted.

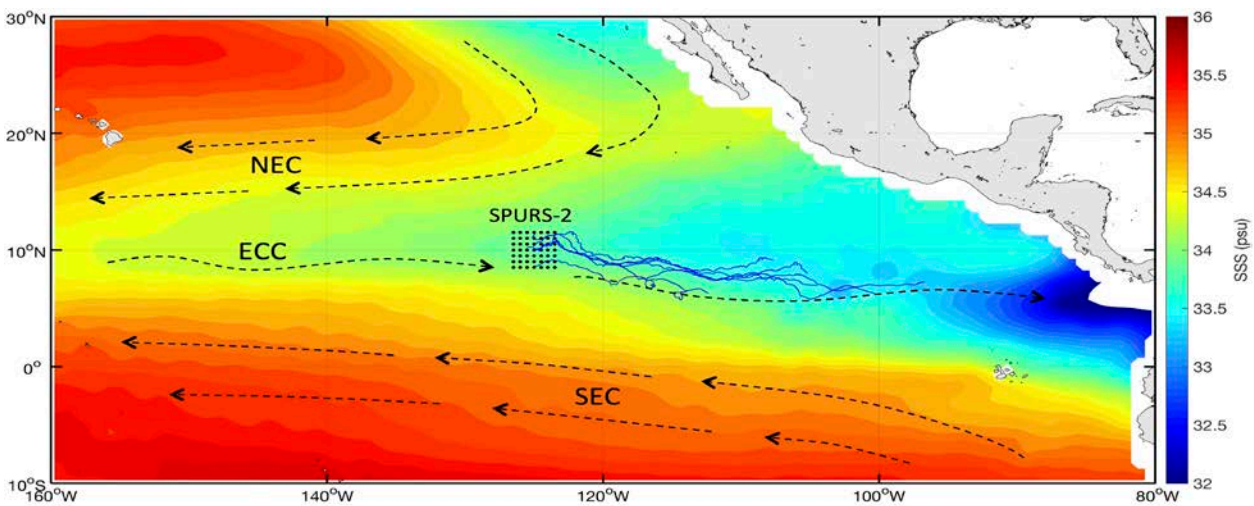

Figure 1: 2011-2015 mean sea surface salinity measured by Aquarius in the eastern equatorial Pacific. SPURS-2 stations are shown by the grid of dots, and the dual-sensor salinity drifter trajectories are shown by blue curves. Surface circulation is schematized by dashed arrows. Abbreviations: NEC – North Equatorial Current, ECC – Equatorial Countercurrent, and SEC – South Equatorial Current.

As part of this field campaign, we deployed 6 dual-sensor Lagrangian drifters, specifically designed to measure temperature and salinity near the surface (~0.2 m) and at 5 m depth (Figures 2). The unique aspect of these drifters is that they are equipped with two sets of conductivity and temperature sensors. One (SBE 37SI) is mounted to the bottom of an upgraded (41 cm in diameter) surface float to avoid direct radiative heating at about 0.2 m depth. The second CTD is tether-mounted at 5 m depth (SBE 37IM) just above the drogue.

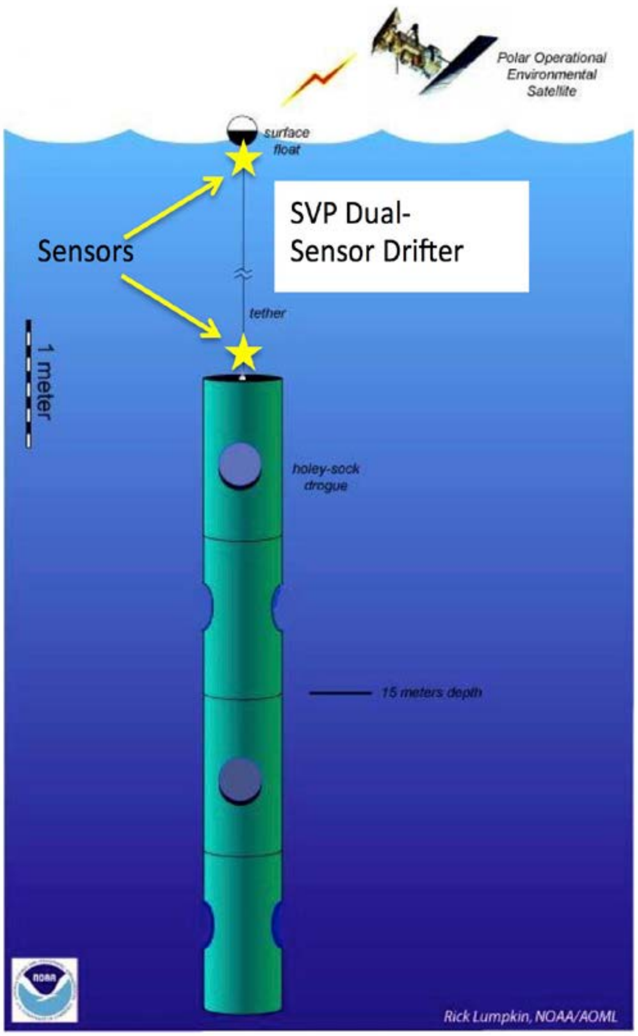

Figure 2: Schematic representation of a dual-sensor salinity drifter.

Our drifter observations have shown that salinity differences between 0.2 and 5 m depth are generally small (0.03-0.04 g/kg), but persistent precipitation in combination with low winds can cause differences between the two depths of up to 2 g/kg. Based on the salinity differences, during the first three months after the deployment the SVP-S drifters experienced over 100 rain events. Although the dependence of salinity differences upon precipitation and wind speed is obvious, no linear relationship could be established between the drifter measurements and available products for precipitation (TRMM, MERRA-2) and wind (ASCAT, MERRA-2). This is possibly due to differences in spatial and temporal resolutions of data products. The SVP-S drifters have revealed a well-defined diurnal cycle of temperature at both depth levels and a noisier, but still significant, diurnal cycle of salinity at 0.2 m depth, with up to a 0.01 g/kg increase during daytime due to evaporation. The diurnal amplitude and phase of temperature strongly depends on wind speed. Our drifter observations reveal that rain puddles in North Pacific ITCZ are relatively short-lived features with a lifetime of less than a day.

Research Performance Measure: The objectives of the deployment were fully met. All drifters worked and provided high-quality data. The analysis of drifter data is in progress as part of a NASA-funded project.

RESEARCH REPORTS

THEME 2: Tropical Weather

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

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

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** 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: Robbie Hood

Research Summary:
The potential of the Coyote unmanned aircraft system (UAS) to improve hurricane analyses and forecasts is evaluated in Observing System Simulation Experiments (OSSEs) for vortex-scale hurricane data assimilation in NOAA/AOML/HRD'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.

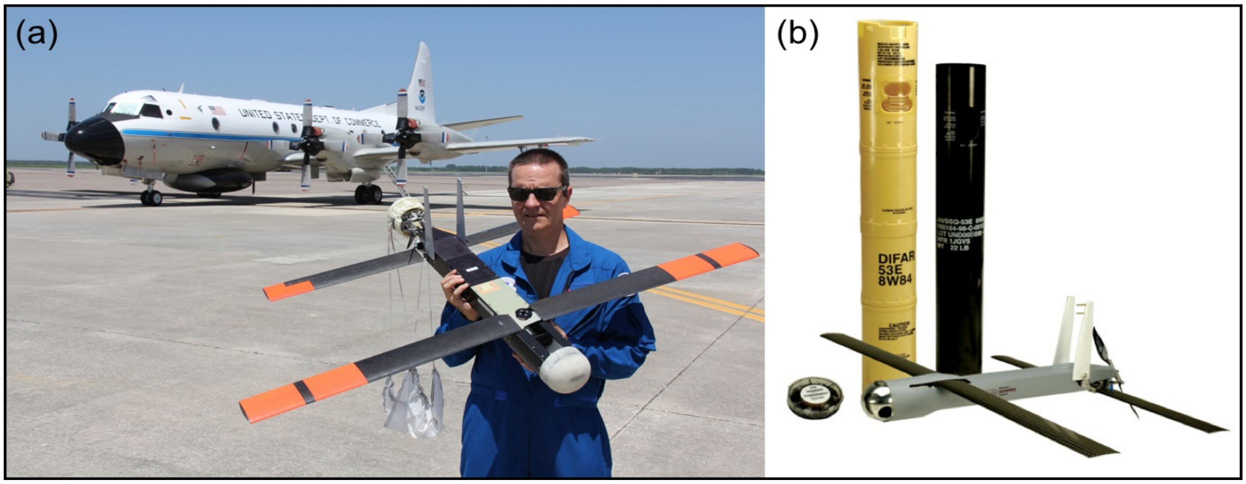

Figure 1: (a) The Coyote is shown with a crew member in front of the NOAA P-3 aircraft that typically deploys it. (b) The Coyote is shown in front of the canister which is used as the housing during deployment from the NOAA P-3 dropwindsonde chute.

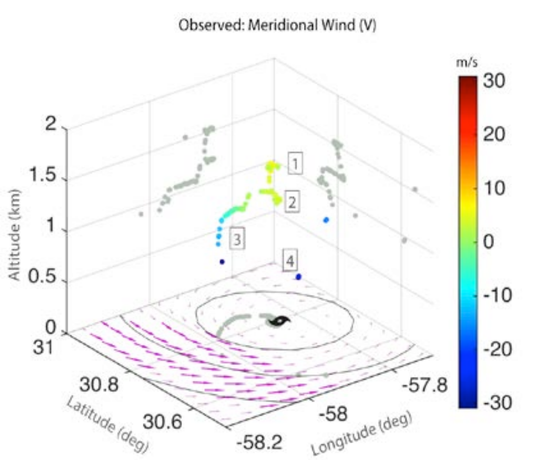

Figure 2: Observed meridional (north to south) wind speed (m s^{-1}) along the Coyote flight path during its 16 September 2014 mission. Analyzed pressure isobars are shown in black contours and surface wind vectors are shown in purple (darker vectors indicate the region with the strongest 20% of wind speed).

The simulated Coyote flight track is based on the inaugural hurricane flight of Coyote conducted by NOAA in Hurricane Edouard on 16 September 2014, which was an eye/eyewall sampling mission that lasted 28 minutes and sampled horizontal wind speeds of up to 100 kt in magnitude. The track of this Coyote mission is shown in Fig. 2, where Coyote was released from the P-3 near the center of Edouard and then flew radially out to the eyewall sampling the high-wind-speed eyewall region of the hurricane. In the present OSSE study, the same Edouard flight track is adapted to Nolan et al. (2013) nature run by rotating the track counterclockwise, expanding it radially outward, and lifting it upward to match the strongest wind speed region simulated in the nature run. These modifications are depicted in Fig. 3, where the gray circles represent the original track and the black circles represent the modified track. However, the shortcomings of the original Edouard flight are still maintained: There exist gaps between the black circles because of radio communication issues and the track only extends halfway around the eye although nominal battery capacity is expected to allow flights up to 1 hour in duration.
Thus, two further incremental modifications were also carried out that first interpolated between the black circles (white circles) and extrapolated for complete circumnavigation around the eye (blue circles).

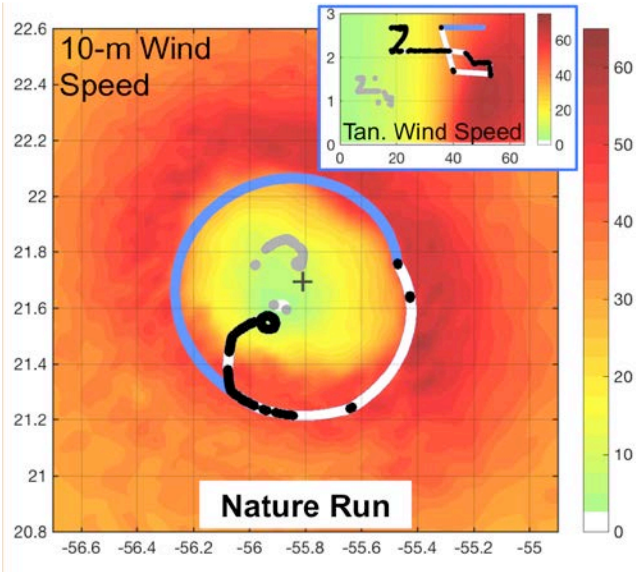

Figure 3: Simulated Coyote flight path relative to the nature run 10-m wind speed field (m s^{-1}) shaded in the background. The hypothetical position of the actual 16 September 2014 Hurricane Edouard Coyote flight track is shown in gray. The simulated flight track as adapted to the nature run wind field is shown in black. Further modifications include interpolation between black circles to represent a track with no data loss (white circles) and full circumnavigation around the eye to represent utilization of full battery capacity (blue circles). Horizontal and vertical axes represent longitude and latitude, respectively (degrees). The vertical projection of the same tracks is shown in the inset against the nature run azimuthally averaged tangential wind speed (m s^{-1}), shaded.

These various simulated Coyote tracks were assimilated in HEDAS in addition to the simulated conventional reconnaissance aircraft observations that include dropwindsondes, flight-level measurements, tail Doppler radar radial wind speed estimates, and Stepped Frequency Microwave Radiometer (SFMR) surface wind speed retrievals. Preliminary results suggest that the full circumnavigation scenario provides the strongest impact on the HEDAS high-resolution analyses of the vortex inner-core structure. As shown in Fig. 4, improvements are observed within the inner core (within 100 km of the storm center) for both kinematic and thermodynamic aspects of the vortex. Both tangential and radial wind improvements are most prominent in the planetary boundary layer vertically (symbolized by the vertical range up to 3 km height from ocean surface) with additional improvements in the radial wind speed in the upper levels where the outflow is the strongest. Likewise, temperature improvements are seen in the middle levels (3-10 km) where the warm core anomaly is typically strongest. These findings indicate the potential impacts that can be obtained from UAS such as the Coyote by sampling regions of the hurricane inner core that manned aircraft otherwise cannot sample due to safety concerns. More importantly, noticeable improvements are obtained at locations well away from the immediate vicinity of the Coyote flight track thanks to the advanced data assimilation capabilities of HEDAS that utilize ensemble-based spatial correlation information among variables and assimilate observations at high temporal frequency allowing the numerical model to spatially distribute the localized impact of observations.

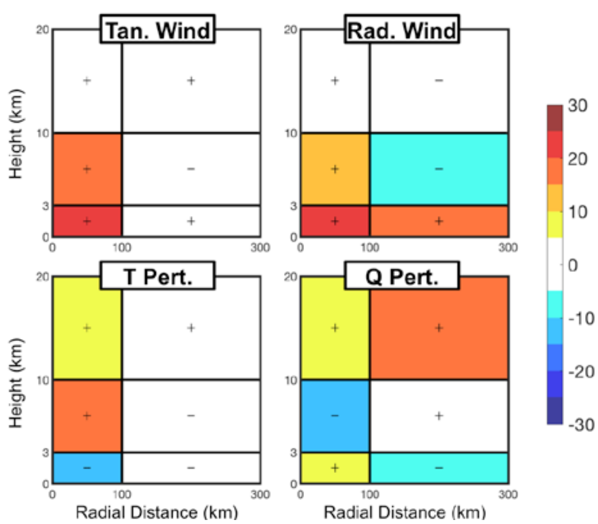

Figure 4: Improvements from assimilating simulated Coyote observations relative to only assimilating conventional aircraft reconnaissance observations as depicted by the azimuthally averaged kinematic (tangential and radial wind speed) and thermodynamic (temperature and moisture perturbations) structures of the vortex. Improvements are shown as spatial averages in distinct regions (horizontally 0-100 km and 100-300 km, vertically 0-3 km, 3-10 km, and 10-20 km). Improvements are measured in percent error relative to the nature run.

Research Performance Measure: This work supports efforts by NOAA to demonstrate and test a prototype small-UAS concept to collect observations within critical regions in a hurricane vortex that manned reconnaissance aircraft can't otherwise sample due to safety restrictions. For this purpose, NOAA has successfully deployed two Coyote aircraft during its Hurricane Field Program in Hurricane Edouard (2014). Results here expand on the data collected in these missions by simulating Coyote observations in a hypothetical hurricane and considering scenarios that could not be realized during the actual Edouard flights due to various technical limitations encountered. Preliminary findings indicate that, when Coyote is flown at its specified technical capabilities, its observations have the potential to positively impact the model representation of the hurricane vortex structure even when conventional observations from manned reconnaissance aircraft are also utilized.

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A study of the HWRF analysis and forecast impact of realistically simulated CYGNSS observations assimilated at scalar wind speeds and as VAM wind vectors

Project Personnel: B. Annane, B. McNoldy and R. Hoffman (UM/CIMAS)
NOAA Collaborators: R. Atlas and S. Murillo (NOAA/AOML); M. Leidner (AER)

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 events*

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

Research Summary:

In preparation for the launch of the NASA Cyclone Global Navigation Satellite System (CYGNSS), a variety of observing system simulation experiments (OSSEs) were conducted to develop, tune, and assess methods of assimilating these novel observations of ocean surface winds. From a highly detailed and realistic hurricane nature run (NR), CYGNSS winds were simulated with error characteristics that are expected to occur in reality. The OSSE system makes use of NOAA's HWRF model and GSI data assimilation system in a configuration that was operational in 2012. CYGNSS winds were assimilated as scalar wind speeds and as wind vectors determined by a Variational Analysis Method (VAM). Both forms of wind information had positive impacts on the short-term HWRF forecasts, as shown by key storm and domain metrics. Data assimilation cycle intervals of 1, 3, and 6 hours were tested, and the 3-h impacts were consistently best. One day forecasts from CYGNSS VAM vector winds were the most dynamically consistent with the NR. The OSSEs have a number of limitations- most noteworthy that this is a case study and static background error covariances were used.

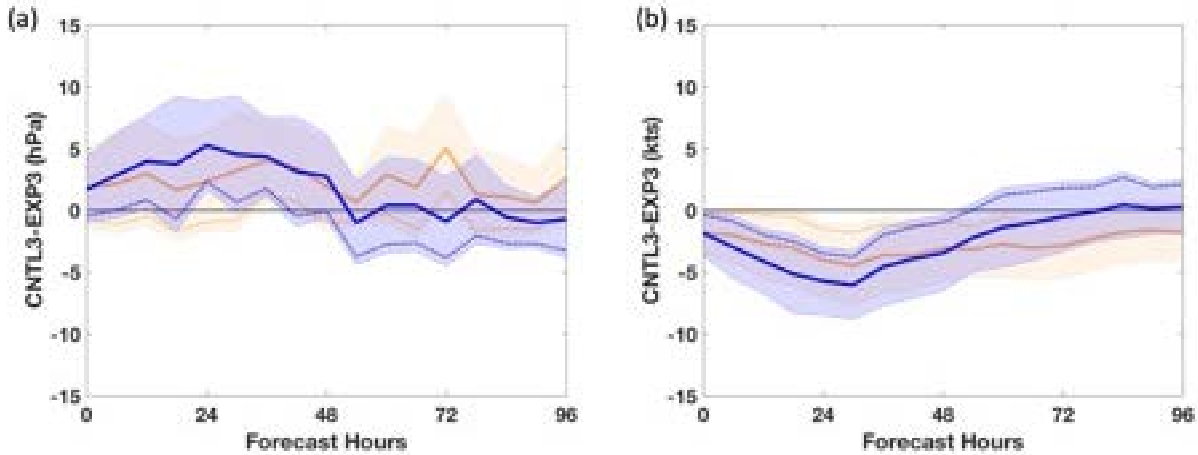

Figure 1: (a) Minimum sea-level pressure forecast error and (b) maximum wind speed forecast error of experiments CYG3 (orange) and VAM3 (blue) with respect to CNTL3. 95th percentile confidence intervals (CI) are plotted: 2-sided CIs are plotted in transparent colors and 1-sided CIs are plotted with thin dotted lines.

Research Performance Measure: The research program is on schedule.

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Airborne Doppler Wind Lidar

Project Personnel: L. Bucci, K. Ryan and J. Zhang (UM/CIMAS)
NOAA Collaborators: R. Atlas (NOAA/AOM)
Other Collaborators: G. Emmitt and C. O'Handley (Simpson Weather Associates)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To test the capabilities and validated the data collected from an airborne Doppler Wind Lidar (DWL) in the near storm and inner core region of tropical cyclones.

***Strategy*:** To fly the DWL on the NOAA P-3 Orion into a various regions of TCs and compare observations to other airborne instruments.

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:

While meteorological observations have improved in both quality and density, there remain important data-sparse regions in the tropical cyclone (TC). Instruments flown on the NOAA's P3 Orion Hurricane Hunter Aircraft provide some in situ inner-core observations of Atlantic TCs. The Tail Doppler Radar (TDR) provides the most comprehensive coverage of the wind field in TCs. TDR has the ability to measure winds in areas of precipitation but outside of these regions and below about 1 km, it either cannot make observations or the data is less reliable. This leaves regions such as the TC boundary layer,

moats between the eyewall and outer rainbands or secondary eyewall, and precipitation-free areas largely unobserved.

In the 2015 and 2016 hurricane season, an airborne Doppler Wind Lidar (DWL) was flown for the first time on the P3 Orion into TCs of different intensities in the Atlantic and East Pacific (Figure 1). Comparisons show good agreement between coinciding retrieved DWL wind profiles and other wind observing instruments. Figure 2 shows the comparison of 2016 DWL and dropsondes wind speeds and directions. Further analysis of DWL data shows it collects complementary wind observations to data from the TDR. Pending the sampling of additional TC cases, these data have the potential to allow for a more complete depiction of the 3D wind field and therefore improve our understanding of vertical and asymmetric structures that drive TC evolution.

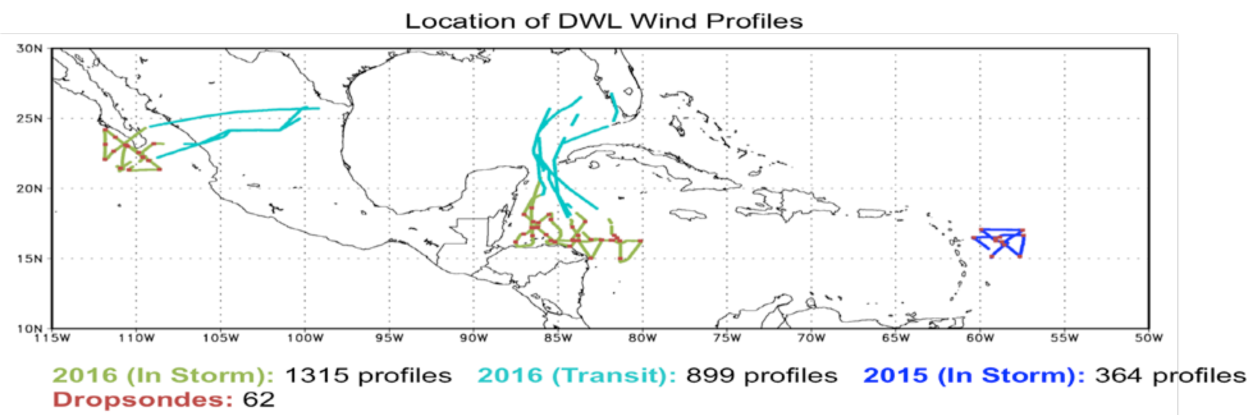

Figure 1: Location of the DWL wind profiles collected in 2015 (dark blue) and 2016 (green). Data collected in 2016 on the transit to/from the TC is in cyan and red dots indicated released dropsondes.

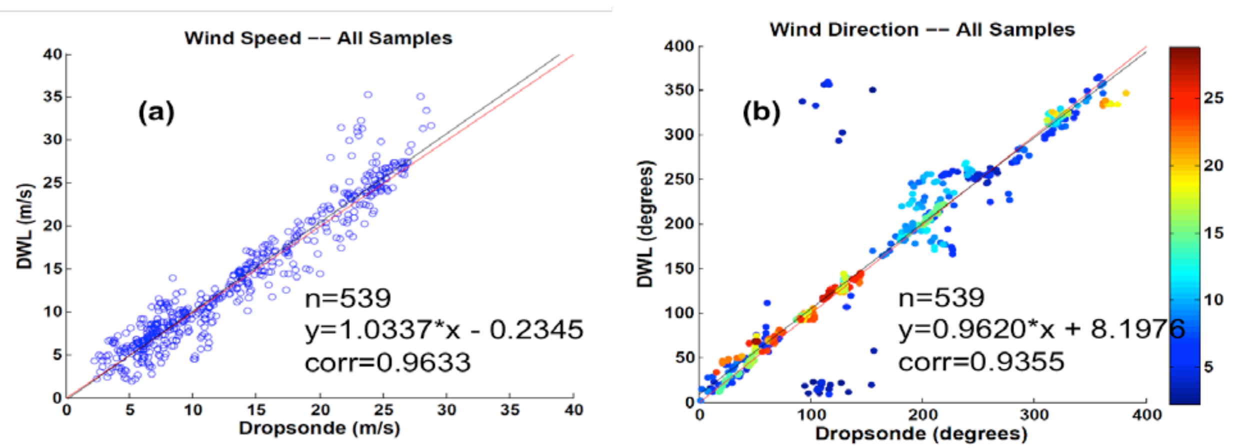

Figure 2: Comparison of DWL and dropsondes wind speeds (a) and wind directions (b). Color in (b) indicates the dropsondes speed. Dropsondes are within 5km of DWL observation.

Research Performance Measure: Research is progressing on time as planned.

Global Observing System Simulation Experiments (OSSEs)

Project Personnel: S. Casey and R. Hoffman (UM/CIMAS)
NOAA Collaborators: R. Atlas and L. Cucurull (NOAA/AOML
Other Collaborators: A. Kren, R. Li and M. Mueller (NOAA/ESRL); N. Shahroudi (NOAA/NESDIS/STAR)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To provide quantitative assessments of the impacts of future observing systems on a global scale.
***Strategy*:** To improve simulated representations of the Earth's atmosphere, including observations, model analysis, and model forecasts; to apply said improvements to experiments involving prospective new observation systems.

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:

Observing System Simulation Experiments (OSSEs) can show us the impacts of potential new satellites before they are even built. Most CIMAS and AOML research is focused on improving tropical weather forecasts on regional scales. By working globally we can demonstrate how large-scale meteorology and changes in observing systems on a global scale can improve our understanding of tropical weather, in pursuit of NOAA's strategic goal of being a more weather-ready nation.

A key component of global OSSEs involves making the observations and model skill realistic; if the observation/model skill is too good compared to real-world skill, the results are less credible. Work in this regard in the past twelve months includes more realistic observation error simulations, including adding land-type masks so that errors observed over different land surfaces match those observed in the real world. In addition, when it was discovered that the NOAA/GFS model better produced better 5-day forecasts of the simulated environment (based on NASA/GMAO/GEOS5) than the real world, parameters were adjusted to bring the OSSE forecast skill more in line with real-world forecasts.

These improvements are currently being used to assess the impact of a five-satellite constellation (Geostationary Hyperspectral Sounders, or GeoHSS), in accordance with HB353, which became law in April 2017. Work continues to ensure that a summary of initial results can be submitted on time by August 16th, also in accordance with HB353. Additional work will continue in the next twelve months to refine and report these global OSSE results, in addition to continuing work to improve the observation and forecast systems and apply these to new global OSSEs.

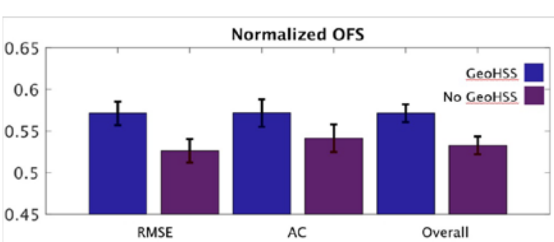

Figure 1: Overall Forecast Score for two experiments run with non-error-added simulated observations, comparing forecast skill with including the simulated Geostationary Hyperspectral Sounder (GeoHSS) constellation compared to only including currently-operational satellites. Significant improvement in forecast skill is noted here, though experiments including accurate simulated errors are ongoing.

Research Performance Measure: All major objectives are being met, and this project is on schedule.

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A Uniformly-High Resolution Nature Run for Hurricane OSSEs

Project Personnel: J. Delgado, L. Bucci, K. Ryan and S. Casey (UM/CIMAS).
NOAA Collaborators: R. Atlas, S. Murillo and S. Gopalakrishnan (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To run and evaluate a nature run using the Non-hydrostatic Multiscale Model on the B grid (NMM-B) in order to perform Observing System Simulation Experiments (OSSEs) of hurricane forecasts.

***Strategy*:** To perform nature run using NASA's GEOS-5 Nature Run as initial and boundary conditions, using increasingly higher horizontal resolutions. A thorough evaluation will follow each nature run.

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 is 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. This project focuses on the nature run. Specifically, we set a goal of running a uniform (i.e. non-nested) *regional* model forecast over a region spanning over 120x60 degrees to use as a nature run, at the highest horizontal resolution possible. We used the Non-hydrostatic Multiscale Model on the B-grid (NMM-B) to create the nature run. The regional nature run is based off of NASA's GEOS-5 Global Nature Run (G5NR)

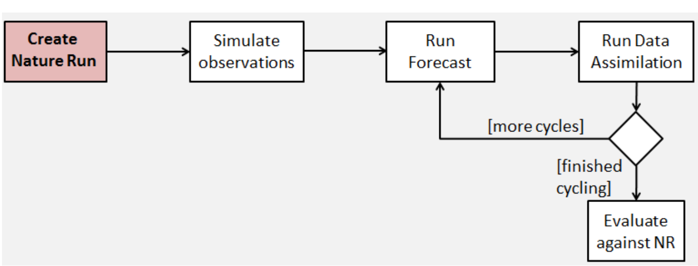

Figure 1: Overview of the process involved in running OSSEs

Due to issues we encountered when running NMM-B with an unprecedented grid size, an incremental approach was taken. We started with a 3 km nature run, as reported last year. This year, we achieved a 2 km forecast. We are now simultaneously performing an in-depth evaluation of the 2 km nature run and addressing technical issues necessary to increase the resolution to 1 km.

Several of the technical issues we addressed in order to run simulations with grids with more than 12 million points with NMM-B, and with initializing NMM-B from G5NR data, were summarized in last year's report. We have addressed additional issues with file size limitations and file corruption. To aid in model evaluation, we also developed a post-processing system capable of working with this large dataset,

using the Uniform Post Processing (UPP) suite. We have addressed additional technical issues in order to achieve a 1 km nature run, although further work is needed.

As previously mentioned, we have begun a thorough evaluation of our 2 km nature run. To this end, large scale and storm-scale analyses were performed. Various fields, including precipitation rate, geopotential height, and mean sea level temperature were analyzed and compared to the G5NR. We are currently performing a more in-depth analysis. Figure 2 shows the brightness temperature at the 139th forecast hour of our regional nature run. The G5NR storm #8 can be seen at the Gulf of Mexico. Our analysis includes evaluating how realistic our storm of interest is and all results thus far have demonstrated that it is.

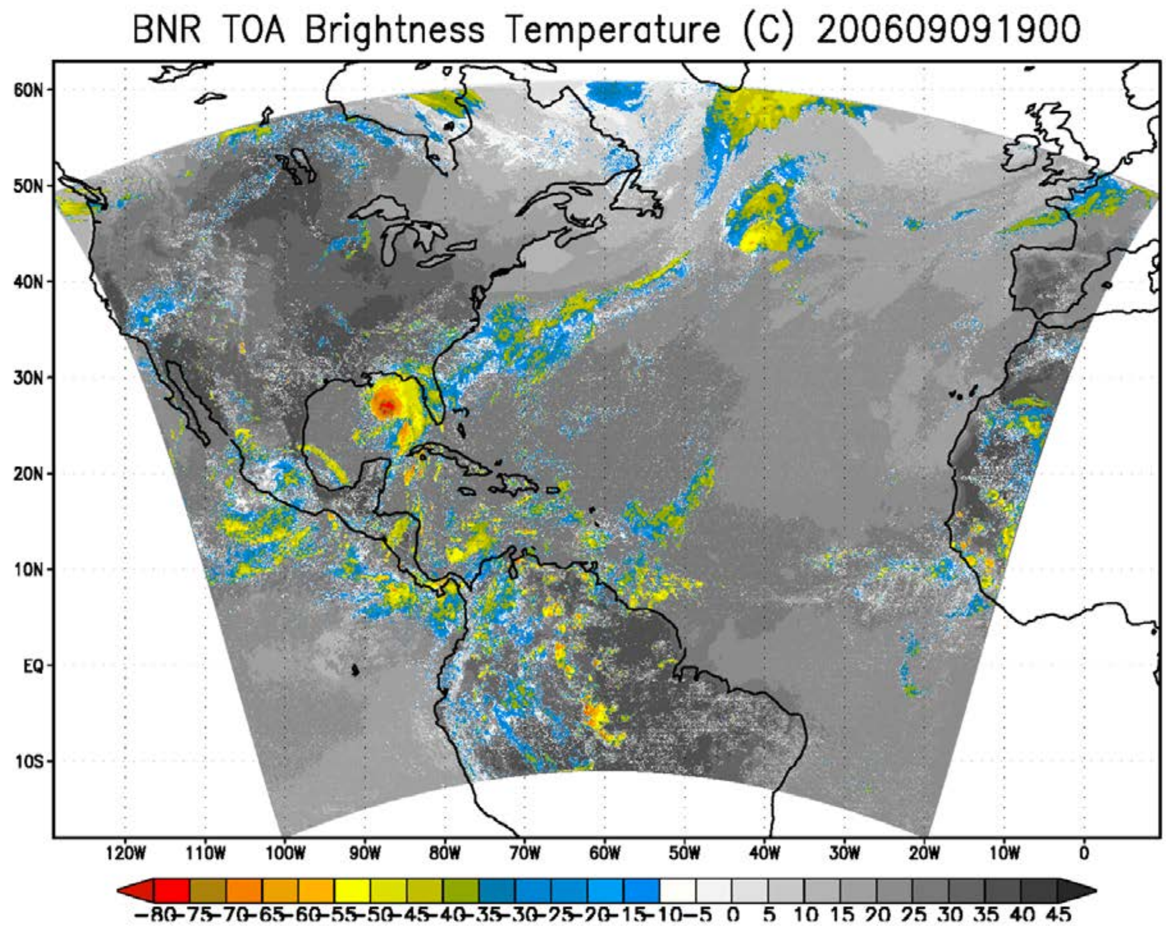

Figure 2: Snapshot of our 2km regional nature run showing brightness temperature after 139 forecast hours. The hurricane being evaluated can be seen in the Gulf of Mexico.

Research Performance Measure: Our original goal was to develop a uniform-3km nature run, which was accomplished. We took this one step further by generating a 2km nature run. This step was crucial considering that operational models currently have 2km nests. Our analysis thus far indicates that the nature run is realistic and viable for use in OSSEs.

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

Project Personnel: S. Delgado and B. Moses (UM/CIMAS)
NOAA Collaborators: C. Landsea (NOAA/NHC); F. 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 up to 1970 are complete. A summary of significant results since July of 2016 follows:

The 1968 hurricane season was about average with most of the tropical cyclone activity developing over the western Atlantic. Hurricanes Abby and Gladys (see revised track figure) 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.

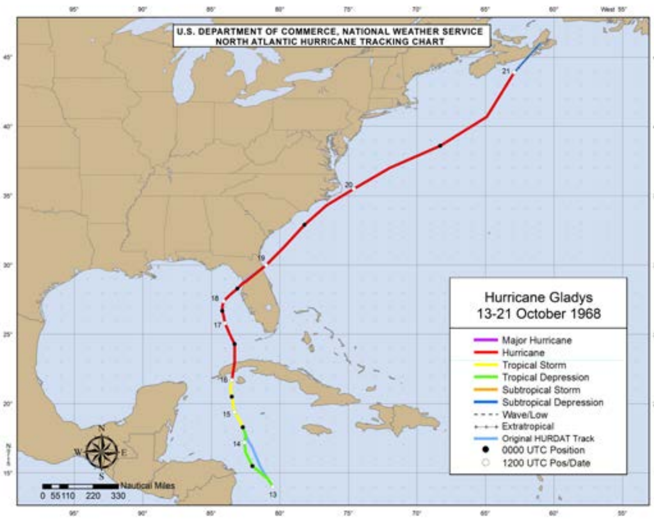

Figure 1: Original and revised track of Hurricane Gladys of 1968.

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 (see Camille track map in figure). 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.

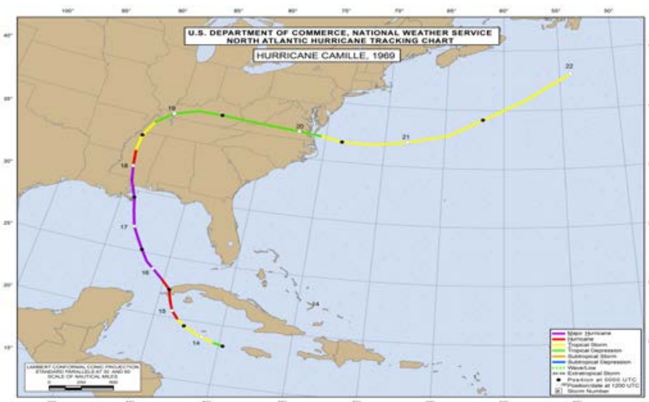

Figure 2: Revised track of Hurricane Camille of 1969.

In contrast to 1969, 1970's hurricane season was quiet. Of the original seven named Atlantic storms of 1970, only three reached hurricane intensity and only Celia brought hurricane-force winds to the U.S. mainland. Nevertheless, 1970 will be remembered as the year of Celica, the most destructive storm ever to reach the Texas coast. It is recommended that Celia be upgraded from a Category 3 to a Category 4 on the Saffir-Simpson Hurricane Wind Scale at landfall in Texas (see Hurricane Celia track map figure). After the 1970 hurricane seasonal summary was published in Monthly Weather Review, two

additional systems – an unnamed tropical storms and unnamed hurricane - were added to HURDAT. Our team also recommends removing a non-developing tropical depression in August, adding one additional tropical storm in September, upgrading a non-developing tropical depression to a tropical storm also in September, adding a new hurricane in October, and adding a new tropical storm in late November-early December.

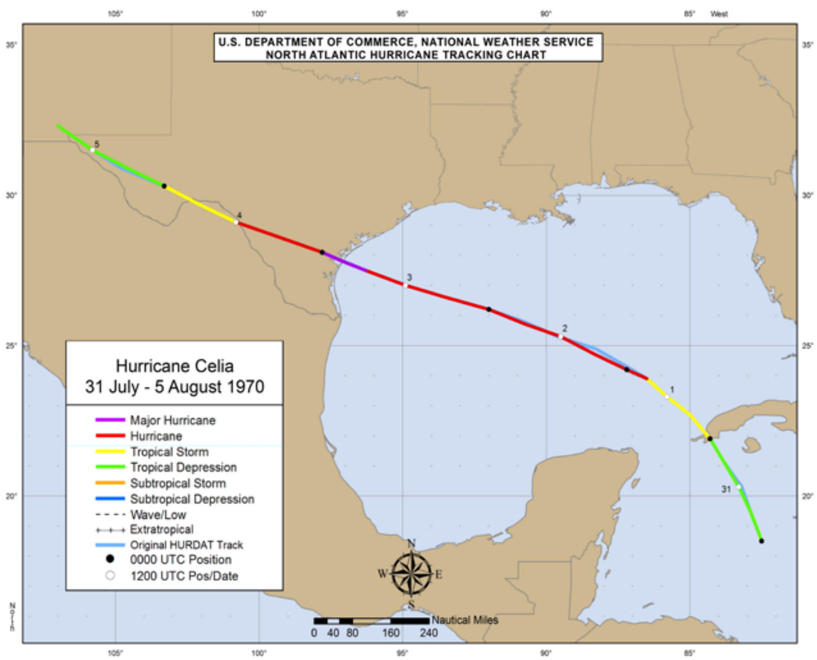

Figure 3. Original and revised track of Hurricane Celia of 1970.

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.

Research Performance Measure: Originally, it was hoped to have completed the reanalysis through the 1975 hurricane season by June 2017. 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.

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Developments in the Next-Generation Global Prediction System

Project Personnel: S. Diaz and E. Ehrbar (UM/CIMAS)
NOAA Collaborators: F. Marks and G. Gopalakrishnan (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To create a global-to-local-scale hurricane prediction system working at cloud-resolved resolution which provides 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 NEMS frameworks.
***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/AOML
NOAA Technical Contact: Molly Baringer

Research Summary:

HRD's contribution to the Next-Generation Global Prediction System (NGGPS) Program during the 2016-2017 year consisted of the development of the Next-Generation Generalized Nesting Framework (NGGNF).

During the 2015-2016 year, HRD, in part, developed a nested, global version of the Nonhydrostatic Multiscale Model on the B-grid (NMMB) under the HIWPP program (see 2015-2016 Annual Report). In Q3 of 2015, NOAA made the decision to forego the NMMB model as a potential future global forecasting system and further development on the global nested configuration was suspended. However, the lessons learned from the global model development spawned a new approach to hurricane modeling, the 'Free Floating Nest', which sought to de-couple the high-resolution hurricane nest from constraints imposed by the coordinate system of the much larger low-resolution model (as the nest moves towards the poles, the shape of the nest becomes distorted due to the convergence of lines of longitude.).

The concept was proposed and accepted as part of the NGGPS program and development resumed under the name 'NGGNF'. NGGNF was designed to transfer field data from a low-resolution global (or regional) model to an *independent* high-resolution hurricane model using the tools of the Earth System Modeling Framework (ESMF), in lieu of a traditional embedded nest. NMMB continued to be used as the base solver for both the low-resolution and high-resolution models, due to HRD developers' familiarity with it. A system was created that was able to successfully transfer data from the low-resolution model to a static (i.e., non-moving) high-resolution hurricane model.

Many features of the prototype NGGNF system were dependent on the 'Internal State' of each of the NMMB models. In unrelated developments at EMC during 2016/2017, the structure and framework of the NMMB/NEMS system was so heavily altered (in support of NOAA's 'Unified Modeling' effort), as to make current versions of NMMB completely incompatible with NGGNF. Thus, in Q2 of 2017, the existing NMMB-dependent NGGNF was shelved and a 'model-independent' version was recreated from scratch using the same ESMF routines.

As of the writing of this report, this new coupling system has demonstrated the ability to transfer static data (not actual solver-generated meteorological fields) from a low-resolution component to a high-resolution component for *moving* nests. This represents a significant advancement over the previous incarnation of NGGNF, and towards the project's goal of using this modular system to dynamically couple NOAA's recently announced "FV3 Global Forecasting System" to a local hurricane model.

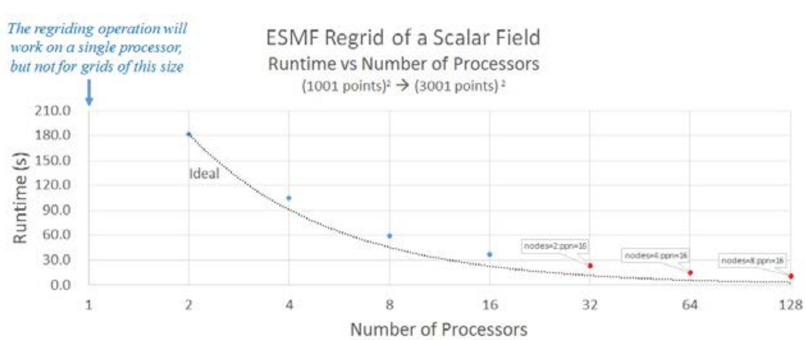

Figure 1: Scalability of the ESMF_Regrid Operation
The ESMF_Regrid Operation displays nearly ideal scalability for a 1–to-3 interpolation of a scalar field as a function of an increasing number of processors on large grids.

Research Performance Measure: All objectives are the track.

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

Project Personnel: R. Domingues, G. Rawson and T. Sevilla (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, L. Pomales (University of Puerto Rico Mayaguez); J. Dong and 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 gliders in the Caribbean Sea and tropical North Atlantic. Data transmissions are performed in real-time into the Global Telecommunication System (GTS) for assimilation in the forecast system.

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

Link to NOAA Strategic Goals:
***Goal 2*:** Weather-Ready Nation - *Society is prepared for and responds to weather-related events (Primary)*
Goal 3: Climate Adaptation and Mitigation – *An informed society anticipating and responding to climate and its impacts (Secondary)*

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

Research Summary:

Tropical Cyclones (TC) 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 during the Atlantic Hurricane Season (June to November). Despite being generally relevant for the genesis and intensification of TCs, no sustained ocean observation efforts were in place in these areas, which have been very poorly sampled during past decades. To address the lack of sustained observations in these areas, AOML's Physical Oceanography Division, the Caribbean Coastal Ocean Observing System (CARICOOS), and NOAA's Integrated Ocean Observing System (IOOS) are leading a multi-institutional effort that brings together the research and operational components within NOAA and the university community to implement and carry out sustained and targeted ocean observations from underwater gliders in the Caribbean Sea and southwestern tropical North Atlantic Ocean in support of hurricane studies and forecasts. 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.

An underwater glider is an autonomous underwater vehicle (Figure 1) that can be remotely operated including under hurricane wind conditions. These vehicles use small changes in buoyancy together with

wings to propel itself by converting vertical motion into horizontal motion. They 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.

To date, **six underwater glider missions** have been successfully completed with the collection of over **14,000** temperature, salinity, dissolved oxygen, and chlorophyll-a profiles were collected by this effort. The current glider fleet is composed of **four underwater gliders**, namely gliders: SG609 (purchased June 2014), SG610 (purchased June 2014), SG630 (purchased June 2016), and SG635 (purchased Feb 2017).

During July 1st, 2016 – June 30, 2017, two underwater glider missions (Figure 2) were successfully carried out: Mission 5 during the 2016 Hurricane Season from July-November, 2016, and the off-Hurricane Season Mission 6, in March, 2017:

Mission 5 – Two gliders (SG609 and SG630) were successfully deployed in the Caribbean Sea on June 21, 2016. The deployment marked the beginning of the 2016 Atlantic Hurricane Season deployment. Two additional gliders (SG610 and SG547 - a glider on loan from Kongsberg) were then deployed in the tropical North Atlantic as part of the Hurricane season operations. All gliders were recovered in early November 2016, marking the successful completion of AOML's fifth underwater glider mission during the 2016 Hurricane Season. Over 5,000 temperature, salinity, dissolved oxygen, and chlorophyll-a profiles were collected during this mission. The data collected during Mission 5 included upper ocean observations during Hurricane Matthew (September, 2016).

Mission 6 – in March 7, 2017 gliders SG610 and SG630 were deployed in the Caribbean Sea. Three days after the mission was initiated, an issue with the pumped CTD from glider SG630 was identified. The issue consisted of the pumped CTD drawing excessive power from the glider, and started interfering with the Vehicle Buoyancy Device, posing risks of losing the vehicle. The pilots operating the gliders identified the issue immediately, and an emergency recovery plan for the gliders was then put in place. Both gliders were successfully recovered in March 10, 2017, after collecting over 100 temperature, salinity, dissolved oxygen, and chlorophyll-a profiles.

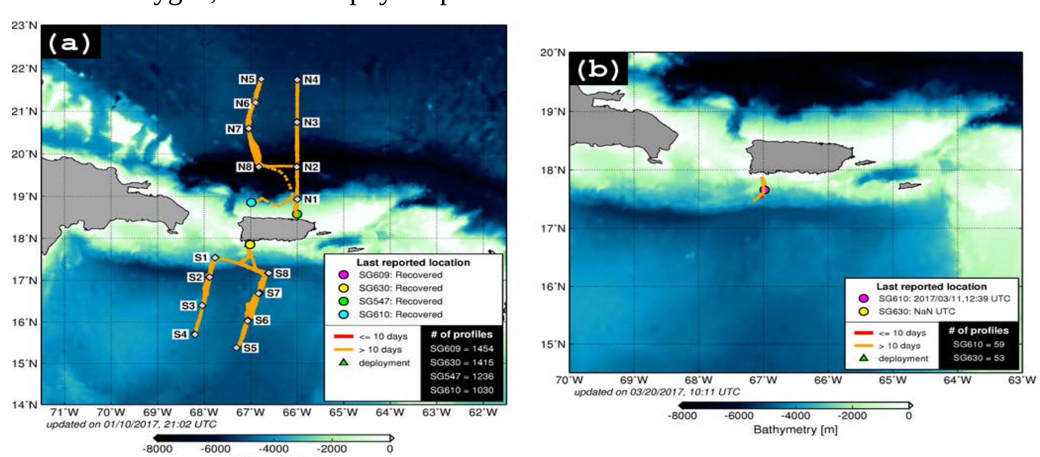

Figure 2: Track travelled by four underwater gliders during (A) the Hurricane Season (July-November) Mission 5 from 2016, and (B) during the off-Hurricane Season (March) Mission 6 from 2017.

All the data collected during Missions 5 and 6 were distributed in real-time through the Global Telecommunications System (GTS), through AOML webpages (http://www.aoml.noaa.gov/phod/goos/gliders/data.php), and in delayed time through the NOAA Integrated Ocean Observing System (http://data.ioos.us/gliders/providers/).

Following each mission, the glider fleet is refurbished by the science support team at AOML. Usual refurbishment procedures include the replacement or addition of sensors, batteries and new software. Consequently, after each refurbishment procedure the science support team then ballasts the gliders to accommodate for their new configurations. For Mission 7, the gliders were converted from pumped CTDs to CT sails in order to improve battery life as well as maneuverability of the glider through the water.

During the current reporting period, additional software was also implemented by the science support personnel to conduct real-time visual quality control of underwater glider data. The new developed software provides interactive analysis of recorded profiles in delay mode, where the operator ensures that good data are not discarded and bad data are not distributed. The first version of the software focuses on the temperature, salinity and pressure observations. Some of the tests presume a time-ordered series of observations, with each data point being quality controlled and assigned a flag using the tests coded according to the recommendation of Integrated Ocean Observing System (IOOS). The application was developed in Java in the Integrated Development Environment (IDE) NetBeans 8.1 under Windows 7.

The Hurricane Underwater Glider network will collect ocean observations during the upcoming 2017 Atlantic hurricane season as part of NOAA’s Hurricane Field Program. The effort has already gathered and distributed large, unique datasets of upper-ocean observations in real-time from the Caribbean and tropical North Atlantic.

Science Update

In a recent study published in Weather and Forecasting,* AOML researchers and their colleagues used NOAA’s HWRF-HYCOM operational hurricane forecast model to quantify the impact of assimilating underwater glider data and other ocean observations into the intensity forecasts of Hurricane Gonzalo (2014). Gonzalo formed in the tropical North Atlantic east of the Lesser Antilles on October 12, 2014 (Figure 3a). On October 14, Gonzalo traveled northeast of Puerto Rico to within 85 km of an underwater glider.

In their previous study of Hurricane Gonzalo (Domingues et al., 2015), the team reported that ocean conditions were characterized by the presence of a layer of low salinity close to the surface, which caused strong vertical density gradients. This near-surface layer, often called a barrier layer by oceanographers, may have likely contributed to the further intensification of Hurricane Gonzalo. Gonzalo reached Category-4 hurricane status on October 15, 2014, making it the most intense Atlantic hurricane during 2011-2014.

For the current study, it was found that the barrier layer observed prior to the passage of Hurricane Gonzalo and its associated sharp density gradients were only successfully represented in the ocean initial conditions with the inclusion of underwater glider data. An analysis of glider observations gathered during Gonzalo’s passage revealed that the ocean was better represented in the operational model with the assimilation of underwater glider data. Results show that the pre-storm thermal (Figure 3b) and saline structures of the upper ocean, used as initial conditions for the hurricane forecasts, were substantially improved when compared to HYCOM numerical experiments that did not include underwater glider data and other ocean observations.

Results from the coupled model simulations developed for Hurricane Gonzalo also showed that the largest improvement in hurricane intensity forecasts occurred when all upper-ocean observations were assimilated into the ocean component of the model (Figure 3c). The assimilation of ocean observations and underwater glider data reduced intensity forecasts errors by as much as 50% when compared to

experiments that did not include ocean observations. This work represents the first study of its kind to quantify the impact of assimilating underwater glider data and other ocean observations into NOAA's ocean-atmosphere coupled operational model.

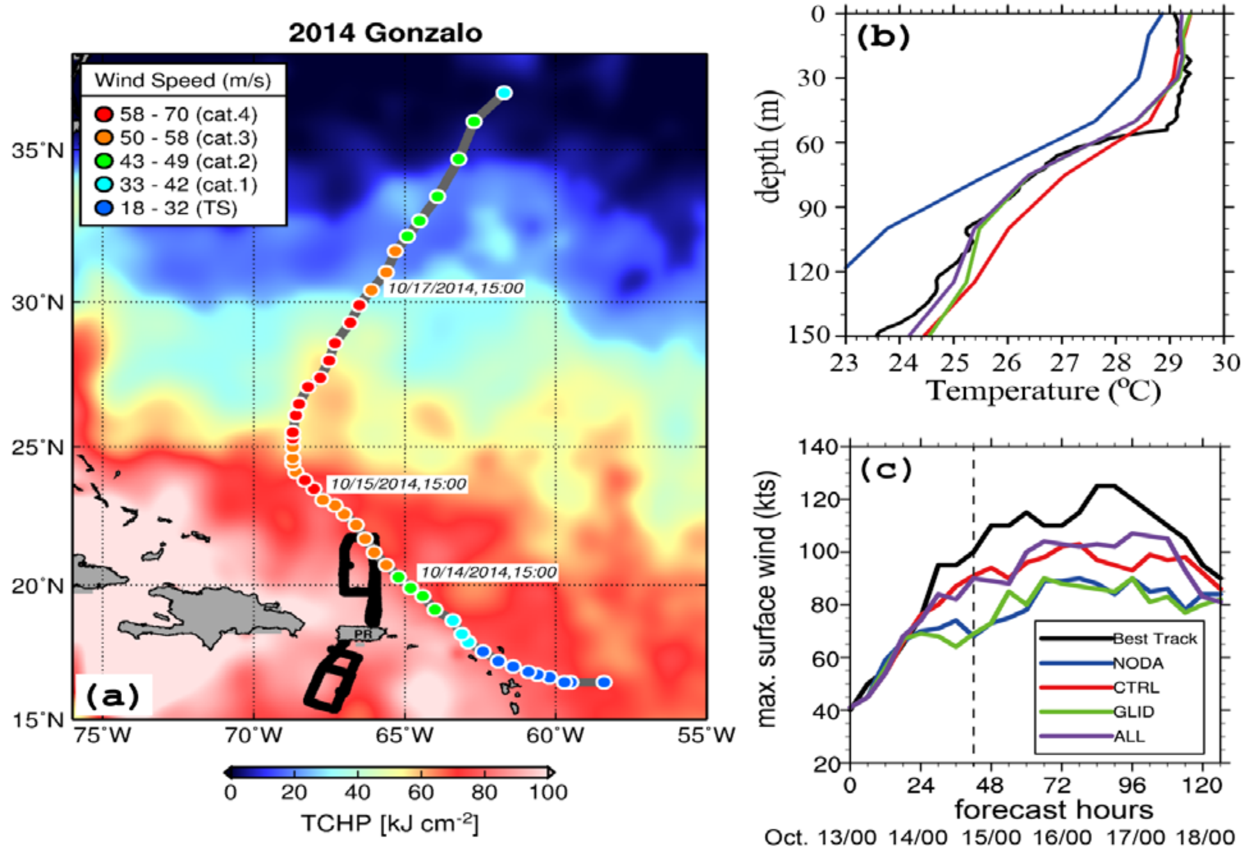

Figure 3: (a) Track of Hurricane Gonzalo overlaid on a tropical cyclone heat potential (TCHP) for October 10, 2014. (b) Temperature profile (black line) at the location of the glider on October 13, 00:00 GMT before the passage of Hurricane Gonzalo for the different simulations developed in this study (colored lines) compared with the observations (black line). (c) Maximum wind forecasts, along with the best track for the different numerical experiments compared with the observed best track data (black line) made available by the NOAA National Hurricane Center. Numerical experiments are developed with: no assimilation of ocean observations (NODA), assimilation of underwater glider data only (GLID), assimilation of all ocean observations excluding gliders (CTRL), and assimilation of all ocean observations available (ALL). Panels (b) and (c) are adapted from Dong et al., (2017).

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, 2016 to June 30, 2017, over 5,200 temperature, salinity, dissolved oxygen, and chlorophyll-a profiles were collected in the Caribbean Sea and Tropical North Atlantic and distributed in real-time through the GTS and AOML webpages.

Improvement to the Tropical Cyclone Genesis Index (TCGI)

Project Personnel: J. 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, and deriving a real-time Pacific version of TCGI. An experimental real-time web page was implemented that includes TCGI output in text and graphical formats (Fig. 1).

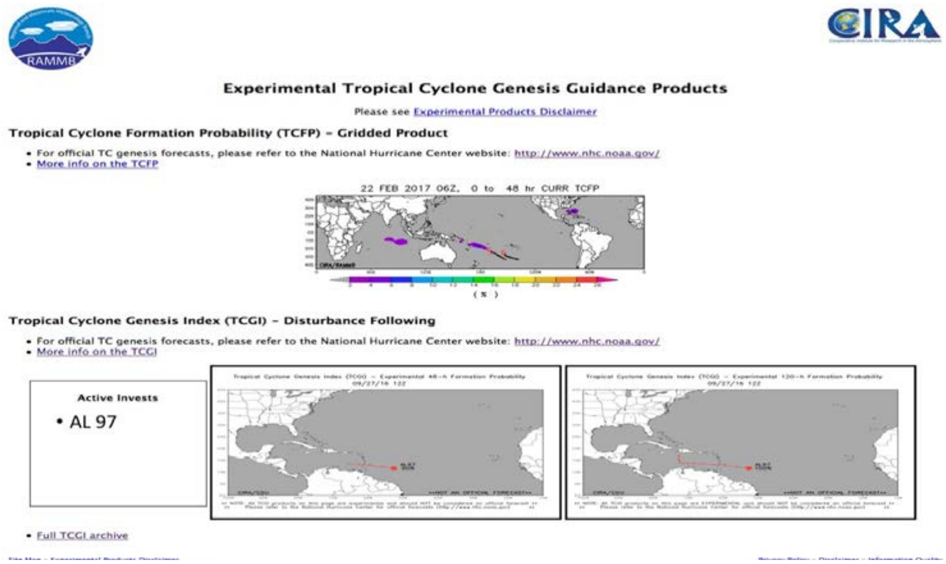

Figure 1: TCGI experimental web page showing the (top) Cooperative Institute for Research in the Atmosphere (CIRA) Earth-centric Tropical Cyclone Formation Probability Product (TCFP) and (bottom) TCGI output for tropical disturbance AL97 on 27 September 2016 1200 UTC. TCGI text output is viewable by selecting *AL97* in the *Active Invests* box. Graphical versions of TCGI forecasts for AL97 are also shown for 48- and 120-hr, where red curves indicated the AL97 track forecast, large red circles show the time zero location of AL97, and small red circles show the forecast positions for AL97 every 12-hr out to 120-hr. The text next to the large red circles indicate the tropical disturbance number (AL97) and the TCGI forecasted genesis probabilities at 0-48- and 0-120-hr respectively.

Research Performance Measure: This project is in the year-2 phase of a proposed 2-year effort and deliverables are on track for the anticipated August 2016 project completion. The project team presented an update of the proposed and planned deliverables at the 2017 *Tropical Cyclone Operations and Research Forum (TCORF), the 71st Interdept. Hurr. Conf.*, Miami, FL in March 2017 and submitted a year-2 report to NOAA in April 2017.

Code for running an eastern North Pacific and European Center for Medium Range Weather Forecasting (ECMWF) -based Atlantic TCGI has been installed on the NOAA/NCEP Weather and Climate Operational Supercomputing System (WCOSS) and testing was completed in spring 2017. Several new TCGI predictors using the 2001-2014 Atlantic and Pacific datasets were tested alongside ~60 other previously tested predictors. All area-averaged predictors were calculated using the original TCGI 0-500 km search radius, as well as smaller 200, 300, and 400 km search radii. Although dependent dataset tests using the smaller search radii produced superior statistics (relative to 0-500 km) for 0-48 hr and 0-120 hr TCGI forecasts similar tests were made using simulated real-time scenarios (2011-2016) showed that TCGI had significantly less skill. This is likely related to track forecast uncertainty inherent in tracking weak tropical disturbances.

As the TCGI project nears completion, the team will perform real-time tests of 0-48 and 0-120 h Atlantic and Pacific TCGI (GFS version) on NESDIS computers at CIRA with output being made available online at: http://rammb.cira.colostate.edu/realtime_data/nhc/tcgi/. Additionally, real-time tests of 0-48 and 0-120 h Atlantic and Pacific TCGI (ECMWF version) at NHC will be performed and development/evaluation of the prototype ECMWF-based Atlantic TCGI will be completed. The project team will also work with IT personnel at NOAA NHC to establish a means to more efficiently access real-time NOAA TAFB Dvorak fix information. This will help ensure increased reliability of real-time TCGI forecasts for use by NHC forecasters. Final code for running both the Atlantic and Pacific TCGI on operational NCEP computers will be provided to NHC/NCEP IT personnel if the project is accepted for operational transition in the August/September timeframe.

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. Dunion, A. Aksoy, L. Bucci, H. Christophersen, B. Dahl, B. Klotz, K. Sellwood and J. Zhang (UM/CIMAS)

NOAA Collaborators: R. Atlas, S. Aberson, S. Murillo and M. Black (NOAA/AOML)

Other Collaborators: L. Bosart and R. Torn (University at Albany-SUNY); W. Linwood Jones (University of Central Florida); D. Cecil (NASA/MSFC Earth Science Office)

Long Term Research Objectives & Strategy to Achieve Them:

***Objectives*:** To support the NOAA 2016 Sensing Hazards with Operational Unmanned Technology (SHOUT) Hurricane Rapid Response field campaign 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, Director, NOAA UAS Program

Research Summary:

The NOAA UAS program successfully conducted its 2016 SHOUT Hurricane Rapid Response (HRR) field program to observe North Atlantic tropical cyclones (TCs). The Global Hawk (GH) was equipped with multiple instrument platforms that include aircraft-deployed GPS dropwindsondes (dropsondes) 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 a TC's upper-level cirrus clouds, and a dual frequency Doppler radar for detecting 3-dimensional winds in the TC environment. The project team helped design and execute various aspects of the 10-week 2016 SHOUT HRR field campaign. The team designed and edited the 2016 SHOUT HRR Mission Operations Plan (MOP) in preparation for campaign. The MOP included an overview of the 2016 SHOUT HRR mission science objectives, mission science needs, daily planning procedures, and detailed flight patterns that were used for GH missions that were conducted during the field campaign. Project team members also enhanced the NOAA Hurricane Research Division's flight track drawing software so that it could be better used to sample tropical cyclones in a storm relative framework and improved the code to more accurately account for the GH ascent and descent maneuvers that affect the total aircraft mission duration. During the month leading up to the campaign, the team worked with NOAA/NCEP/Environmental Modeling Center (EMC) and staff at the European Centre for Medium- Range Weather Forecasts (ECMWF) to establish the capability to access Hurricane Weather Research and Forecasting model (HWRF) and ECMWF model ensemble output in real-time. This information was used to help guide GH sampling strategies and helped

support the SHOUT objective to use adaptive sampling techniques to target GH GPS dropsonde observations in model-sensitive regions with the goal of improving forecasts of TC track and intensity.

For each of the nine Global Hawk missions flown during 2016 SHOUT HRR, the project team provided a combination of on-site and remote mission science and real-time GPS dropsonde processing support and helped design aircraft flight tracks that optimally sampled the TC inner core and its surrounding environment. The team quality controlled all of the GH GPS dropsonde data in real-time and transmitted the observations to the Global Telecommunication System (GTS), so that it was available for assimilation in models such as the NOAA HWRF, ECMWF, and United Kingdom Met Office's (UKMET's) Unified Model. A total of 629 GPS dropsonde observations were sent to the GTS during the nine 2016 SHOUT HRR GH missions flown into Hurricane Gaston, Hurricane Hermine, Tropical Storm Karl, and Hurricane Matthew. Finally, project team members functioned in various on-site and remote capacities, including acting as co-science lead, on-site mission scientists, and remote mission scientists and organizing and scheduling the 30 mission scientists who supported the 2016 SHOUT HRR field campaign

A composite analysis was conducted for the dropsonde data collected in collaboration during NOAA's annual Intensity and Forecasting Experiment (IFEX), NASA's HS3 and NOAA's SHOUT projects. The research focus was on investigating the atmospheric boundary layer (ABL) structure and hurricane intensity. We found that the location of the peak boundary layer convergence is different in intensifying and steady-state hurricanes, in that it is located inside the radius of maximum wind (RMW) during the rapid intensification of Hurricane Earl (Fig. 1a) while it is located outside the RMW in the steady-state phase of Hurricane Edouard (Fig. 1b). This result was reported in Rogers et al. (2015; 2016). We also used the dropsonde composites to evaluate the performance of the operational Hurricane Weather Research and Forecasting (HWRF) model for representing the ABL structure. The result was reported by Zhang et al. (2015) and Smith et al. (2017).

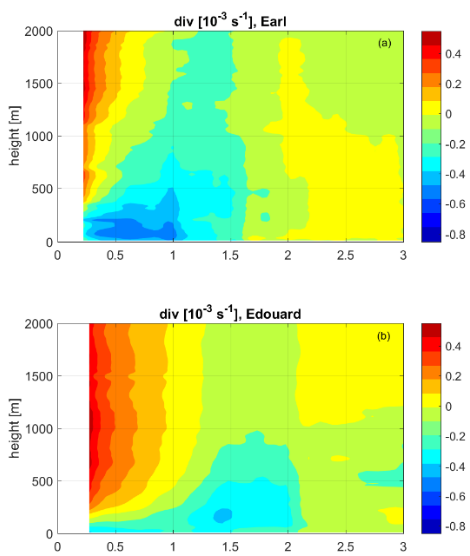

Figure 1: Plot of the boundary layer convergence as a function of height and radius normalized by radius of maximum wind speed (r/RMW) for (a) intensifying Hurricane Earl (2010) and (b) steady-state Hurricane Edouard (2014) from dropsonde composites.

The potential for UAS assets to improve hurricane analyses and forecasts was further evaluated by investigating the impact of Global Hawk dropsondes for vortex-scale hurricane data assimilation in NOAA/AOML/HRD's Hurricane Ensemble Data Assimilation System (HEDAS). As a follow-up to a case study that was reported in Christophersen et al. (2017), a comprehensive composite investigation is carried out to examine the impact of GH dropsonde observations collected on tropical cyclones during both the SHOUT and NASA HS3 campaigns.

The analyses included data from ten storms as shown in Fig. 2. The cases are stratified by intensity change. To eliminate sample deficiency, the intensifying and weakening cases are combined into one group, labeled as non-steady state (non-SS), while the rest is classified as steady state (SS) The dropsonde data are taken from traditional TEMP DROP messages with reduced vertical resolution at mandatory and significant levels. Horizontal drift at each vertical level is estimated from initial launch position and measured winds. The first set of experiments is run by withdrawing all NOAA P-3 and/or G-IV reconnaissance observations, including flight-level high-density observations, Stepped Frequency Microwave Radiometer (SFMR), tail Doppler radar (TDR), and dropsondes. A set of parallel experiments with and without GH dropsondes is carried out to assess the impact of GH dropsondes without the influence of reconnaissance observations. Other datasets assimilated in this scenario (when available) are the Atmospheric Infrared Sounder (AIRS) cloud-cleared retrievals, Constellation Observing System for

Meteorology, Ionosphere, and Climate (COSMIC) Global Positioning System (GPS) Radio Occultation retrieved profiles, nearby rawinsondes, and flight-level data from the Aircraft Communications Addressing and Reporting System (ACARS). The second set of experiments is run with all reconnaissance observations included to evaluate the impacts of GH dropsondes when data from reconnaissance aircraft are present.

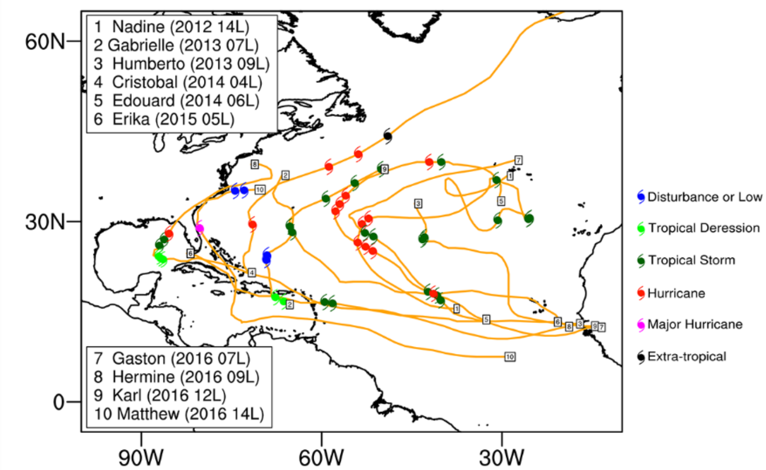

Figure 2: The storm location and strength (indicated by colored symbols) at the time of the GH mission for the cases incorporated into the composite dropsonde impact assessment.

The overall performance of assimilated dropsondes in the data assimilation (DA) system is evaluated to ensure that data are assimilated properly as expected. By the end of DA, the storms in the experiments with GH dropsondes are generally accompanied with less position and intensity errors and better wind-pressure relationship in the final mean analyses. Storms also present better structure (in terms of IKE) in the final mean analysis when GH dropsondes are included. When the storms are stratified based on intensity change, GH dropsondes demonstrate larger impact on the non-SS group than the SS group. This impact is evident in terms of large reduction of position errors, intensity errors, and IKE errors during the DA window, as well as superior relative skills of position, intensity and structure in the final mean analysis. As a consequence, the resulting forecasts for non-SS cases are generally associated with higher skills (by more than 25%) for both track and intensity than SS cases (Fig. 3). Providing a better initial state is expected to be an important factor in improving subsequent forecasts initialized with these initial conditions.

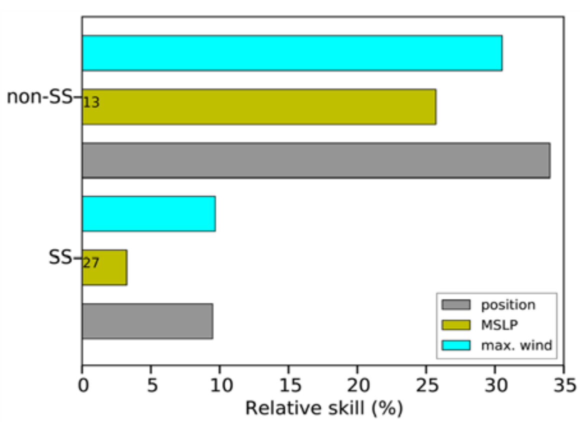

Figure 3: Illustration of the change in analysis skill in HEDAS resulting from the assimilation of GH dropsondes for steady-state (SS) and non-steady-state (non-SS) storms in the composite investigation. Results are presented separately for the analyzed storm position, minimum sea level pressure (MSLP), and maximum wind speed. Error is measured relative to NHC's Best Track dataset.

The GH dropsonde impact on the corresponding forecasts was similarly encouraging. The average impact of the added dropsonde observations on the HEDAS forecasts was investigated separately depending on whether other reconnaissance data were collected from manned aircraft as presented in Fig. 4. While the track forecasts were generally improved for all cases, the forecasts of intensity and minimum pressure were generally improved only when there were no other reconnaissance observations. The improvement in the track forecasts is frequently very large with values commonly between 10-30%. With other reconnaissance data, the improvement is greatest at longer lead times, consistent with results obtained from the operational HWRF model. With no other reconnaissance data, the observations show an increased impact at shorter leads. For intensity, the impact in the absence of other reconnaissance data is greatest at longer lead times and approaches peak values of over 30%. The composite study clearly underscores the importance of designing flight patterns

strategically to exploit the strengths of UAS and manned reconnaissance aircraft in order to maximize data impact on TC prediction.

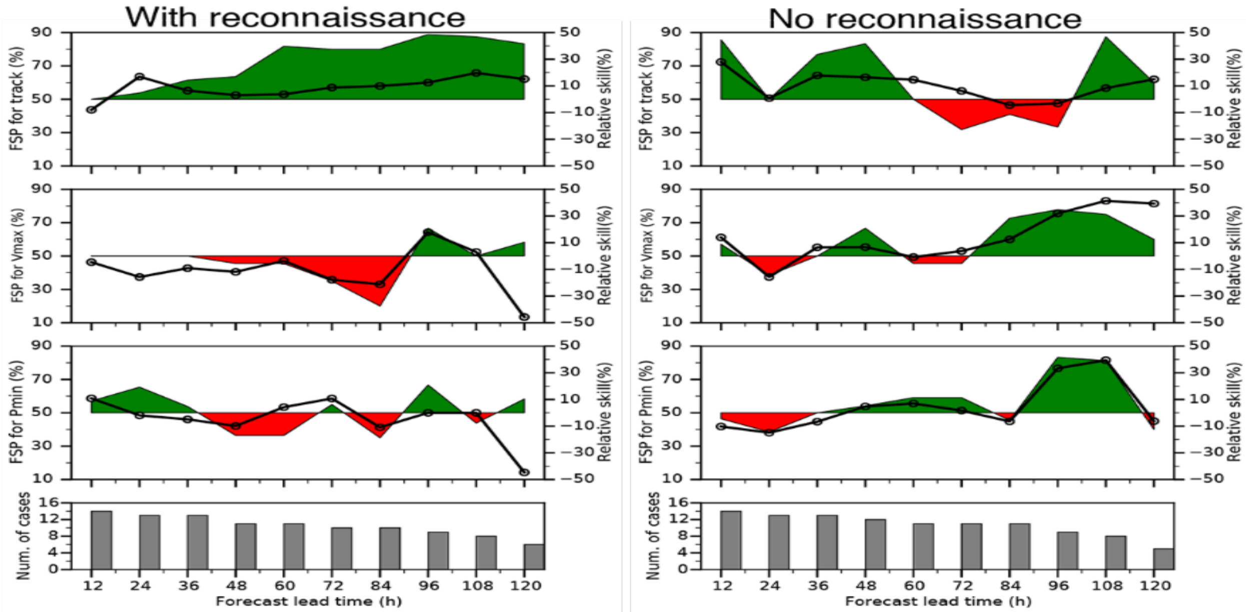

Figure 4: Summary of GH dropsonde impact on the HEDAS track and intensity forecast error for the composite analysis of ten storms. Results are stratified based on whether other aircraft reconnaissance data were available (left) or not (right). The upper panels show the results for track error; the middle panels for intensity error as reflected by maximum wind speed; and the lower panels for MSLP. Results are shown both for frequency of superior performance (FSP, left axis and red/green shading) and percent improvement in forecast error (right axis and black trace with circular markers). Error is measured relative to NHC's Best Track dataset.

HEDAS was also utilized to evaluate the impact of assimilating observations taken using UAS technology on TC surface wind structure, focusing on the Hurricane Imaging Radiometer (HIRAD). HIRAD was developed for use on high-altitude UAS to obtain ocean surface wind speeds and rain rates in the vicinity of TCs. The instrument provides frequent measurements in an approximately 60-km swath along the flight track when flown at typical altitudes. Such observations are capable of providing reliable estimates of the magnitude and extent of damaging winds and have the potential to improve numerical model analyses and forecasts of TCs when assimilated. This potential was tested within an observing system experiment (OSE) in which HIRAD observations obtained in 2015 Hurricane Joaquin were assimilated in addition to conventional wind and temperature measurements. Additional experiments were performed with adjustments to the data assimilation (DA) system to address some of the difficulties specific to assimilating surface data.

In all three cases for which HIRAD data were available, the addition of these observations was found to improve initial surface wind analyses in terms of magnitude and radial location of maximum wind speed, extent of tropical storm force winds and symmetry (Fig. 5). Above the surface, the impact was not as prominent due to the relative sparseness of conventional data and exaggerated influence of HIRAD within the default DA configuration. In order to mitigate these effects, adjustments to the DA scheme to reduce the number of assimilation cycles and lessen the horizontal and vertical range of HIRAD data impact were tested.

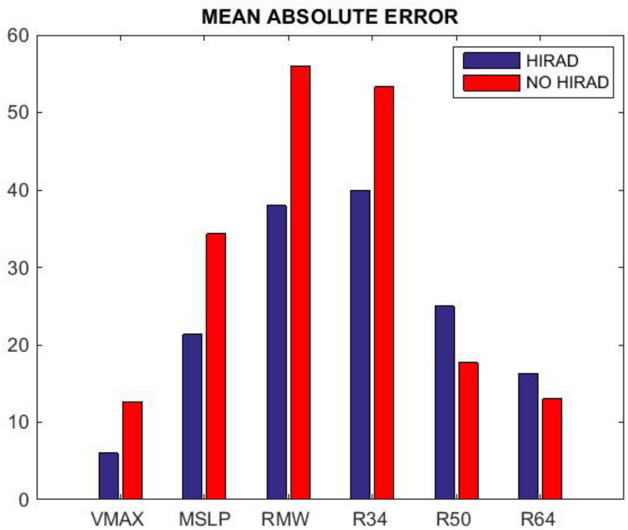

Figure 5: Impact of HIRAD data on surface wind analyses in terms of maximum wind speed in kt (VMAX), minimum sea level pressure in hPa (MSLP), radius of maximum wind in nautical miles (RMW) and radial extent of tropical-storm-force (R35), 50-kt (R50), and hurricane-force (R64) wind speeds in nautical miles. Errors are calculated relative to the NHC Best Track dataset. Estimates of 50- and 64-kt wind radii have greater uncertainty than other values.

It was found that reducing the number of DA cycles greatly improved the analyses at all levels. Further benefits were realized by reducing the radius of influence of the HIRAD data. In this better optimized configuration, the addition of HIRAD data was found to not only improve the initial representation of the wind speed, but also resulted in more skillful forecasts for both track and intensity out to 96 and 48 hours, respectively (Fig. 6). The impact of the HIRAD data was greatest for the case that had the fewest conventional observations. The results found here indicate the potential value of HIRAD, particularly in cases where few conventional observations are available. Furthermore, the improvements realized from adjusting the DA configuration may prove important for the assimilation of other types of surface observations such as scatterometer or SFMR.

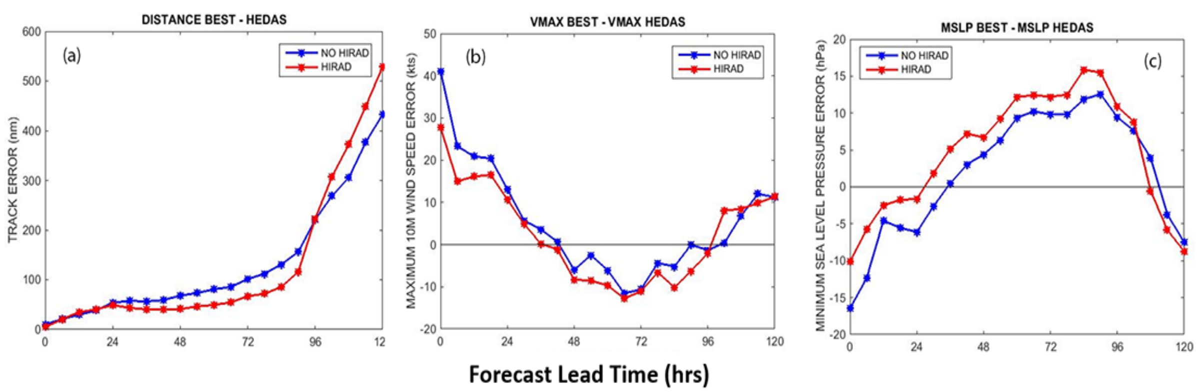

Figure 6: Impact of HIRAD data on (a) track and (b) intensity error compared to the NHC Best Track dataset.

Observing system simulation experiments (OSSEs) were also carried out with the HEDAS data assimilation system using synthetic observations sampled from the Nolan et al. (2013) nature run. The studies focused on evaluating what areas of the storm should be targeted to achieve the greatest forecast impact from GH observations and if sampling at different times with respect to the diurnal cycle had any preferential impact. In particular, the studies examined whether sampling closer to the center of the storm or further away from the inner core was most beneficial.

Figure 7 summarizes the results of adding simulated dropsonde measurements relative to a control run that assimilates only conventional observations. The impact of the GH observations on the initial model analysis is observed to be positive for the storm position (track) and minimum seal level pressure (MSLP) but limited for intensity as reflected by the maximum wind speed. For the initial position, unsurprisingly, the largest benefit is obtained for more observations near the center of the storm. With respect to MSLP, adding more observations including more sampling near the storm center improves the analysis. For forecasts, the impact of the observations on the track is short lived, but large and persistent for the MSLP and storm intensity. The positive impact of the observations on MSLP and maximum wind speed are

consistently largest when more observations are added near the inner core (2xRMW). These OSSE results generally agree with the Global Hawk dropsonde OSE studies in showing positive impact of GH dropsonde observations within HEDAS forecasts with greatest benefit resulting from enhanced sampling near the storm center as opposed to at greater distances extending into the surrounding environment.

As part of the OSSE work, the aircraft observation simulation system was modified to process simulated TDR data for the NOAA P-3 aircraft in a more realistic way by making it compatible with the HRD radar superobservation program, which is used on actual TDR data that HEDAS assimilates in real world cases. An additional post-processing capability was developed so that simulated data that are sampled from multiple nested model domains with different resolutions can be blended together, which allows observations to be sampled from the highest-resolution model domain possible.

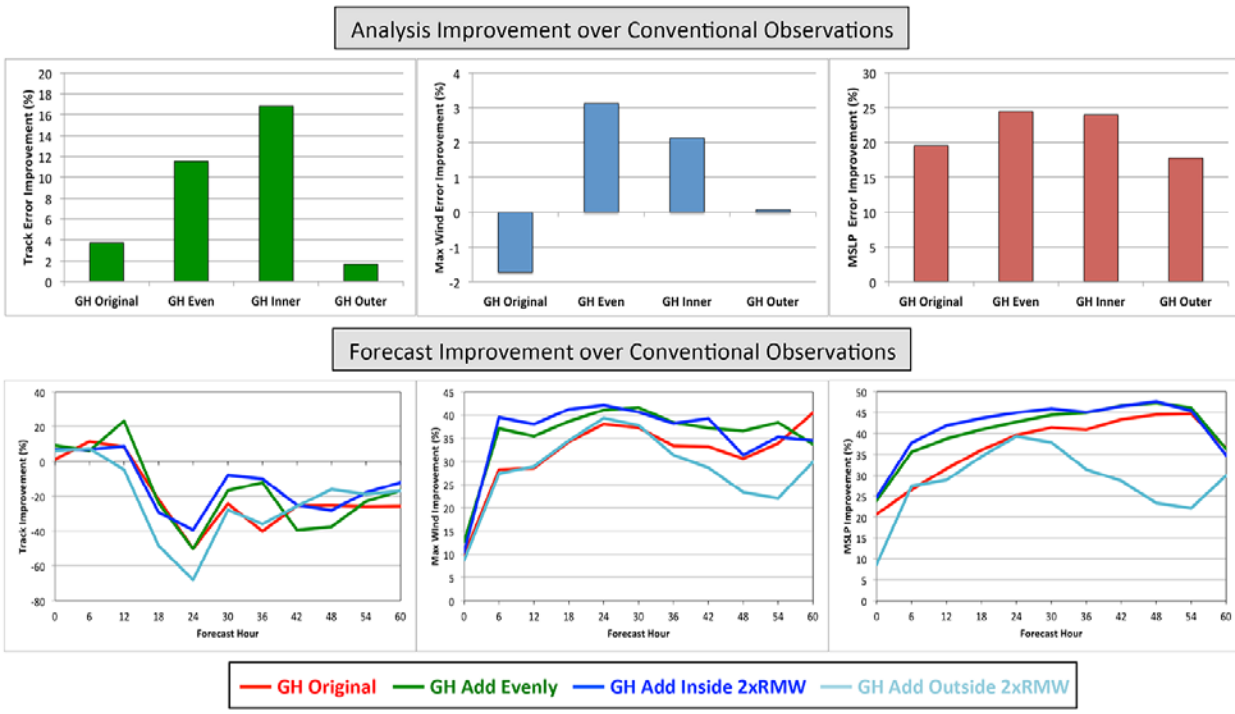

Figure 7: Summary of the impact of adding the simulated GH dropsonde measurements relative to a control run assimilating only conventional observations. The impact on the initial analysis is shown in the upper panels while the forecast impact is shown below. The leftmost panels are for the track error, the middle panels are for the maximum wind speed, and the right panels are for MSLP.

Research Performance Measure: The 3rd and final year of this project was completed on 30 June 2017. All objectives were met within 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 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.

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 an intense Hurricane Bill (2009) and idealized simulations at Category 2 and 5 strength are used for comparison. Previously, it was shown that model configuration played an important role for a particular simulation to capture the strongest wind speeds. In order to maintain continuity, the five simulations are re-run under the constraints defined by HNR1. SFMR flight tracks are initially simulated in the single figure-4 pattern starting at eight incidence angles within each specified time window of a simulation (i.e., starting at zero degrees and rotating at 45 degree intervals). Additional flight patterns were also used to determine which options could lower the underestimate. These additional patterns include a single butterfly, rotated figure-4, and repeated figure-4. Examples of these three patterns in addition to the single figure-4 pattern are provided in Fig.1.

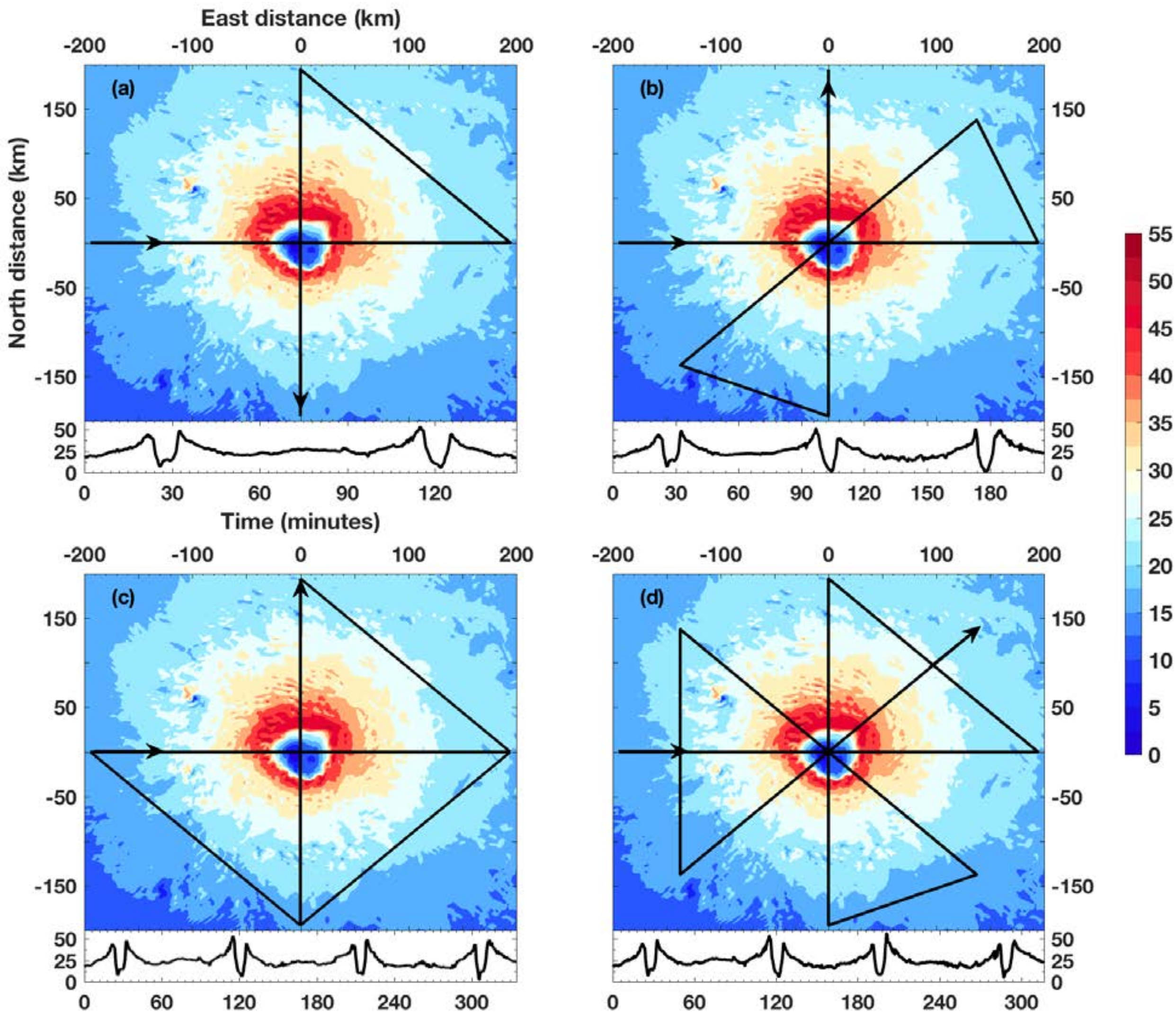

Figure 1: Simulated flight tracks for (a) single figure-4, (b) single butterfly, (c) repeated figure-4, and (d) rotated figure-4 patterns are overlaid on an image of the surface wind speeds produced during the mature stage of HNR1 (00 UTC on 4 August, 2005). The trace of the observed wind speed for the complete patterns are shown in the lower section of each panel to convey the amount of time it takes for each flight as well as to highlight differences between the patterns.

To quantify the underestimation of the 1-minute maximum, the average of the eight observed maxima within each sampling window is calculated (start times begin every 3 hours). Initial results indicate that very disorganized and weaker systems had a much higher underestimate (~16%) than small intense hurricanes, such as Hurricane Bill (~5-6%). However, it is more useful to compute the correlation coefficient between the underestimates and several variables that could be attained in a real-time, operational setting. These variables include the flight-level and surface radius of maximum wind (RMW), the flight-level and surface maximum tangential wind speed, and an asymmetry parameter. Figure 2 provides these correlations using the data from the five simulations and indicates that the relationship between the underestimate and surface RMW would be most useful because it provides an idea of the size of the storm and implies information about the asymmetry without actually calculating asymmetry. For the single figure-4 pattern related to the 10 m RMW, the underestimate is ~16% for a large tropical storm but as low as 2% for a small major hurricane. Considering the rotated figure-4, which doubles the sampling to all quadrants, these percentages drop to ~13.5% and 0.5%, respectively.

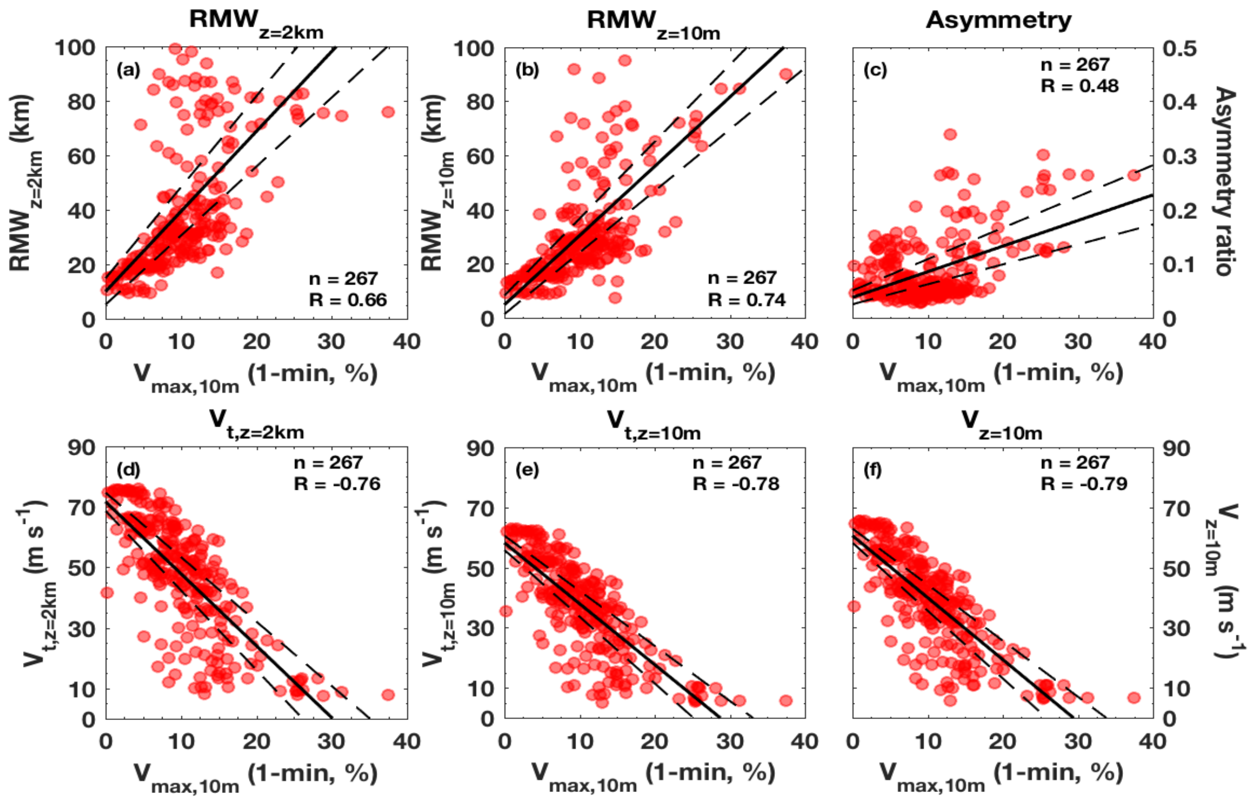

Figure 2: Scatter and linear best fit functions are plotted for the relationship between the percent underestimate as determined by the single figure-4 pattern and the (a) 2 km radius of maximum wind, (b) 10 m radius of maximum wind, (c) asymmetry parameter, (d) 2 km maximum tangential wind speed, (e) 10 m maximum tangential wind speed, and (f) 10 m maximum wind speed. The number of points and a correlation coefficient are provided in each panel. The dashed lines indicate the 95% confidence intervals.

Another objective of the second year of this study is to simulate satellite scatterometer swaths and underestimate the maximum wind speed. Scatterometers provide a depiction of the surface wind field but are much coarser in horizontal resolution than SFMR data. Because of the known degradation with scatterometer performance at high wind speeds and from rain interference, these analyses only include wind speeds at or below Category 1 strength. Operational products are available at 12.5 and 25 km resolution, and results will be presented for both conditions. Additionally, the impacts of rain are estimated by applying a rain flag, which is calculated in a similar manner to operational products. Comparisons are then made to identical simulations without taking rain into account. Figure 3 provides an example of a swath of data at three incidence angles for both resolution products of the ASCAT scatterometer. The overall results from the simulated wind speeds indicate that without (with) considering rain impacts, a ~21-22% (~25-26%) underestimate is expected. At 25 km resolution these values jump to 26% and 29%, respectively. Scatterometer wind speeds are not often the first choice for intensity estimates but they could be used to determine a likely intensity in the absence of aircraft or other in-situ data.

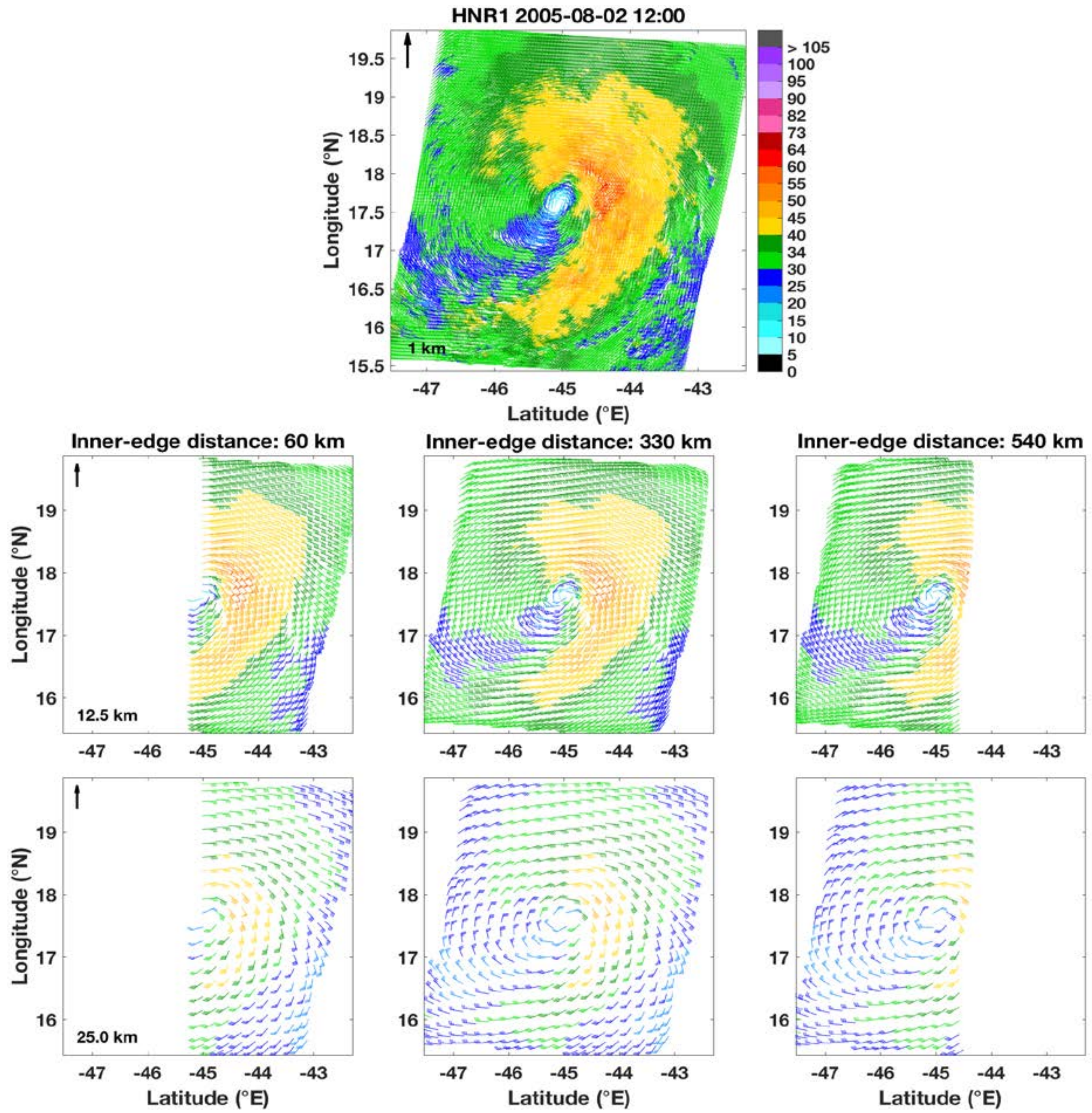

Figure 3: In the top panel, the original wind vectors from the HNR1 10 m wind speeds are provided at 12 UTC on 2 August, 2005. The middle row displays the simulated ASCAT scatterometer swath at 12.5 km resolution for incidence angles near the inner swath edge, middle of the swath, and outer swath edge. The bottom row is similar to the middle row but for the 25 km resolution product. These panels do not incorporate the rain flag.

Research Performance Measure: All research goals for year-2 are currently on schedule. We have been in correspondence with the JHT points of contact, and our results are moving closer to being tested in an operational setting.

Reprocessing the SFMR Database

Project Personnel: B. Klotz (UM/CIMAS)
NOAA Collaborator: P. Reasor and F. Marks (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives: To create a consistent and coherent dataset that contains the updated processing method and formatting type.

***Strategy*:** To collect, process, and formalize all existing SFMR data using the current operational algorithm and to analyze the data for performance standards.

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 17+ 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 has been used since the 2015 hurricane season on all NOAA and Air Force Reserve (AFRC) aircraft.

Because data collected from 2015 and beyond are collected in real-time using this updated algorithm, it was determined that there might be some confusion to data users on the version or corrections needed for a particular flight or storm. To help mitigate this issue, all SFMR data between 1998 and 2014 were gathered and processed using the updated (current) processing algorithm. These data were then quality controlled and stored in a consistent format for user friendliness. All data have been uploaded to the HRD website for public access as well.

To verify that these reprocessed data are performing better than the previous algorithm version (i.e., less bias within rain and able to get accurate wind measurements at high wind speeds), statistical comparisons were made between the two processing versions by comparing the wind speed bias against dropsonde surface-adjusted wind speeds. In Figure 1, 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 hurricane strength or greater (> 33 m s^{-1}, right panel). 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. The hurricane wind regime results confirm that the updated algorithm wind speeds are mostly unchanged compared to the previous algorithm.

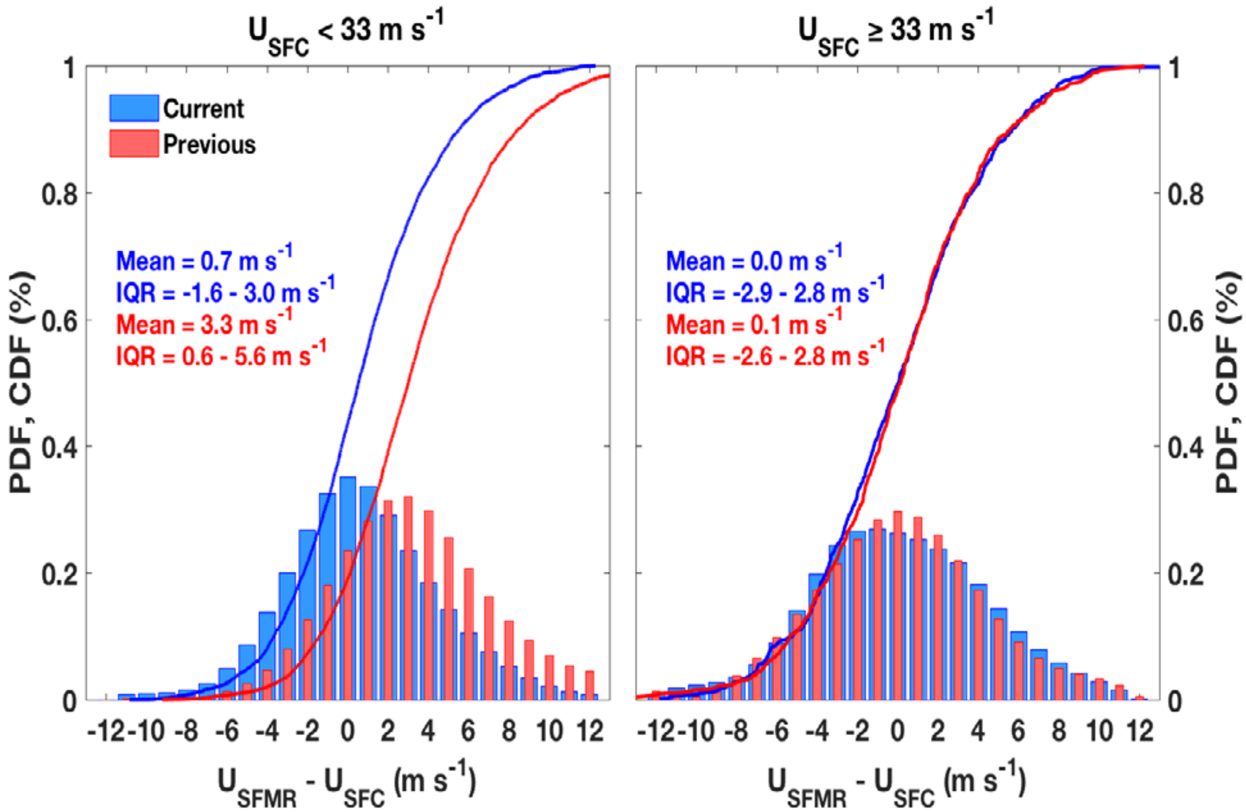

Figure 1: Probability density functions and cumulative distribution functions are plotted for non-hurricane wind speeds (< 33 m s^{-1}, left) and hurricane wind speeds (> 33 m s^{-1}, right) for the previous (red) and current (blue) processing algorithm versions. The average SFMR bias and middle 50% 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 2 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). The 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 2 provides the quantitative mean bias as a function of wind speed for four rain rate bins. While all the panels indicate statistically significant changes at wind speeds below hurricane strength, the most significant change is at weak wind speeds and high rain rates (Fig. 2d, average difference ~5-7 m s^{-1}). While the bias was not completely eliminated, this reduction provides evidence for increasing our confidence in the weak wind speed regime in rainy conditions. Notice also that there were minimal impacts on the hurricane force wind speeds, which was a desired outcome of this work. Therefore, the SFMR algorithm used from 2015 onward 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.

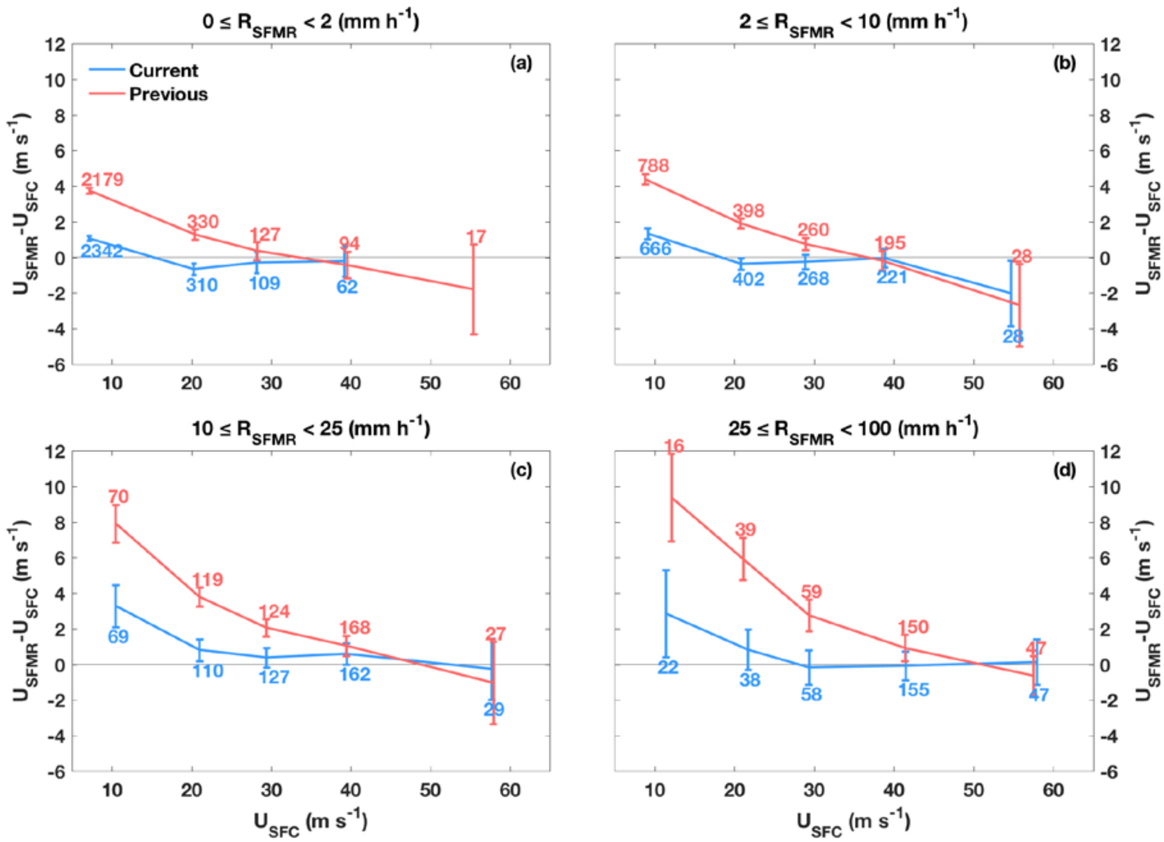

Figure 2: Bin-averaged surface wind speed biases are shown as a function of wind speed for four rain rate bins, including (a) no rain, (b) light rain, (c) moderate rain, and (d) heavy rain. The colors represent the same data as in Figure 1. Error bars indicate the 95% confidence intervals and the numbers above each point indicate the amount of data included in the mean calculation.

Research Performance Measure: All research goals have been met. Reprocessing and broadcasting of the reprocessed data is complete and evaluation of the operational algorithm performance indicates an improved wind speed and rain rate estimate from SFMR.

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Rainfall Evaluation for Developments in the High-Impact Weather Prediction Project

Project Personnel: M. Ko, X. Zhang, S. Diaz and G. Alaka (UM/CIMAS)
NOAA Collaborator: F. Marks and S. Gopalakrishnan (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives: To examine and provide a guideline for improving the forecast performance of High-Impact Weather Prediction Project (HIWPP's) high-resolution, multiscale hurricane prediction system – HMON (a.k.a. HNMMB).

***Strategy*:** To design a methodology of evaluating model-produced precipitation, to evaluate forecast capability with observation data, and to specifically identify HMON's precipitation evaluating performance.

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:
HIWPP project was funded in 2013 and has achieved almost all the major milestones by the end of 2015, including developing a high-resolution, multiscale hurricane prediction system (HMON). The last milestone of this project was "Multi-Season Testing and Rainfall Evaluation" which was postponed until the end of 2016 hurricane season due to lacks of land-falling storms during 2014 and 2015. Ms. Ko joined the team in early November in 2016 and took the lead of rainfall evaluation for this project. With two notable land-falling storms in 2016, 09L Hermine and 14L Matthew, this evaluation task was completed on schedule. This evaluation has two major perspectives - one based on the "total precipitation" field of HMON model output; the second one examined with the "precipitation rate" field.

HMON Total Precipitation Evaluation
Ms. Ko led the verification of HMON's forecast capability on total precipitation along a tropical cyclone track. The experiment revealed that HMON forecasts have higher precipitation along the track and wider precipitation range (Fig. 1 and Fig. 2) compared to corresponding Stage IV radar data. Based on the figures, HMON model output has also proven its capability to produce the correct rainfall patterns while tending to overestimate the total amount of rain.

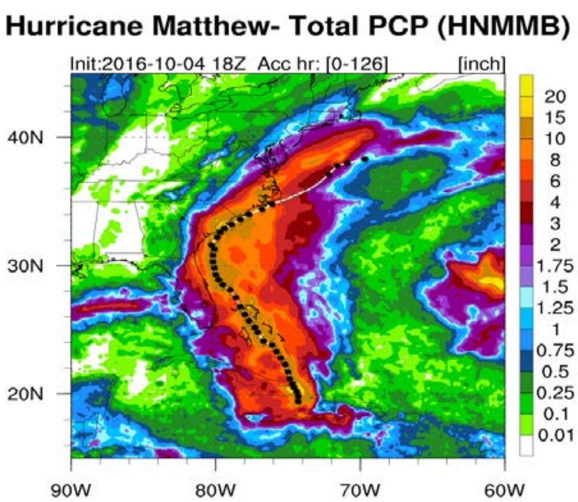

Figure 1: Total Precipitation of 2016 14L Matthew - HNMMB/HMON. This figure indicates HMON's forecast for Hurricane Matthew on 04 Oct 2016 18Z. The precipitation data accumulates 126 forecast hour model simulated rains in inches. The white line is model-simulated hurricane track overlaid by tropical cyclone symbols indicating corresponding tropical cyclone status.

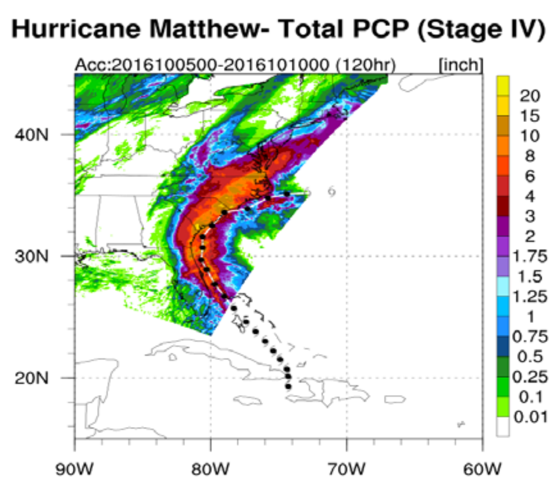

Figure 2: Total Precipitation of 2016 14L Matthew - Stage IV. This figure shows radar data of total precipitation accumulating from 05 Oct 2016 to 10 Oct 2016. White line is hurricane track from observations; the overlaid tropical cyclone symbols indicate hurricane intensity status. The white region is out of radar reachable distance.

HMON Precipitation Rate Evaluation
The other perspective to evaluate precipitation forecast capability for HMON system is to examine instantaneous precipitation rate (PRATE). HMON has been shown to produce realistic instantaneous rain structure in both eyewall and rainbands with reasonable consistency with Stage IV radar data. This results also shows HMON has the capability to simulate the peak rainfall region in the eye wall in a well-structured case. However, with a realistic structure, HMON has too high a frequency of heavy rain rate and too low a frequency of light rain rate in the core of the storm (Fig. 3). It appears that the microphysics parameterization in HMON system has potential issues to produce too high rain rates in convective regions.

These results were fully reported to OAR/NOAA and UM/CIMAS. The information was disseminated to NOAA/AOML and partners in M. Ko's talk at April's HRD Science Meeting and at F. Marks' local AMS chapter seminar at AOML. This comprehensive testing and evaluation will be merged with the on-going HMON R2O efforts at NOAA/EMC.

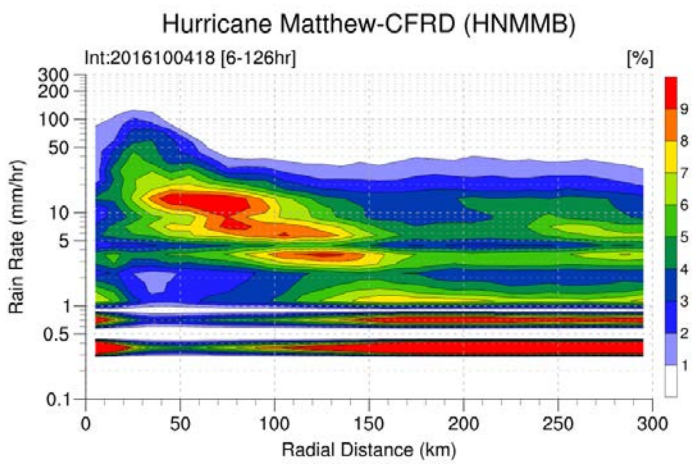

Figure 3: Contoured Frequency by Radial Distance (CFRD) of 2016 14L Matthew - HNMMB/HMON. This figure shows model-simulated frequencies of rain rates in 10 km bins. Within 0 to 30 km, most of rain rate is below 1 mm/hr. Between 30 km to 100 km (core region), rain rate is mostly above 5 mm/hr. Outer rainband (150 km to 300 km) rain rate is mostly below 1 mm/hr.

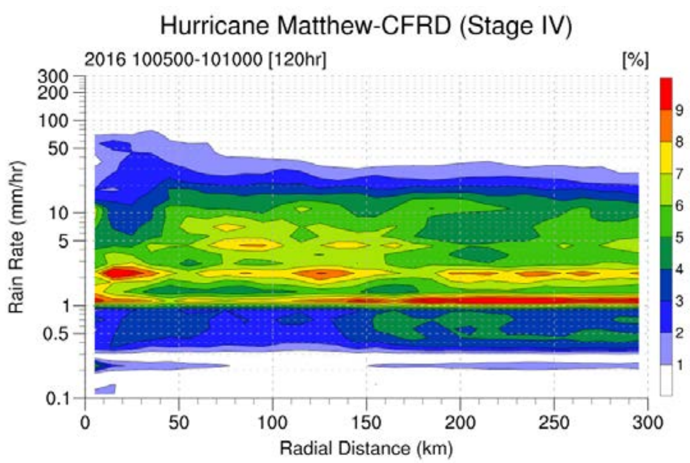

Figure 4: Contoured Frequency by Radial Distance (CFRD) of 2016 14L Matthew - Stage IV. This figure shows radar-observed frequency of rain rate. In the core region (30 km to 100 km), most of rain is between 1 mm/hr to 5mm/hr.

Research Performance Measure:
All objectives are met on schedule.

Improving Hurricane Forecasts Using Multimodel Ensembles through Neural Networks Approaches

Project Personnel: T. Ghosh (FSU)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives: To improve tropical cyclone and hurricane intensity forecast.

***Strategy*:** To utilize artificial neural network algorithm for developing a consensus model aiming to better intensity forecasts.

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: CIPO

NOAA Technical Contact: Ruth Almonte

Research Summary:

This project has been undertaken to provide improved hurricane or tropical storm intensity forecasts using multimodel consensus. More specifically, to improve the multi-model superensemble forecasts (Krishnamurti et al. 2016) using neural network algorithms. Multi-Layer Perceptron and Generalized Regression Neural Network have been studied. Artificial neural network algorithm works on the principle of human brain. Human brain takes best possible decisions on past experiences through prioritizing some requirements or needs. Similarly, here we examined to develop a consensus model based on past observed and model forecasted values.

We considered hurricane forecast models like AVNI, GHMI, DSHP, HWFI, LGEM. Historical forecasts and observed values for different storms of these models were taken together. We divided the entire dataset, randomly, into three sets. The first set contained 70% of the data and other two 30% each. First set was named as training set. Other two sets are called testing set and validating set. Training set was used to develop the neural network where validating set was used to tune the parameters of the network. This tuning is required to check when a un seen data (data not used to develop or tune the network) is given to the network then how does it perform with respect to the prediction of the interested variable (here hurricane intensities). Testing set is used to judge how the fitted network performs in case of data not seen during the developing or tuning the network.

We examined the algorithm using two neural network approaches namely, multi-layer perceptron (MLP) and Generalized Regression Neural Network (GRNN). We applied the GRNN for the seasons 2012, 2013, 2014, 2015 and 2016. Skill of different models with respect to a base model, namely Climatology and Persistence (CLIPER5), is computed and shown in Fig. 1 and Fig. 2 for comparison purpose. In most of the seasonal summary result we see that GRNN methodology provides almost 3-10% improved forecasts at various forecast leads, than other muti-model consensus forecasts. For comparison purposes, we have taken National Hurricane Center (NHC) consensus model IVCN and interpolated official (OFCI) forecasts and ensemble mean (arithmetic mean of the participating model forecasts).

In case of MLP the procedure is same. We tried two versions of MLP. One is when we took all participating model forecasts as input values in network. We named this MMSE1 (see Fig. 2). The second one is take a EM of the participating models and then use that mean forecast as the input in the neural network. This MLP product is named as MMSE2 (see Fig. 2).

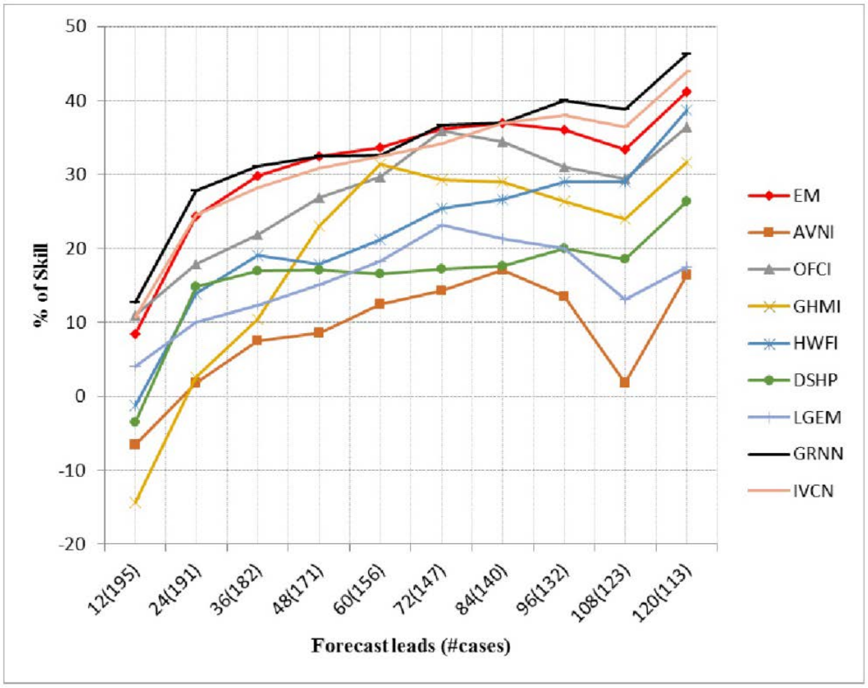

Figure 1: Intensity forecasting skills of GRNN, along with different models, with respect to Climatology and Persistence in case of 2016 season. Ordinate denotes skill based on climatology and persistence, formula provided in text, and the abscissa denotes forecast hours at 12-hour intervals, the number of cases are shown in parenthesis.

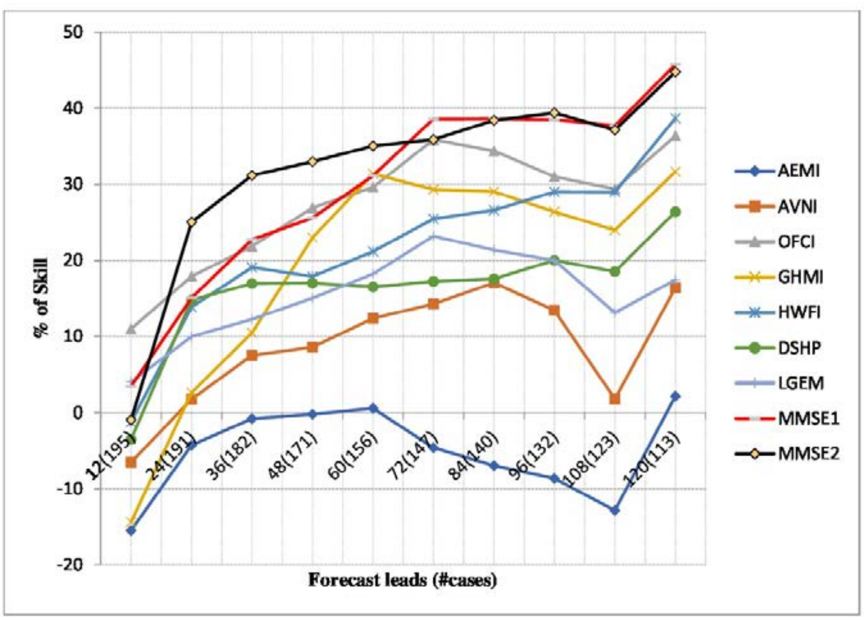

Figure 2: Skills of different models relative to CLIPER5 computed for season 2016. Ordinate denotes skill based on climatology and persistence, formula provided in text, and the abscissa denotes forecast hours at 12-hour intervals, the number of cases are shown in parenthesis.

Research Performance Measure: Observed results shows that, mostly, applying neural network in developing consensus forecasts for hurricane intensities provides less errors (around 3-10%) than other consensus (viz. ensemble mean, IVCN) models. It is encouraging that GRNN has generated less forecast errors than interpolated official (OFCI) forecasts. The similar feature is obtained in case of MLP as well. Especially for longer forecast leads (72 hours onwards) neural network based consensus gives much better forecasts than the other models. It would help in emergency management planning.

Using NASA observations to advance the understanding of the predictability limits regarding tropical cyclone rapid intensification and cyclogenesis processes

Project Personnel: S. Hristova (NASA/JPL); H. Leighton (UM/CIMAS)
NOAA Collaborators: S. Gopalakrishnan (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives: I) to use NASA observations to determine the most representative members from an ensemble of forecasts; II) to use these members to study how the structure and evolution of clouds is linked to thermodynamic and kinematic characteristics of the environment; III) to understand the limits of predictability and to define new metrics that will allow the development of "guidance on guidance"

***Strategy*:** To achieve this objective, we will study both genesis and rapid intensification, using satellite and airborne data obtained during two NASA field campaigns – GRIP and HS3. In particular, we will use observations of hurricane Edouard (2014; HS3) and observations of the 2010 hurricanes Earl and Karl (GRIP).

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/AOML
NOAA Technical Contact: Molly Baringer

Research Summary:

Currently there are still many unanswered questions about the physical processes that determine hurricane genesis and evolution. Furthermore, a significant amount of work remains to be done in validating and improving hurricane models. A major goal of this project is to bring the wealth of satellite and airborne observations collected over the past two decades to bear on addressing the outstanding scientific questions and improving our forecast models. Despite the significant amount of satellite and airborne data today, they are still underutilized in hurricane research and operations, due to their complexity and volume.

We will use satellite and airborne data obtained during two NASA field campaigns – GRIP and HS3, together with state-of-the-art operational forecast models to study the physical and dynamical processes that lead to tropical cyclogenesis and rapid intensity changes. In particular, we will use observations of hurricane Edouard (2014; HS3) and observations of the 2010 hurricanes Earl and Karl (GRIP). We will i) create ensemble forecast using the state-of-the-art HWRF modeling system; ii) Determine the available observations to be used, iii) adopt existing analysis and develop new metrics for establishing consistency between observations and forecasts and then valuate ensemble forecasts to define the sub-set of realistic members according to comparison to the satellite observations, iv) attribute the success or failure of particular members (more versus less realistic) to how well they represent the detailed vertical structure of the storm and the nearby environment and use the successful members to study the relationship between convection (intensity, organization, location), thermodynamics of the environment, vertical shear of the horizontal wind, low level moisture convergence, upper-level flow/divergence/outflow channels, v) determine the predictive skills of the successful members and the predictability limits and formulate the satellite-based metrics that allow the selection of the realistic members.

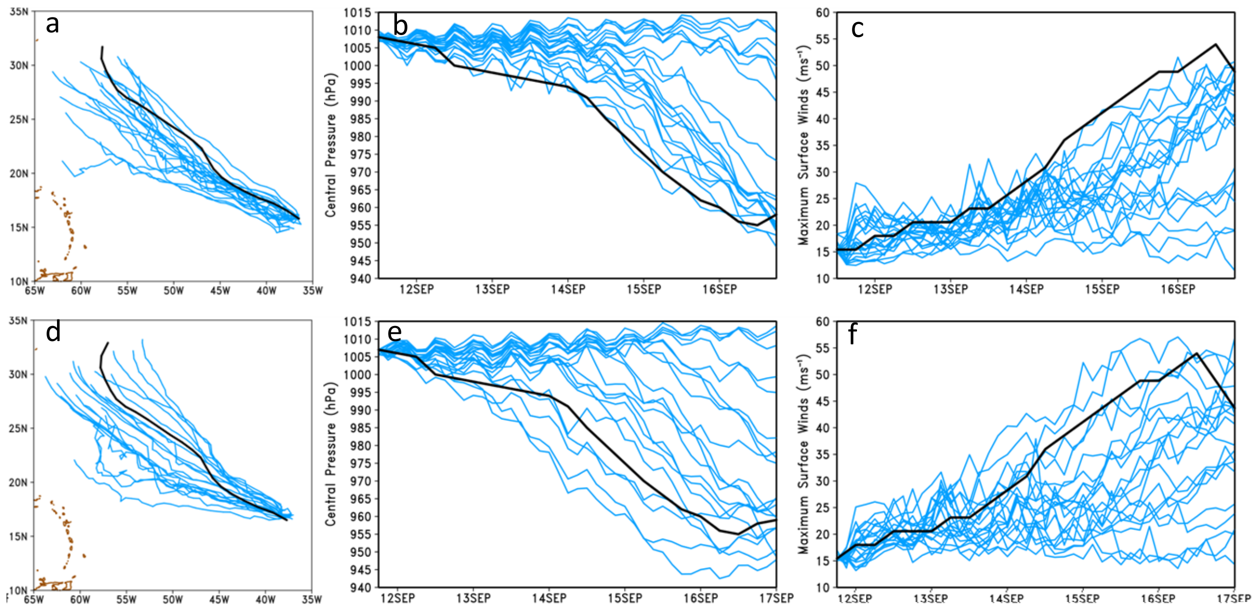

Figure 1: (a) Tracks and time series of (b) central pressure and (c) maximum winds with an initial time of 2014091112. (d), (e), and (f) are the same as (a), (b), and (c) but with an initial time of 2014091118. Thin blue lines represent the ensemble forecast, and thick black lines indicate the best track.

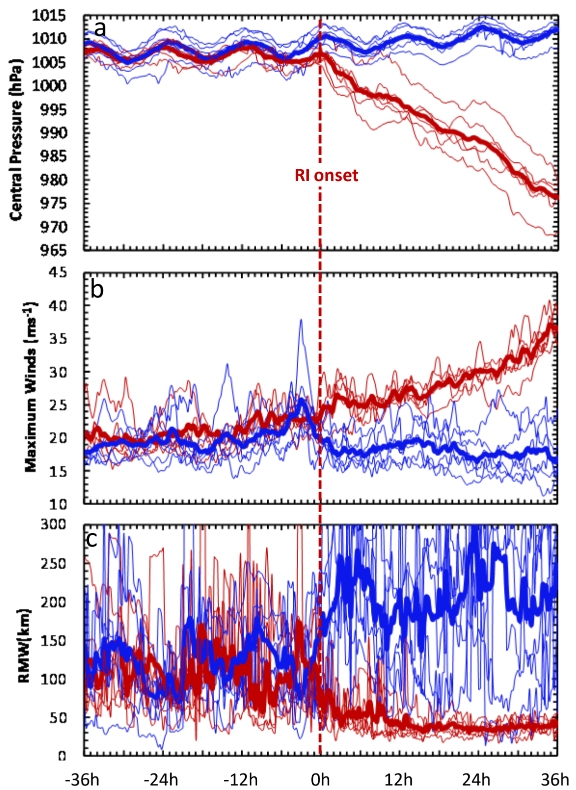

Figure 2: (a) Time series of central pressure, (b) maximum winds, and (c) the RMW for 6 RI (red line) and 6 NI (blue line) members. Thick lines represent the mean value of each group and thin lines represent individual members.

Research Performance Measure: The program started two month ago and is on schedule. The HWRF ensemble forecasts of hurricane Edouard (2014) have finished.

Development and Testing for Production of a Next-Generation Hurricane Nature Run for Observing System Simulation Experiments

Project Personnel: D. Nolan (UM/RSMAS)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To determine the best strategy for the development and production of a next-generation hurricane nature run to be used in OSSEs for improving hurricane prediction.

***Strategy*:** Building on the strengths, weaknesses, and lessons learned from the first two hurricane nature runs, we will attempt to determine the model design and model parameters that will be best for a next-generation nature run that will be embedded in the NASA GEOS-5 Global Nature Run.

CIMAS Research Theme:

***Theme 2*:** Tropical Weather

Link to NOAA Strategic Goals:

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

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

NOAA Funding Unit: OAR/AOML

NOAA Technical Contact: Molly Baringer

Research Summary:

The goal of this project is to determine the best strategy for producing a next-generation hurricane nature run/ This nature run would be a very high resolution, regionally-downscaled simulation of one or more hurricanes that occur in the NASA GEOS-5 Global Nature Run (hereafter G5NR). In the past year the PI worked with AOML scientists Bob Atlas and Javier Delgado to assess whether or not the basin-scale HWRF model could be used for this purpose. First, a hurricane in the G5NR that travels north through the Gulf of Mexico and makes landfall near New Orleans was selected as the storm that we would try to reproduce. Preliminary tests found numerous problems initializing HWRF from the G5NR data and boundary conditions, such as missing soil temperature data and differently defined units for water vapor. One by one these problems were identified and overcome. After some trial and error the basin scale nature run was selected to use a single domain with 2 km grid spacing, 5500 x 4000 grid points, 61 vertical levels up to 2 hPa, the GFDL shortwave and longwave radiation schemes, the updated Ferrier microphysics scheme, and the Mellor-Yamada-Janjic planetary boundary layer scheme.

The simulation was initialized 8 days before the landfall of the storm, and successfully reproduced the genesis and development of a tropical cyclone with a track very similar to the track of the G5NR hurricane. The only significant disagreement is that the HWRF nature run hurricane only reaches category 2 strength, whereas the G5NR storm reaches category 5. However, the G5NR simulation uses 7 km grid spacing and cumulus parameterization, so the HWRF hurricane may be in fact more realistic in its response to the environmental conditions. Examination of the precipitation and wind fields of the HWRF storm shows realistic distributions of each, consistent with a moderately sheared cyclone moving north through the Gulf (see Fig. 1). The simulated hurricane has a good wind-pressure relationship, consistent with the Atkinson-Holliday profile (not shown).

Presently we are working with other scientists at AOML/HRD to further assess the realism of the HWRF nature run hurricane. We are exploring whether or not a 1 km version of the same simulation is feasible.

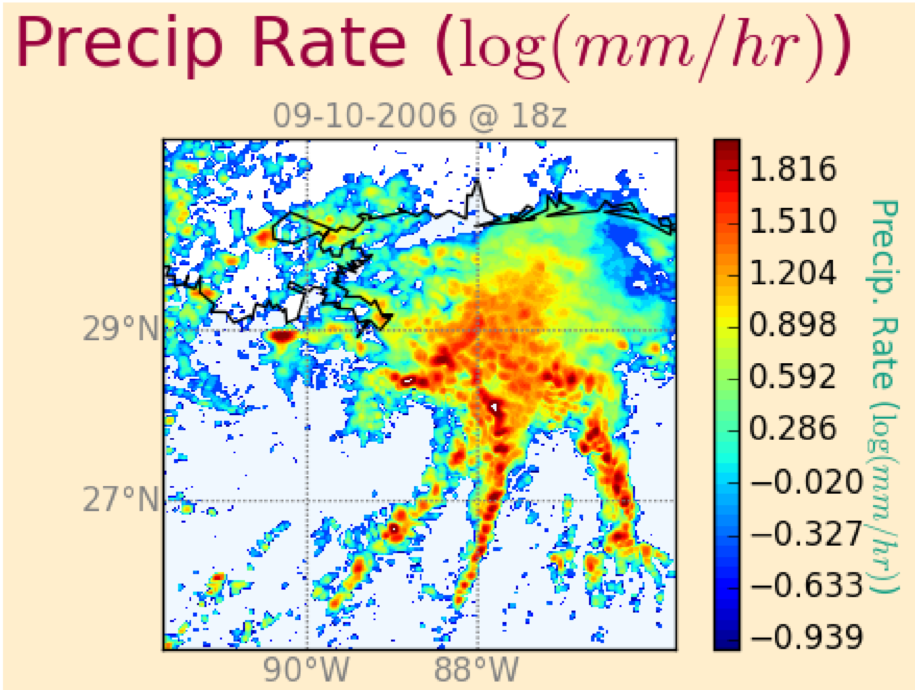

Figure 1: This figure shows the surface rain rate in the new HWRF 2km nature run a few hours before the storm makes landfall on the Gulf coast. Colors show the base 10 logarithm of the rain rate, ranging from -1 to 2, indicating rain rates from 0.1 mm/hr to 100 mm/hr.

Research Performance Measure: A new larger-domain, single-grid, high resolution nature run has been produced. However, we have not yet fully established the realism of the storm and the utility of the simulation. We have requested a 1-year no-cost extension on the project and our work will continue.

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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.

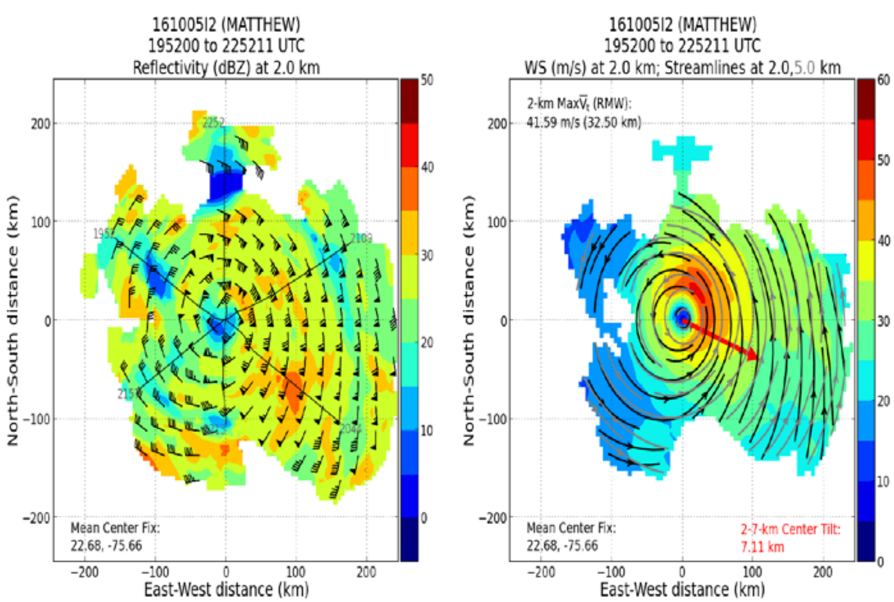

Figure 1: Real-time structure analysis of Hurricane Matthew, October 5, 2016, depicting the flight trajectory.

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.

A python program was developed that provides improved real-time analyses of Tail Doppler radar wind and rain distribution, with the flight-track information integrated. These improved displays of horizontal and vertical structure can suggest how rapidly a TC is likely to weaken or intensify, and they are now made available to NHC (National Hurricane Center) operationally.

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

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Impact of Aircraft Reconnaissance Observations on the Prediction of Tropical Cyclones

Project Personnel: K. Ryan, L. Bucci and J. Delgado (UM/CIMAS)
NOAA Collaborators: R. Atlas and S. Murillo (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To evaluate the potential impact of aircraft reconnaissance observations on Tropical Cyclone forecasts and to optimize the collection of aircraft reconnaissance data.
***Strategy*:** To conduct thorough regional Observing System Simulation Experiments (OSSEs).

CIMAS Research Theme:

***Theme 2*:** Tropical Weather

Link to NOAA Strategic Goals:

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

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

Research Summary:

Aircraft reconnaissance missions remain the only means of collecting direct measurements of marine atmospheric conditions affecting tropical cyclone formation and evolution. Each year, NOAA/AOML's Hurricane Research Division (HRD) conducts its Hurricane field Program in which observations are collected via NOAA aircraft to improve the understanding and prediction of hurricanes. Mission experiments suggest a variety of flight patterns and sampling strategies aimed towards their res*pective goals described by the Intensity Forecasting Experiment (IFEX).* In addition, the National Hurricane Center (NHC) tasks the NOAA G-IV aircraft to sample environmental conditions that may impact the development of a tropical cyclone (TC) threatening to make landfall in the United States or its territories. These aircraft data are assimilated into deterministic models and used to produce real-time analyses and forecasts for a given tropical cyclone. Existing G-IV targeting techniques aim to optimize the use of reconnaissance observations and rely on regions of highest uncertainty in the Global Ensemble Forecast System (GEFS). Evaluating the potential impact of various trade-offs in the targeting process and experimental design of field experiments is valuable for determining the ideal aircraft reconnaissance flight track for a prospective mission.

Observing System Simulation Experiments (OSSEs) have been developed to examine the potential impact of proposed observing systems on hurricane track and intensity forecasts and analyses. The following results focus on sensitivity experiments that aim to optimize NHC's current G-IV targeting

procedure. Using our in-house aircraft observation simulator, dropsonde measurements were collected from a regional WRF ARW Nature Run (Nolan et al., 2013) which spans 13 days, covering the life cycle of a rapidly intensifying Atlantic tropical cyclone. Sensitivity experiments were performed over the rapid intensification stage of this TC. These experiments explore the impact of dropsonde measurements obtained via a spectrum of various existing G-IV flight tracks.

Results from our previous radial sensitivity experiments revealed that locations of dropsonde observations should be determined based on TC characteristics (size of TC wind field) in order to determine the causes of different impacts given different flight patterns. This is due to inconsistencies in location as the TC evolves with time.

G-IV distances for investigating the sensitivity to radial location of dropsondes are defined in terms of the radius of gale-force (34-knot) winds. The radii tested were 0.5 to 3 units of R34 in increments of 0.5 units. Average error statistics for TC track and intensity for 1.5 (purple) and 3 (yellow) units of R34 are displayed in Figure 1. A positive impact on track forecast out to almost 2 days is apparent when using data obtained in the 1.5xR34 G-IV aircraft configuration compared to a much shorter-term impact using a flight track at a distance of 3xR34 from the center. Although a positive impact on intensity forecasts beyond 48 hours is shown for both radii, there is little distinction between the two radial distances. Figure 2 displays a comparison of 500 mb geopotential height fields and indicates that the reason for this impact is due to differences in the near-TC and downstream environmental conditions. These differences cause an improvement in track prediction when assimilating dropsonde measurements near the radius of gale-force winds. The track forecast errors are influenced by the strength and location of the vortex within the synoptic scale frontal boundary and subtropical ridge patterns.

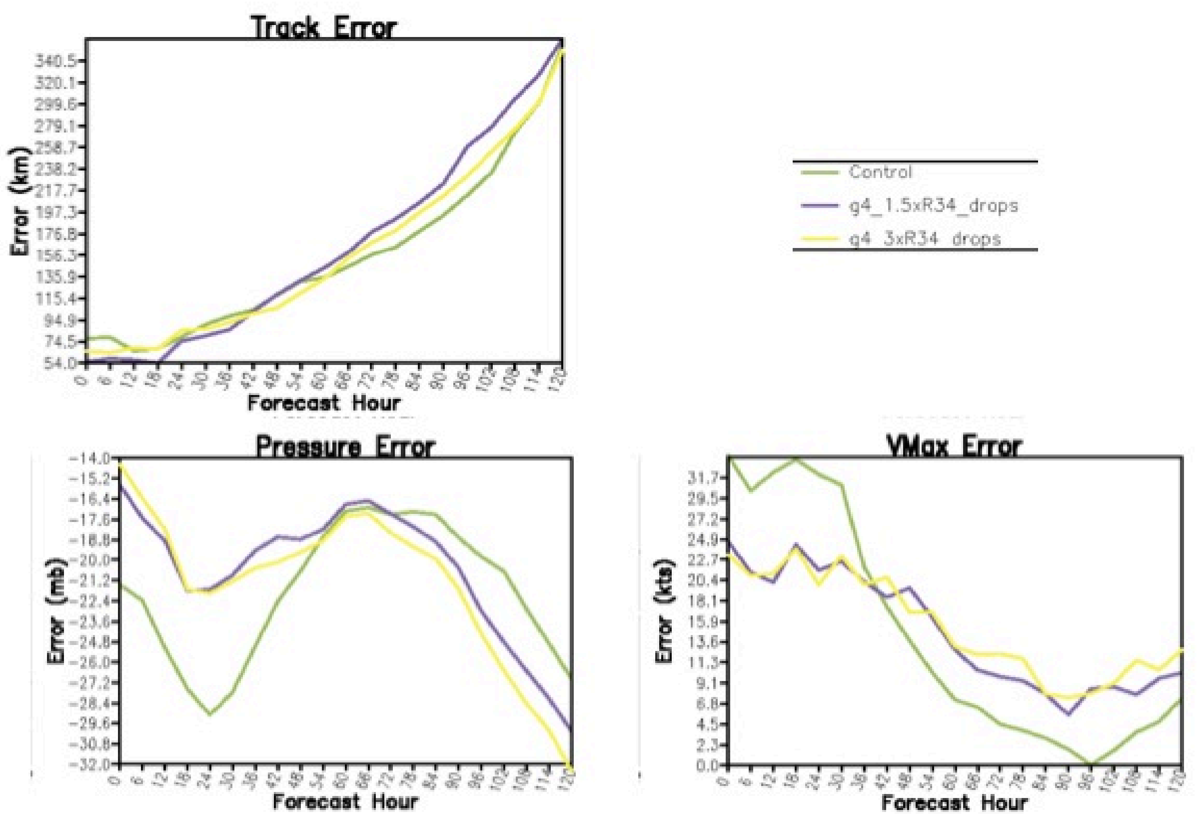


Figure 1: Comparison of control (green), 1.5xR34 experiment (purple), and 3xR34 experiment (yellow) track and intensity errors averaged over 12 cycles.

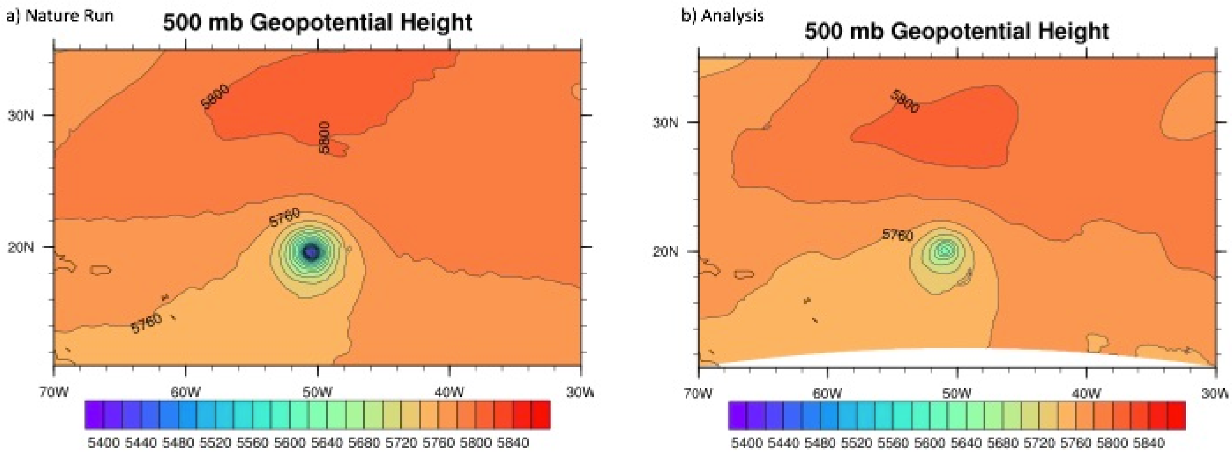


Figure 2: 500 mb geopotential height fields for a) the Nature Run and b) 1.5xR34 experiment.

Given the two G-IV radial distances discussed above, various distributions of dropsondes were also tested. The sensitivity to azimuthal location of these measurements includes OSSEs for each distribution determined by azimuthal location relative to the storm center position. Dropsondes were simulated at 15, 20, 30, 40, 45, and 60 degree spacing. Figure 3 shows the average skill score statistics using dropsondes deployed at the aforementioned radii for 20 and 40 degree azimuthal distributions. Although the track forecast improves the most using dropsonde data every 40 degrees near the boundary of 34-knot winds, the results do not differ by much. The intensity forecast improves through 3 days using the more frequent dropsonde coverage at the farther distance (3xR34) from the TC center. It's important to note that these two dropsonde distributions share the same absolute resolution of dropsonde observations. As expected, the environment in these experiments are fairly comparable (not shown), and changes in the near-vortex environment impact the intensity forecast as seen in Figure 4 which displays the mid-level moisture fields for the two best experiments (1.5xR34 at 40 degree spacing and 3xR34 at 20 degree spacing) compared to the Nature Run. The intensity forecast errors are influenced by the asymmetry of the vortex as well as the position of the center within the large-scale flow. However, this improvement in intensity comes at the expense of a more accurate track forecast due to differences in strength and size of the vortex. While there is an improvement in intensity prediction with these configurations, none of the experiments mitigate the degradation of the forecasts during rapid intensification.

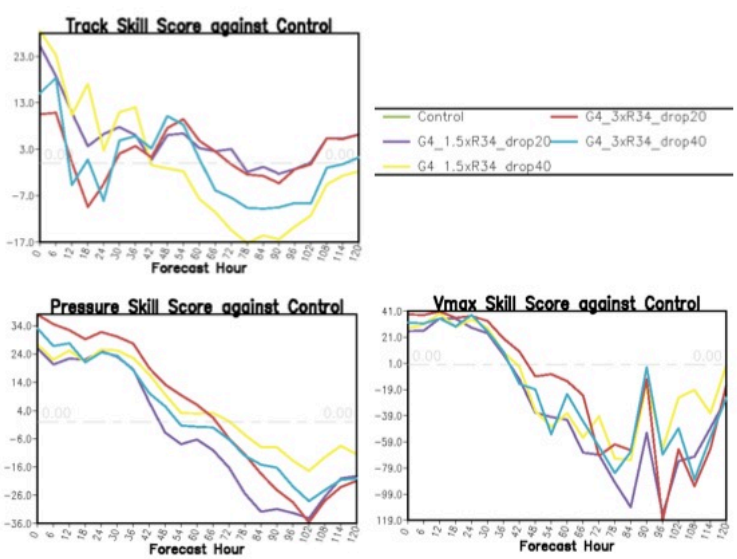
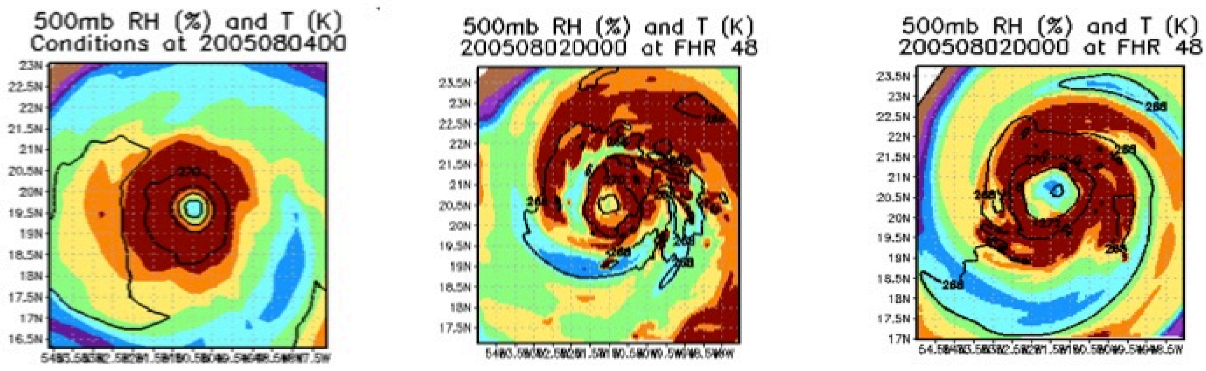


Figure 3: Comparison of track and intensity skill scores averaged over 12 cycles for 1.5xR34 experiment with a dropsonde spacing of 20 degrees (purple),1.5xR34 experiment with a dropsonde spacing of 40 degrees (yellow), 3xR34 experiment with a dropsonde spacing of 20 degrees (red), and 3xR34 experiment with a dropsonde spacing of 20 degrees (blue). The control experiment is represented by the zero line.



a) Nature Run　　b) 1.5XR34　　c) 3xR34

Figure 4: 500 mb moisture field for a) Nature run, b) 1.5xR34 experiment (dropsonde spacing of 40 degrees), and c) 3xR34 experiment (dropsonde spacing of 20 degrees).

Future work includes a continuation of sensitivity OSSEs that assess the impact of various aircraft reconnaissance configurations of G-IV dropsonde observations which can therefore be used to improve current G-IV targeting techniques. Additional experiments using NOAA WP-3D Hurricane Hunter aircraft will be evaluated, and combinations of multiple aircraft and supplementary instruments will be tested to determine optimal configurations with all aircraft are available. An upgrade to the OSSE framework with the hybrid 3DVar-EnKF data assimilation system will be implemented, and these experiments will be repeated using both HWRF and GFS forecast models.

Research Performance Measure: This project is on track.

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Validation of Tropical Cyclone Precipitation in HWRF using Satellite Observations

Project Personnel: J. Zawislak (FIU/UM/CIMAS); K. Sellwood (UM/CIMAS)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To evaluate the extent to which NOAA's Hurricane Weather Research and Forecasting (HWRF) model can replicate observed tropical cyclone precipitation distributions, and inherently precipitation processes, during intensification.

***Strategy*:** Develop a framework for comparing model synthetic (simulated) brightness temperatures to satellite observed brightness temperatures for a single case, Hurricane Edouard (2014). By comparing distributions of passive microwave brightness temperature, which serve as proxies for precipitation organization, we can quantify biases in model forecast precipitation organization. We can use that framework to accumulate statistics over multiple cases.

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:

While we need to accumulate statistics from multiple cases to quantify robust precipitation biases within Hurricane Weather Research and Forecasting (HWRF) model forecasts of hurricanes, we first developed the framework for generating those statistics by analyzing a single storm — near-rapidly intensifying Hurricane Edouard (2014), a well-observed case in the Atlantic in 2014. *The goal was to compare inner core distributions of model-simulated and satellite-observed passive microwave (PMW) brightness temperatures, which serve as proxies for precipitation organization.*

We chose two PMW frequencies to validate precipitation organization: 37 (low frequency) and 85–91 GHz (high frequencies). At low frequency, the sensor is sensitive to emission from liquid water (e.g., cloud and raindrops) at lower altitudes. Areal coverage of warm brightness temperatures at low frequencies thus serves as a proxy for the overall raining area. At high frequencies, the sensors detect scattering of the emission from liquid water by relative large size and quantities of ice at higher altitudes. Brightness temperatures at these high frequencies serve as a useful proxy for convective intensity (i.e., depth and strength of convective cloud).

We produced synthetic (simulated) PMW brightness temperatures at low and high frequencies by passing HWRF model forecast output from an operational run of Edouard through the Community Radiative Transfer Model (CRTM). The CRTM can simulate brightness temperatures from two space-borne PMW sensors: the Advanced Microwave Scanning Radiometer – Earth Observation (AMSR-E) and the Special Sensor Microwave Imager (SSMI).

Figure 1 compares the inner core (within 200 km) cumulative distribution function (CDF) of AMSR-E-simulated polarization corrected temperature (PCT) (similar to brightness temperature, except removes the difference in land/ocean emissivity) from the CRTM with observed PCT from an AMSR-2 (an equivalent follow-up sensor to AMSR-E) overpass near the valid time (24-h forecast, 0600Z 15 Sept.). At 89 GHz, the PCT distribution from the CRTM is lower than observed, which suggests that the *convective intensity is too strong over a larger area in HWRF*. The areal coverage of precipitation is greater in the HWRF forecast and the organization of precipitation within the eyewall and primary rain band is organized in more intense banding. This result is consistent at all lead times. At 37 GHz, the difference in the distributions is substantially larger than the distributions at 89 GHz. This difference is due to unrealistic CRTM 37-GHz vertical polarization temperatures for AMSR-E. The CRTM incorrectly prescribes the emissivity in the vertical polarization as being the same as the emissivity for the horizontal polarization. The emissivity at 37 GHz in the vertical polarization is typically ~0.6, while for horizontal, ~0.4.

Figure 2 is similar to Figure 1, except compares CRTM simulated brightness temperatures from SSMI with an SSMIS (SSMI sounder) overpass near the HWRF 24-h forecast valid time. The emissivity for 37-GHz vertical polarization is correct in the CRTM for SSMI, therefore the distribution compares better between the model and observations. Although there is a contribution due to the difference in resolutions (SSMIS is much lower than the model output), both the 37- and 89-GHz distributions again strongly suggest that HWRF produces too much inner core deep convection, in both areal coverage and intensity.

Analyses that compare GOES IR brightness temperatures with simulated IR brightness temperature from the CRTM were also produced (bottom row of Figures 1 and 2). Overall, these analyses provide the framework for generating comparisons over multiple cases retrospectively. We suspect that the bias in HWRF towards too intense of convection, over a larger area, will be robust over a larger sample of cases.

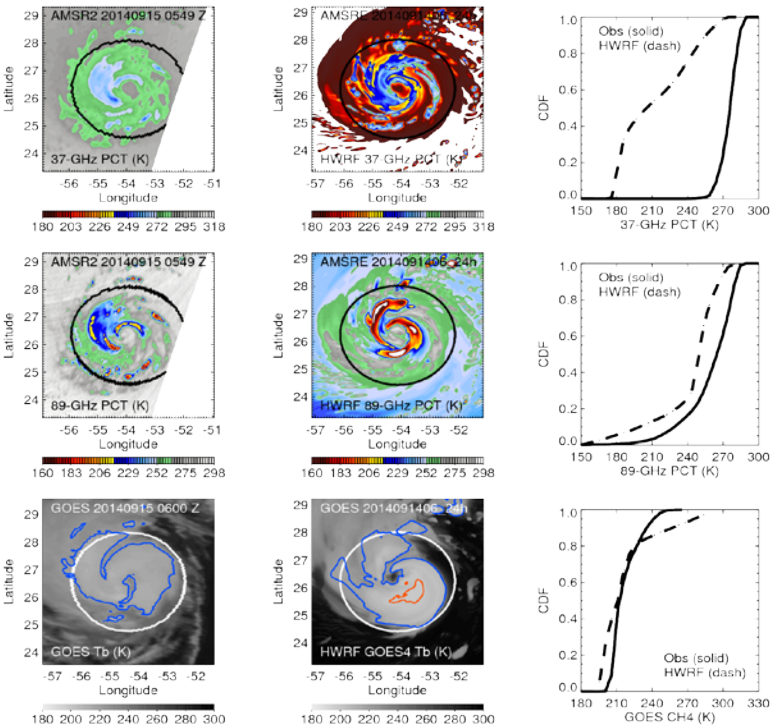

Figure 1: The first row shows a map of 37-GHz polarization corrected temperature (PCT) for an AMSR-2 overpass of Hurricane Edouard (2014) at 0549Z 15 September (left column), 37-GHz PCT output from the CRTM for an HWRF forecast valid at 0600Z 15 September (center column), and the cumulative distribution functions (CDF) of 37-GHz PCT for both the model (dash) and AMSR-2 observation (solid). The middle row is similar to the top row, except for 89-GHz PCT. The bottom row is similar to the top and middle rows, except shows the GOES channel 4 IR brightness temperature (Tb). The left and middle columns of the bottom row also indicate the 200 (red) and 220 (blue) K Tb contours. The black and white circles in the left and middle columns are the 200 km ("inner core") range ring.

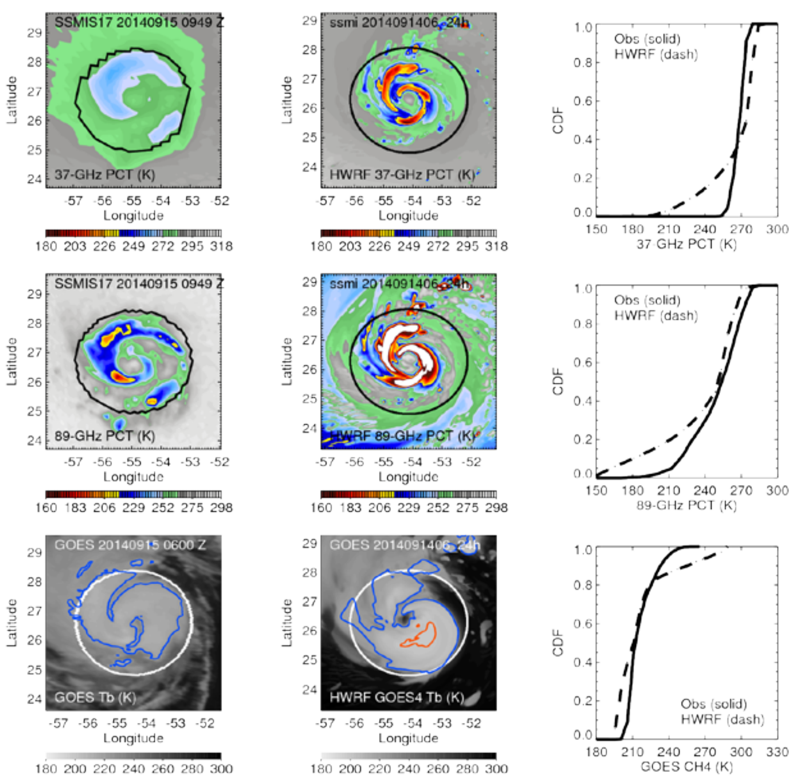

Figure 2: Same as Figure 1, except compares SSMI simulated output from the CRTM with an SSMIS overpass at 0949Z 15 September.

Research Performance Measure: Many of the steps towards meeting the overall objective were completed; however, some key steps remain. We were able to develop a framework for which passive microwave satellite observations can be compared against CRTM simulated brightness temperatures from HWRF model output — a key accomplishment towards the main objective. One of the important steps that remain, prior to accumulating multiple cases, is to identify the storm intensity in HWRF forecasts.

This information provides a basis for which comparisons with satellite observations can be fairly quantified in a composite framework over multiple cases. Completion of this task is a final step before accumulating multiple cases and identifying robust biases in HWRF.

Development of an Integrated Coastal Inundation Forecast Demonstration System in Caribbean Region – Pilot Project for the Dominican Republic and Haiti

Project Personnel: K. Zhang, Y. Li and Y.C. Teng (International Hurricane Research Center, FIU)
NOAA Collaborators: J. Rhome (NHC); A. Westhuysen (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) 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).

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: NHC
NOAA Technical Contact: Jaime Rhome

Research Summary:

NHC, NCEP, and FIU propose 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 parametric 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 German Space Agency (DLR), NOAA, USA, NASA, USA, ESRI, USA, METI, JAPAN, and GEBCO, UK.

Research Performance Measure: The derivation of DTM from DLR's TanDEM-X data is delayed because DLR approved the request for the data in December 2016 and the PI experienced a long-term illness. We have examined the quality of the TanDEM-X data by comparing TanDEM-X data with LiDAR data in Miami-Dade County. We have generated preliminary DTM by filtering and interpolating TanDEM-X data for Hispaniola Island and integrated this data with bathymetric data for the SLOSH basin.

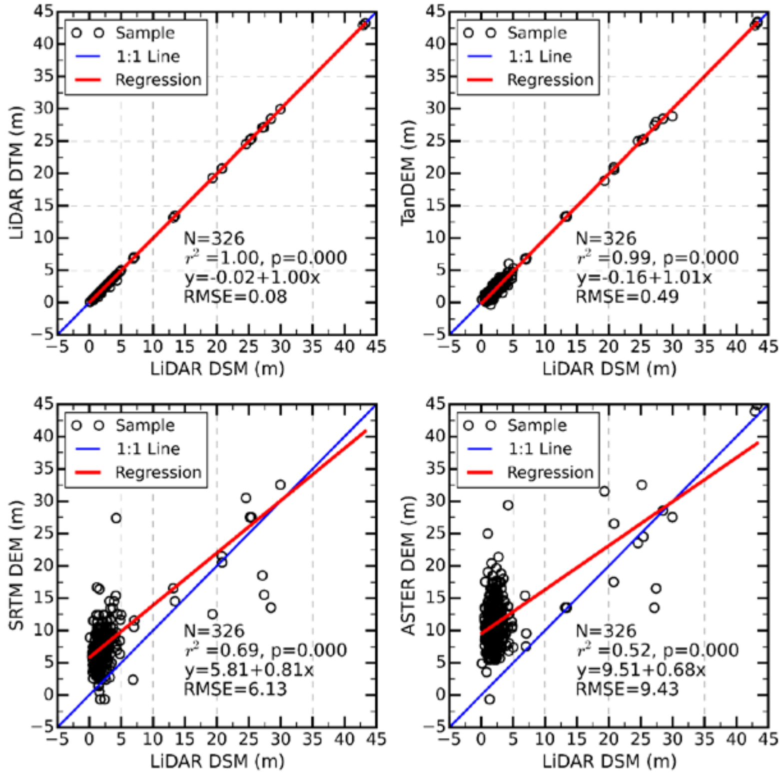

Figure 1: (a) LiDAR digital surface model (DSM) at sample points in Miami-Dade County versus LiDAR digital terrain model (DTM) which is derived by removing buildings and vegetation in DSM, (b) TanDEM-X DEM versus LiDAR DSM, (c) SRTM DEM versus LiDAR DSM, and (d) ASTER DEM versus LiDAR DSM. The sample points are located at open spaces such as baseball, football, and track fields, golf courses, grass lawns, and trash mounds with sufficient sizes for consistent ground elevations. The root mean square error (RMSE) of the TanDEM-X DEM versus LiDAR data is about 0.5 m, much smaller than the RMSEs of SRTM and ASTER DEMs.

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Addressing Deficiencies in Forecasting Tropical Cyclone Rapid Intensification in HWRF

Project Personnel: J. Zhang, H. Chen and K. Sellwood (UM/CIMAS); D. Nolan (UM/RSMAS)
NOAA Collaborators: R. 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). Composite analyses of the TC structure at the RI onset show that the RI cases have stronger boundary layer inflow, stronger and deep convection that is located in a radius closer to the storm center than the on-RI cases. The key finding is that the RI cases have stronger boundary layer convergence than the non-RI cases (Fig. 2). This result is consistent with observational studies of Hurricanes Earl (2010) and Edouard (2014). The HWRF ensemble forecasts are also analyzed to document key physical processes associated with RI in comparison with non-RI cases.

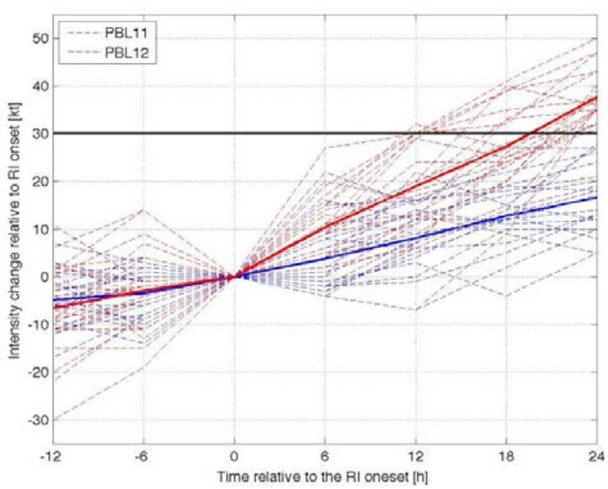


Figure 1: Plot of intensity change in kt for PBL11 (blue) and PBL12 (red) HWRF forecasts as a function of time relative to the onset of RI events that are seen in PBL12 not in PBL11. Note that the boundary layer vertical diffusion in HWRF was upgraded based on aircraft observations for PBL12.

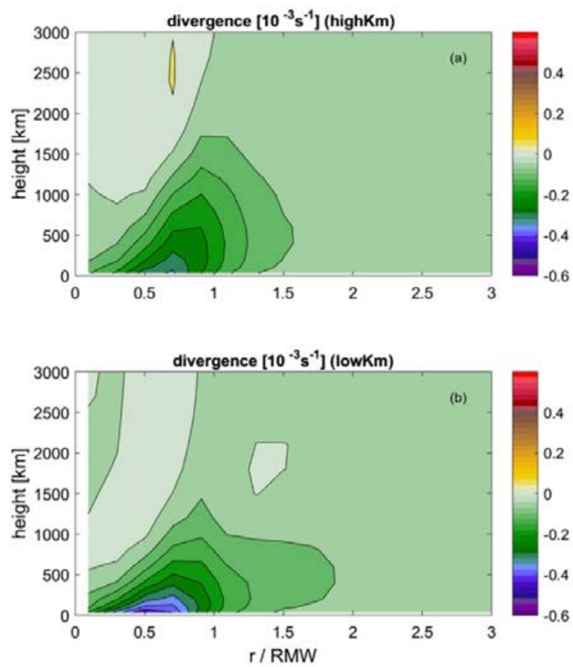
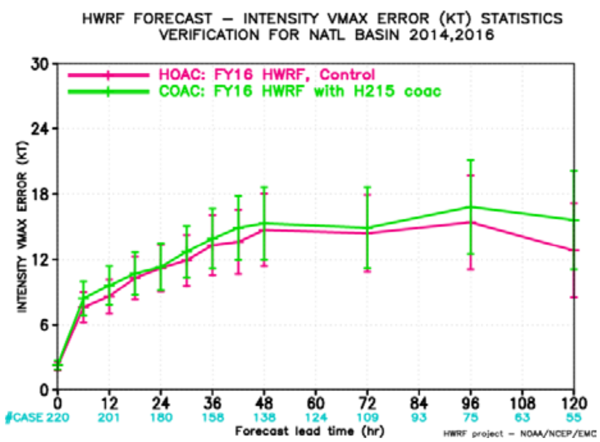


Figure 2: Azimuthally averaged divergence as a function of r/RMW and height for the (a) high-Km and (b) low-Km composites at the RI onset.

Model errors are analyzed by comparing the HWRF real-case forecasts to observations to identify deficiencies in model physics. It is found that the horizontal mixing length used in the HWRF model was too large. Reducing the horizontal mixing length lead to 10-15% improvement in the intensity forecast although the improvement is not statistically significant at 95% confidence interval (Fig. 3). Forecasts of biases of both the intensity and storm size are significantly improved (Fig. 4) by lowering the horizontal mixing length based on aircraft observations and previous numerical studies.



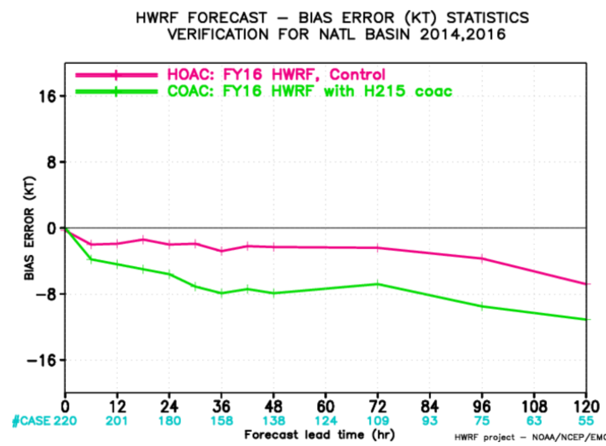


Figure 3: Plots of the absolute error for intensity in HWRF retrospective forecasts of with two different setups of the parameterization of horizontal diffusion in terms of the horizontal mixing length (L_h). In the control experiment (referred to as HOAC), L_h = 800 m as in H216, while the other experiment used L_h = 1900 m and the same "coac" value as in H215 but with the H216 model. The error bar represents 95% confidence interval.

Figure 4: Plots of the biases in intensity in HWRF retrospective forecasts of with two different setups for the parameterization of horizontal diffusion in terms of the horizontal mixing length (L_h). In the control experiment (referred to as HOAC), L_h = 800 m as in H216, while the other experiment used L_h=1900 m and the same 'coac' value as in H215 but with the H216 model.

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

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Development of the Basin-Scale HWRF Modeling System

Project Personnel: X. Zhang, G. Alaka, B. Thomas, R. St. Fleur, H. Chen, K. Sellwood and M.-C. Ko (UM/CIMAS)

NOAA Collaborators: S. Gopalakrishnan, S. Goldenberg, F. Marks and R. Rogers (NOAA/AOML); V. Tallapragada, B. Liu, D. Sheinin, Z. Zhang and J. Sippel (NCEP/EMC)

Other Collaborators: J. Frimel and E. Kalina (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: NOAA/OAR/AOML
NOAA Technical Contact: Molly Baringer

Research Summary:

Basin-Scale HWRF Verification and post-processing
The Basin-Scale HWRF is an experimental modeling system that was developed at HRD to better understand multi-scale and multi-storm interactions and to improve tropical cyclone track and intensity forecasts in the future. This model is very similar to the operational HWRF, except that it is configured with: 1) large outermost domain ("basin-scale") that covers almost a quarter of the globe and 2) multiple sets of high-resolution nests that follow each tropical cyclone in the Atlantic or eastern Pacific Oceans. The Basin-Scale HWRF is effectively a proof of concept for producing high-resolution forecasts for multiple tropical cyclones in NOAA's next generation global prediction system.

Dr. Alaka led an evaluation of the 2013 version of the Basin-Scale HWRF (HB13), with extra scrutiny placed on its comparison with the 2014 version of the operational HWRF (H214). Due to the fast-evolving nature of the HWRF system, H214 had the closest configuration to HB13 and, thus, was the most applicable comparison. In addition to the large outermost domain and the multiple storm configuration options, HB13 also had no data assimilation and no ocean coupling (H214 had both). Forecasts from these models were produced retrospectively and in real-time for the 2011-2014 hurricane seasons. The corresponding sample included 1119 verifiable forecasts (i.e., the system was classified as a tropical cyclone at the initial time) in the Atlantic Ocean. In this analysis, "track improvement" means that HB13 average errors were lower than those from H214, while "track degradation" means the opposite. Average track errors from HB13 and H214 were within 5% of one another at all forecast lead times after 12 h, with HB13 showing slightly degraded track forecasts after 24 h (Fig. 1). HB13 produced significantly improved track forecasts at 12 h, an interesting result considering this model does not include data assimilation.

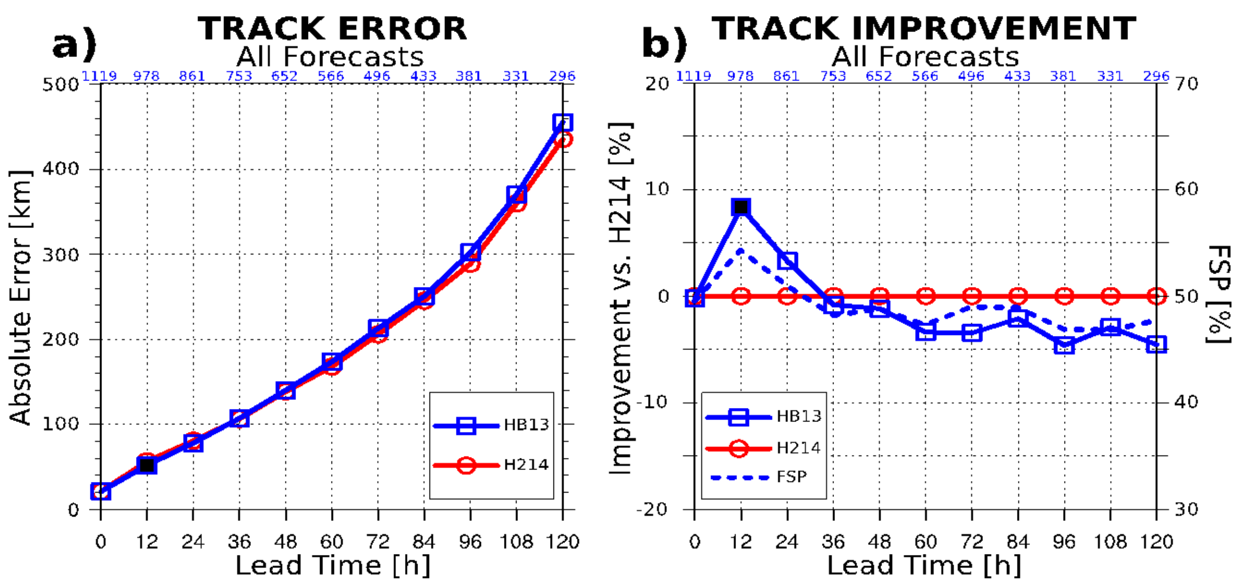


Figure 1: (a) Track error and (b) track improvement (vs H214) are shown for Atlantic basin TC forecasts from HB13 (blue squares) and H214 (red circles) for 2011-14. FSP is shown for HB13 vs H214 (blue dashed). The number of cases at each lead time is given at the top of each column. HB13 track improvements that are significant at the 95% (90%) confidence level are marked with black (cyan).

Dr. Alaka and his colleagues discovered that HB13 track forecasts improved when at least two additional tropical systems (i.e., tropical cyclone or invest) were present in the Atlantic or eastern Pacific basins. However, HB13 track forecasts improved notably when stratifying for additional "far-field" tropical

systems. "Far-field" tropical systems are over 3500 km from a given tropical cyclone. In Fig. 2, a red-dashed circle with a radius of 3500 km shows that HB13's outermost domain includes far-field tropical cyclones, whereas H214's outermost domain does not. Consequently, HB13 track forecasts improved when additional far-field tropical systems were present (Fig. 3). Therefore, the mere inclusion of other tropical systems in the model outermost domain might be enough to improve track forecasts. In H214, information from far-field tropical cyclones must have been delivered through the lateral boundaries, where it was subject to errors. Finally, HB13 track forecasts improved for tropical cyclones initiated north of 25°N, which might be related to improved prediction of the synoptic-scale flow in association with a larger outermost domain.

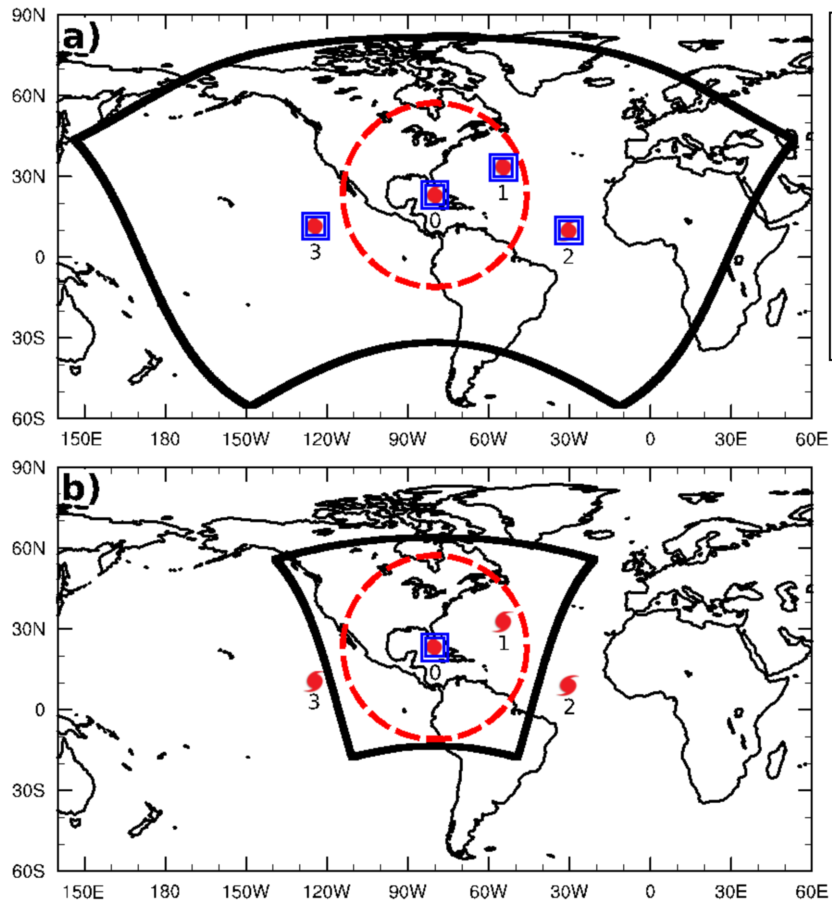


Figure 2: Examples of outermost domains and high-resolution nests in (a) Basin-Scale HWRF and (b) operational HWRF. The red circle denotes a radius of 3500 km around TC 0. In (a), high-resolution nests are configured for all four TCs. In (b), one set of high-resolution nests is configured for TC 0.

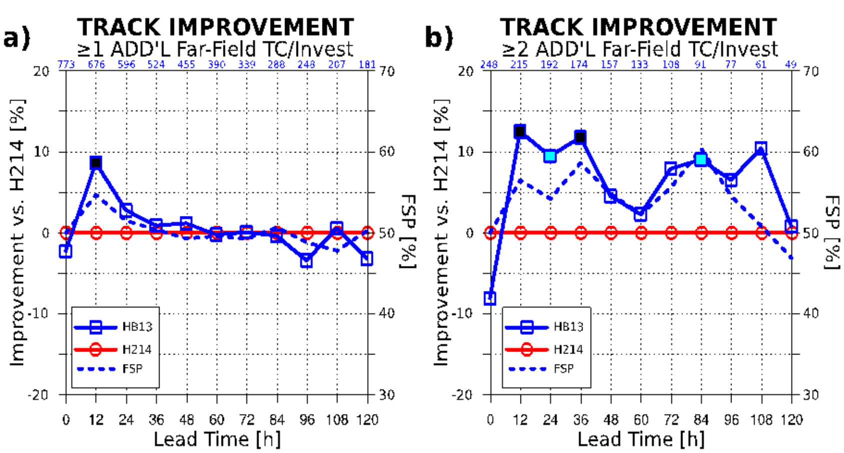


Figure 3: As in Fig. 1b, but for (a)$1 additional far-field TC/invest in the Atlantic or eastern Pacific basins and (b) ≥ 2 additional far-field TCs/invests in the Atlantic or eastern Pacific basins.

The results from this work were published in the June 2017 issue of the American Meteorological Society's Weather and Forecasting.

Dr. Alaka expanded basin-scale HWRF post-processing products. The products now included track and intensity trend. Dr. Alaka and Mr. St. Fleur also led an effort to streamline the verification for each storm in real-time and published on the website (see basin-scale HWRF website: storm.aoml.noaa.gov/basin). Dr. Alaka led the evaluation and verification of 2016 real-time/retrospective basin-scale HWRF Atlantic and East Pacific track forecasts.

Retrospective Forecasts With and Without GSI

HRD ran retrospective forecasts with the 2016 version of the Basin-Scale HWRF (HB16). Like the operational HWRF, HB16 is a triply-nested model with grid spacings of 18 km, 6 km, and 2 km, respectively. Unlike the operational HWRF, HB16 features a large outermost domain that covers a quarter of the globe and can produce high-resolution forecasts for multiple tropical cyclones in the same integration. For this project, Dr. Alaka worked with HRD scientists to create a list of 13 tropical cyclones from the Atlantic or eastern Pacific Oceans to target with HB16 forecasts, including some high-profile cyclones like Hurricane Matthew (2016), Hurricane Patricia (2015), and Hurricane Joaquin (2015). For these cases, three configurations of HB16 were proposed: (1) GSI on & ocean coupling off, (2) GSI off & ocean coupling off, and (3) GSI on & ocean coupling on. The main point of these retrospective runs is to supply HRD scientists with model data to supplement their research.

Ms. Ko was responsible for running and maintaining the HB16 retrospective forecasts. Although many difficulties arose with the NOAA Jet supercomputer, Ms. Ko led a series of tests to reconfigure HB16 using different processor counts and different computer partitions. Ultimately, Ms. Ko was able to overcome all computer-related issues and produced hundreds of forecasts for each of the first two HB16 configurations. However, computer resources and other delays prevented the production of forecasts using the "GSI on & ocean coupling on" configuration.

Ms. Ko and Dr. Alaka began investigating the impacts of GSI on HB16 forecasts (see Figs. 4 and 5). For reference, "HB16a" represents the "GSI on & ocean coupling off" experiment and "HB16b" represents the "GSI off & ocean coupling off" experiment. For track, HB16b showed more track improvement (i.e., lower track errors) than HB16a or HWRF in the first 60 h of the experiment. This result suggests that GSI alone may degrade track forecasts by 5-10% in early lead times. However, by 72 h, HB16a track forecasts recover and improvement is very similar to HB16b. On the other hand, turning off GSI results in higher intensity errors, especially after 48 h. These results are being used to guide data assimilation activities at HRD.

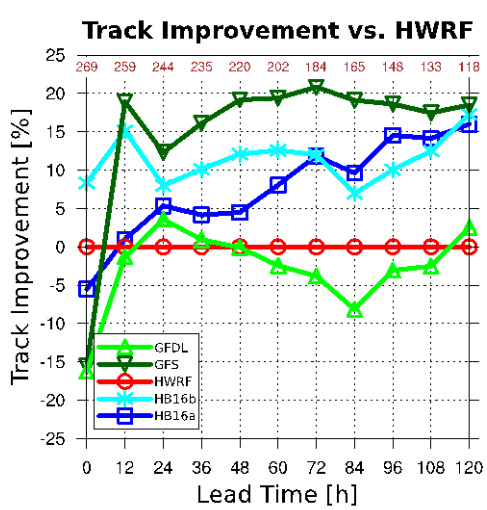


Figure 4: Track improvement (%) vs. HWRF in the Atlantic basin for the following models: HB16a (blue), HB16b (cyan), HWRF (red), GFS (green), and GFDL (light green). Track improvement is calculated as the Brier skill score using HWRF as the reference model. Errors are calculated using NHC's Best Track.

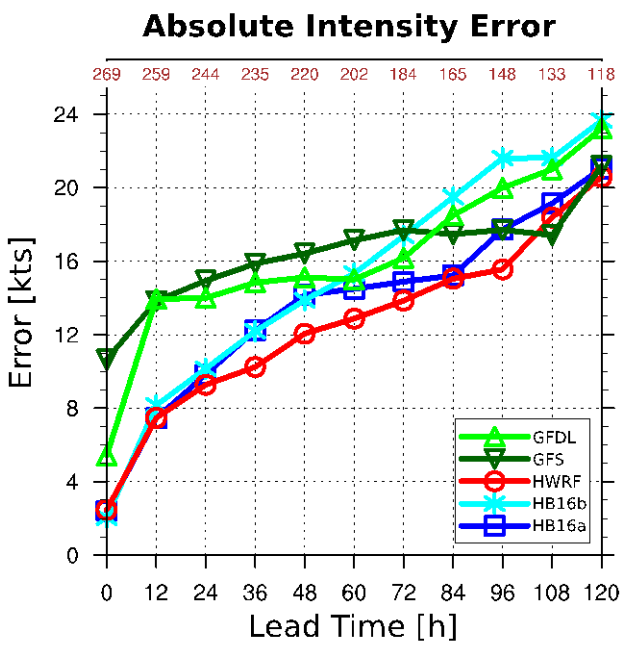


Figure 5: Absolute intensity errors (kts) in the Atlantic basin for the following models: HB16a (blue), HB16b (cyan), HWRF (red), GFS (green), and GFDL (light green). Errors are calculated using NHC's Best Track.

Basin-Scale HWRF Coupling

Dr. Zhang and EMC collaborators developed multiple storm coupler for basin-scale HWRF. Dr. Thomas developed MPIPOM for basin-scale HWRF including ocean initialization for basin-scale HWRF from operational RTOFS ocean data. The coupling processes and domain configuration are illustrated in Fig. 6 and Fig. 7. Due to the requirement of HFIP real-time demo project, Dr. Zhang is developing a simplified coupler for basin-scale HWRF system. Dr. Jun Zhang and Dr. Xuejin Zhang are still investigating the performance of the atmosphere-ocean coupled basin-scale HWRF modeling system.

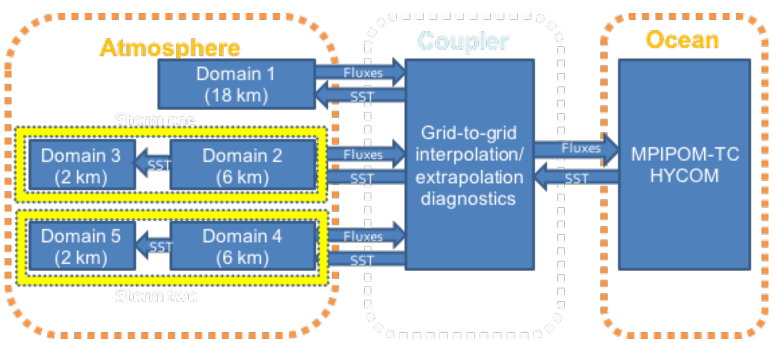


Figure 6: Coupling scheme of the basin-scale HWRF modeling system.

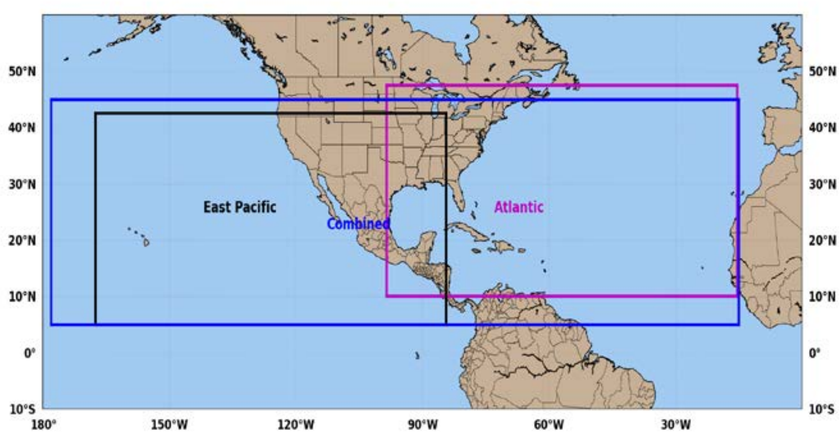
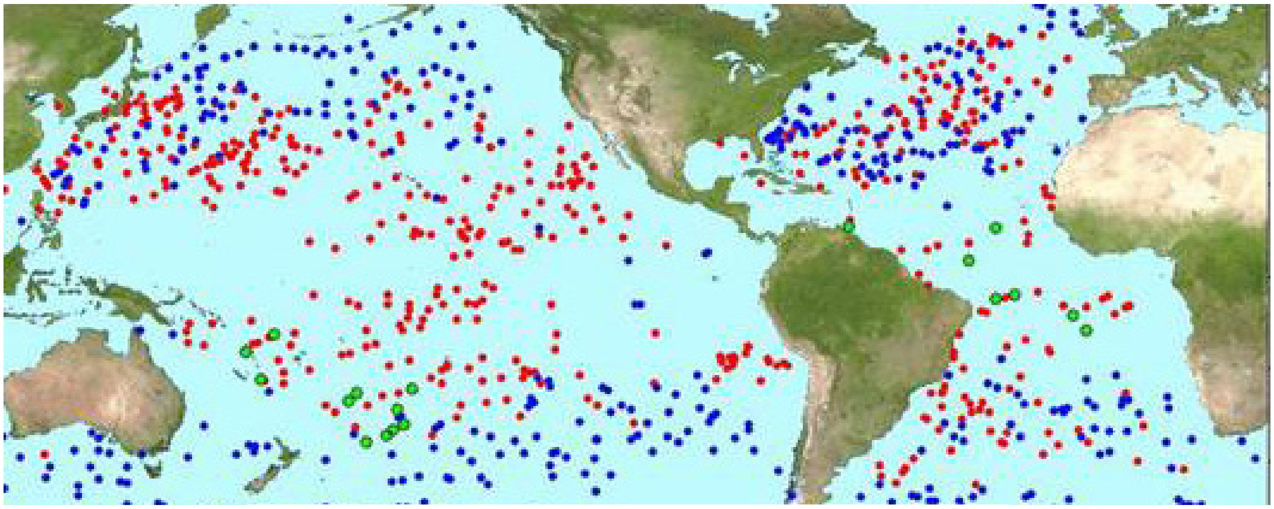


Figure 7: Configuration of MPIPOM for the coupled Basin-scale HWRF modeling system (blue box). For comparison, the MPIPOM configuration for the Atlantic Ocean basin (pink box) and the East Pacific basin (black box) were showed.

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



RESEARCH REPORTS

THEME 3: Sustained Ocean and Coastal Observations

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

Project Personnel: C. Atluri, Z. Barton, E. Forteza, S. Garzoli, V. Halliwell, S. Majumder, J. Nair, R. Perez, R. Sabina and D. Volkov (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 of 1500 profiling floats as a part of a global array of 3000 floats.

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

Link to NOAA Strategic Goals:
***Goal 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 (DAC) at AOML is responsible for deploying floats, and for acquiring and processing the data. The US Argo 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 during this time period are:

- 422 floats were deployed by the US institutions.
- 80 of these floats were deployed jointly by AOML and CIMAS.
- 2,651 US floats actively reported data during this period.
- 95,400 profiles have been distributed on Global Data Centers.
- 76,800 profiles were sent to GTS by the US Argo DAC; 93% of them were distributed within 24 hours of observation.

Numerous improvements and enhancements have been made in our quality control/file production process:

- We are now producing Argo Version 3.1 profile NetCDF files for the Global Data Assembly Center (GDAC) for those floats with only Core-Argo data (pressure, temperature, salinity, conductivity).
- The handling of different format versions was generalized and improved, so transition to future Argo format versions will be easier.
- Determination of the pressure offset at the surface, used in the pressure adjustment process, was improved to account for individual profiles for which the surface pressure was not received.
- Modifications were made to read/write modules to accommodate inclusion of trajectory-specific lines in the position block of profiles.
- A new module was developed to identify times when the PI-supplied estimate of a position has an invalid flag in the input data. These cases are now being reported, and invalid values are now ignored.
- Development continued to improve warning and error messages as well as the assignment and interpretation of job and error status flags throughout the processing system.
- Software was developed and implemented to produce the Argo v3.1 trajectory NetCDF files.
- We adapted the system to fully process deep Argo floats.
- The software package that generates Meta and Technical NetCDF files was modified in order to accommodate new configuration and technical parameters from newly deployed floats.
- Continuous monitoring and trouble shooting of NetCDF file generation programs continues to improve the quality as well as the accuracy of the final product.

Decoders/data ingestion software developments:

- Decoding capability for two new float formats was added: one for an Argos float (APEX_TS45) and the other for an Iridium float that is part of deep Argo (APEXDIR_TS11).
- Changes to existing decoder software were made to properly handle corrupt input files automatically transmitted to the US Argo DAC

- Improvements to the software that checks the completeness of supplied data files were made to improve data quality.
- We implemented a system for archiving floats after the scientific quality control has been completed.

The US Argo DAC at AOML maintains a website: http://www.aoml.noaa.gov/phod/argo/index.php that provides documentation and information about the operations at the DAC, which is updated daily by automatic processes. Information about the Argo program as well as scientific use of the data has been updated on this web page.

US Argo Atlantic deployments were coordinated and done in collaboration with Woods Hole Oceanographic Institution. The deployments are done from research vessels and ships of opportunity. Our contribution consists in finding vessels and providing float deployers as needed.

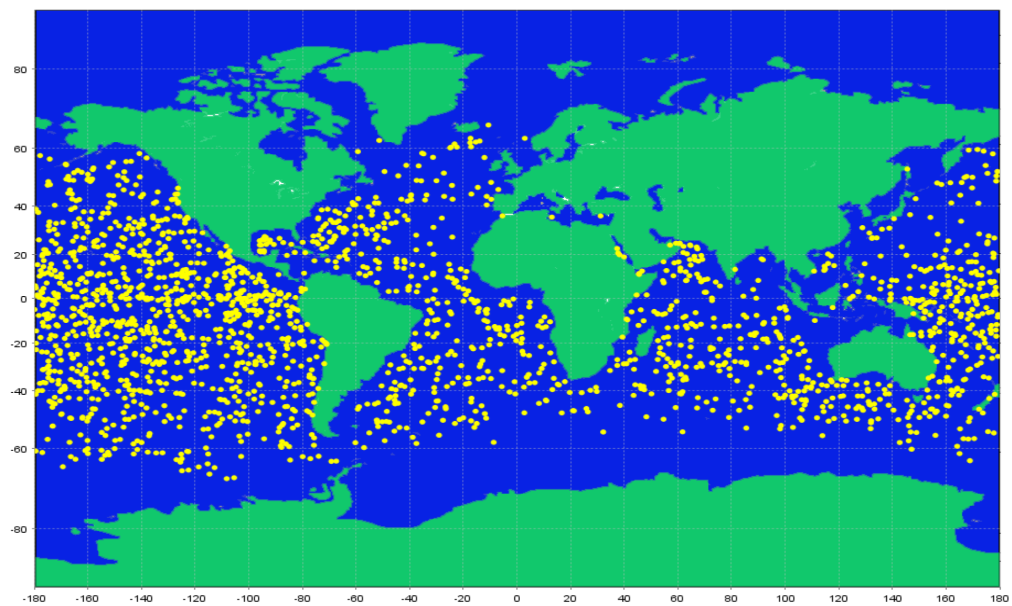


Figure 1: Location of US Argo floats in July 2017.

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

The GO-SHIP Repeat Hydrography Program

Project Personnel: L. Barbero, G. Berberian, J. Hooper, K. Sullivan and N. Mears (UM/CIMAS)
NOAA Collaborators: R. Wanninkhof, J.-Z. Zhang and 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: OOMD/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 2016/2017 the Pacific Ocean P18S and P06 transects were completed in full (Figure 1).

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 sored in 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 leads to improved forecasting skill for oceans and global climate.

During 2016/2017 we completed two meridional sections in the Pacific Ocean from 60 ˚S to 18 ˚N, called P18S, and along 30 ˚S, called P06 with full physical and chemical characterization of over 300 water column profiles. CIMAS project personnel and NOAA collaborators were responsible for inorganic carbon measurements.

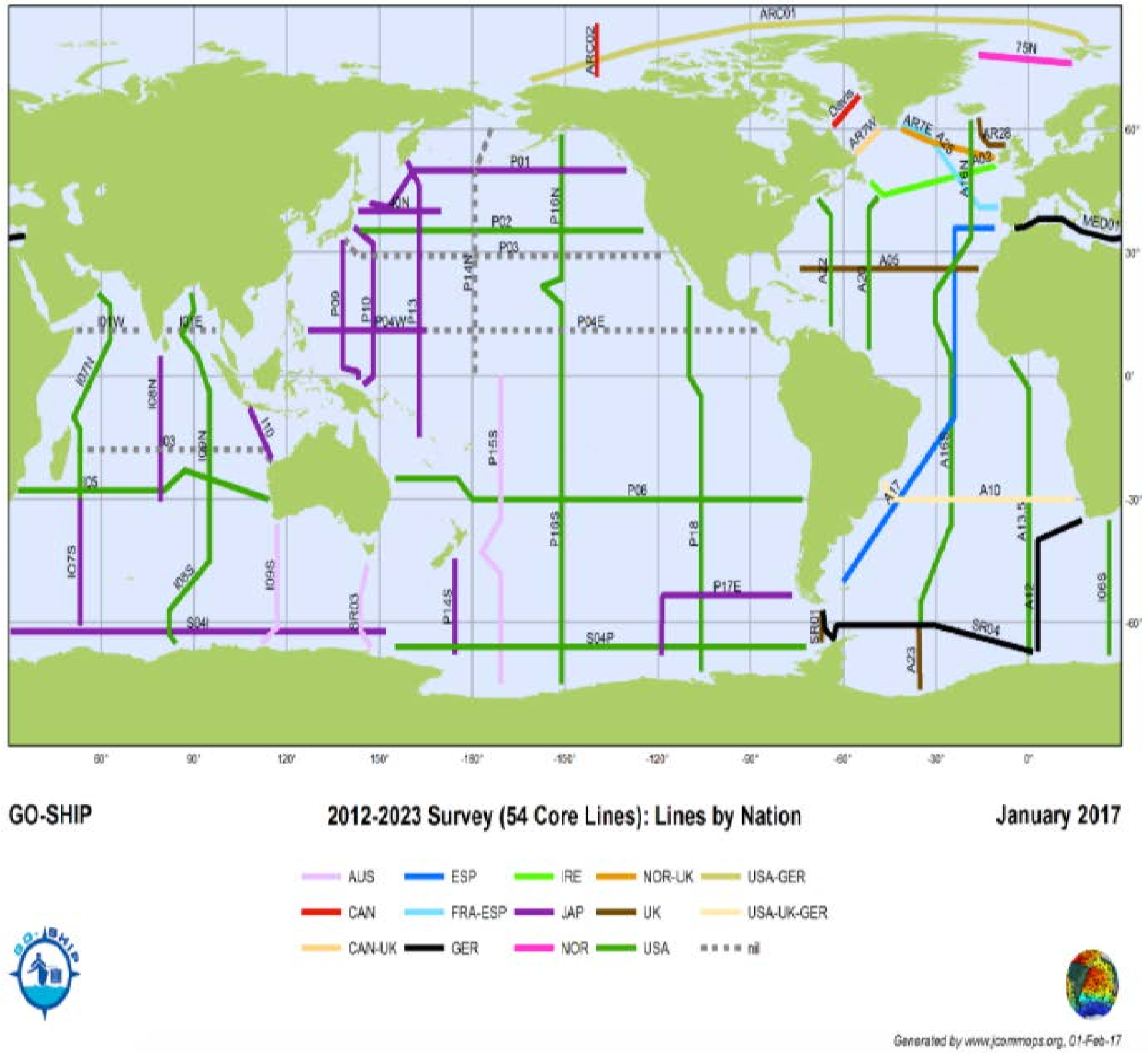


Figure 1: Tracks of the GO-SHIP lines. In FY17 the Pacific cruises P18S and P06 were occupied.

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-17 of completing the re-occupation of the P18S and P06 cruises was met.

PIRATA Northeast Extension

Project Personnel: S. Dolk, J. Hooper, R. Perez, E. Valdes and G. Rawson (UM/CIMAS)
NOAA Collaborators: R. Lumpkin, C. Schmid, G. Foltz (NOAA/AOML); K. Connell, M. McPhaden, M. Strick, L. Stratton, S. Kunze and R. Wells (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/OOMD
NOAA Technical Contact: Sidney 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 personnel participated in the PNE cruise aboard the NOAA Ship Ronald H. Brown from February 19 to March 25, 2017. During the 35 day, nearly 7,500 nautical mile journey from Montevideo, Uruguay to Charleston, South Carolina, the science team measured the upper ocean and near-surface atmosphere of the tropical Atlantic. R. C. Perez served as Chief Scientist for the cruise, with scientific support provided by S. Dolk, J. Hooper, and E. Valdes. G. Rawson prepared and calibrated instruments prior to the PNE cruise. CIMAS personnel were joined by mooring technicians from NOAA/PMEL, a scientist from GEOMAR who was deploying total dissolved oxygen loggers on the 23°W PNE moorings, a volunteer C. Valdes, and scientists from the Saharan Dust AERosols and Ocean Science Expeditions (AEROSE) Group.

Four PNE buoys were recovered and redeployed along 23°W at 4°N, 11.5°N, and 20.5°N, and at 20°N, 38°W. Along 23W, the three PNE moorings were deployed with total dissolved oxygen loggers with real-time data being reported at 11.5°N and 20.5°N. The 4°N, 23°W mooring was deployed with 11 Nortek Aquadopps to sample velocities in the upper 100 m at high vertical resolution as part of the NOAA/AOML funded Tropical Atlantic Current Observations Study (TACOS). We also serviced a rain gauge at 19°S, 35°W Brazilian PIRATA mooring and communicated with the 0°, 23°W French PIRATA mooring. Conductivity-temperature-depth (CTD) casts were conducted at 61 stations, including calibration casts for the total dissolved oxygen loggers and a tandem CTD cast was conducted with French colleagues at 0.45°S, 23°W aboard the French R/V Thalassa. Eight Argo profiling floats and sixteen surface drifters were deployed, as well as 69 XBTs. A GEOMAR Sloccum glider that lost the ability to maneuver and was drifting towards PNE cruise track by the crew of the Ronald H. Brown. The glider was recovered near 16.5°N, 22°W just east of the Cape Verde islands.

Research Performance Measure: All major objectives are being met. One PNE-related paper was published in the Journal of Climate (Rugg et al., 2016). The lead author of this paper was an undergraduate NOAA Hollings Scholar, Allyson Rugg, that interned with G. Foltz and R. C. Perez at AOML in June-July 2015. G. Foltz, C. Schmid, and R. Lumpkin developed an enhanced PIRATA data set for tropical Atlantic ocean-atmosphere research that is in revision for J. Climate, and the data will be updated and made publically available.

Eleven current meters were deployed at the 4°N, 23°W PNE mooring as part of TACOS in March 2017. Fine-scale vertical variations in the currents impact sea surface temperature and air-sea fluxes, and we need to understand how upper ocean velocity and shear is modified by wind events and tropical instability waves. Approximately four months of data have been collected (Figure 1), and we already see that the vertical structure of currents (i.e., shear) changes over time and that the maximum mean currents are found between 30 and 40 m rather than at the surface. The vertical structure of the currents also changes dramatically due to the onset of TIWs.

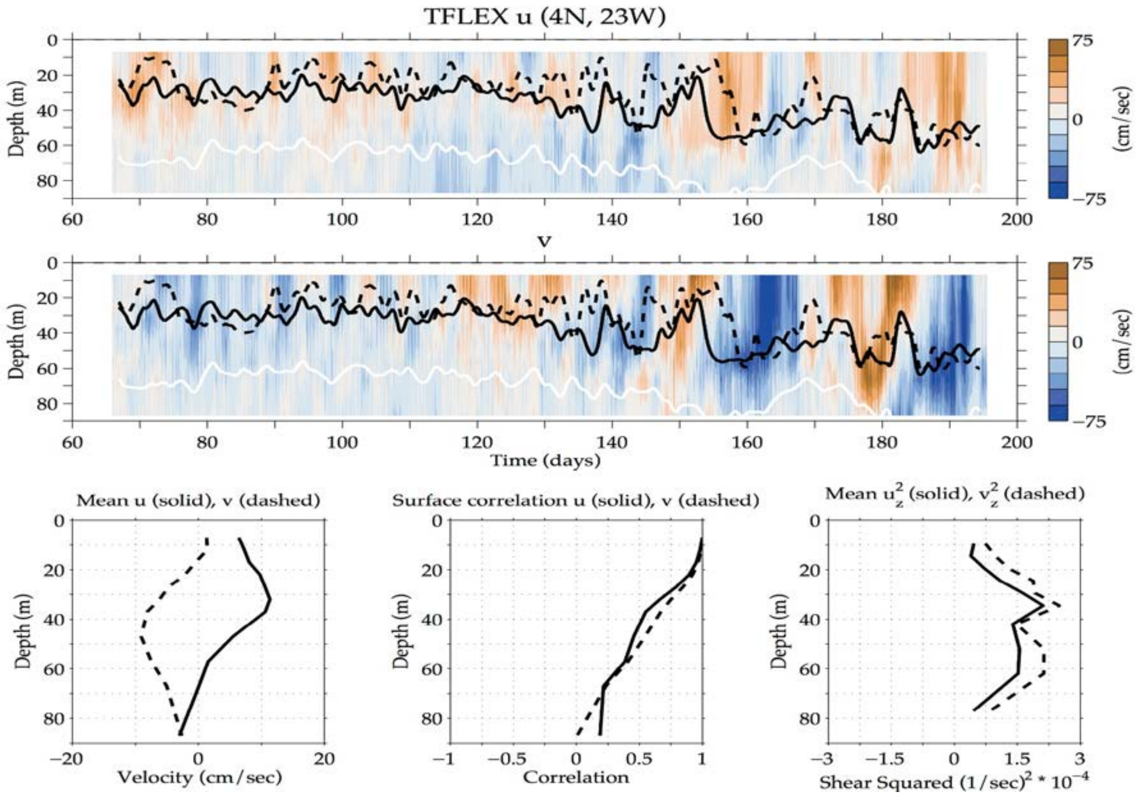


Figure 1: Daily averages of a) zonal and b) meridional velocity in the upper 90 m of the water column from the Tropical Atlantic Current Observations Study (TACOS) current meters at 4°N, 23°W. Brown shading indicates positive velocity and blue shading indicates negative velocity. White solid line shows depth of thermocline, black solid line shows depth of maximum shear, and black dashed line shows the depth of the mixed layer. Lower panels show the c) mean zonal (solid line) and meridional (dashed line) velocities, d) correlations between velocities at depth with the near-surface (7-m) velocity, and e) the mean velocity shear squared.

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

Project Personnel: S. Elipot (UM/RSMAS)
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 and temperature field on a global scale; to improve our understanding on the distribution and characteristics of inertial motions, tides (diurnal and semidiurnal) and sub-mesoscale motions.

***Strategy*:** To update the quality-controlled global dataset of hourly surface drifter positions and velocities, adding estimates of sea surface temperature, and implement analyses of the resulting dataset.

CIMAS Research Theme:
***Theme 3*:** Sustained Ocean and Coastal Observations (*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/AOML
NOAA Technical Contact: Molly Baringer

Research Summary:
In the previous fiscal year, project PI Elipot generated a global product of hourly drifter locations and velocities since January 2005. It resulted in a peer-reviewed publication describing the methodology chosen for the product, as well as giving initial scientific results from the product (doi:10.1002/2016JC011716).

This year, PI Elipot streamlined the code that generates the hourly drifter product and updated the product to version 1.01, with formal error bars for both GPS-tracked and Argos-tracked drifters. The update adds newer data to the previous version, one year of quality-controlled data up to 30 June 2016 for Argos-tracked drifters, and more than one year of GPS-tracked data, up to 1 October 2016. In addition, data was added from before 1 September 2005 (the start date of v1.00) when sufficient temporal resolution was assessed (see Figure 1). In summary, the 1.01 dataset now totals over 117.4 million estimates of position and velocity with confidence intervals from 12,287 Argos-tracked drifter trajectories, and over 5.6 million estimates of position and velocity with confidence intervals from 985 GPS-tracked drifter trajectories.

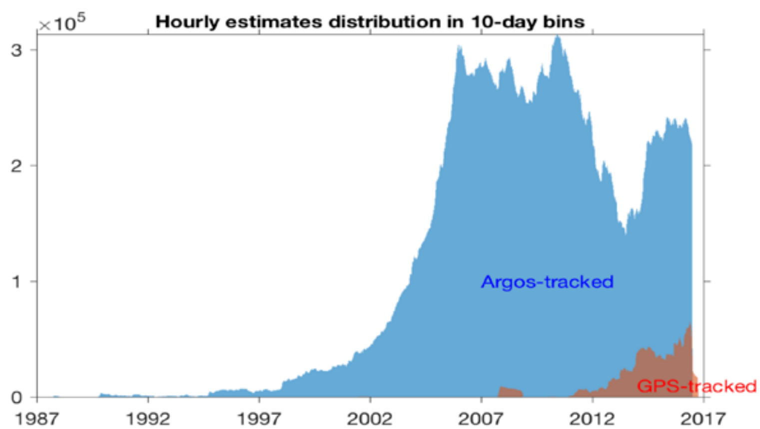

Figure 1: Temporal distribution of hourly estimates of position and velocity of surface drifters in 10-day bins for Argos-tracked drifters and GPS-tracked drifters.

Research Performance Measure: The updated hourly data product version 1.101 was released in January 2017 and made available freely on the GDP Data Assembly Center website (http://www.aoml.noaa.gov/phod/dac/hourly_data.php).
Contrary to anticipations, the updated version of the dataset does not include sea surface temperature estimates. This project's goal was not achieved because the needed resources were underestimated.
The new code was and "handed off" to the GDP Data Assembly Center personnel for future updates. Simplified versions of the Matlab codes used to generate this dataset are available through a GitHub repository.

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: M. Gidley, G. Rawson, I. Smith and L. Visser (UM/CIMAS)
NOAA Collaborators: L. Anderson (NOAA/FKNMS); E. Johns, C. Kelble, C. Sinigalliano and B. Vandine (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
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 CERP. The South Florida coastal ecosystem is economically and environmentally important and a large portion of the ecosystem is contained within the FKNMS. The aim of this project is to quantify and comprehensively understand the variability of inter-related physical, chemical, and biological water column properties. This is achieved through a sustained research and monitoring program that incorporates analysis from 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.

The South Florida Program has been collaborating with the Marine Biodiversity Observation Network (MBON) and scientists from University of South Florida as part of a pilot demonstration in the FKNMS. They conducted a multivariate classification of dynamic coastal seascapes in surrounding waters of the FKNMS using sea surface temperature (SST), chlorophyll-a (Chl-a), and normalized fluorescence line height (nFLH) satellite data. To validate seascape distributions, they compared synoptic patterns to in situ chlorophyll-a measurements and pigment observations collected aboard the R/V Walton Smith as part of the South Florida Program.

Another aspect of the MBON project has been to conduct diving surveys at six MBON Water Quality sites near sentinel reefs for coral metagenomics studies. AOML, in cooperation with CIMAS, has developed a pilot Coral Genomic Observing Network (CGON) for reefs in Southern Florida. These coral ecosystem genomic observations are integrated into a number of NOAA programs, including the Coral Reef Conservation Program (CRCP), the Coral Health and Monitoring Program (CHAMP), the AOML 'Omics Initiative, and the NOAA MBON program. CGON research in the Florida Keys is conducted by CIMAS personnel and collaborators from NOAA and from Nova Southeastern University (NSU) to supplement and enhance the wider MBON program in the FKNMS. This research is characterizing coral microbiome community metagenomic structures and biodiversity by Next-Generation-Sequencing (NGS) and measuring land-based microbial contaminant exposure of reefs by molecular microbial source tracking (MST) for corals, near-coral sediments, and near-coral water column communities in the FKNMS. This past year, six bi-monthly sampling events took place with divers collecting coral tissue, sediment, and water column samples from coral heads of three different essential coral species at these six reefs, preserving samples, extracting environmental DNA, and conducting MST analyses. Additional MST analysis and NGS analysis of samples will continue into FY 2018.

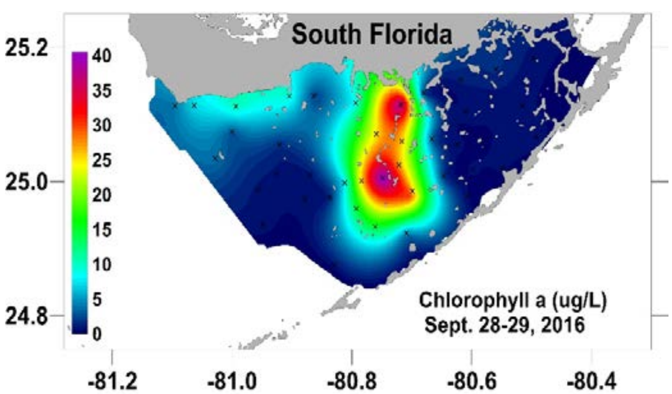

Figure 1: Chlorophyll a contour of Florida Bay showing an algal bloom (cyanobacteria) in the central bay. Chlorophyll levels reached twice that of the previous bloom in 2005-2007 and were the highest measured over the last 20 years of monitoring.

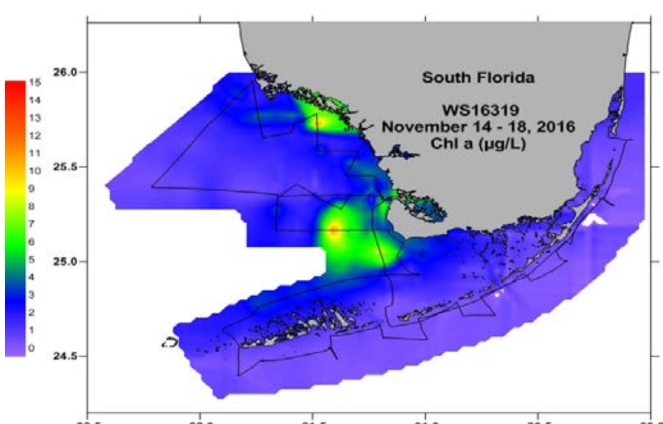

Figure 2: Chlorophyll a contour of South Florida coastal waters showing elevated chlorophyll levels off the coast of Florida Bay and the Shark River, and along the southwest Florida shelf. These maps and numerous other measured parameters are posted on the SFP web site at www.aoml.noaa.gov/sfp.

Research Performance Measure: All major research objectives are being met on schedule. The emphasis during this report period (1 July 2016 – 30 June 2017) 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.

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Ship of Opportunity Program

Project Personnel: C. Gonzalez, Z. Barton, R. Domingues, M. Goes, H. Lopez, J. Christophersen, G. Rawson, P. Halsall, T. Sevilla 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 maintain the High Density XBT transects with the main scientific objectives of: (I) measuring the seasonal and interannual fluctuations in the transport of mass, heat, and freshwater across transects; (II) determining the long-term mean, annual cycle and interannual fluctuations of temperature, geostrophic velocity, and large-scale ocean circulation in the top 800 m of the ocean; (III) obtaining long time-series of temperature profiles at approximately repeated locations in order to unambiguously separate temporal from spatial variability; (IV) determining the space-time statistics of variability of the temperature and geostrophic shear fields; (V) providing appropriate in situ data (together with Argo profiling floats, tropical moorings, air-sea flux measurements, sea level etc.) for testing ocean and ocean-atmosphere models; (VI) determining the synergy between XBT transects, satellite altimetry, Argo floats, and models of the general circulation; (VII) identifying permanent boundary currents and fronts, and describe their persistence and recurrence and their relation to large-scale transports, and (VIII) estimating the significance of baroclinic eddy heat fluxes.

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 one 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.

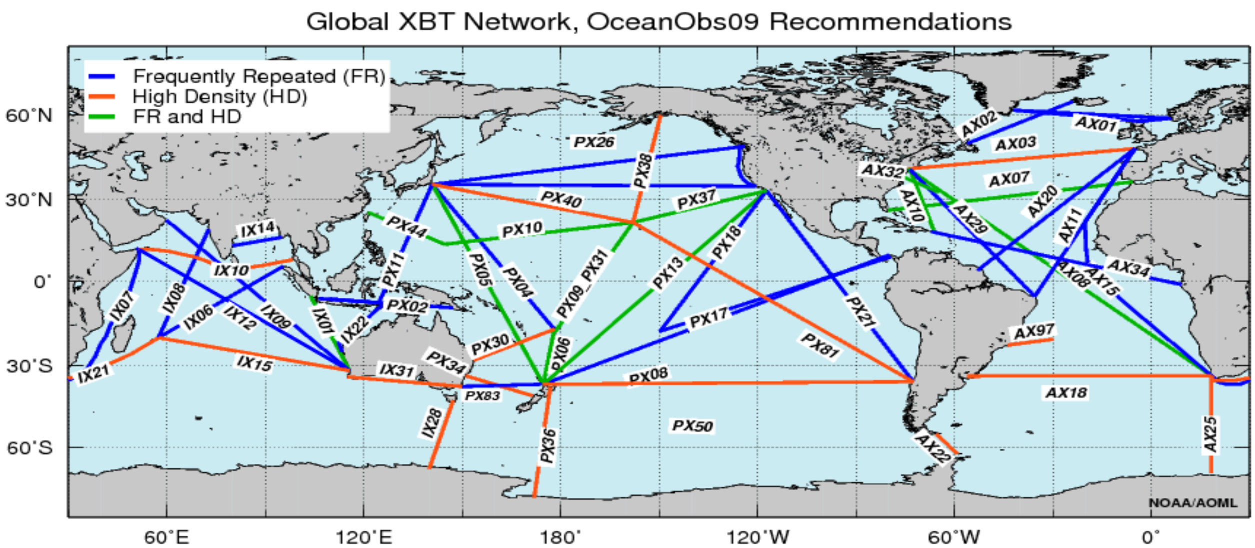

Figure 1: OceanObs09 XBT transects recommended by the scientific community to be occupied in frequently repeated mode (FR, in blue), high density mode (HD, in orange) or both (in green).

The XBT operations address both operational and scientific goals of the NOAA program for building a sustained ocean observing system for climate. The global XBT network and operations (Figure 1), formed by 55 repeat transects (19 in HD mode, 23 in FR mode, 13 in HR and FR modes, and none in LD mode) recommended by the scientific community is a multi-national (US, France, Australia, South Africa, Brazil, Germany, Japan, Argentina, India, Canada, China, and Taiwan), multi-institutional effort. Of these 55 transects, 38 are active and currently being maintained by the international community. AOML, together with its US and international partners, maintain 27 transects, where AOML plays an active and continuous lead role in the deployment of XBTs, or transmission, data quality control, or data distribution of XBT observations, and is involved with the deployment of approximately 8000 XBTs in High Density

mode. 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, AX07, AX08, AX10, AX18, AX22, AX25, AX32, AX97, 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.

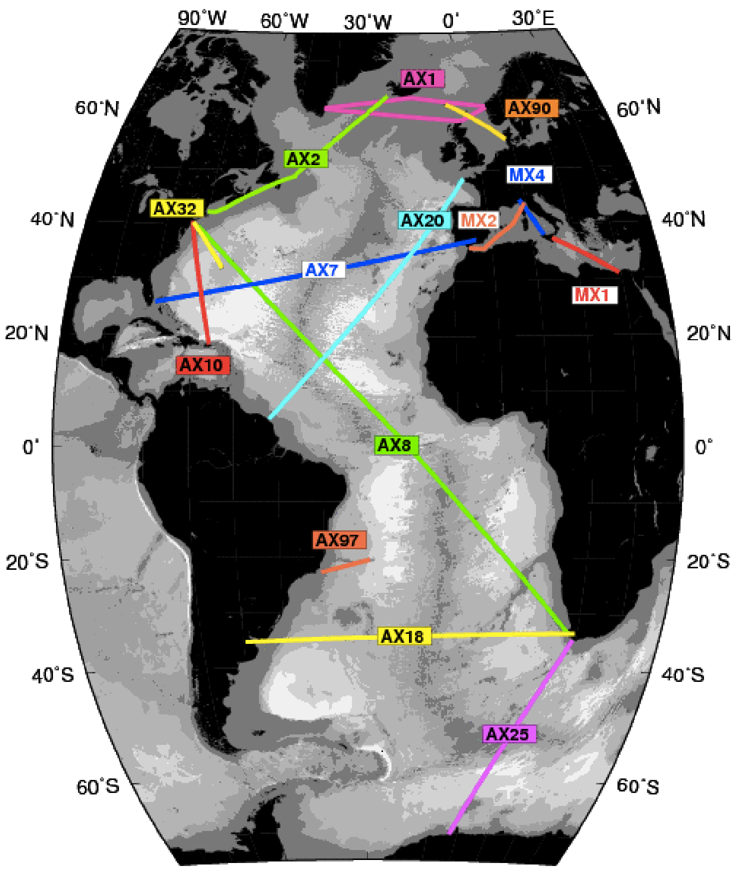

Figure 2: Location of the 4 High Density XBT transects (AX07, AX08, AX10, and AX18) maintained solely by NOAA/AOML, and the 7 transects (AX01, AX02, AX20, AX25, AX32, AX90, AX97, IX01, IX12, IX28, MX01, MX02, and MX04) maintained by NOAA/AOML in collaboration with the University of Paris, IRD/France, 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 10-30 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.

To facilitate the data collection effort, this project has developed and currently maintains the Shipboard Environmental data Acquisition System (SEAS), a software to collect and transmit observations from XBTs, ThermoSalinoGraphs (TSGs), and meteorological observations, which contribute to the largest

source of marine meteorological observations used by the NOAA National Weather Service for marine forecasting. In addition, this software provides regular (several times daily) 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, in order to save lives and property.

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 2016 (total of 17,221 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).

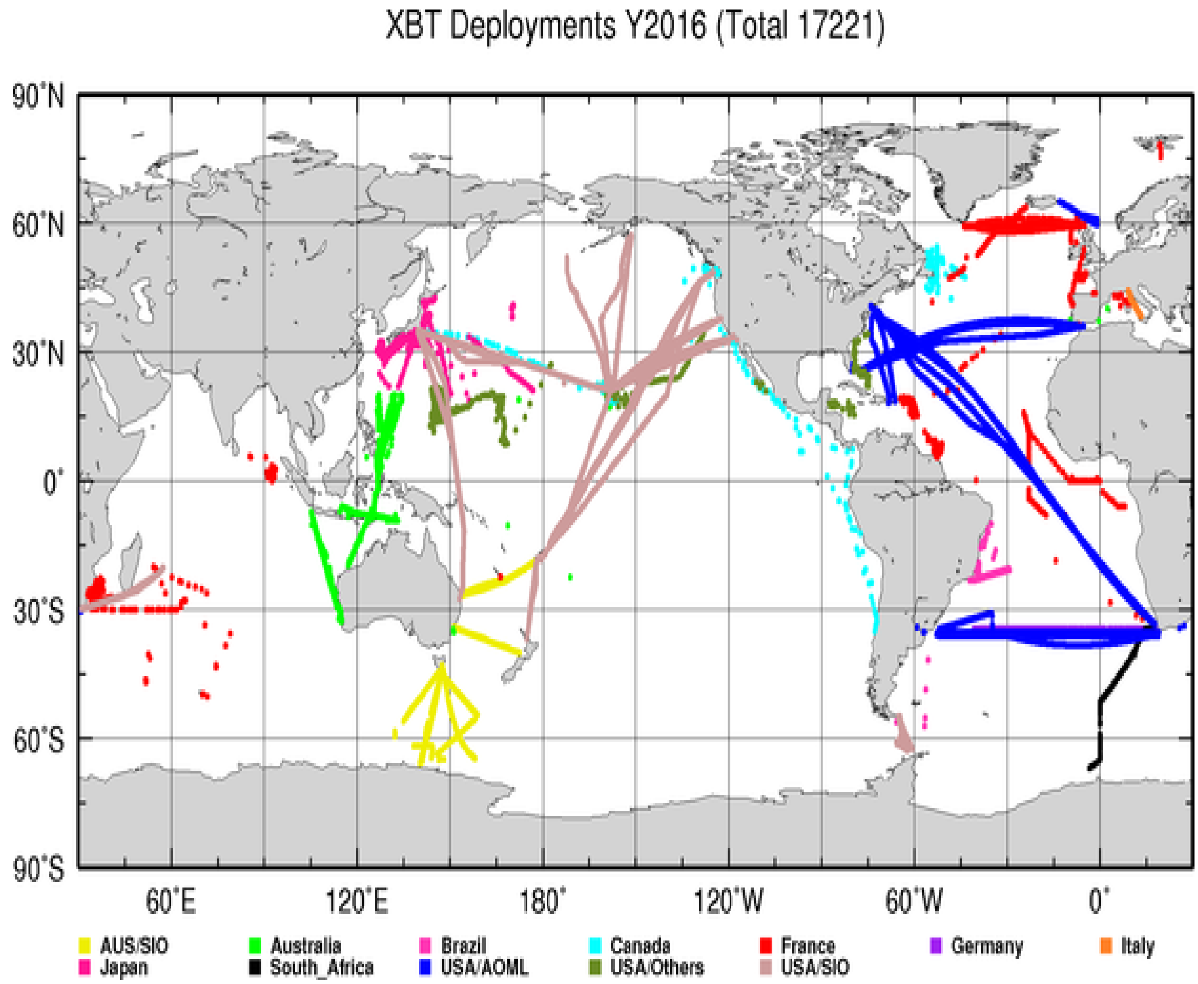

Figure 3: Locations of XBT deployments by AOML and the international community during calendar year 2016.

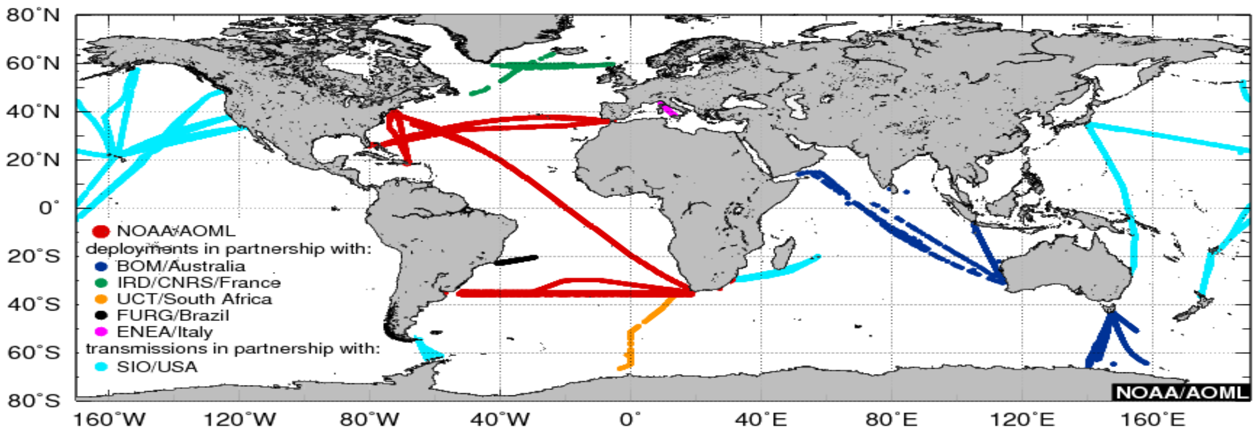

Figure 4: Location of the AOML XBT deployments and AOML-supported XBT deployments/transmissions during FY2016 carried out by AOML or in partnership with national and international collaborators.

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. To access AOML's XBT data, please see *www.aoml.noaa.gov/phod/hdenxbt/*. During FY2016 AOML continued the TSG operation in support of the pCO2 operations. During this period AOML received, processed and distributed TSG data from 4 ships of the SOOP (MV Skogafoss, MV Bernardo Houssay of the Argentinean Coast Guard and Royal Caribbean's Allure of the Seas and Equinox in collaboration with University of Miami/RSMAS) and 7 ships of the NOAA fleet (RV Okeanos Explorer, RV Pisces, RV Oregon II, RV Bell M Shimada, RV Oscar Elton Sette, RV Gordon Gunter, RV Oscar Dyson). Approximately 6 million TSG records were processed at AOML during FY2016 (Figure 5), and distributed through several data centers. The operation of TSG equipment is performed with the SEAS software.

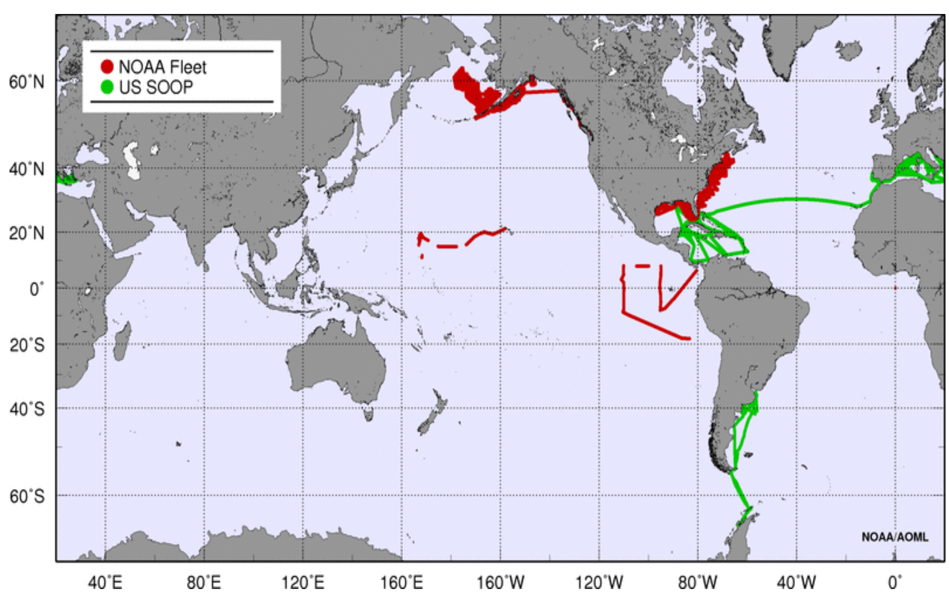

Figure 5: Location of approximately 300,000 TSG observations received and processed by AOML during July 1st, 2016 to June 30, 2017.

The SEAS software, which is supported by this project, is also used by the NOAA National Weather Service VOS (Voluntary Observing Ships) program. AOML transmits and distributes approximately 500,000 meteorological messages from SEAS and other systems (Figure 6), constituting the largest source of marine meteorological observations, which are used in weather forecast prediction models and analysis by university and government laboratories, such as the Tropical Analysis and Forecasting Branch of the National Hurricane Center.

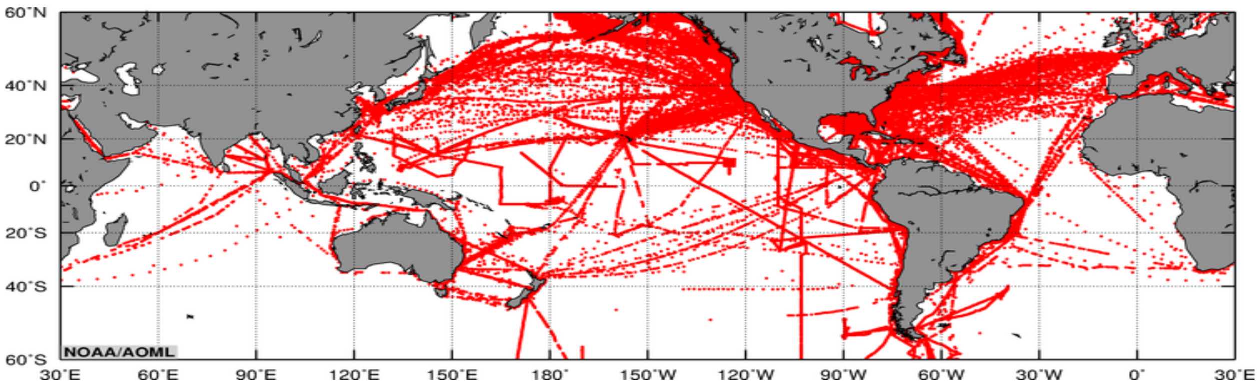

Figure 6: Locations of approximately 400,000 marine weather observations obtained from 800 ships of the VOS distributed through the GTS using SEAS software during July 1st, 2016 to June 30, 2017.

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 provides support to other observational networks by performing deployment of instruments along the XBT transects. This project contributes, at no cost, to the global Argo array (Figure 7) and to the Global Drifter Program (Figure 8) to maintain its array by having the XBT ship riders deploy their instruments along XBT transects.

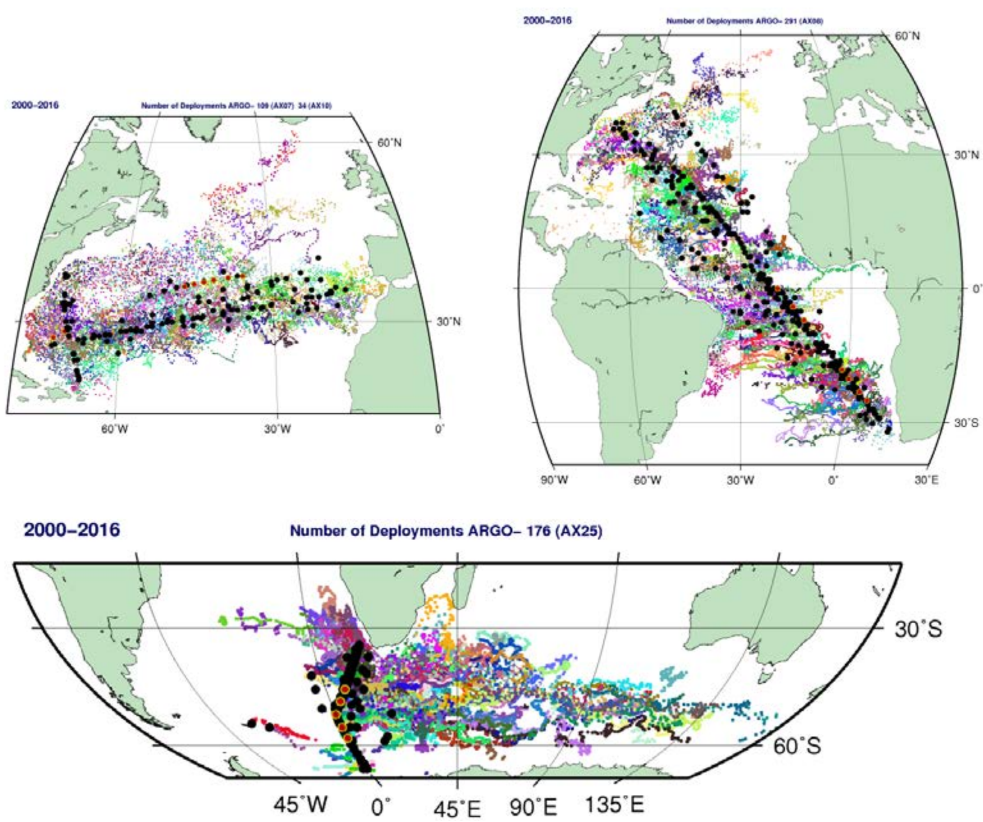

Figure 7: Location of deployments (black circles) of profiling floats carried out by XBT ship riders since 2000. Locations of observations from these floats are indicated by color dots.

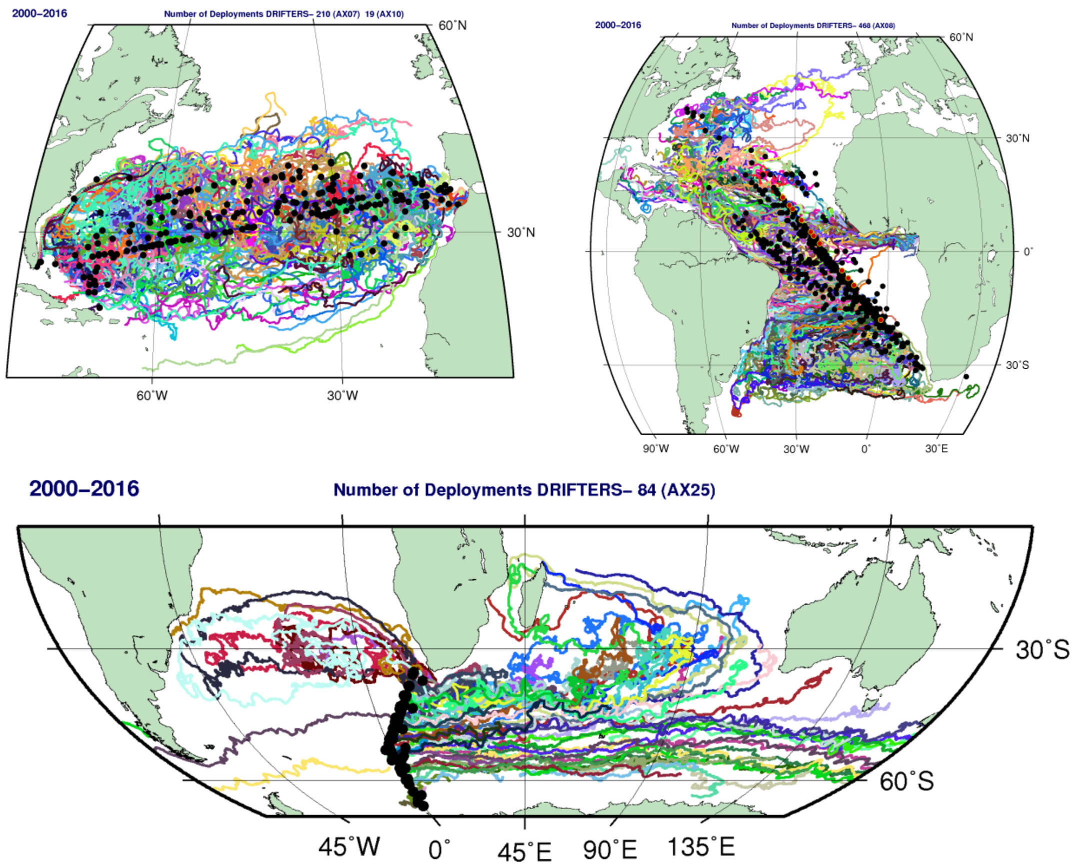

Figure 8: Location of deployments (black circles) of surface drifters carried out from XBT ship riders since 2000. Trajectories of these drifters are color lines.

<u>Science Update</u>

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) in the Atlantic Ocean. 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 9), and AX07 in the North Atlantic (Figure 10). In the North Atlantic, five transects took place along AX7 during FY2017. The cruises occurred during the months of July, September, and November in 2016 as well as February and April of 2017. During the reporting period, the MHT XBT across AX7 showed a higher than average annual mean of 1.26 PW, versus the total average of 1.1 PW, and the MOC across AX7 showed an average of 16.42 Sv (Sv = 10^6 m^3 s^{-1}), which is slightly less than average MOC of 16.92 Sv, calculated from data collected by the 26˚N array. In the South Atlantic, four transects occurred during FY2017 during the months of August, December of 2016 and January and May of 2017. The average heat transport calculated across AX18 was 0.73 PW, which is slightly above the overall average of 0.59 PW.

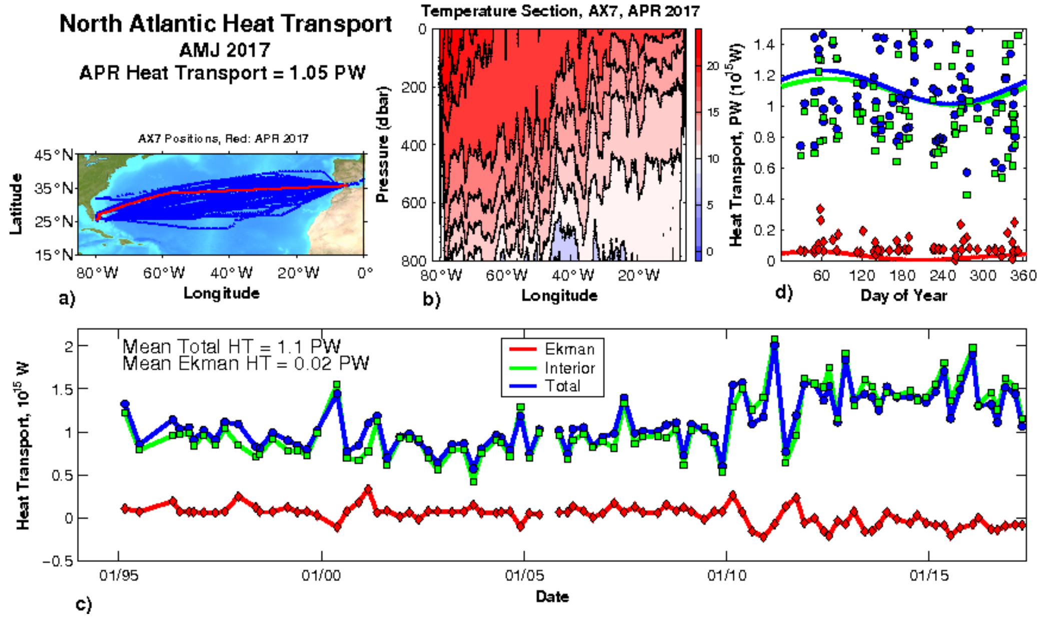

Figure 9: North Atlantic MHT calculated using data from the AX07 high density XBT transect, which runs from Florida, USA, to Gibraltar.

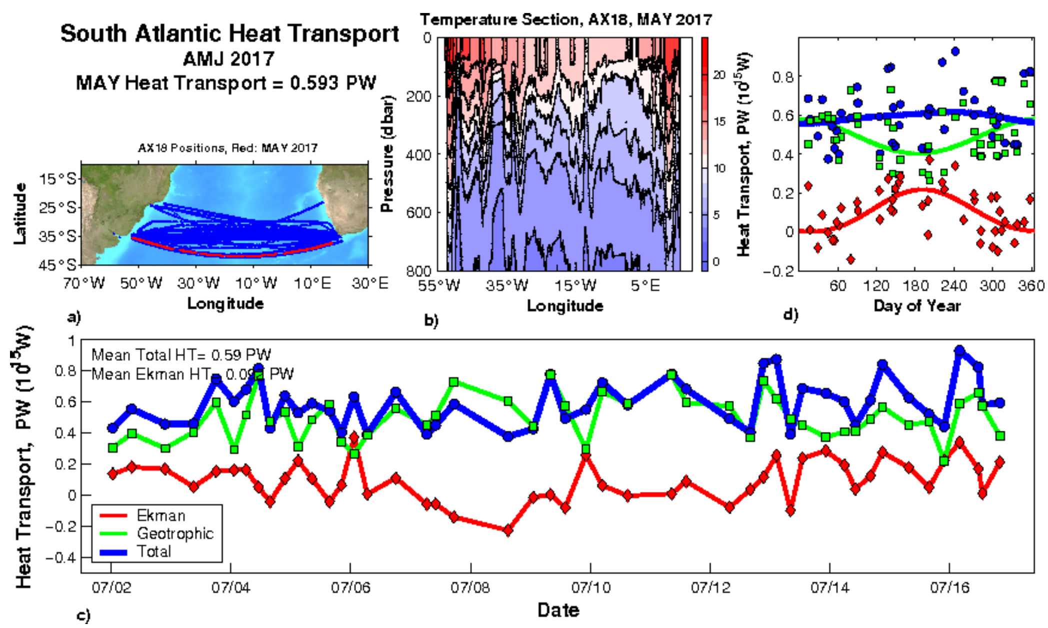

Figure 10: South Atlantic MHT calculated using data from the AX18 high density XBT transect, which runs from the Rio de la Plata region to South Africa.

In addition, the research component of the project provided advances in the following topics:

(a) Goes et al. (2017): This paper shows the analysis of experiments carried out in three cruises by NOAA/AOML, in collaboration with Sippican/Lockheed Martin, the manufacturer of XBTs. The experiments consisted on deploying XBTs side-by-side with CTD stations, with XBTs varying in their methods of calibration and mass variability. The main goal of this work was to explore the efficacy of thermistor calibration and reduction of mass variability of the probe on reducing temperature and depth biases on XBT data. Results show that one specific type of calibration (known as the bath thermistor calibration) can reduce the mean pure temperature bias in XBT measurements to nearly zero, and reduce the manufacturer tolerance from 0.1C to 0.03C. Results also indicated that the reduction of mass variability of the XBT probes did not produce any significant changes in the depth biases. XBTs currently provide 15% of global ocean thermal observations and are key to monitor meridional heat transport and variability of surface and subsurface currents. These results help to improve quality control of XBT probes production and, consequently, improve the state of the ocean assessments that use XBT data.

(b) Lopez et. al. (2016a): 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.

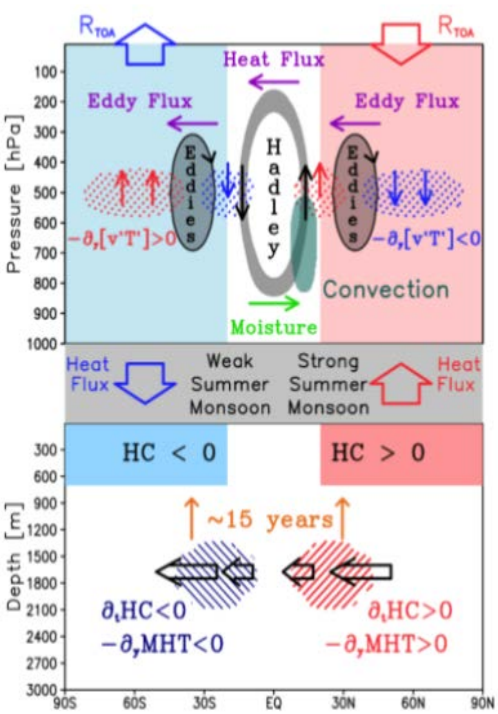

Figure 11: Schematic diagram of the role of weaker-than-normal MHT in the anomalous atmospheric circulation at 15-20 years lead-time. Weakened MHT is shown by thick lack arrows on the bottom panel. Negative (positive) tendency in heat content is labeled by dark-blue (red) hatching. There is negative (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 and 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.

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.

(c) Lopez et al (2016b): This study explores potential factors that may influence decadal variability of the South Atlantic meridional overturning circulation (SAMOC) by using observational data as well as surface-forced ocean model runs and a fully coupled climate model run. Here we show that SAMOC is strongly correlated with the leading mode of sea surface height (SSH) variability in the South Atlantic Ocean, which displays a meridional dipole between north and south of 20°S. A significant portion (~45%) of the South Atlantic SSH dipole variability is remotely modulated by the Interdecadal Pacific Oscillation (IPO). Further analysis shows that anomalous tropical Pacific convection associated with the IPO forces robust stationary Rossby wave patterns, modulating the wind stress curl over the South Atlantic Ocean. A positive (negative) phase IPO increases (decreases) the westerlies over the South Atlantic, which increases (decreases) the strength of the subtropical gyre in the South Atlantic and thus the SAMOC.

(d) Lopez et al., (2017): This study reconstructs a century-long South Atlantic Meridional Overturning Circulation (SAMOC) index. The reconstruction is possible due to its covariability with sea surface temperature (SST). A singular value decomposition (SVD) method is applied to the correlation matrix of SST and SAMOC. The SVD is performed on the trained period (1993 to present) for which Expendable Bathythermographs and satellite altimetry observations are available. The joint modes obtained are used in the reconstruction of a monthly SAMOC time series from 1870 to present. The reconstructed index is highly correlated to the observational based SAMOC time series during the trained period and provides a long historical estimate. It is shown that the Interdecadal Pacific Oscillation (IPO) is the leading mode of SAMOC-SST covariability, explaining ~85% with the Atlantic Niño accounting for less than 10%. The reconstruction shows that SAMOC has recently shifted to an anomalous positive period, consistent with a recent positive shift of the IPO.

(e) 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.

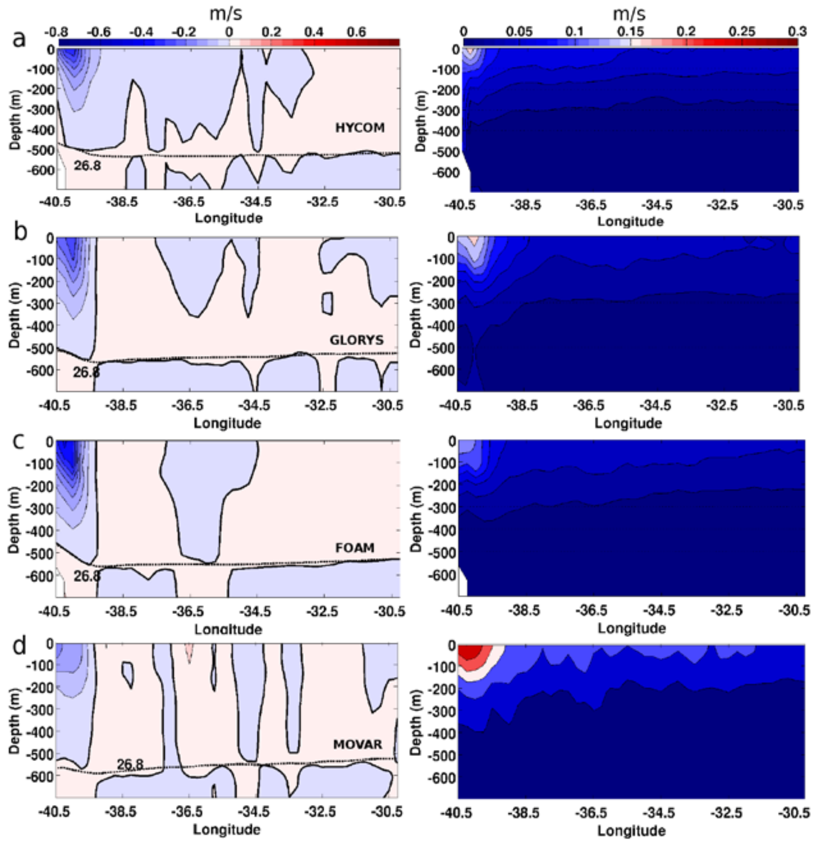

Figure 12: Mean cross-sectional component of the baroclinic velocity (left panels) and associated standard deviation (right panels) for the OFAS and MOVAR at the AX97 reference transect for the whole period (2004-2012). The OFAS are represented in the vertical panel panels from top to bottom in the following 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 $\sigma_\theta = 26.8$ kg/m3. A black dashed line in the left panels represents the mean depth of this isopycnal, for each data.

Operations Update

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

(i) Continued 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 revision of the instrument now called the AOML XBT Recorder (AXR) performs the same operations as the MK-21 by Lockheed Martin. Production cost for the AXR 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. Additionally, the new and final version of the AXR now boasts a modular design allowing for seamless integration with future XBT hardware developments such as the wireless auto launcher. Likewise, the modular design will likely also reduce overall maintenance costs.

(ii) Incorporating Turo Devil and the AOML XBT Recorder, which are XBT data acquisition systems fully compatible with SIPPICAN launcher and probes.

(iii) Adding a new alert "Ship starts moving". This alert indicates when the ship starts moving - so when the ship is in port overnight it will wake the rider up if leaving before the scheduled time. XBT Data Recorder checks every 10 min if the ship has moved 100 meters from the given initial position.

(iv) Adding option to export the generated cruise report to an RTF file that can be used by other programs such as Microsoft Word and Windows WordPad. This feature allows editting the report after the cruise. Main menu > Tools > Generate Cruise Report, option File > Export to RTF document.

(v) The automatic quality controlled procedures has been updated and re-written in a newer language for a new server, which will allows for easier troubleshooting, maintenance handling, and accessibility.

(vi) The automatic quality controlled process was also updated and is now in full compliance with requirements to transmit in BUFR to GTS.

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.

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Remote Sensing in Support of Climate Research

Project Personnel: M. Goes (UM/CIMAS),
NOAA Collaborators: G. Goni (NOAA/AOML)
Other Collaborators: J. 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 the management of the satellite receiving station at the NOAA Atlantic Oceanographic and Meteorological Laboratory (AOML) and the associated workstations and the tasks linked to the operational distribution of satellite telemetry and Data Collection System (DCS) products to the NOAA National Satellite, Data, and Information Service (NESDIS) and Service Argos. We use IPOPP and CSPP for processing VIIRS telemetry and obtain products that can be integrated within our data distribution schema.

We have implemented procedures for automatically downloading S-3 L1B data from ESA's Sentinel Scientific Data Hub. These fields are being used to estimate the FLH&MCI fields in a region covering the East US coast, the Gulf of Mexico and the Caribbean Sea. In addition, we are creating a 3-day AFAI alternative floating algal index (sargussum) product for the Caribbean and Gulf of Mexico using individual passes from USF (Chuamin Hu). Those fields were incorporated to our THREDDS server.

The Vibrio Suitability fields, which delineate world areas where Vibrio-related outbreaks can occur, have been updated to include monthly fields, which are computed from the daily estimates. This dataset includes the mean and maximum values.

A new paper has been published in the Journal of Operational Oceanography and was awarded the Denny Medal from the Institute of Marine Engineering, Science, and Technology (IMarEST). The Denny Medal is bestowed annually to the authors of the best paper published over the course of a year in the Journal of Operational Oceanography. Malaysian Airlines flight MH370 disappeared in March 2014. Potential sites of where the plane entered the water are considered within a vast region of the Indian Ocean. We present a methodology to assess the potential crash site based on where airplane debris was found, with an emphasis on the first debris discovery on Reunion Island. This methodology uses the historical dataset of surface drifters and numerical modeling results. Marine debris, depending on its buoyancy, is exposed to varying amounts of wind, and we conducted tests for a suite of different scenarios. The methodology proposed enables us to generate fields of particle density probability to assess debris trajectories and, therefore, hypothesize on the potential crash site. We provide an estimate of the most likely windage affecting floating debris on its way to Reunion Island by assuming the plane entered the sea in the defined search area. Our results indicate that areas within the Indian Ocean subtropical gyre, including the search area, could be a source of the debris found on Reunion Island. We also identify zones that can be excluded as potential crash sites and provide estimated travel times and probable ashore positions of plane debris through an analysis of the historical surface drifter dataset. Recent discoveries of new debris linked to flight MH370 in Mozambique, South Africa, Mauritius, and Tanzania are consistent with our results and confirm the general westward drift and travel time of debris from the search area.

We participated in the following meetings and courses:

a) OceanTeacher Global Academy-Invemar Training course: "From Measurement to Mean Fields: Aggregating Oceanographic Data for Science using World Ocean Database and World Ocean Atlas tools" 21 - 23 November 2016, Santa Marta , Colombia. Lecturers: Tim Boyer (NOAA/NCEI) and Joaquin Trinanes. The course incorporated sections on remote sensing, database management and on using R for time series processing.

b) Between Nov 16-19, Joaquin Trinanes participated in the GOSUD and GTSPP meeting in Osstend, Belgium. One of his presentations was about interoperability and involved CoastWatch/OceanWatch activities.
c) During the week of Mar 20-24, Gustavo Goni and Joaquin Trinanes attended the NOAA XBT/TSG Operations Meeting at NOAA/AOML. **d)** Between Mar 27-31, Gustavo and Joaquin participated in the 9th Session of the Ship Observations Team (SOT-9), held at the International Maritime Organization headquarters in London,UK where they discussed and presented research work related to BUFR, NETCDF4 and data management & tracking.

Other activities related to this project implies to update the inputs of the algorithm to estimate the parameters of the seawater carbonate system, such as pH, alkalinity and partial pressure CO_2 in seawater. The objective was to improve robustness and reduce latency. In addition and besides the daily fields, the weekly and monthly fields are being estimated in NRT. On a related subject, the Ocean Acidification Program needed to examine the feasibility and appropriateness of redeploying one of its OA mooring system in the northern GoM. The main purpose is to examine the dynamic variability of chlor_a as a proxy for pCO2 variability. Chlor_a monthly climatology from Modis Aqua data between 2003-2015 (both full years included) has been created from the daily fields. It has been extended to other sensors and is available from our servers. It includes the chlor_a mean field, the std_dev (dynamic range), the minimum and the maximum. They will serve to develop and implement new indicators in conjunction with other parameters.

A new algorithm to estimate the wind moments has been implemented to study the Carbon fluxes in the Gulf of Mexico. It is applied on 5 regions (4 of them coastal) that together cover the whole Gulf. We also participated, in collaboration with AOML/OCED, in the assessment of the effects of changing winds speeds on global air-sea CO2 fluxes. The results show that the changes in air-sea CO2 fluxes resulting from wind speed trends are greatest in the equatorial Pacific and cause a 0.03–0.04 Pg C decade−1 increase in outgassing over a 27 year time span. This leads to a small overall decrease of 0.00 to 0.02 Pg C decade−1 in global net CO2 uptake, contrary to expectations that increasing winds increase net CO2uptake.

The online data visualization package has been improved with new features (Figure 1). As part of the node operations, our ERDDAP, THREDDS and OceanViewer servers distribute new products (e.g. global night-time VIIRS imagery) and the node's associated webpages have been updated. We are continuously enhancing the viewer features: animation window comprising the whole visualization area, template for data representation, link to download URL, refactor and migrate code, bug fixing, among other tasks. We have also incorporate in-situ data to the viewer and the capability to display dynamic features (geostrophic currents) from JSON files obtained from ERDDAP servers.

The procedures that download and process the global Chlor_a data from STAR TDS server have been completed and we are routinely processing global VIIRS 750 meter (NRT) unprojected swath data from STAR TDS server. We are also generating 1km mapped global SST fields from individual ACSPO SST granules. The objective is to provide low latency high-resolution SST fields and implement processing techniques that can be used for other future datasets.

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.

During this year, we completed the migration to the new PDA distribution system (Pull user through sftp).

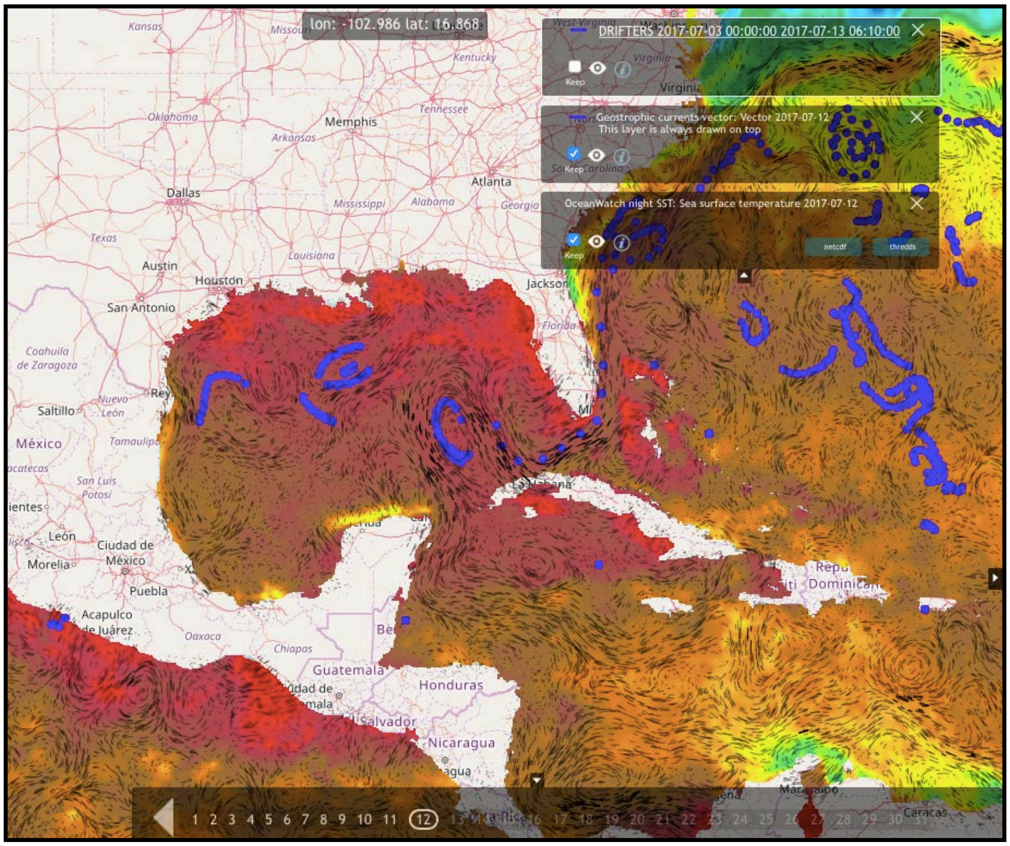

Figure 1: Snapshot of the OceanViewer interface showing SST, geostrophic currents and drifter locations.

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.

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 (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 collaborated with The Billfish Foundation and University of Southern Mississippi to deploy 11 pop-up satellite archival tags (PSATs) to understand behavior and movement blue marlin in the Gulf of Mexico. Unfortunately a manufacturing defect caused premature release of all 11 tags, resulting in a limited amount of data collection. The longest movement recorded was about 264 nm in a southerly direction over six days at-large (Figure 1). Replacement tags are being provided and deployments will resume in 2018.

In 2016, a study was undertaken to determine the maximum size and longevity attained by blue marlin *Makaira nigricans*. Blue marlin are large, long-lived, vagile, predatory billfish inhabiting tropical and subtropical waters. They represent an economically important recreational fishery, and are overexploited as bycatch by commercial longline fleets targeting swordfish and tunas. 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}. 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.

J. Hoolihan continued duties as coordinator of the Enhanced Program for Billfish Research for the International Commission for the Conservation of Atlantic Tunas (ICCAT). This included oversight, budget development and report writing for billfish landing studies off West Africa, genetic sampling of white marlin and roundscale spearfish, and biological sampling of billfish off West Africa for age and growth studies.

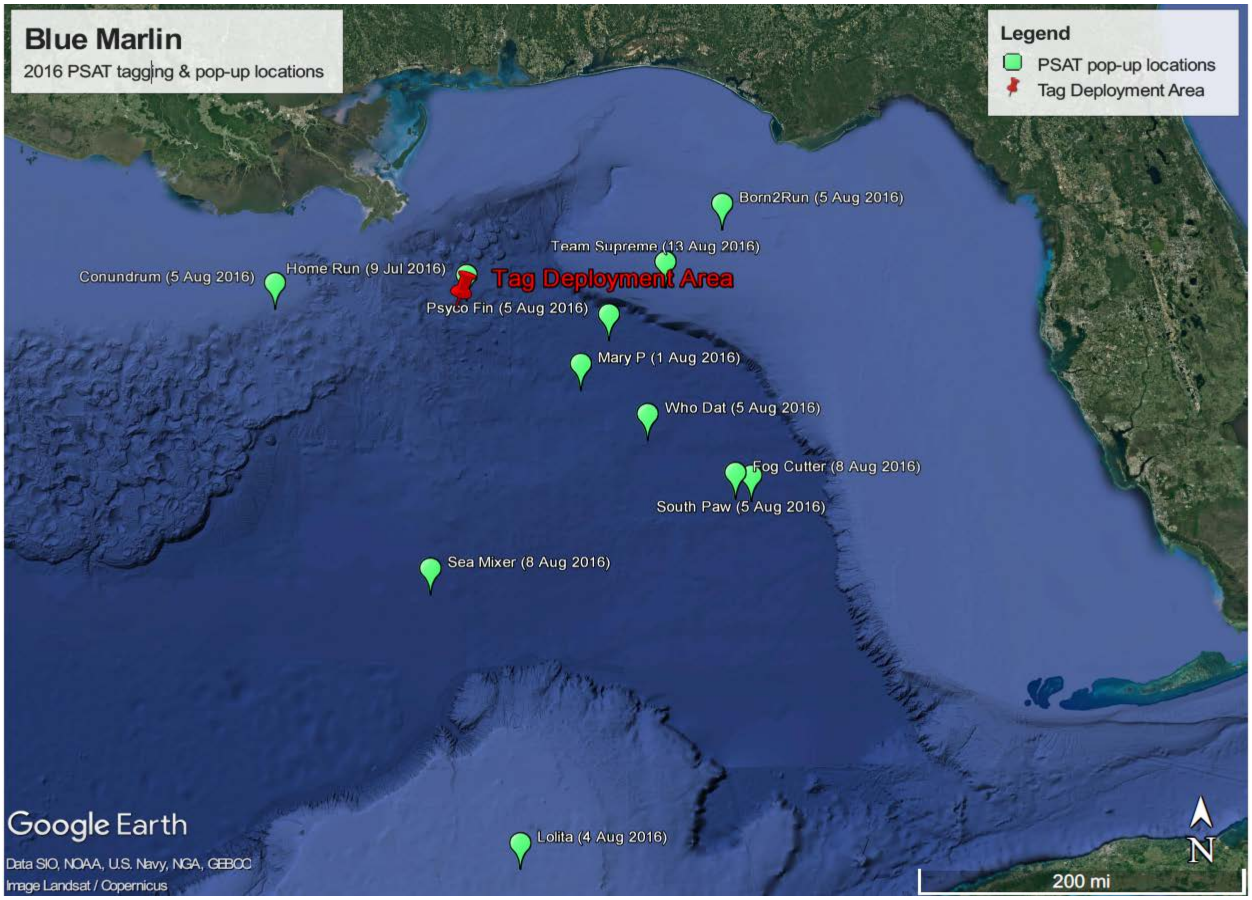

Figure 1: Deployment and pop-up locations of 11 PSATs deployed on blue marlin in the Gulf of Mexico during 2016.

Research Performance Measure

- High recovery rate for data collected by PSATs indicates that fish tagging protocols and deployment durations are appropriate. However, the blue marlin PSATs that malfunctioned and released within a few days in the GOM did not prevent much useable data, primarily because blue marlin are known to exhibit a post-release period of ~10-12 d of abnormal behavior before recovering from capture and tagging.
- Many joint authored (NOAA/RSMAS) peer review papers have resulted from these studies. Most 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)
NOAA Collaborators: M. Wang (NOAA/STAR)

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: Dr. Menghua Wang

Research Summary:

To date, during the reporting period of 7/1/2016 – 6/30/2017, the following activities have been conducted to achieve the project objectives:

- *C*ollected water samples to determine chlorophyll a concentrations, CDOM absorption, and particle absorptions. These data have been used to evaluate VIIRS performance in coastal waters. A manuscript is being prepared (Barnes et al., in preparation).
- Participated in the cruise survey onboard the NOAA ship Nancy Foster to collect bio-optical data in the South Atlantic Bight and Bahamas in October 2016. 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 2016 and reported progress.
- Performed simultaneous same view (SSV) calibration of VIIRS using MODIS total at-sensor radiance (Lt) as the truth. This effort is currently ongoing.
- Implemented alternative floating algae index (AFAI) algorithm for VIIRS, and applied it to VIIRS near real-time imagery in the Sargassum Watch System (SaWS, Hu et al., 2016). The VIIRS AFAI data product is expected to provide continuity to MODIS for detecting and tracking Sargassum and other types of floating algae.
- We also analyzed VIIRS imagery, provided by the NOAA STAR group using the most current msl12 processing, during a *Karenia brevis* bloom (red tide) off Florida's NW coast. The purpose is to evaluate the VIIRS capacity in capturing short-term changes.

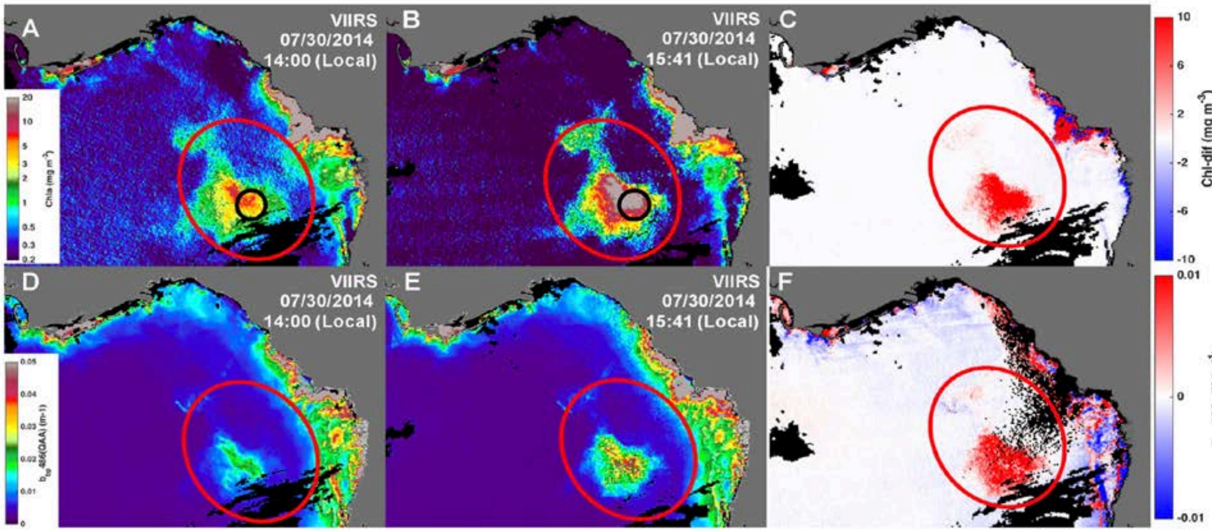

Figure 1: shows that in 100 minutes VIIRS showed dramatic changes in surface Chl and particulate backscattering. These changes were interpreted as being due to vertical migration of *K. brevis* (Fig. 2, Qi et al., 2016). VIIRS Red-Green-Chlorophyll-Index (RGCI) Chl and QAA b_{bp}486 images for two consecutive satellite passes within one day. The pass at 15:41 local time shows higher Chl (B) and b_{bp}486 (E) than the pass at 14:00 local time (A&D), possibly due to vertical migration of *K. brevis*. The images in (C) and (F) show the difference between the two passes. The use of the RGCI algorithm to derive Chl between 0.5 and 20 mg m^{-3} has been demonstrated in Qi et al. (2015). RGCI Chl for relatively clear waters (Chl < 0.5 mg m^{-3}) is not trustable.

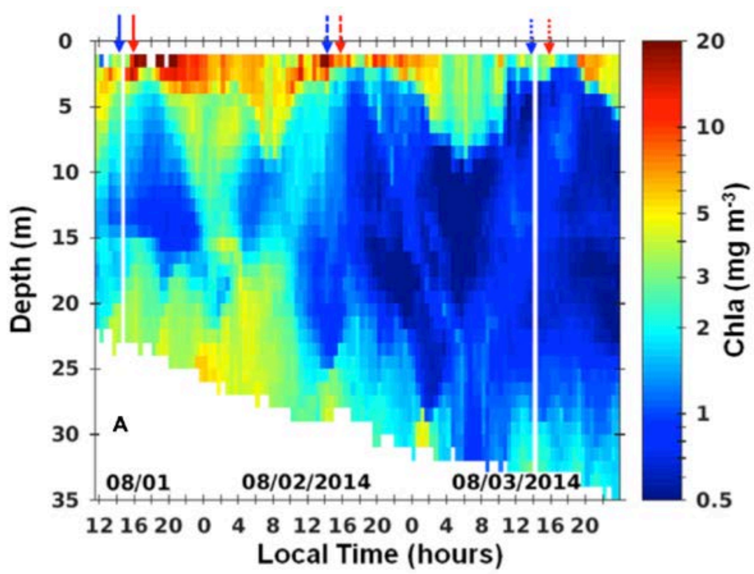

Figure 2: Glider-measured Chl in between 1 and 4 August 2014 in the same bloom as shown in the VIIRS imagery on 30 July 2014. Blue and red arrows annotate local time 14:00 and 15:41, respectively, corresponding to the two VIIRS passes on the same day.

Research Performance Measure: The accomplishments have met the original objectives.

Marine 'Omics and eAUV Technology to Support Ecosystem Understanding and Fisheries Assessments

Project Personnel: B. Kirtman (UM/RSMAS/CIMAS)
NOAA Collaborators: K. Goodwin (NOAA/AOML/SWFSC)
Other Collaborators: J. Birch (MBARI); A. Allen (JCVI)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives**:** To test whether autonomous sampling coupled with DNA analysis can combat rising ship-time costs, with emphasis on fisheries applications.

Strategy**:** To field test a prototype autonomous instrument that can search for oceanographic features and filter water remotely for molecular analysis, with comparison to traditional ship-board measurements.

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* (*Primary*)

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

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

Research Summary:

The Monterey Bay Aquarium Research Institute (MBARI) has developed an instrument to provide adaptive biological sampling via a mobile platform. The prototype is a long-range autonomous underwater vehicle (LRAUV) equipped with genomic sampling capability via a 3rd generation Environmental Sample Processor (3G ESP). The ESP is an in-situ molecular biology lab. Sampling occurs in cartridges, each outfitted with the necessary reagents for sample preservation or analysis of genomic information. Sampling is adaptive; for example, triggered by temperature, chlorophyll, or oxygen signals. Such episodic events are the main drivers of ocean productivity in upwelling regimes.

In April and May 2017, we conducted field tests with the 3G ESP/LRAUV ("eAUV" for short) to compare traditional ship-board sampling to the eAUVs ability to intelligently sample water column features. The eAUV rendezvoused with stations during two NOAA-led cruises and worked in conjunction with a MBARI Controlled, Agile, and Novel Observing Network (CANON) expedition. Personnel from the J. Craig Venter Institute (JCVI), NOAA (AOML and SWFSC), and Stanford University participated on-board the California Cooperative Oceanic Fisheries Investigations (CalCOFI) cruise during April 14-April 21, 2017 and aboard the Pelagic Juvenile Rockfish Recruitment and Ecosystem Assessment Survey (Rockfish) April 26-May 6, 2107. Sample filters collected during these two research cruises are currently being extracted for DNA analyses. DNA from these samples will be allocated to qPCR analyses and metagenomic sequencing (12S mtDNA, 16S rDNA and 18S rDNA).

Prior to these field operations, work proceed to establish method equivalency for 3G ESP sample preparation (filtration, preservation) utilizing samples collected from the Kelp Forest Exhibit at the Monterey Bay Aquarium and from Station C1 (36.797N, -121.847W) in Monterey Bay, CA. Experiments to establish method equivalency for molecular methods were conducted, with emphasis on eDNA for

anchovy, sardine, and market squid. No significant differences were observed in the qPCR concentration of anchovy (*Engraulis spp*.) DNA when comparing traditional and 3G ESP filtration methods. Illumina sequencing libraries for 12S mtDNA have been constructed and samples are currently being sequenced to assess whether the two methods provide comparable community compositions.

Figure 1: The MBARI vehicle, the Aku, in rendezvous with the NOAA Bell M. Shimada during CalCOFI cruise R4107 on April 15, 2017.

Figure 2: The Aku deployed by MBARI from a small boat as viewed from the Shimada.

Research Performance Measure: a) Conduct equivalency testing of DNA sample collection and processing using water from the Monterey Bay Aquarium (defined water composition) and natural seawater. b) Field test the 3G ESP/LRAUV in rendezvous with NOAA cruises to allow comparison of samples collected by the AUV and ship-board.

Biogeochemical Measurements

Project Personnel: C. Langdon (UM/RSMAS); G. Berberian (UM/CIMAS)
NOAA Collaborators: M. Baringer (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To determine the changing oxygen content of the global ocean and to use the change in oxygen to constrain the changes in CO_2 inventory due to formation and breakdown of organic matter to obtain the changes due to anthropogenic factors by difference.

Strategy: Revisit hydrographic sections in the Atlantic and Pacific that were sampled ten years earlier and make discrete dissolved oxygen measurements for the surface to the bottom (24 depths) every 30 nautical miles.

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: CPO/CPD
NOAA Technical Contact: Kathy Tedsco

Research Summary:

The Biogeochemical Measurements project funds my involvement (dissolved oxygen) in the Global Ocean Ship-based Hydrographic Investigation Program (GO-SHIP). The objective is to re-occupy select hydrographic sections to quantify change storage and transport of heat, fresh water, carbon dioxide, oxygen nutrients, chlorofluorocarbon tracers and related parameters. The program began in 2003.

One of the main objectives of the program is to determine where and how much excess atmospheric CO_2 is entering the ocean on decadal time scales. Key to achieving this objective is assessing changes in the ocean's biogeochemical cycle that also impact the CO_2 inventory. The uptake of excess CO_2 by the ocean is the total observed change in CO_2 inventory plus/minus changes due to formation/breakdown of organic matter estimated from changes in oxygen, NO_3 and PO_4.

During FY-2016 we completed P18S, a meridional section in the Pacific from 22.9°N to 69.5°S along 110°W jogging to 103°W below 10°S, completing 211 water column profiles. My group performed a total of 5,490 high precision oxygen measurements. Figure 1 shows the oxygen concentrations measured along 110/103°W in 2016. Figure 2 is a difference section showing how oxygen concentrations have changed since 2007 when this line was last occupied. Data have been interpolated to neutral density surfaces to correct for internal tide activity. Areas shown in violet have experienced a highly significant 40 μmol kg^{-1} decrease in oxygen concentration. Referring to Figure 1 the violet areas in Figure 2 have gone from hypoxic conditions (i.e. ~40-50 μmol kg^{-1}) in 2007 to almost anoxic in 2016. As oxygen levels fall below 40-50 μmol kg^{-1} conditions become increasing stressful for marine life. Activity of any type needs to be curtailed and even digesting food becomes problematic because oxygen is needed to metabolize food. If the oxygen decline continues the area risks becoming a dead zone with only bacteria able to survive. The factors responsible for this change, presumably climatic, are not well known and need to be investigated.

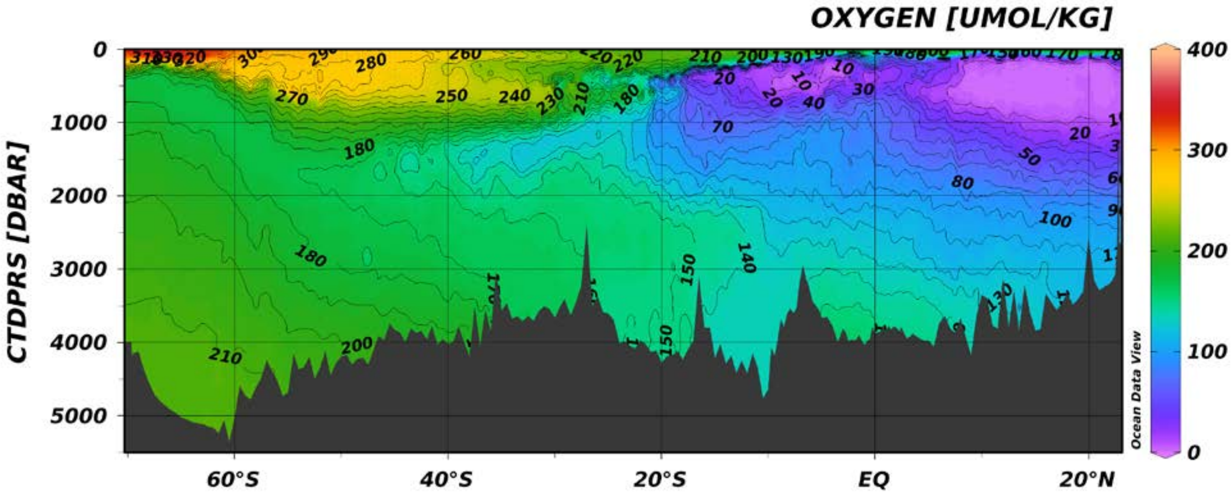

Figure 1: Oxygen section through the Pacific along 110/103W for the P18S line in 2016/2017.

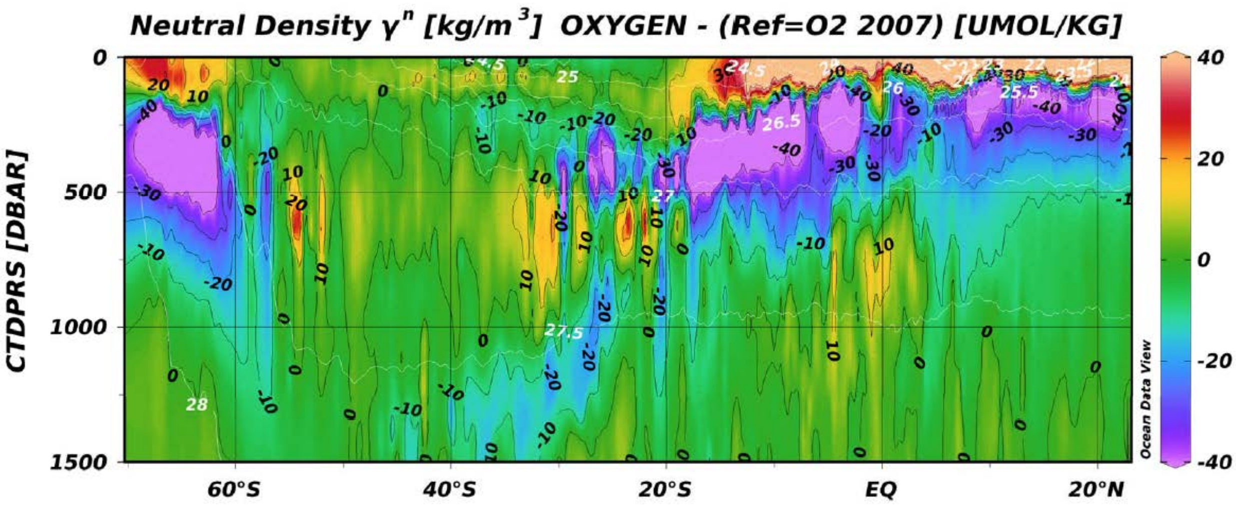

Figure 2: Difference section along P18S line showing how oxygen concentration has changed between 2007 and 2016/17. Neutral density isopycnals are shown in white.

Research Performance Measure: The repeat hydrographic sections are progressing according to the timeline provided by the GO-SHIP plan (http://www.go-ship.org). All data have been quality controlled and archived with CCHDO (http://cchdo.ucsd.edu/) within the six-months of completion of the cruise. The performance measure for FY-16 of completing the re-occupation of the P18S cruise and archiving the data was met.

Juvenile Sportfish Monitoring in Florida Bay, Everglades National Park

Project Personnel: M. La Martina, D. Sinnickson, I. Smith, L. Visser and I. Zink (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 *(Quaternary)*

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.

Over time, there is a significant negative trend in spotted seatrout frequency of occurrence from 2004 – 2016. In 2016, the salinity was lower in Florida Bay than the previous two years and it had the highest mean frequency of occurrence of spotted seatrout since 2007. Florida Bay experienced extreme hypersalinity during the summer of 2015, and it was considered to be a low-population year for seatrout. During July 2015, salinity reached 65.4 and temperatures were up to 38°C in the northern basin in Rankin sub-region. These measurements were immediately followed by a significant seagrass die-off in the areas

with the highest salinities in the Rankin and West sub-regions. In three of the four sub-regions of Florida Bay, both the frequency of occurrence and density were inversely correlated with salinity. Thus, the frequency of samples capturing juvenile spotted seatrout decreases with increasing salinity, as does the overall density.

Overall there was a significant positive linear relationship between seagrass percent cover and spotted seatrout density and frequency of occurrence. When separated by sub-region, the density and frequency of occurrence of *C. nebulosus* variable had a significant linear relationship with the overall seagrass percent cover variable in the West alone. This suggests that as percent cover increases juvenile spotted seatrout are caught more frequently and at higher concentrations in the West. However, in the other sub-regions, salinity has a stronger effect on seatrout frequency of occurrence than seagrass percent cover does.

Results of a multiple logistic regression showed that overall all three variables: salinity, temperature, seagrass percent cover, and the interaction between salinity and temperature all provided significant information on spotted seatrout frequency of occurrence in every region. 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. Mean annual seatrout frequency of occurrence is higher when there is a combination of low to moderate salinities (31-36), moderate temperatures, and moderate to high seagrass percent cover (Fig 1).

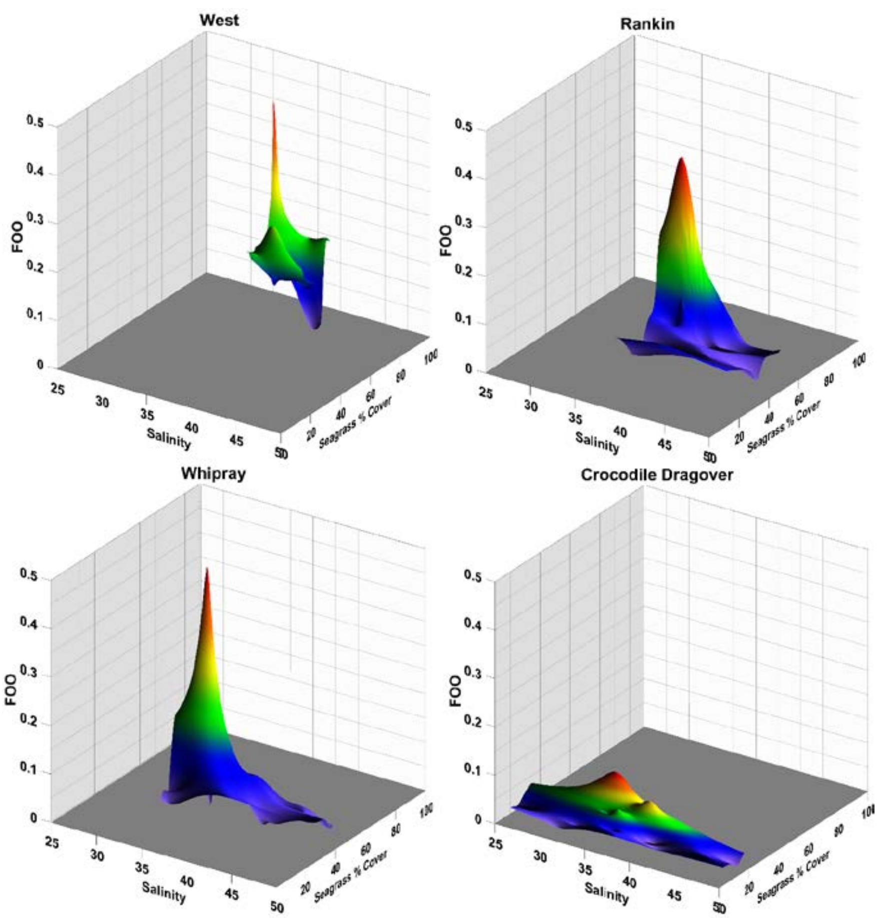

Figure 1: Contour plots depict the relationship between the juvenile spotted seatrout population, salinity, and seagrass within each sub-region of Florida Bay. Spotted seatrout occur more frequently with lower salinities and higher seagrass percent cover.

We examined the stomach contents of 266 spotted seatrout < 100 mm length caught from 2009 – 2016. The three most abundant prey items found in the stomach are shrimp from Family *Penaeidae*, shrimp from the infraorder *Caridea*, and rainwater killifish (*Lucania parva*). Among 16 other groupings of prey items, Anchovys (*Engraulidae*), Mojarra (*Gerridae*), and mullet (*Mugliidae*) were the next most abundant in biomass.

Perhaps most importantly, our analyses this year with our new water-quality-model-based HSI confirmed that simulated NSM conditions provided a sound restoration target for juvenile spotted seatrout

abundance in each of our Florida Bay sampling sub-regions. Furthermore, the HSI model sufficiently discriminated between the alternatives of the Central Everglades Project design and future without CEPP, with regards to differences in juvenile spotted seatrout abundances.

Research Performance Measure:

We have quantified a significant relationship with juvenile spotted seatrout to salinity that has allowed for the development of a testable 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, and the 2017 CERP System-wide Performance Measure, indicating that this project is contributing to science-based management within CERP.

We have developed a revised performance measure for juvenile sportfish in the southern coastal systems. This focuses on the development of Habitat Suitability Index (HSI) models that are used to predict the habitat suitable for juvenile *C. nebulosus* and other sportfish from submerged aquatic vegetation and water quality parameters. The performance measure examines 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 is 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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Dimensions: Analysis of Microbiomes from Three Coral Species

Project Personnel: J. Lopez, M. Wickes and H. Won Lee (NSU); M. Gidley (UM/CIMAS)
NOAA Collaborators: C. Sinigalliano, B. VanDine (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To metagenomically characterize the microbiomes of three coral species within the Florida Keys National Marine Sanctuary coral reef system.

***Strategy*:** To conduct bimonthly and supplemental event-focused monitoring cruises and dives with the incorporation these results into reports and system models supporting resource management decisions.

CIMAS Research Theme:

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

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

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

Research Summary:

As an aspect of the MBON project NOAA AOML and NSU personnel have been conducting diving surveys at six MBON Water Quality sites near sentinel reefs for coral metagenomics studies. AOML, in cooperation with CIMAS, has developed a pilot Coral Genomic Observing Network (CGON) for reefs in Southern Florida. These coral ecosystem genomic observations are integrated into a number of NOAA programs, including the Coral Reef Conservation Program (CRCP), the Coral Health and Monitoring Program (CHAMP), the AOML 'Omics Initiative, and the NOAA MBON program. CGON research in the Florida Keys is conducted by CIMAS personnel and collaborators from NOAA and from Nova Southeastern University (NSU) to supplement and enhance the wider MBON program in the FKNMS. This research is characterizing coral microbiome community metagenomic structures and biodiversity by Next-Generation-Sequencing (NGS) and measuring land-based microbial contaminant exposure of reefs by molecular microbial source tracking (MST) for corals, near-coral sediments, and near-coral water column communities in the FKNMS. This past year, six bi-monthly sampling events took place with divers collecting coral tissue, sediment, and water column samples from coral heads of three different essential coral species at these six reefs, preserving samples, extracting environmental DNA, and conducting MST analyses. Additional MST analysis and NGS analysis of samples will continue into FY 2018.

The South Florida Program has also been collaborating with others in the Marine Biodiversity Observation Network (MBON) including scientists from University of South Florida as part of a pilot demonstration in the FKNMS. They conducted a multivariate classification of dynamic coastal seascapes in surrounding waters of the FKNMS using sea surface temperature (SST), chlorophyll-a (Chl-a), and normalized fluorescence line height (nFLH) satellite data. To validate seascape distributions, they compared synoptic patterns to in situ chlorophyll-a measurements and pigment observations collected aboard the R/V Walton Smith as part of the South Florida Program. Samples are also collected at one of the Coral sites (Cheeca Rocks) and processed for eDNA, chlorophyll-a, HPLC, and protozoans.

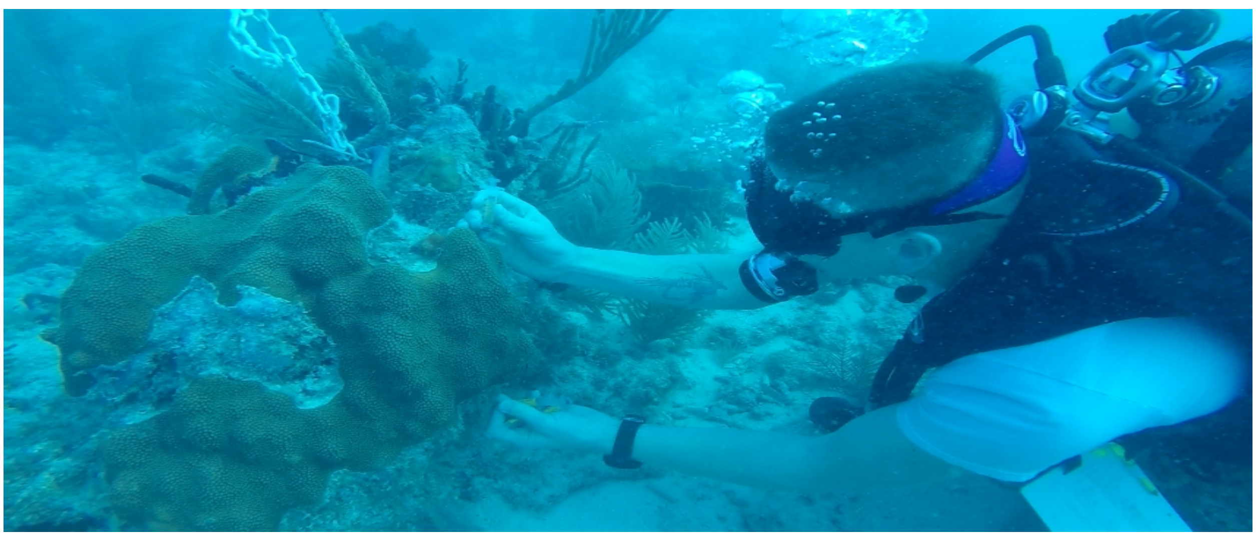

Figure 1: An AOML diver collects coral tissue by syringe biopsy in the Florida Keys National Marine Sanctuary for genetic characterization of coral microbiome.

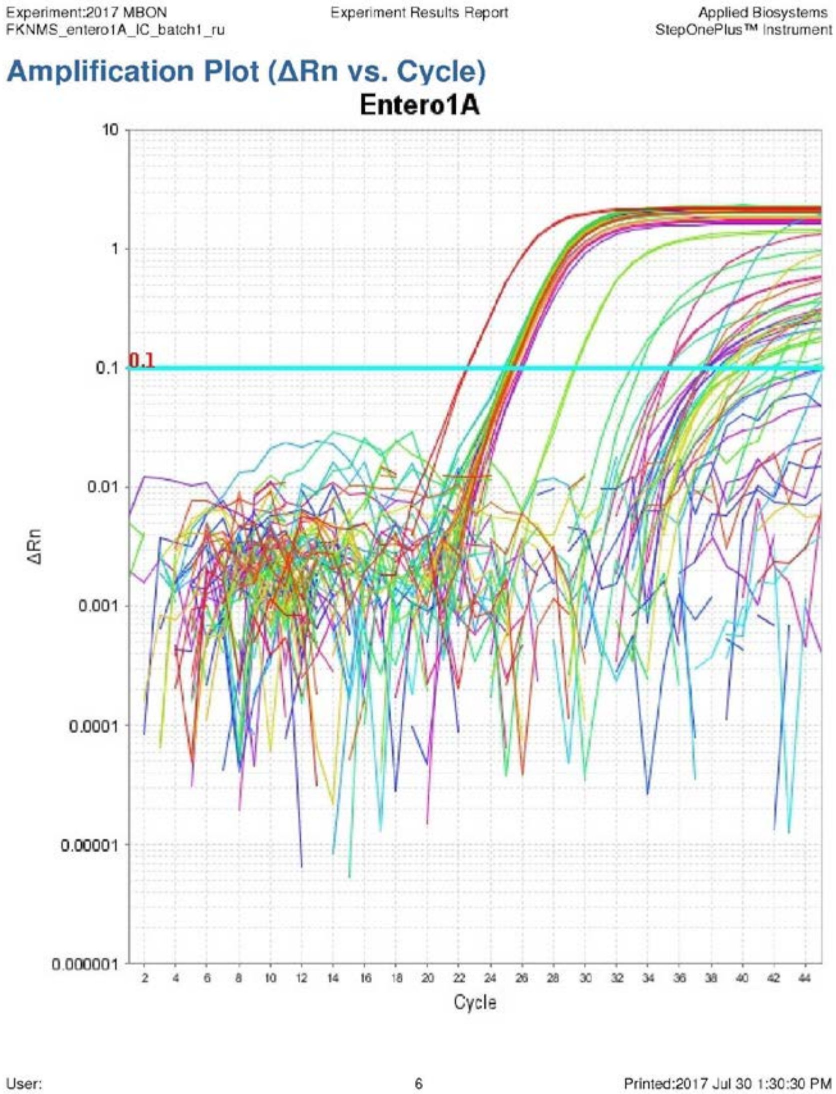

Figure 2: Quantitative real-time PCR amplification plot measuring the abundance of 16S ribosomal genes from enterococci bacteria in selected reef waters and coral tissues of the Florida Keys National Marine Sanctuary.

Research Performance Measure: All major research objectives are being met on schedule. The emphasis during this report period (1 July 2016 – 30 June 2017) has been on coral reef surveying, initial sample collection, processing, sample extraction and preliminary MST (microbial source tracking) analysis. Regularly scheduled sampling could not commence until the full surveys were completed and applied for sanctuary sampling permits were awarded.

Ocean OSSE System Development and Applications for QOSAP

Project Personnel: M. Mehari and M. Le Henaff (UM/CIMAS)
NOAA Collaborators: G. Halliwell and R. Atlas (NOAA/AOML)
Other Collaborators: V. Kourafalou and H.-S Kang (UM/RSMAS)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** Perform Observing System Experiments (OSEs) and Observing System Simulation Experiments (OSSEs) to evaluate existing and new ocean observing systems. 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 is now being expanded to global and work has begun 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. After initial development in the Gulf of Mexico, it has been expanded to, and applied in, a new Atlantic Ocean domain (98ºW to 20ºW, 5ºS to 45ºN). Work to expand to global is now underway.

CIMAS Research Theme:

***Theme 3*:** Sustained Ocean and Coastal Observations (*Primary*)
Theme 1: Climate Research and Impact (*Secondary*)
Theme 2: Tropical Weather (*Tertiary*)
Theme 4: Ocean Modeling (*Quaternary*)

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/QOSAP
NOAA Technical Contact: Robert Atlas

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 validation of the expected realism of quantitative observing system impact assessments. 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. The primary effort over the past year has been to complete OSSEs in the North Atlantic domain under support from the Disaster Relief Act (Sandy Supplemental) and continuing under support from the NOAA Quantitative Observing System Assessment Program (QOSAP). Work also began toward expanding the ocean OSSE system to global to perform both OSEs and OSSEs to evaluate ocean observing systems for climate monitoring and prediction applications.

The first round of OSSE work within the new Atlantic Ocean domain (98ºW to 20ºW, 5ºS to 45ºN) was completed during the previous year. The system Nature Run has been validated for representing the "true"

ocean based on realistic representation of ocean climatology and variability, and these results have been published in Kourafalou et al., 2016 and Androulidakis et al., 2016). Validation of the OSSE system forecast model (FM) and overall system performance, along with initial observing system impact assessments, has been published in two papers by Halliwell et al. in 2017. These two papers demonstrated the positive impact of the existing operational ocean observing system, seasonal underwater glider enhancements to this system, and rapid-response airborne profiler surveys to improving ocean model initialization for coupled hurricane prediction. The first effort to directly evaluate the impact of ocean observations on coupled hurricane intensity prediction was conducted. Ocean fields generated from an OSE comparing an unconstrained run to one that assimilated all existing in-situ ocean observations were both used to initialize the HyCOM-HWRF hurricane prediction model. Results from these two forecasts are summarized in Figure 1. The unconstrained model produced initial ocean conditions that were too cold compared to an observational analysis. Data assimilation essentially eliminated this cold bias, and the resulting predicted intensity was much closer to observed intensity.

The initial effort toward expanding the system to the global ocean involves performing OSEs to quantitatively assess the impact of observing systems on the ability to monitor important indices of seasonal to interannual ocean variability using global ocean analysis systems. Evaluation is based on error reduction with respect to long-term observations of ocean variability indices such as the Atlantic Meridional Overturning Circulation transport and associated meridional heat flux. Initial global experiments to perform OSEs are now underway. A snapshot surface salinity field from the long unconstrained run of the global model is presented in Figure 2. Also shown in that figure is time series of the meridional heat flux associated with the Atlantic Meridional Overturning Circulation, comparing the long unconstrained model run to observed heat flux near 25ºN. Data denial experiments will be performed to quantitatively assess the impact of global ocean observing systems toward monitoring this heat flux and other climate indices.

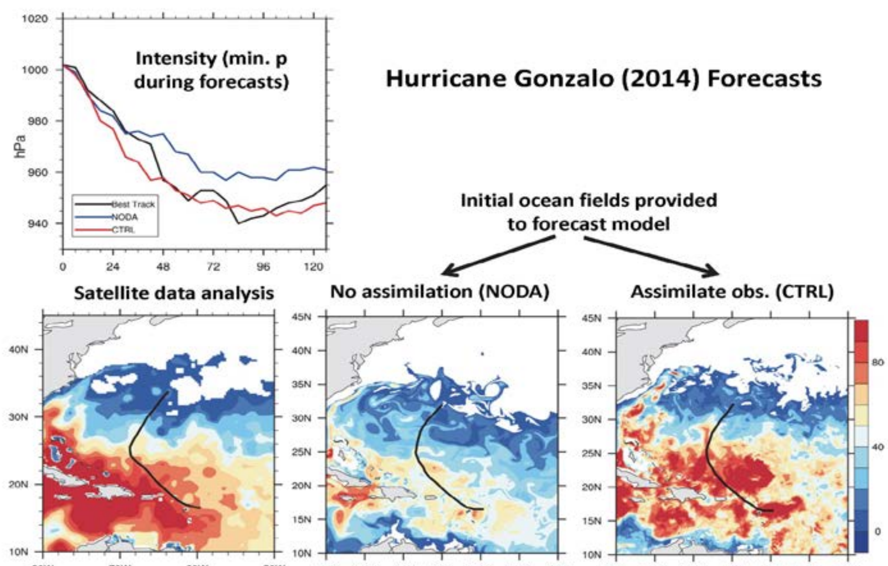

Figure 1: Results from an Observing System Experiment evaluating the impact of ocean observations on Hurricane Gonzalo (2014) intensity forecasts. The lower left panel is a map of Ocean Heat Content (OHC) relative to the 26ºC isotherm analyzed from satellite altimetry and SST observations. The lower middle and right panels map OHC from two HYCOM runs used to initialize a coupled hurricane prediction model for Gonzalo forecasts. The middle lower panel is from an unconstrained HYCOM run while the right lower panel is from a run that assimilates all ocean observations. The upper left panel compares intensity from forecasts initialized by these two cases to the observed best track intensity. Without assimilation, the ocean was too cold and the predicted intensity was too week. Assimilation reduced this cold ocean bias and the resulting intensity forecast was more realistic.

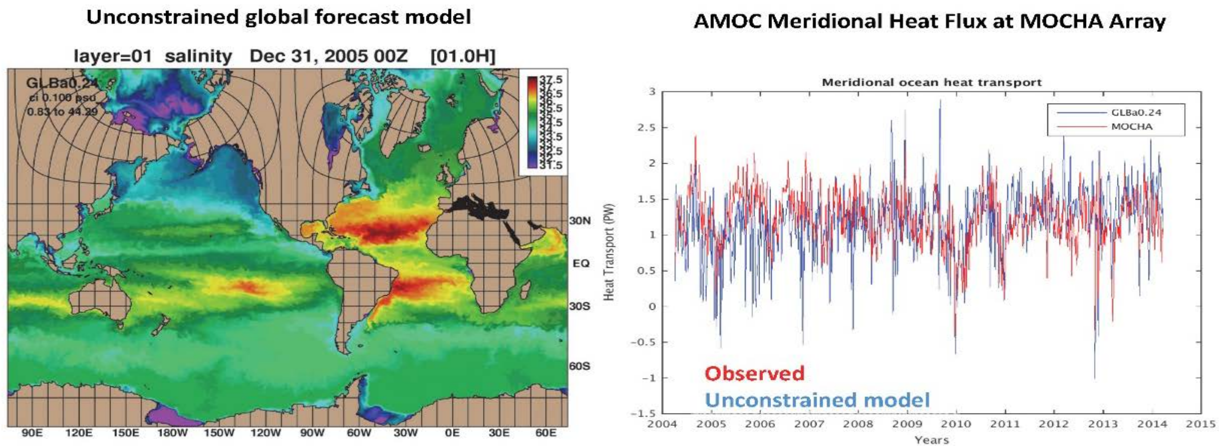

Figure 2: (left panel) Sea Surface Salinity snapshot from a long unconstrained simulation from the new global HYCOM configuration that will be used to perform global OSEs and OSSEs. (right panel) Atlantic Meridional Overturning Circulation meridional heat flux near 25ºN from RAPID-MOCHA observations and from the long unconstrained global ocean simulation.

Research Performance Measure: We have met the fundamental objectives of this project during the previous year. Planned OSSEs conducted in the North Atlantic domain were completed and the results published. This work described OSSEs performed 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 also 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 were run to demonstrate that the operational ocean observing system exerts a significant influence on couple hurricane intensity forecasts of Hurricane Gonzalo (2014). The next phase of OSE-OSSE system development, expansion to global capabilities, is now underway.

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Development of New Drifter Technology for Observing Currents at the Ocean Surface

Project Personnel: S. Morey, N. Wienders, D. Dukhovskoy and M. Bourassa (FSU); S. Dolk (UM/CIMAS)
NOAA Collaborators: R. Lumpkin (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To develop, test and mature an innovative drifter technology for observing currents at the very surface of the ocean, such that the technology is readily available for implementation in observing systems, scientific studies, and practical application.

Strategy: Develop an existing novel idea for implementing an ultra-thin (5 cm or less) flappable satellite tracked surface drifter into a mature technology ready for widespread application, specifically: maturing the electronic and mechanical design such that it is suitable for inexpensive mass production, test the design with large-scale field experiments, use data from the field experiments to evaluate the drifter design and perform scientific studies to highlight the utility of the new measurements.

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/PMEL
NOAA Technical Contact: Chris Sabine

Research Summary:

Immediately upon commencement of this project, two technicians were hired (one a recently discharged Army veteran and the other a recent graduate of the FSU College of Engineering) specializing in mechanical and electrical engineering to assist in completion of the drifter design. During the project, we contracted an outside consultant, Computer Servants, to provide technical guidance related to logic board design and programming. Design of the drifter was conducted in parallel to prototype testing. To date, the final drifter design has been developed, constructed, and laboratory tested to prepare for a field experiment in conjunction with AOML in the upcoming weeks. A field experiment conducted in the Gulf of Mexico deployed proxy prototype drifters using stock components to demonstrate the utility of the ultra-thin drifter in measuring surface currents over standard methods.

In January, 2017, we conducted the first large-scale field test of a proxy design of the ultra-thin drifter in the Gulf of Mexico following the proposed methodology. 30 drifters were constructed with thin-wall PVC hulls 20 cm in diameter and 5cm thick containing two SPOT Trace GPS/satellite transmitters ballasted such that 1 cm was exposed above the water line. The two SPOT Trace devices had custom firmware installed to track/transmit locations every five minutes, and were oriented in opposite directions so that GPS fixes were obtained no matter the orientation of the drifter (to allow flipping by waves). 28 similar drifters were constructed with 10cm heights (again, 1 cm above the water line), each containing one SPOT Trace device (since they were ballasted to be self-righting). In addition, 14 CODE-style (or Davis) drifters with drogue depth between 0.5 and 1.0 meters were also assembled using a SPOT Trace device, and 300 drift cards were released. These instruments were deployed off Orange Beach, AL, a region with surface currents measured by coastal HF radar (Figure 1) and tracked for up to 90 days (Figure 2). Analysis of co-located velocity measurements clearly shows the difference between the currents measured by the different methods. The thin surface drifters recorded velocities that were on average 29% faster than the CODE-style drifters. The 5-cm and 10-cm drifters had similar velocity, except at higher wind speeds were vertical shear became evident. There were substantial differences between the velocity measured by the thin drifters and the HF radar-inferred velocity (which was similar to the CODE drifter velocity). These results were presented in a special session on surface currents organized by the PIs at the 2017 ASLO Aquatic Sciences Meeting, and a manuscript is being prepared to publish the findings.

The final drifter design consists of a high density polyethylene plastic cylindrical hull with similar dimensions as the proxy PVC hulls. The logic board consists of a single GlobalStar STX3 satellite receiver/transmitter connected to dual API Technologies patch antennae and an ATMEGA 328 microcontroller. The microcontroller programming receives the GPS data from the GPS receiver and transmits the position and other data via the upward-facing antenna (determined from an accelerometer). This novel approach greatly reduces the satellite communication costs over using dual transmitters. In preparation for the final large-scale field test in conjunction with the NOAA Surface Velocity Program drifter deployment, we have assembled and tested a set of these drifters and have developed software and a web interface for data processing and dissemination.

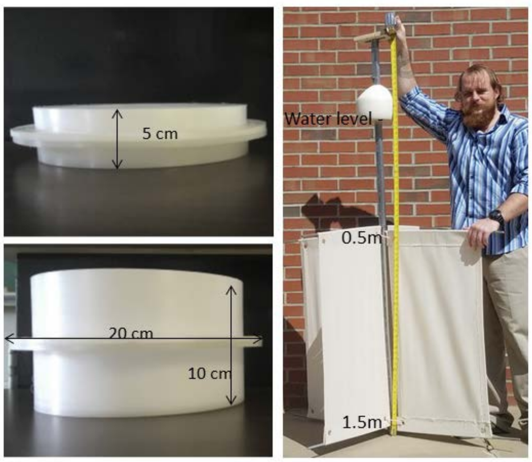

Figure 1: Photographs of the 5-cm, 10-cm and CODE- (Davis) Style surface drifters deployed off Orange Beach, AL, on 24 January 2017.

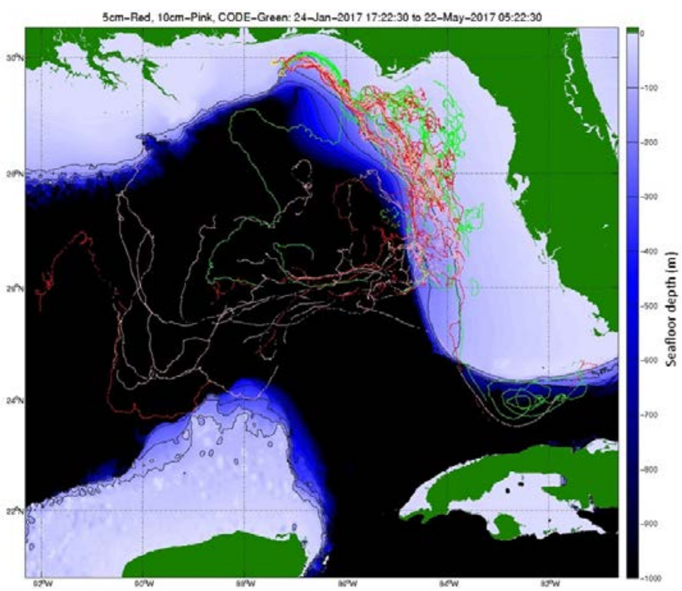

Figure 2: Drifter tracks from the 24 January 2017 Orange Beach, AL deployment. Red tracks indicate 5-cm drifters (4 cm below the water line), pink tracks indicate 10-cm drifters (9 cm below the water line), and the green tracks represent the drogued (CODE- or Davis-style drifters, drogue depths 0.5-1.0m). Yellow triangles indicate deployment locations.

Research Performance Measure: This project is on track to accomplish its overall objective of developing, testing, and maturing a new ultra-thin surface drifter design to where it is ready for widespread use. The project is presently in a no-cost extension period to allow for the final phase of field testing (deployment cruise scheduled for the week of July 17). As evidence of the achievement of the project objectives, the drifter design now has a U.S. patent pending, and the FSU Office of Commercialization has awarded internal funding to co-PI Wienders for transitioning the technology to a commercialized product (https://www.research.fsu.edu/research-offices/oc/technologies/stokes-drifters-very-thin-drifters-to-study-ocean-surface-circulation/). This continuing funding will provide for, among other things, FCC compliance certification, set-up costs for mass production of components, and marketing. Scientific analysis of data from the field tests is ongoing and manuscript submission will likely occur near the end or shortly after the project completion date.

Surface water partial pressure of CO2 (pCO2) measurements from ships

Project Personnel: D. Pierrot, K. Sullivan and L. Barbero (UM/CIMAS); F. Millero and R. 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 (Primary)*
Goal 1: Healthy Oceans – *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems (Secondary)*

NOAA Funding Unit: OOMD/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 project of its kind in the world. The project 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 4 containing over 19 million pCO_2 data points, was released in June 2017 (Fig. 1). Efforts to produce SOCAT version 5 are underway with the annual release in the summer of 2018.

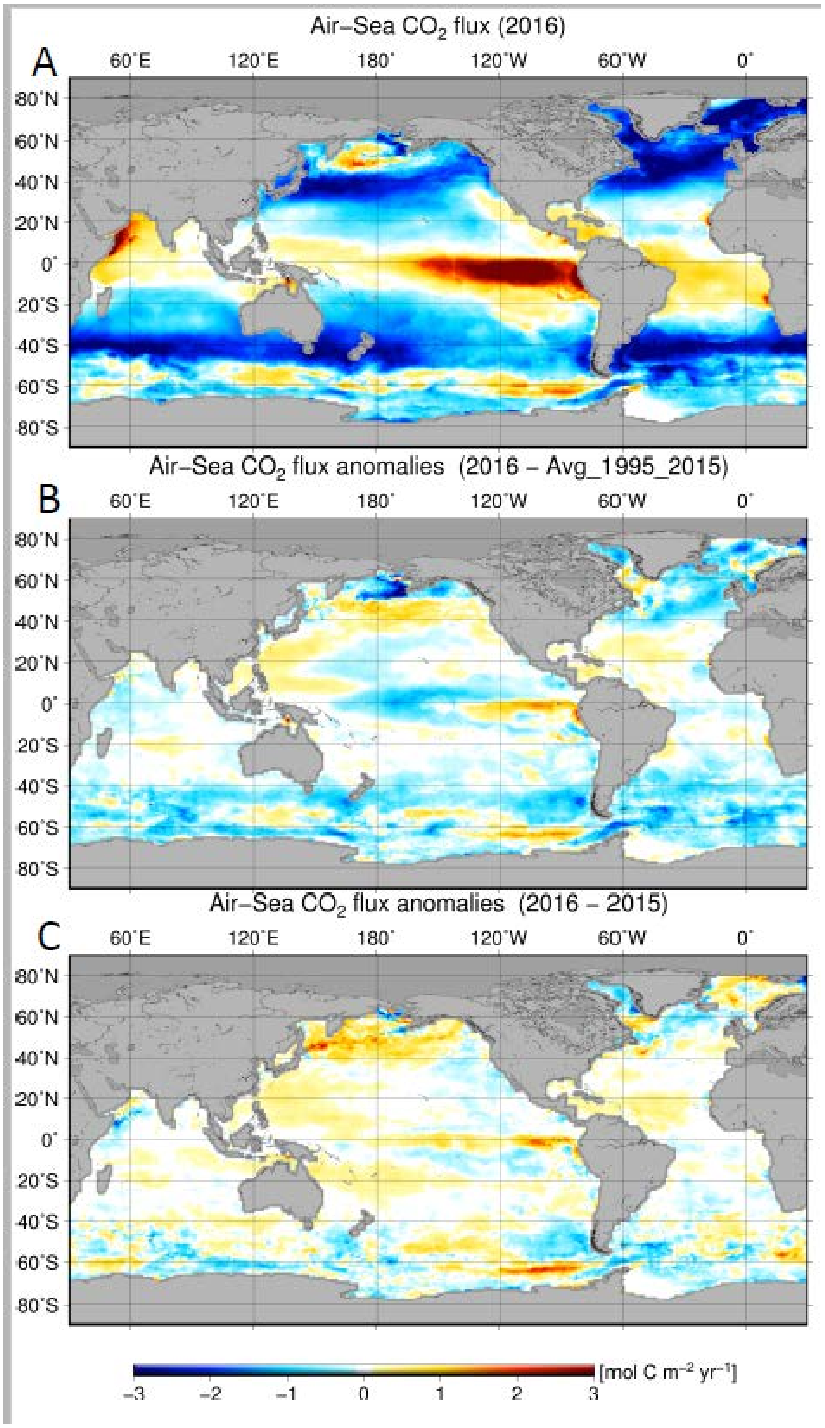

Figure 1: Sea-air CO_2 fluxes (mol C / m^2 y) centered on the year 2016 (A); the climatological average (B); and difference (C) computed using SOOP pCO_2 measurements and interpolated CCMP winds.

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*, *Henry Bigelow* and *Gordon Gunter*, cruise ships *Equinox* and *Allure of the Seas* and 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.

Frank J. Millero and R.J. Woosley, University of Miami/Rosenstiel School of Marine and Atmospheric Science (UM/RSMAS)

As part of this project, an underway pCO_2 system was maintained onboard the University of Miami vessel R/V *Walton Smith*. The ship collected near real-time data in the areas around the Florida Bay, Caribbean, and Gulf of Mexico. The primary goal was to improve understanding of CO_2 gas exchange with the atmosphere in the coastal waters of the southern United States, the Gulf of Mexico and the Caribbean.

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

About 10 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 2.5 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 0.6 Pg C/yr. This is counteracted by the two major sinks located over colder ocean regions: a 1 Pg C/yr sink each centered around 40ºS in the southern hemisphere and

around 40ºN in the northern hemisphere. The Arctic and Antarctic Ocean take up about 0.3 Pg C/yr each. 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 investigation was to observe and document a long-term change in ocean pCO_2 in different areas. Its seasonal change and interannual variation needed to be characterized. Because of the importance of the high latitude areas as sinks for atmospheric CO_2, the Lamont field program was focused on the measurements of surface water pCO_2 in the high latitude oceans of both hemispheres including the Southern Ocean and the Arctic Ocean. Approximately 10 million pCO_2 measurements were made and to date have been assembled and archived at the National Center for Environmental Information (NCEI) for public access (Takahashi et al., 2016). Our data, accumulated since 1957, has contributed to achieving a reliable estimate for multi-decadal mean rate of change in the oceanic CO_2 sink flux (e.g. Landschützer et al., 2015; Le Quéré et al., 2016; Yasunaka et al., 2016). The results were also used to test and validate Ocean General Circulation models (OGCM) coupled with biogeochemistry models for the future prognosis for atmospheric CO_2 levels.

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

As part of this project, two pCO_2 systems have been maintained onboard the Bermuda Institute of Ocean Sciences (BIOS) vessel R/V *Atlantic Explorer* and the Merchant ship M/V *Oleander*. The ship collected near real-time data in the areas of the Sargasso Sea, across the North Atlantic from the eastern seaboard to Bermuda and the region between Bermuda and Puerto Rico. The primary goal was to improve understanding of CO_2 variability and gas exchange with the atmosphere in the coastal waters of the eastern United States, the Gulf Stream and the subtropical gyre of the North Atlantic Ocean.

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

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

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

Long Term Research Objectives and Strategy to Achieve Them:

Objectives**:** 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: Ocean Acidification Program (OAP)
NOAA Technical Contact: Libby Jewett

Research Summary:

This effort implements the North Atlantic Ocean, East and Gulf Coast Ocean Acidification (OA) observing system in response to the requirements of the Federal Ocean Acidification Research and Monitoring (FOARAM) Act. The observing system 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 Gulf of Mexico Ecosystem and Carbon Cruise (GOMECC-3) cruise on the *NOAA ship Ronald H. Brown* with surface and subsurface measurements to develop process level understanding of the controls on ocean acidification.
- The continued development of the observing system.

The development component includes analysis of 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 has been submitted to data repositories and made publicly available.

During the performance period the first ECOA (East Coast Ocean Acidification) cruise along the East coast of the US took place (Figure 1).

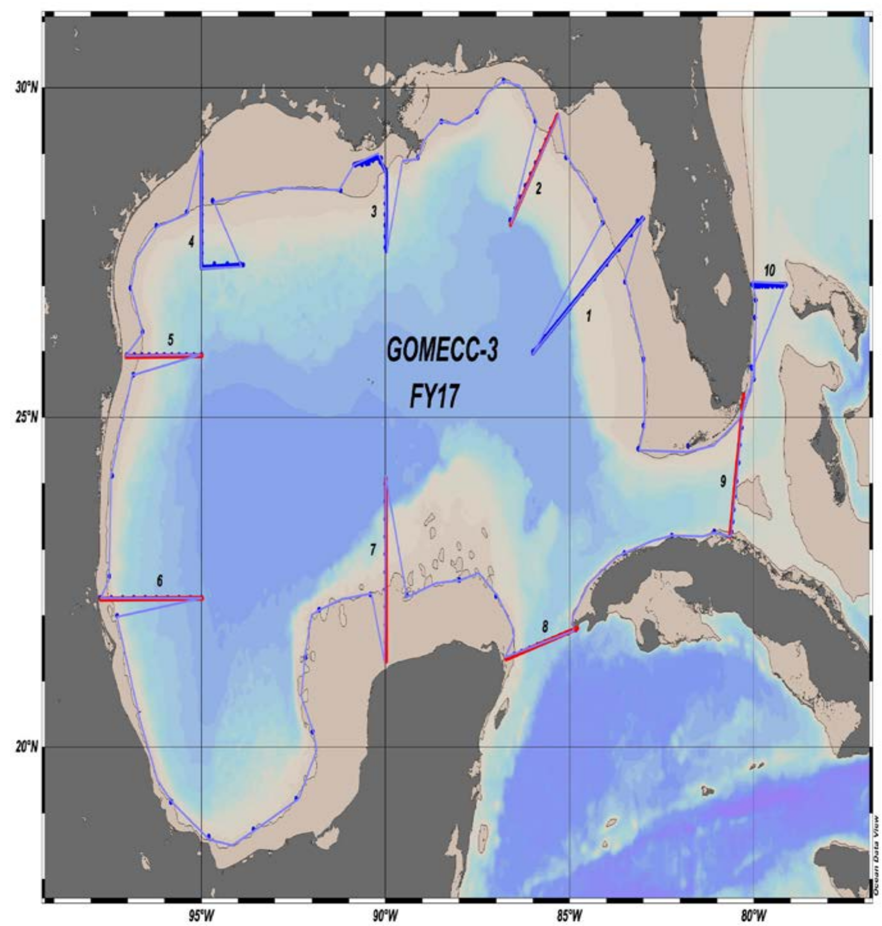

Figure 1: Map of the stations occupied during the GOMECC-3 cruise in 2017.

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 is possible by the large increase of observational data that has been obtained from the ship of opportunity programs run by our group.

Research Performance Measure: Provide quality-controlled data that is used to determine patterns and rates of OA in the realm. The data from the cruises has been submitted on time to the NCEI and were released to the public in 2017.

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Ocean technology development: bottom drifter development

Project Personnel: K. Speer, L. Schulze and C. Hancock (FSU)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** Development and testing of an observation platform designed to measure various physical and biochemical parameters in the near bottom environment of the ocean. Investigate the interaction between the large-scale circulation on the shelf, bottom flow and environment, and how events such as eddies and wind influence circulation and upwelling on the shelf. Observe and understand turbulence and the mechanisms that control vertical and lateral mixing.

Strategy: Development of a lagrangian observation platform capable of regulating its depth and investigating near bottom environments. The platform is equipped with high resolution ADCP's capable of capturing velocities and turbulence down to a scale of 10 cm. In addition other sensors will help to relate the observed flow and mixing characteristics to large-scale circulation and forcing mechanisms. We are targeting two deployments sites, both in the Gulf of Mexico. The first will be a 24 hour deployment in the Apalachicola Bay where we will investigate sheer across a river plume over several tidal cycles and various wind conditions as well as the impact topography might have on changing the plume. The second will target the benthic boundary layer as well as the pycnocline on the outer shelf on the rim of the De Soto Canyon. We will determine turbulent flux parameters as well as bulk/thermodynamic fluxes over a period of six days.

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 (Primary)*

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

NOAA Funding Unit: NOAA/PMEL
NOAA Technical Contact: Chris Sabine

Research Summary:

Code to control the drifter and all incorporated instruments was tested and refined during several untethered deployments in the open water of St Joe's Bay and St George Sound. The emergency procedures that were implemented as well as the emergency drop weight release worked well. Different mission scenarios were tested during several 24 hour deployments. The returned velocity and CTD data that showed the tidal cycle as well as velocity shear, the same data that will be collected during the

science deployments on the shelf. In addition bottom tracked data during surface drifts has shown that the trajectories calculated from the acoustic tracking device agree well with trajectories obtained from GPS. Matlab code to quickly read and edit the instrument output data of the CTD, ADCP and buoyancy engine has been developed. The drifters ability to track changing bottom topography was tested and is working well. (See Figure 1 for a picture of the drifter during an untethered deployment and Figure 2 for an example of the bottom tracking abilities of the platform).

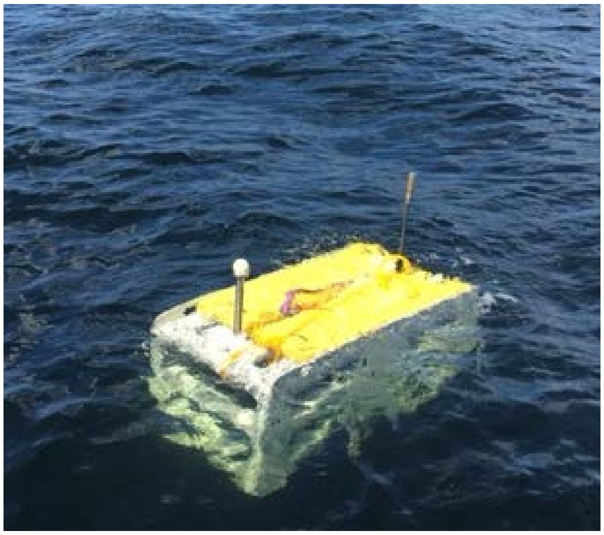

Figure 1: The platform during an untethered deployment in St. George Sound in May 2017.

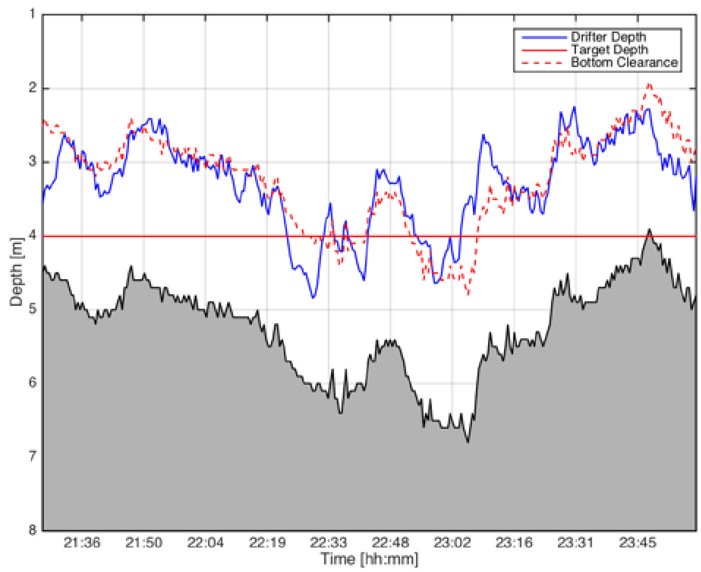

Figure 2: An example of the platforms ability to track changing topography. The red solid line shows the target depth of this dive, and the red broken line shows the 2 m bottom clearance in case of topography. The blue line indicates the actual dive depth if the platform.

Research Performance Measure: The first objective of the original proposal was the instrumentation and sensor tests. Such tests are vital in order to detect and address possible issues that otherwise could lead to a loss of the instrument during a real deployment. The tests conducted in controlled environment such as the workshop and pool revealed a range of problems with the buoyancy engine. After addressing these problems with the engineers further tests in a local Bay helped develop and test emergency bailout procedures as well as different mission commands. Some delays occurred here due to problems with the code and drop weight. A test at the shelf break, hence in deeper water, was planned for mid-May but had to be postponed. It will be carried out at the beginning of August and is the last in the testing phase of the platforms.

SEFCRI – Fishery – Independent Assessment

Project Personnel: R. Spieler, K. Kilfoyle and B. Walker (NOVA)
NOAA Collaborators: K. Gregg (ERT)
Other Collaborators: S. Smith and J. Blondeau (UM/CIMAS)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives**:** The goal of the FIA is to provide continued implementation of a statistically robust, habitat-based, tiered protocol to assess coral reef fish populations in the southeast Florida coral reef segment. This project not only expands upon the previous Reef Visual Census (RVC) work done in the SEFCRI region (Kilfoyle et al., 2015), but also ongoing work in Biscayne National Park, the Florida Keys National Marine Sanctuary, and Dry Tortugas National Park to include fishery-independent data collection along the entire Florida coral reef tract. By using equivalent methods, the FIA and RVC will provide statistically comparable data for reef fish along the entire Florida Reef Tract (Dry Tortugas to St. Lucie Inlet). The FIA will inform the current state-led Local Action Strategy (LAS) efforts which are implementing conservation and management actions on coral reefs within state waters off southeast Florida.

Strategy: The FIA project contains 4 primary tasks: 1) project planning and update of sampling design, 2) fieldwork, 3) data analysis, and 4) report writing. 1) SEFCRI partner agencies have hired and trained NSU personnel to conduct the fishery-independent assessment of the southeast Florida region and refine subsequent sampling designs using the previous four years' worth of data; 2) NSU will conduct field sampling using the RVC protocol (Brandt et al. 2009) at sites identified with the statistical methods used in the previous FIA designs (Smith et al. 2011). 3) NSU will perform an analysis of the data collected to provide statistically robust trends of reef fish composition, occurrence, density, size structure, and distribution within each mapped habitat and for the entire region. 4) NSU will provide the raw data and analyses from FY 2016 for inclusion within a final report on the combined five year (FY 2012 through FY 2016) project dataset.

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

NOAA Funding Unit: NOAA/NOS/CRCP
NOAA Technical Contact: Dana Wusinich-Mendez

Research Summary:

From August through early November 2016 NSU conducted visual surveys of coral reef fish abundance and species richness during the course of 468 individual dives at 117 sampling stations. [Note: Prior to August, RVC sampling by NSU in the SEFCRI region was funded by FDEP-CRCP; during May and June 2016, an additional 70 sites were surveyed over the course

of 280 dives] A further 392 survey dives at 98 sampling stations were completed by partner agencies [Florida Fish and Wildlife Conservation Commission (FWC) – Tequesta Laboratory, Florida Department of Environmental Protection-Coral Reef Conservation Program (FDEP-CRCP), Miami-Dade County - Department of Environmental Resources Management (DERM), Broward County – Natural Resources Planning and Management Division (NRPMD)], with methodology training, logistical coordination assistance, and data collection oversight provided by NSU (with assistance from NOAA-SEFSC support staff). FWC sampled all sites in the far northern portion of the survey domain north of Jupiter Inlet (i.e., Martin County), Broward County (NRPMD) sampled a small selection of sites near Port Everglades in Broward County, FDEP-CRCP and Miami-Dade County (DERM) both collected the majority of the sites in the far southern portion of the survey domain south of Haulover Inlet. NSU sampled all remaining sites from Jupiter Inlet to Government Cut.

In December 2016, all data entry was completed and proofed for errors by each individual survey diver. This was immediately followed by a rigorous quality assurance/quality control procedure with assistance from NOAA-SEFSC support staff. Following that, in early 2017, the process of creating an analysis-ready dataset was initiated. The analysis-ready dataset was completed in the spring, and the final 5-year summary report is on track for submission at the end of July. With all five years of data combined, 1,238,951 individual fishes were counted, representing 305 species domain-wide. Multivariate analyses showed patterns in reef fish assemblages associated with the reef fish assemblage strata, particularly among shallow and deep sites (Figure 1). Most of the exploited species evaluated here indicated a cosmopolitan but unequal distribution across all strata. Among the eight target species, with all years and strata combined, White Grunt (*Haemulon plumierii*) and Gray Triggerfish (*Balistes capriscus*) exhibited the highest densities. Yellowtail Snapper (*Ocyurus chrysurus*), Bluestriped Grunt (*H. sciurus*), and Gray Snapper (*Lutjanus griseus*) were ranked in the middle, while Hogfish (*Lachnolaimus maximus*), Mutton Snapper (*L. analis*), and Red Grouper (*Epinephelus morio*) exhibited the lowest densities (Figure 2). When the data for each species are divided into separate pre-exploited and exploited phases, it is clear that for many of these species (*B. capriscus*, *E. morio*, *L. maximus*, *L. analis*, *L. griseus*, and *O. chrysurus*) the pre-exploited phase is largely responsible for driving the observed trends in mean density. For example, the length frequency curve for Red Grouper (Figure 3) revealed that only 8.4% of the observed population qualified as exploited phase.

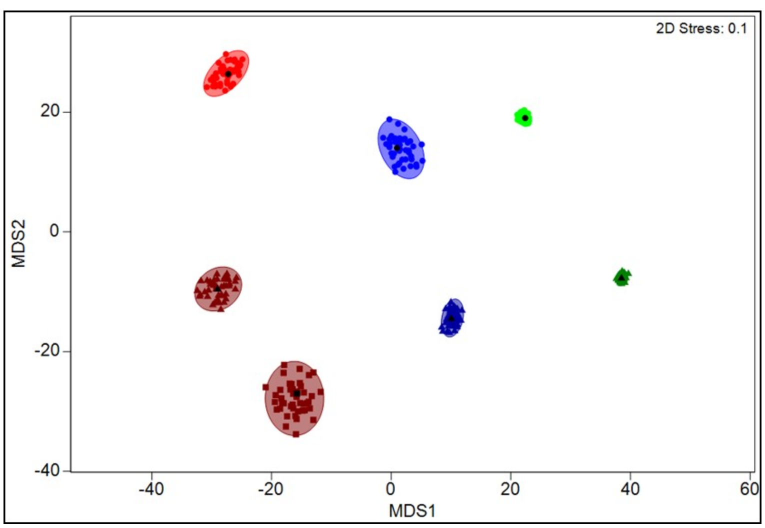

Figure 1: Plot of forty-three bootstrap means of the Reef Fish Assemblage Regions using all site data (2012 – 2016). "S" indicates Shallow (≤ 10 m) and "D" indicates Deep (> 10 m) Assemblage Regions. Shallow sites are denoted by solid circles and the Deep sites are solid triangles. Solid square is Deep Low Relief. Point cloud indicates 95% about the mean. Point cloud separation indicates distinct categories.

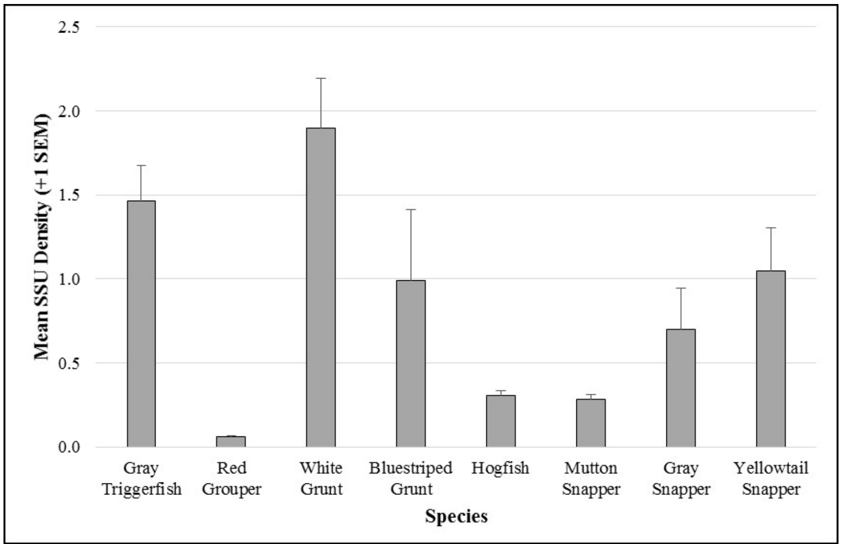

Figure 2: Mean SSU density for exploited species, with all years and strata combined.

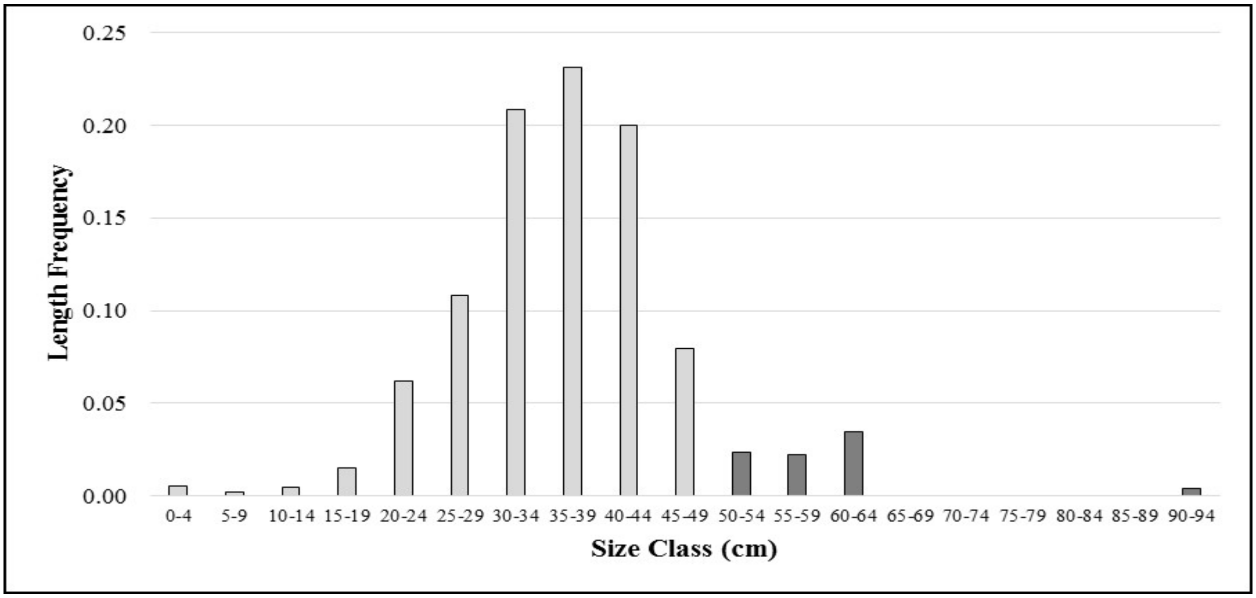

Figure 3: Domain-wide length frequency of Red Grouper (*Epinephelus morio*) by size class, with all years and strata combined. Darker gray indicates exploited size classes; minimum legal size of harvest for this species is 50 cm TL (20" state and federal waters).

Research Performance Measure: The sample allocation was based on NSU completing surveys at 180-200 out of an estimated total of 290 sites likely to be surveyed throughout the entire SEFCRI survey domain by the combined efforts of NSU and the other partner agencies that contributed with pro-bono support. NSU completed surveys at 187 out of a total of 285 sites that were surveyed by all parties (65%). All field related and QAQC milestones were met and objectives completed, and the reporting objective is on-track for on-time completion as outlined in the project timeline.

Marine Optical Buoy (MOBY) Operations and Technology Refresh

Project Personnel: K. Voss (UM/RSMAS); M. Yarbrough (SJSU/Moss Landing Marine Lab)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives**:** To provide the most accurate measurement of the water leaving radiance to be used as the primary calibration point for the international community of ocean color satellites, but primarily 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 it's end of life and it was critical that a technology refresh occur. Thus we are building a new optical system for MOBY. This system is being 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 mounted on the MOBY buoy for the August 2016 deployment. The spectrometer is being used along with the heritage optical system for testing. In November 2017 we will be installing a full blue and red system to begin a one-year cross-over experiment with the heritage MOBY optical system.

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 been using the new control system that we developed. In addition we installed the new blue spectrometer on two deployments (in August 2016 and in February 2017). We have been working with this system tracking instrument stability and determining optimal operation characteristics. The first planned deployment of the full refresh optical system is planned for November 2017.

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Estimating effective sample size for head-boat-caught length (weight) distributions and estimate recreational head-boat landings

Project Personnel: Y. Zhang (FIU)
NOAA Collaborators: S. Turner (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** 1) to estimate effective sample size for head-boat-caught length (weight) distributions. 2) To estimate the recreational head-boat landings.

Strategy: 1) to use statistical models to estimate effective sample size. 1) To use computer simulation methods to validate statistical results. 2) To validate captains' reports about trips. 2) To validate captains' reports about landings. 2) To estimate the bias and the uncertainty of the total annual head-boat landings from captains' reported.

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: NMFS/SEFSC
NOAA Technical Contact: Theo Brainerd

Research Summary:

Estimation of length (weight) distributions is critical for fish stock assessment and studying fish growth. An accurate and precise estimation of length (weight) distribution could promote the accuracy and precision of the stock assessment, and consequently the effectiveness of fishery management. The number of samples collected in a survey program is one of the most important decisions in sampling design. An optimal sampling program should not only afford large spatial and temporal resolutions but also minimize the expense of data collection. Therefore, the effective sample size is developed as a trade-off between sampling resolution and cost. The effective sample size is more important than the total sample size, especially in fisheries monitoring, because fish of similar length (weight) tend to shoal and school together and fish sampled in the same location tend to be more similar in age and length structure than the whole population. Consequently, more diverse samples are required for fisheries research.

In this project, the data we used is the headboat landings that are reported by the captains, as well as measures from the observer surveys. The observers were sent by National Marine Fisheries Services (NMFS) to headboats to monitor the recreational fisheries. First, we did some data cleaning. We replaced the incorrect vessel number and areas, excluded abnormal values, and corrected some error records. Second, we used statistical method to derive the effective sample size for the most frequently measured 10 species in the Gulf of Mexico and Atlantic Ocean, respectively. Third, we used simulation methods, randomly selected 50%-100% of trips, and for each trip we randomly measure the length (weight) of 2-10 fish individuals. We repeated this resampling for 100 times, and estimated the distribution of the effective sample size, Kolmogorov-Smirnov test, variation between trips, variation within trips, and their ratio.

The results indicated that in general the effective sample size is in a similar magnitude to the number of trips, and is much smaller than the actual sample sizes, which indicates that an optimal (cost-effective) sampling program can be developed for these species by improving sampling efficiency and maximizing the use of data. Assume the NMFS observer survey as a two-stage survey: first select a number of trips, then randomly measure a group of individuals. The variation among trips is much larger than the variation within each trip. This may be because the fish lengths (weights) measured within a trip do not affect the estimation of the sample mean due to the aggregating behavior of the fish species

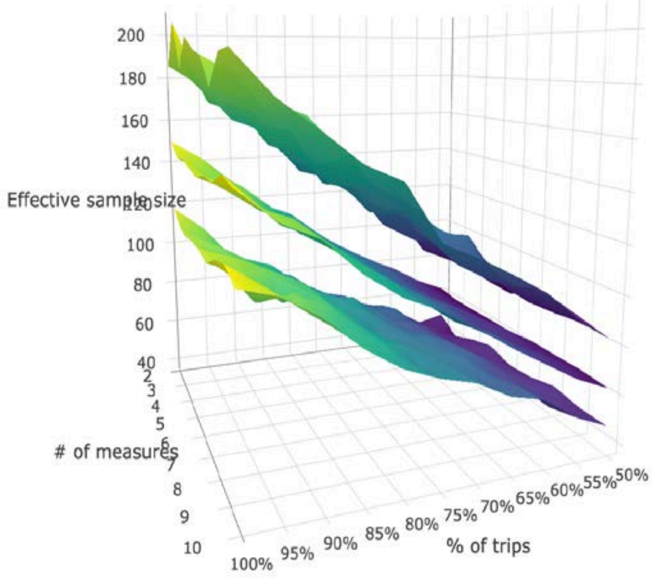
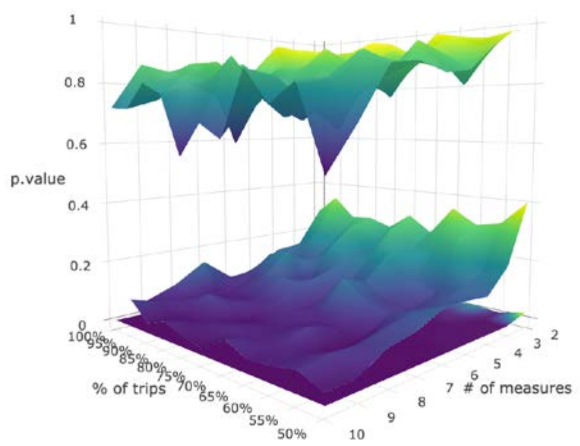


Figure 1: Median, lower 2.5% and upper 97.5% confidence interval of estimated effective sample size for Gulf of Mexico red snapper in 2003 when sub-setting the records from the original survey.



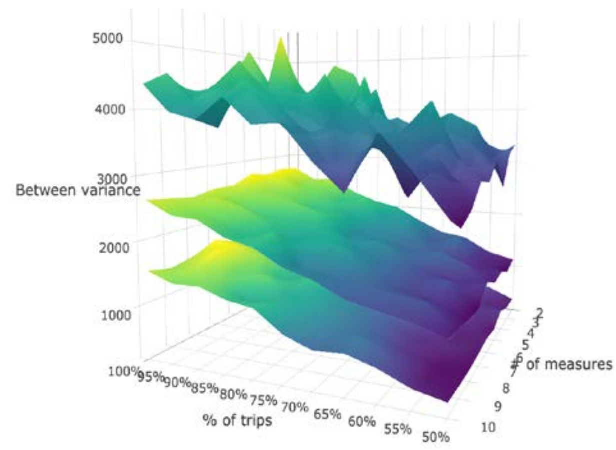


Figure 2: Median, lower 2.5% and upper 97.5% confidence interval of the Kolmogorov-Smirnov test for Gulf of Mexico red snapper in 2003 when comparing subset of the records to the original survey records.

Figure 3: Median, lower 2.5% and upper 97.5% confidence interval of the variation among trips for Gulf of Mexico red snapper in 2003 when sub-setting the records from the original survey.

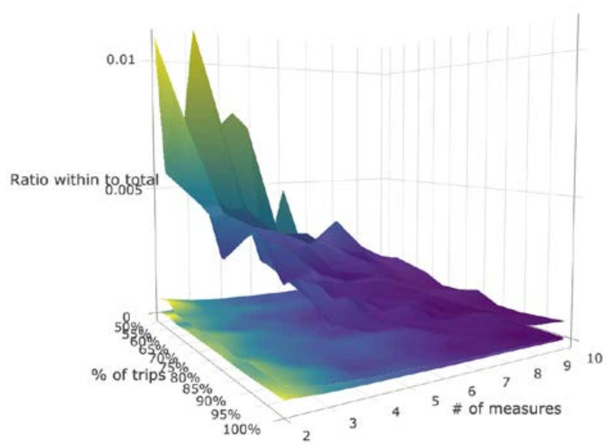


Figure 4: Median, lower 2.5% and upper 97.5% confidence interval of the variation within trips for Gulf of Mexico red snapper in 2003 when sub-setting the records from the original survey.

Research Performance Measure: Objective 1 has been met. This project is on schedule. Objective

Using time series and empirical dynamic models to forecast the fishing prohibition date

Project Personnel: Y. Zhang (FIU)
NOAA Collaborators: S. Turner (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To help the fisheries managers determine the fishing prohibition date earlier (e.g. 3 weeks in advance) and more effectively.

Strategy: 1) to use time series and empirical dynamic models to find relationship to project the prohibition date. 2) To use computer simulation methods to validate statistical results.

CIMAS Research Theme:

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

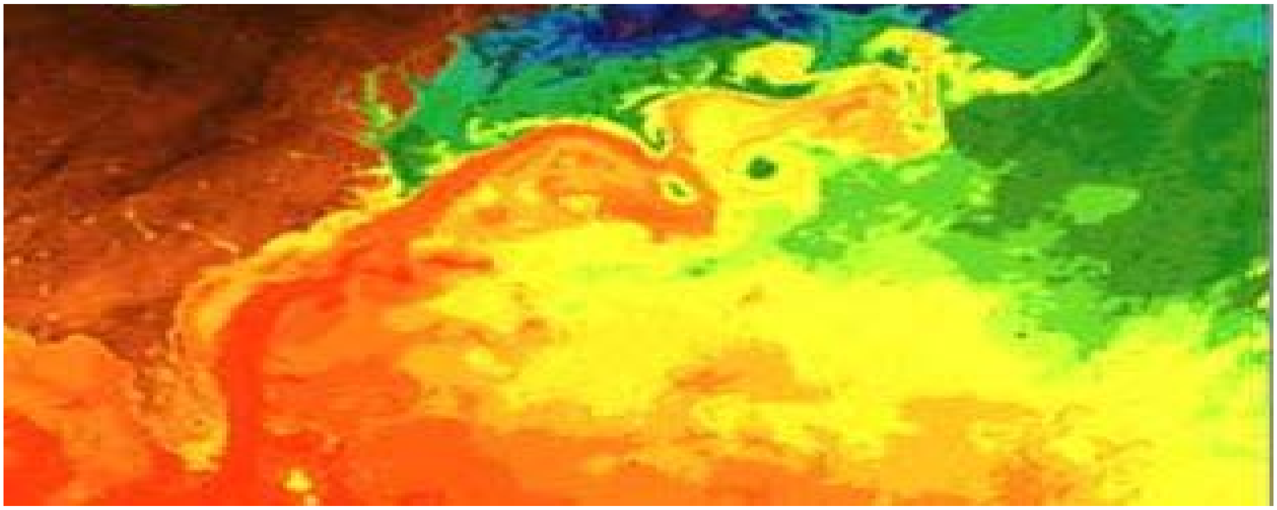
Link to NOAA Strategic Goals:

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

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

Research Summary:

The PI hadn't received any dataset from NOAA before June 30th, 2017. The PI and the NOAA collaborator determined to extend this project for one more year with no cost.



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. 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 overall goal of this project is to address two fundamental questions regarding to the variability and predictability of the Atlantic meridional overturning circulation (AMOC) in the South Atlantic: a) to what extent is the AMOC variability coherent throughout the whole Atlantic, and b) whether the variability of

the Agulhas leakage is directly connected to the AMOC variability at 34.5°S. These questions are to be addressed by performing detailed model-data syntheses/comparison study using the observations near 34.5°S and global eddying simulations with the hybrid coordinate ocean model (HYCOM).

In year 1, we focused on establishing a baseline evaluation of the existing eddying 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. However, the model results exhibit an unrealistic recirculation pattern near 30°S. So the near-term goal becomes to understand its cause and to improve the model representations.

In year 2, we identified that the unrealistic recirculation pattern is due to parameterization of thermobaricity in model and developed model improvement. For the later part of year 2 and in year 3, we focused on performing a long-term integration of the eddying simulation with the DRAKKAR forcing set (DFS5.2) that covers 1958-2015. The simulation is integrated for 43 years (1958-2000). The issue of unrealistic recirculation in the south Atlantic is removed (see Figure 1). Further evaluations will be performed to fully compare with the existing simulation and the observations in the detailed circulation in the South Atlantic Ocean. However, the magnitude of the modeled AMOC in the new simulation is significantly lower (14.6 Sv compared to 19.5 Sv in the earlier simulation, which is close to the observational estimates). We are investigating the reason for the lower AMOC in the new simulation. One likely candidate is the different forcing set. This will be determined by with a separate experiment using the same forcing as the previous simulation.

Separately, we examined the AMOC variability in two large sets of low-resolution simulations, the phase II of the coordinated ocean-ice reference experiments (COREII) and the phased 5 of the climate model inter-comparison project (CMIP5). We found that the AMOC in these forced and coupled simulations exhibit a similar magnitude and meridional coherence on the interannual to decadal time scales. On longer term, multi-decadal time scale, however, the AMOC variability is much stronger (by a factor of 2) and meridionally more coherent in the forced COREII than the coupled CMIP5 simulations (Figure 2). This highlights the fundamental difference between the two sets of the simulations, in particular, the coupled simulations exhibit no linkage between the AMOC variability and the atmospheric pattern in the North Atlantic Oscillation (NAO). We are in the process of submitting a manuscript on these findings.

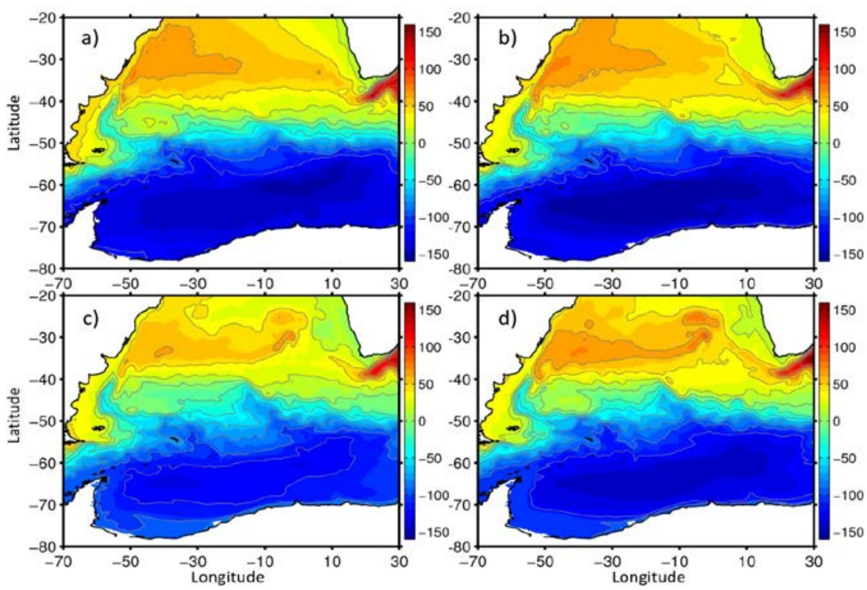


Figure 1: Comparison of long-term mean sea surface height (SSH) based on a) AVISO 1993-2012, b) new 1/12 HYCOM simulation (1991-1999), and c-d) to previous 1/12 HYCOM simulations (2003-2012) that both exhibit unrealistic recirculation pattern near 30S.

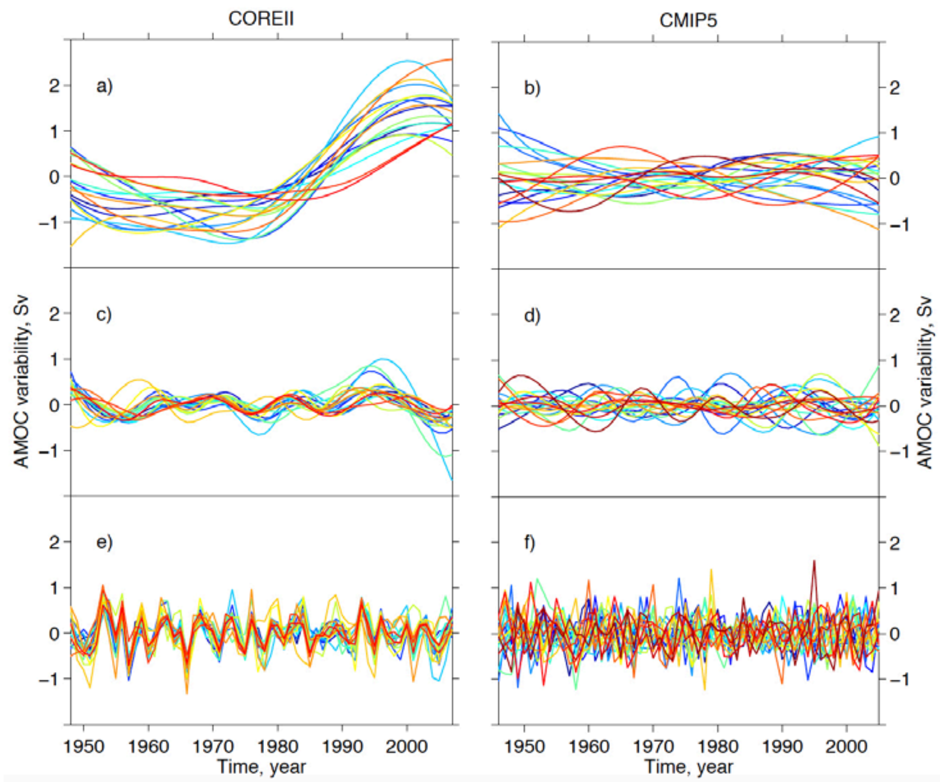


Figure 2: Comparison of AMOC variability (averaged over the Atlantic domain 30S-60N) between the forced COREII and coupled CMIP5 simulations on (a-b) multi-decadal, (c-d) decadal, and (e-f) interanual time scales.

Research Performance Measure: We met our original near-term objective of establishing an overall evaluation of existing 1/12° eddy-resolving global HYCOM simulation in representing the southern Atlantic Ocean circulation and address the cause for the unrealistic model results. The integration of new long-term simulation is slower than expected, and we are still working on it. The new simulation will be used, along with observations, to address the scientific questions with more confidence.

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).

The HYCOM hydrodynamic model has been coupled with the Carbon, Silicate, Nitrogen Ecosystem (CoSiNE) model. This configuration is henceforth referred to as HYCOM-COSINE. This work has been mainly carried out by NRL (UM sub-contract), in collaboration with RSMAS and AOML. Biophysical model results and relevant satellite imagery are being archived for analysis and synthesis. The tuning of

biological parameters is constantly undergoing improvements. Work in the last year focused on advancing model to data comparisons, addressing specific processes that impact the transport and fate of river-borne nutrients in the GoM. An example is shown in Figure 1, where the model chlorophyll (left column) is compared to the MODIS-Aqua satellite-derived chlorophyll (right column). The model distributions are daily means and the MODIS-Aqua are 8-day composites. All figures are overlaid with the model surface currents to aid in the assessment of the relationships of chlorophyll with ocean physical circulation. The figure shows a series of comparisons in August 2015 (8/15, 8/21, 8/23) when the Gulf of Mexico exhibited a large anti-cyclonic Loop Current intrusion extending northward into the Mississippi Bight region and inducing a Mississippi River plume filament extending far towards the Florida Keys. The circulation is clearly seen in the imagery, and the biological response is evident in both model and the satellite imagery, as an interaction of the Mississippi plume and the Loop Current. The comparisons are satisfactory and further tuning of biological parameters is being tested to improve the coupled model. An ancillary project under the RESTORE act is already implementing the coupled model toward a biophysical Observing System Simulation Experiment (OSSE) structure, 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).

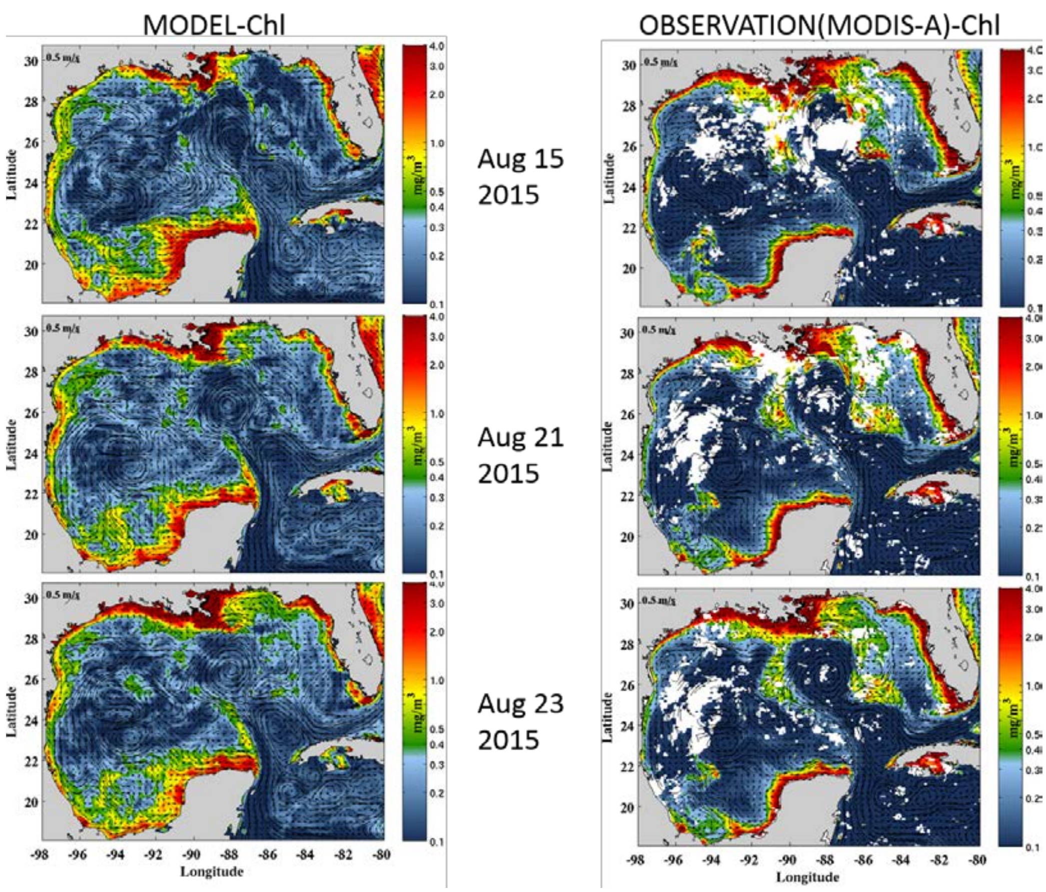


Figure 1: Daily-averaged chlorophyll from the coupled HYCOM-CoSiNE simulation (left column) compared to 8-day composites of satellite derived chlorophyll from MODIS-Aqua (right column). Model surface currents are overlaid on all figures.

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 and have been providing near real time forecasts over the Gulf of Mexico (at $1/50^0$, ~1.8 km resolution) and the Straits of Florida (at $1/100^0$, ~ 900m resolution), including all shelf and coastal areas around South Florida, the Florida Keys, northern Cuba and the western Bahamas. Maps for Sea Surface Height (SSH), Sea Surface Temperature (SST), temperature at 50m and surface currents are being publicly displayed. An example is given in Figure 1, where the Gulf of Mexico forecast model is initialized on 12 July 2017 and then provides up to 7 days of forecasts (the 7^{th} day, 19 July 2016, is displayed). The example fields are 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 and also temperature are displayed on accompanying web pages, see link under "Outreach"). The initial GoM state was dominated by an extended phase for the Loop Current (LC) with indication of a tendency to form a closed anticyclonic cell at the LC top, which happens at the onset of LC Eddy (LCE) formation. The LCE formation and eventual detachment/separation process is very important for Gulf of Mexico dynamics, as it is followed by a dramatic change in LC extension, influencing the broader biophysical connectivity. However, conditions were forecasted to change within a week and the LC would resume a fully extended

phase, turning anticyclonically without a closed cell. Such scenarios are common and their prediction is important for understanding and monitoring the connectivity of remote Gulf ecosystems.

The activities described above 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. Progress is reported in Halliwell et al. (2017).

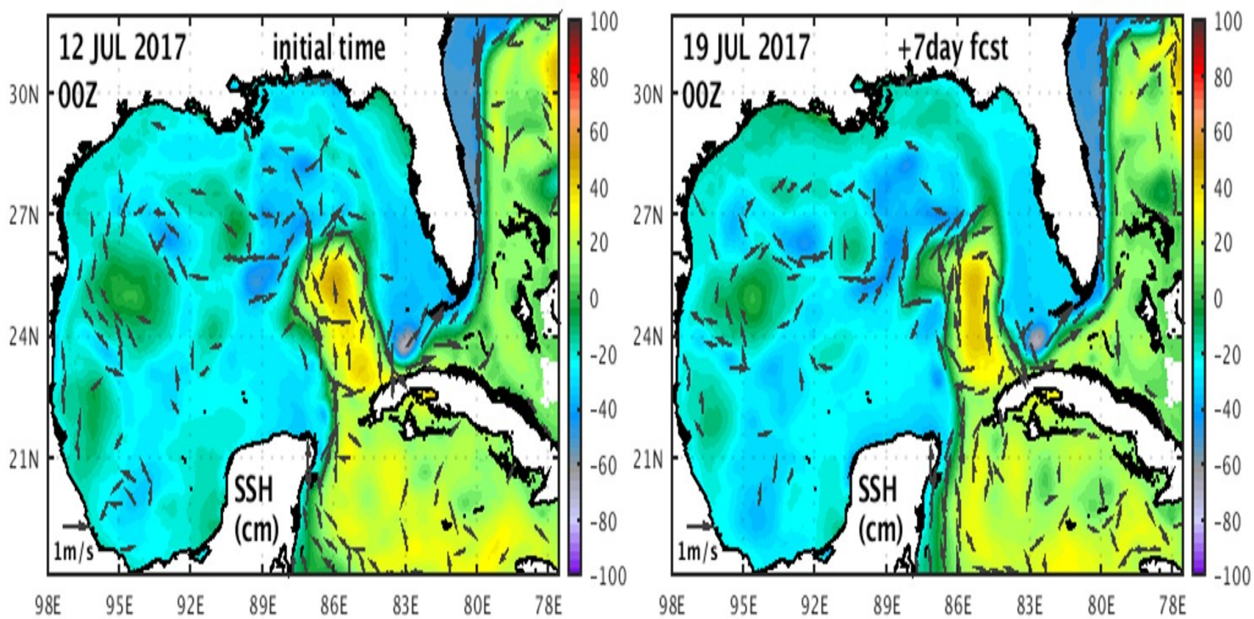
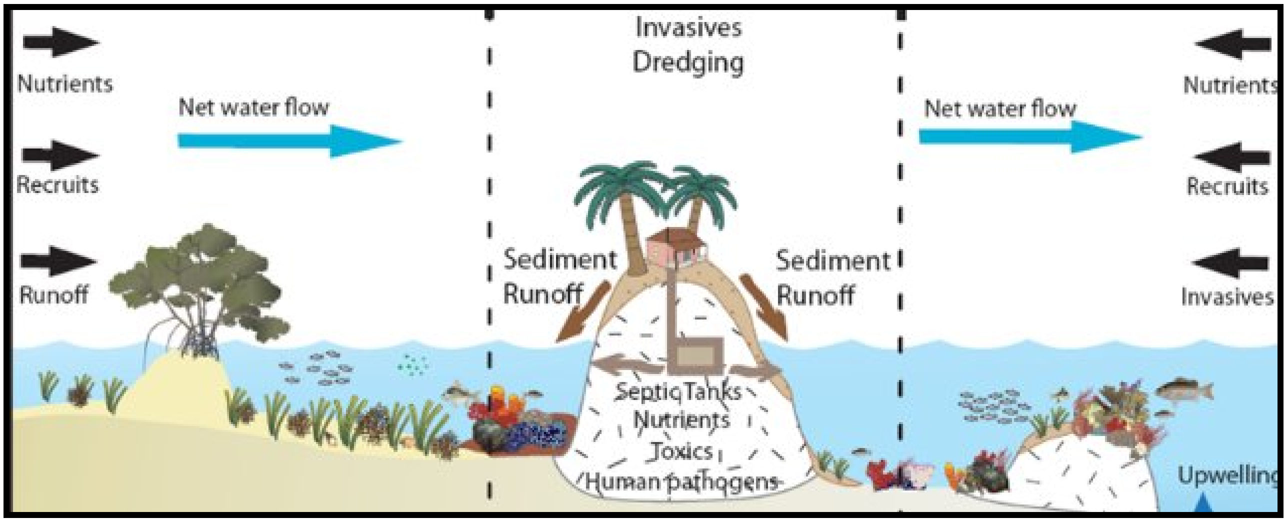


Figure 1: Sea Surface Height and near surface currents (only a few vectors are plotted for clarity) from the GoM-HYCOM forecast modeling system. Example is for the initial and 7th-day forecast, starting from 12 July, 2017.

Research Performance Measure: All major objectives have been met.



RESEARCH REPORTS

THEME 5: Ecosystem Modeling and Forecasting

SEFSC Southeast Atlantic and Caribbean Coral Reef Ecosystem Monitoring and Assessment

Project Personnel: J. Ault (UM/RSMAS)
NOAA Collaborators: J. Bohnsack (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To develop and implement quantitative methods for robust evaluation of status and trends of coral reef fish populations and communities in the Florida Keys, South Atlantic and Caribbean coral reef ecosystems. To determine the efficacy of "no-take" marine reserves in the Florida Keys National Marine Sanctuary (FKNMS -- Sanctuary Preservation Areas SPAS; Tortugas Ecological Reserves TERs) and Dry Tortugas National Park (DTNP -- Research Natural Area RNA) to sustain regional exploited reef fish populations. To transfer the methodological approaches developed here to other jurisdictions in the Southeast Atlantic and U.S. Caribbean.

***Strategy*:** To design and conduct statistically rigorous regional multispecies reef fish assessments, map coral reef habitats and spatially-based monitoring of coral reef fish composition, occurrence, abundance, and size structure on the Florida Keys reef tract (e.g., Smith et al. 2011a,b; Ruttenberg et al. 2012; Glynn et al. 2012; Ault et al. 2013; Nadon et al. 2015; Bryan et al. 2016; Harford et al. 2016). Use strategic applications of probabilistic sampling design theory and acoustic telemetry methods (e.g., Farmer and Ault 2011, 2014, 2017; Ault et al. 2013; Farmer et al. 2014; Lirman et al. 2014) to obtain key spatial population size-structured abundance and movements data to assess population changes, ontogenetic habitat associations, and ecosystem responses to fishing, recreational use, pollution, MPA zoning, and the Comprehensive Everglades Restoration Program.

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

Link to NOAA Strategic Goals:

Goal 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:

Commercial and recreational fisheries target hundreds of fish and shellfish species across the seascape of southern Florida including inshore coastal bays, the flats of barrier islands, coral reefs and offshore pelagic waters. The ecological dynamics and economic sustainability of these valuable fishery resources are key conservation concerns. Overfishing, habitat degradation and prey reduction are the principal threats to sustainability of coral reef and coastal fisheries in Florida. This research emphasizes assessing the effectiveness and impacts of no-take marine reserves and other resource management measures in Biscayne National Park, the FKNMS, and DTNP towards meeting their marine ecosystem management goals. No-take marine reserves (NTMRs) in the National Marine Sanctuary (FKNMS) and Dry Tortugas National Park of the Florida Keys are a joint fishery and ecosystem management effort between the NOAA National Marine Sanctuary Program, National Park Service (NPS), and the State of Florida. The FKNMS has implemented three types of no-take areas: (1) 16 small Sanctuary Preservation Areas (SPAs) totaling approximately 46 km^2 that protect the high-relief coral reef; (2) one large (30 km^2) ecological reserve (ER) that includes several different habitats; and, (3) 4 special-use SPAs designed for research purposes. Two large Ecological Reserves, 206 and 312 km^2, are were added in 2001 west of the Tortugas, Florida. The NPS Service implemented a 100 km^2 Research Natural Area (RNA) in the western half of Dry Tortugas National Park in January 2007.

We continue to evaluate the performance of the SPAs and TERS in the FKNMS. During the past year we conducted spatially-synoptic sampling of reef fish and coral reef habitats in the Florida Keys, and expanded our survey domain to the SEFCRI region which runs north to Martin County. Although still early in the recovery process, our results for the Dry Tortugas and Florida Keys are encouraging and suggest that NTMRs in conjunction with traditional management measures can potentially help rebuild sustainable fisheries while protecting the Florida coral reef ecosystem. This is a win-win scenario; good for the fish, ecosystem, fishermen, and Florida's economy!

The reef fish visual census (RVC) is a collaborative multiagency reef fish monitoring efforts, conducted annually by a large and highly-skilled a team of research divers from the University of Miami's Rosenstiel School of Marine and Atmospheric Science, NOAA Fisheries Service, Florida Fish and Wildlife Conservation Commission, and the National Park Service (Brandt et al. 2009; Smith et al. 2011a; Bryan et al. 2013, 2016). This highly collaborative team effort measures how the protected areas of the Florida Keys National Marine Sanctuary's Tortugas Ecological Reserve and Dry Tortugas National Park's Research Natural Area are helping the regional ecosystem rebound from decades of overfishing and environmental changes (Ault et al. 2013, 2014). Such unprecedented collaboration allows completion of thousands of scientific dives annually, which greatly helps to further establish a baseline for the state of reef fish stocks and coral reef habitats in Florida's dynamic coral reef ecosystem.

Results of community-level applications of fishing impacts on sustainability of reef-fishes are compared in a "community control rule" format for southern Florida (**Fig. 1**). In this case, "average length" in the exploited phase of the stock was the principal indicator variable used to estimate rates of fishing mortality for the reef fish community. Although these analyses were conducted one species at a time, plotting the results together on a control-rule graph provides a community perspective on sustainability status. It is evident that the majority of species analyzed have experienced unsustainably high rates of fishing

mortality. The results also suggest that the severity of overfishing differed among species, even though nominal fishing effort in each area generally affects the reef-fish complex as a whole. This differential response to exploitation is linked to life history characteristics, with slower-growing, longer-lived species such as groupers being more susceptible to fishing impacts compared to faster-growing, shorter-lived species such as grunts.

By statistically comparing a current year's findings to previous baseline survey information collected, scientists can determine what effects no-take marine reserves are having on the productivity of exploited fisheries in the Tortugas and through the entire coral reef ecosystem. For example, for mutton snapper spatial data we found that the extent of occupancy markedly increased after implementation of the protected areas (between 1999-2000 and 2010-2016). There were significantly more (and larger) fish in the two protected areas, but not in the fished areas where the number of large animals continues to decrease, which has been observed for a broad range of intensively exploited reef fish species.

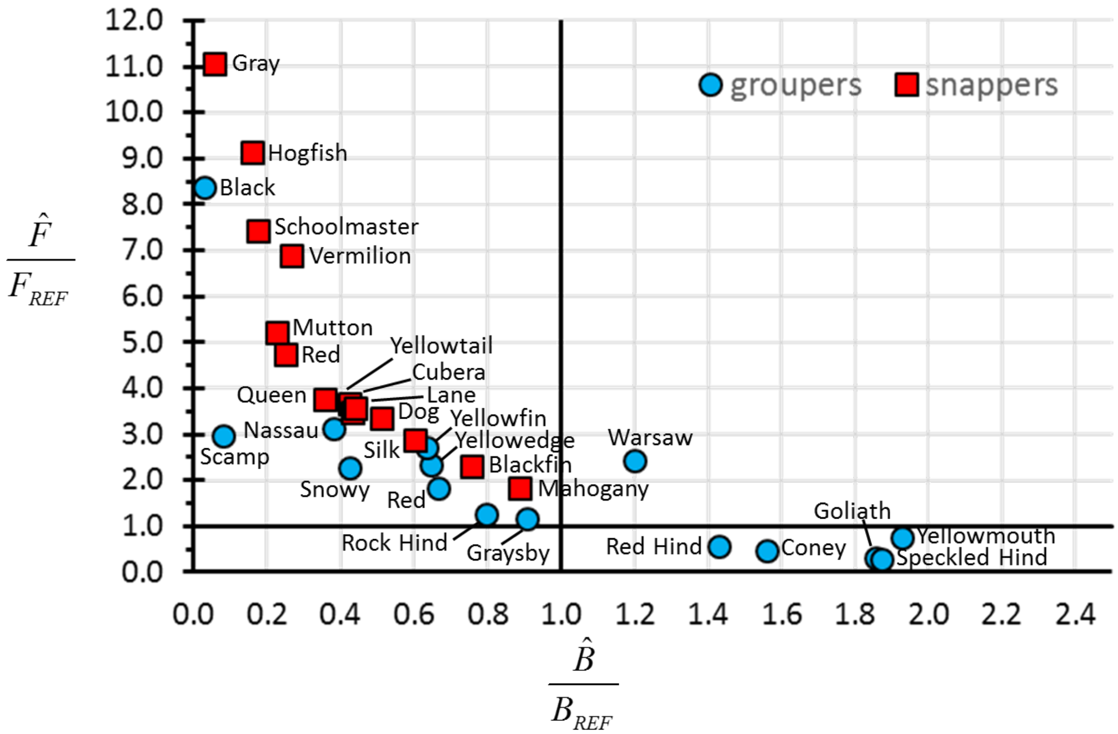


Figure 1: Limit control rule showing estimated spawning stock biomass (x-axis) and fishing mortality rate (y-axis) with respect to resource sustainability reference levels for 35 species of exploited grouper and snapper reef-fishes in southern Florida (Ault et al., 2005b, 2014, 2017; blue circles, groupers; red squares, snappers and wrasses).

Overall, we have been very encouraged to see that exploited stocks have slowly begun to recuperate since the implementation of 'no-take' marine protected areas in the Tortugas region. We noted particular improvements in the numbers of snapper, grouper, and coral recruits. We are currently crunching the data collected to see what adjustments may need to be made in order to help guide future management decisions to address the issues of biodiversity protection, restoration of ecological integrity, and fishery management which are critical to this area.

However, a rather disturbing trend has been the apparent explosion of the exotic invasive Indo-Pacific lionfishes, *Pterois volitans* and *Pterois miles*, venomous members of the scorpionfish family (Scorpaenidae). These species have invaded and spread throughout much of the tropical and subtropical

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

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

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SEFSC Statistical Analysis Support for US Pelagic and Coastal Fisheries in the Gulf of Mexico and Western Atlantic Ocean

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

Long Term Research Objectives and Strategy to Achieve Them:

Objectives: To work with SEFSC staff under the direction of Dr. Stephen Turner to provide statistical analysis support towards improving fishery information systems for the pelagic longline fleet and the Gulf of Mexico vertical line and reef longline fleets.

Strategy: To design and implement statistical sampling for camera auditing of the pelagic longline fleet. To develop a statistical estimation and sampling approach for evaluating the efficacy of Gear Restricted Areas (GRAs) in the Gulf of Mexico and Mid-Atlantic Bight to reduce the bycatch of Atlantic bluefin tuna by the pelagic longline fleet. To review and refine data processing and statistical procedures for accurate estimation of total effort, total landed catch, and total discarded catch by species for the Gulf of Mexico vertical line and reef longline fleets. To evaluate design-based approaches for estimating catch per unit effort (CPUE) as a stock abundance index for principal species using the coastal logbook and coastal observer information systems for the Gulf of Mexico vertical line and reef longline fleets.

CIMAS Research Theme:

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

Link to NOAA Strategic Goals:

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

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

Research Summary:

NOAA's Southeast Fisheries Science Center (SEFSC) conducts extensive and wide-ranging monitoring programs to collect catch, effort, size composition and other vital information for assessing the biological and economic sustainability of US coastal and pelagic fisheries in the Gulf of Mexico and Western Atlantic Ocean, and for evaluating associated impacts on sensitive non-target species. During June 2016 to May 2017, research focused on improving the information systems for the pelagic longline fleet. A sampling plan was designed and implemented for camera auditing of the pelagic longline fleet. In 2015, a camera system was installed on every vessel in the fleet to assess vessel compliance with the reporting of every interaction with bluefin tuna (BFT). Time and budget constraints precluded viewing every longline set of every trip of every vessel to extract data on BFT catch. There was thus a need to develop a sampling strategy to select a subset of the camera data for auditing the BFT catch reported by fishers. Using logbook and observer BFT data for recent years (2011-2015), principles of statistical survey design (Cochran 1977; Lohr 2010; Smith et al. 2011ab) were applied to develop a scientifically robust and cost-effective sampling plan for camera auditing that satisfied two key programmatic criteria: (1) camera data were sub-sampled from every vessel in the fleet; and (2) the sample selection process was objectively and equitably applied across the fleet.

A second research focus was the development of statistical estimators and sampling designs for evaluating the efficacy of Gear Restricted Areas (GRAs) in the Gulf of Mexico and Mid-Atlantic Bight to reduce the bycatch of Atlantic bluefin tuna by the pelagic longline fleet. Using both logbook and onboard observer databases, catch, effort, and CPUE inside and outside GRAs were estimated via a single-stage cluster sampling design (Lohr 2010). Results showed an overall decrease in fleet effort and bluefin tuna catch during the bluefin tuna season (January-June) in the Gulf of Mexico after management measures (including GRAs) were implemented in 2015 (Fig. 1). Using the single-stage cluster design, an efficient sampling plan was developed for allocating observer sampling effort to detect changes in bluefin tuna catch, effort, and CPUE inside and outside GRAs in the Gulf of Mexico and Mid-Atlantic Bight.

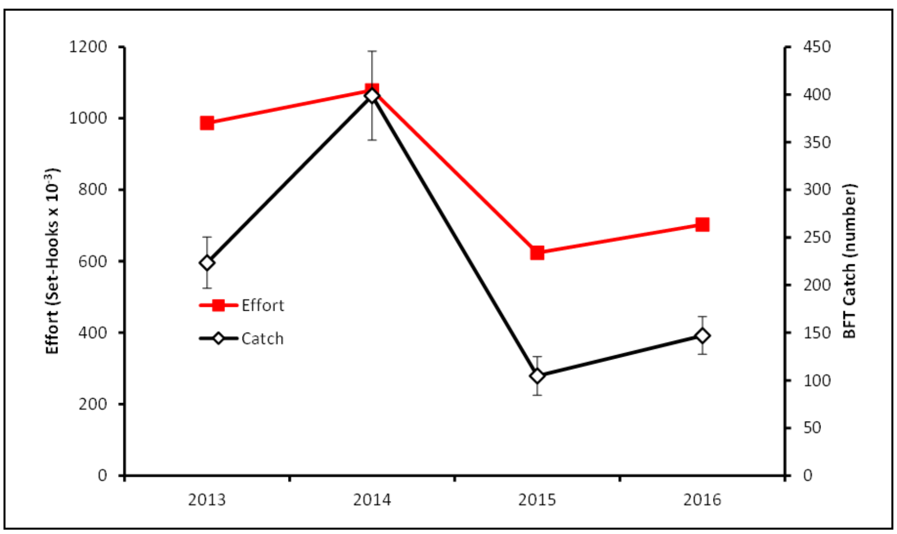

Figure 1: Pelagic longline fleet effort and Atlantic bluefin tuna catch in the Gulf of Mexico during 2013-2016 bluefin season (January-June). Management measures designed to reduce the catch of bluefin tuna were implemented in 2015.

Research Performance Measure: The following objectives were met during June 2016 to May 2017: (1) Designed and implemented statistical sampling for camera auditing of the pelagic longline fleet. (2) Developed a statistical estimation and sampling approach for evaluating the efficacy of Gear Restricted Areas (GRAs) in the Gulf of Mexico and Mid-Atlantic Bight to reduce the bycatch of Atlantic bluefin tuna by the pelagic longline fleet.

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Evaluation of Management Strategies for Fisheries Ecosystems

Project Personnel: E. Babcock and D. Die (UM/RSMAS)
NOAA Collaborators: M. Schirripa, S. Cass-Calay and M. Bryan (NOAA/SEFSC)
Other Collaborators: J. Hoenig (Virginia Institute of Marine Science); 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 the Atlantis whole-ecosystem modeling framework, 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 (*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: 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 used the model to simulation-test the ecosystem impact of several proposed and existing marine protected areas in the Gulf of Mexico, focusing on pelagic species. She defended her dissertation in March 2016, and is in the process of preparing the chapters for publication. Her dissertation results included an improved spatial map of the distribution of pelagic fish functional groups, which incorporated distance from front as a potential predictor of fish distribution, and a simulation test of the effects of the DeSoto Canyon closure and the spring bluefin tuna closure on pelagic fishes and the greater ecosystem. Her Atlantis simulations found that the DeSoto Canyon closure appears to achieve its management objectives of reducing bycatch and helping rebuild

bycatch species (i.e., Atlantic billfish, bigeye tuna, some pelagic sharks, prohibited sharks, and sea turtles) and incidental species (i.e., bluefin tuna), without impacting catch of target species (i.e., swordfish, yellowfin tuna, bigeye tuna, skipjack tuna, albacore, dolphin fish, wahoo, and some coastal sharks). The spring closure has a less obvious impact on the ecosystem.

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

Collections of gonads and associated biological data (length, weight, gonad weight and, for one species, liver weight) in the U.S. Virgin islands have proceeded well. A total of 2650 fish have been collected, of which 1112 were obtained from St. Thomas and 1445 from St. Croix. Samples for the target species are as follows:

Balistes vetula	queen triggerfish	445
Cephalopholis fulva	coney	216
Epinephelus guttatus	red hind	278
Etelis oculatus	queen snapper	4
Lutjanus analis	mutton snapper	472
Lutjanus buccanella	blackfin snapper	67
Lutjanus vivanus	silk snapper	9
Ocyurus chrysurus	yellowtail snapper	176
Scarus taeniopterus	princess parrotfish	171
Scarus vetula	queen parrotfish	40
Sparisoma aurofrenatum	redband parrotfish	131
Sparisoma chrysopterum	redtail parrotfish	389
Sparisoma rubripinne	redfin parrotfish	22
Sparisoma viride	stoplight parrotfish	320

(The remaining number of fish pertains to samples of other species collected opportunistically to explore the possibility of extending this research in the future.) In addition, otoliths were collected from all species and spines were collected from queen triggerfish for a cooperating study (as per the terms of the proposal). Outreach with the fisheries department in the US Virgin Islands consisted of training sessions on St. Croix and St. Thomas in the collection of otoliths.

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

To date we have developed an array of thirty-five acoustic release receivers deployed along the reef edge in Madison Swanson, a marine protected area with high relief in the Northeastern Gulf of Mexico. Twenty-six of these receivers were deployed in August 2015 and downloaded in July 2016. An additional nine were added in April 2016. Throughout 2016 we conducted preliminary research on red snapper barotrauma to help us develop methodology to effectively select and acoustically tag red snapper at the depths they are captured within Madison Swanson (minimum ~ 45 m). A total of 36 red snapper have been acoustically tagged (Vemco V13P low power, random delay 60-180 s, estimated battery life 967 d) and released in Madison Swanson: seven in April 2016 and an additional 29 in November 2016. One of the fish implanted in April was recaptured in February 2017 and was completely healed. Of the 29 fish acoustically tagged in November, 15 received external tags and another 14 had tags implanted. Two of the externally tagged fish were recaptured on March 9, 2017 in zone 2, one of which had lost its external tag (see below). Receivers have just been downloaded and analysis of the data to assess survivorship and residency is on-going.

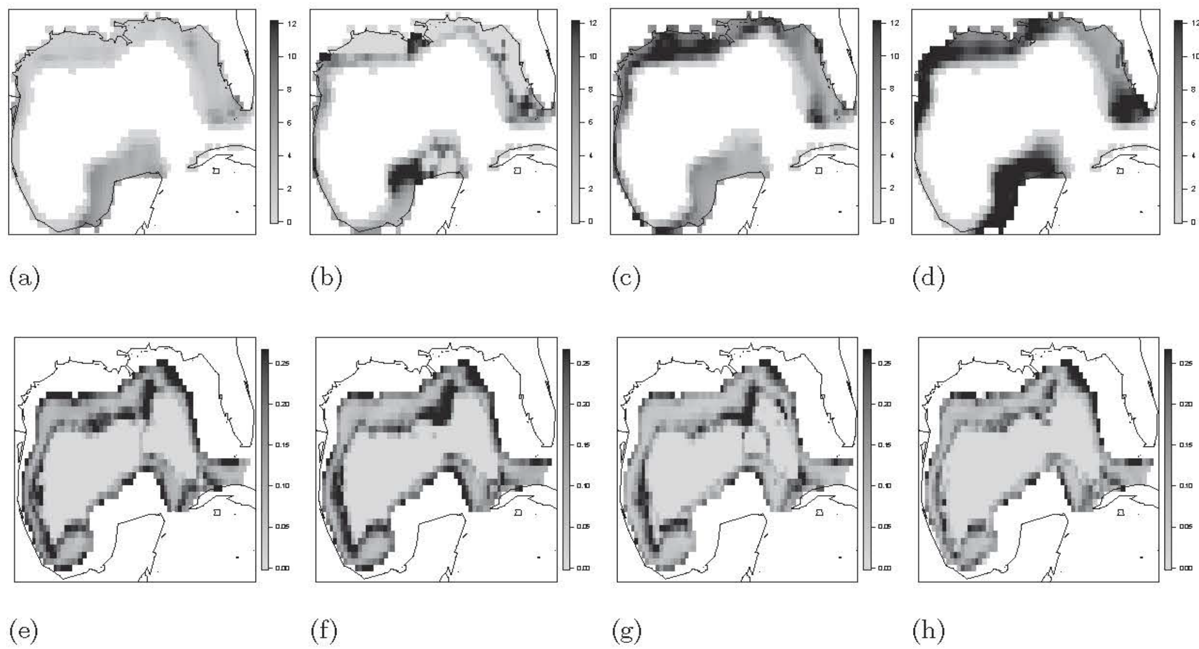

Figure 1: GAM predictions of large shark abundance from bottom longline survey data in (a), winter (b), spring (c) summer, and d) fall, and from pelagic longline observer data in (e) winter, (f) spring, (g) summer, and (h) fall, from Holly Perryman's dissertation.

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 was finished when Holly Perryman completed her dissertation in March 2017.

Islands. Samples are being collected and analyzed.

(2) Collect samples to assess maturity of fishes in the U.S. Virgin Islands. The sampling is ongoing and is expected to be completed this year.

(3) Assess spatial dynamics of red snapper in the Gulf of Mexico. Acoustic telemetry arrays are deployed, and are recording data on red snapper movement.

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. Harford (UM/CIMAS), E. Babcock (UM/MBE)
NOAA Collaborators: M. Karnauskas, J. Walter, S. Sagarese and M. Bryan (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives: To tailor an 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: Completed aspects of this project have focused on evaluating the feasibility of data-limited harvest control rules in the region and identifying how simple management reference point proxies (e.g., broken stick rules) may be best applied under severe data limitations.

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. the project team provided supporting roles in advising the development of MSE for SEDAR 46 (data-limited assessment U.S. Caribbean) and SEDAR 49 (data-limited assessment GOM). This also included making technical (coding) additions to DLMtool that were used in these assessments as well as developing a technical document accompanying assessment documents. Six components of this project are ongoing: (1) using non-equilibrium mean length estimator to develop overfishing limits for data poor species; (2) Simulation-testing of the reliability of non-equilibrium mean-length mortality estimators; (3) Graphical presentation of management strategy evaluation using Bayesian networks; (4) Addressing US national standards for stock recovery using simplified harvest control rules; (5) Length-based indicators as viable management procedures; and (6) Control rule robustness to life history uncertainty.

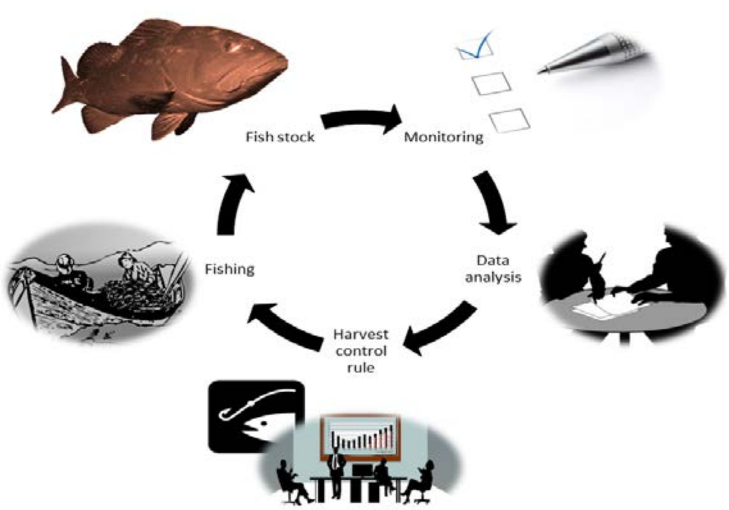

Figure 1: Management strategy evaluation as conducted through closed-loop simulations.

Research Performance Measure: The initial explorations were intended to aid in understanding how various harvest control rules behave under different life histories and stock productivities, and will provide the basis for understanding which control rules are robust in situations of extreme data-limitation.

The original project timeframe was September 2015 – August 2017 and involved two researchers (Harford and Sagarese), each ½ time for two years. As Dr. Sagarese was hired as a FTE shortly after the project began, Dr. Harford took on full-time responsibilities for this project. Along with his other responsibilities related to data-limited MSE, this SAAM funding has enabled Dr. Harford to focus on data-limited fisheries management for the period of September 2015 - August 2018. The benefit of this arrangement has been improved quantity and quality of SAAM-related projects, although project completion is delayed until August 2018.

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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:
We upgraded used the hydrodynamic model GoM-HYCOM of the coupled system, to perform initial observing system experiments during the first half of 2010, which is the time period of the Deepwater Horizon oil spill and thus a very relevant study case for testing the impact of observing systems on the estimate of GoM biological conditions and ecosystems. These initial experiments show that a constellation of along-track altimeters is necessary for the correct estimation of dynamical features in the

Gulf of Mexico, while other components of the observing system have less impact. In terms of Sea Surface Temperature, the use of a single altimeter allows an efficient error reduction, while the assimilation of Argo data has little impact at the Gulf scale, because of the limited number of floats at that time.

In addition, we improved the coupling between HYCOM and the biogeochemical Carbon, Silicate, Nitrogen Ecosystem (CoSiNE), especially in shallow areas. It is now implemented at high resolution over the Gulf of Mexico and additional tuning of biology is taking place, leveraging with in situ data from ancillary projects.

We also improved the Ecospace ecosystem model, which is the third component of the coupled model. We implemented the model over the Florida Keys region. It now incorporates Chl-a and Colored Dissolved Organic Matter (CDOM) data at monthly frequency. We implemented and tested various functional responses to depth, CDOM, distance to reefs, and Chl-a within the model. The model now allows exploring the effects of underlying environmental conditions and fishing pressure on the distribution of biomass through space and time.

In parallel of this modeling effort, we used remote sensing imagery to identify patterns of biophysical interactions at the scale of the Gulf of Mexico. We have identified periods when waters from the Mississippi River are advected to the Gulf interior and, eventually, to the Florida Keys. We derived time-series of Chl-a concentration anomalies from the Sea-Viewing Wide Field-of-View Sensor (SeaWiFS) and MODIS-Aqua sensors from 1997 to 2016 south of the Mississippi Delta. Cross-correlation analysis showed a significant correlation with the Mississippi River discharge, with a maximum correlation of 0.36 (2-week lag). We also started investigating the advection to the Florida Keys, in connection with the Loop Current extension. This work will allow us to define one or more periods of interest during which we will perform Observing System Experiments with the coupled model.

Finally, we also performed extensive analysis of an extreme event that took place in Summer 2016. In late July, localized but intense mortality affected coral reefs in the Flower Garden Banks National Marine Sanctuary (FGBNMS) in the northwestern Gulf of Mexico. The exact causes of this mortality event are not known, but the examination of remote sensing maps indicates that high Chl-a or high turbidity waters unusually spread from the coast toward the shelf break where the FGBNMS is localized. These waters are of riverine origins and associated with the dramatic rains that took place in the region in Spring 2016. The high Chl-a waters expended over the northwestern GoM shelf in two separate, quick steps that took place during late June and mid-July, supported by coastal upwelling favorable winds along Texas. Figure 1 shows that the high Chl-a waters reached the FGBNMS area in late June, and that FGBNMS was affected by such waters for the whole month of July.

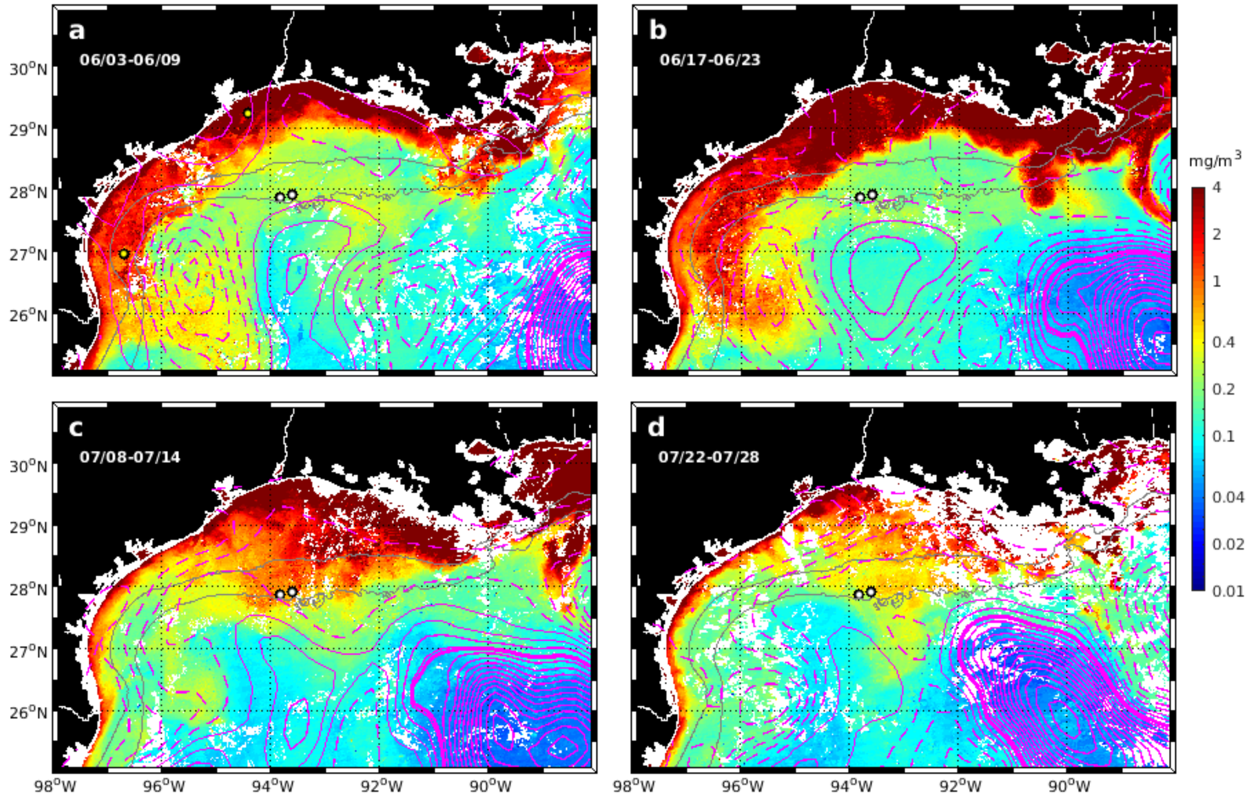

Figure 1: Weekly Chlorophyll-a (Chl-a, mg/m^3) average for: (a) June 3-9; (b) June 17-23; (c) July 8-14; (d) July 22-28; the magenta contours mark the weekly Sea Surface Height (SSH) anomaly with respect to the SSH averaged over the GoM, estimated from AVISO (contours every 4 cm): the dashed lines are for positive anomalies (closed contours are associated with anticyclonic eddies), whereas the solid lines are for negative anomalies (closed contours are associated with cyclonic eddies); the gray contours represent the isobaths at 50 and 200 m; the white circles indicate the locations of the East and West FGBNMS sites

Research Performance Measure: The project has already led to significant results and several publications have been prepared or submitted. Additional tuning of biological parameters is taking place in order to resolve high resolution processes and observing system experiments will be performed with the updated coupled model.

Larval Bluefin tuna ecology in the Gulf of Mexico and Caribbean

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

NOAA Collaborators: J. Lamkin and T. Gerard (NOAA/SEFSC); N. Norton (NOAA Corps)

Other Collaborators: A. Knapp and M. Stukel (FSU); M. Landry (SIO-UCSD); K. Selph (UH); R. Laiz-Carrion and J. Quintanilla (IEO); L. Vasquez-Yeomans, E. Sosa-Cordero and L. Carrillo (ECOSUR)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To investigate bluefin tuna and other highly migratory species' spawning grounds in the Gulf of Mexico and the Western Atlantic. To examine the effects of nitrogen sources and plankton food-web dynamics on habitat quality for larval bluefin tuna.

***Strategy*:** Carry out multi-disciplinary fisheries oceanography surveys of the Caribbean and western Atlantic in May and June to collect plankton and deploy.

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: NOAA/SEFSC & NOAA/RESTORE

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 2017, we refocused our sampling efforts in the Gulf of Mexico. This is the first year of a two-year project funded by the NOAA RESTORE Act Science Program. Our team includes scientists from Scripps Institute of Oceanography, Florida State University, and the University of Hawaii at Manoa to examine the "Effects of nitrogen sources and plankton food web dynamics on habitat quality for larval BFT."

The 2017 research survey conducted intensive sampling to characterize the biogeochemical dynamics by following water parcels, deploying drifters, collecting water samples, carrying out multiple incubation experiments, collecting and preserving larvae for studies of growth, isotopic trophodynamics, condition and feeding patterns. Scientists from the Instituto Español Oceanográfico (IEO) in Spain and El Colegio de la Frontera Sur in participated in the surveys through the ECOLATUN project.

Figure 1: Year one of the NOAA RESTORE project successfully executed a fisheries oceanography survey in the Gulf of Mexico during May and June, 2017.

Research Performance Measure: The research program is on schedule and sample processing has already started. This year's (NF1704) survey was successfully completed on June 5, 2017 aboard the NOAA research vessel Nancy Foster. 129 stations were completed and all plankton samples were preliminarily sorted at sea with larvae being preserved for stable compound specific isotope analyses or bulk stable isotope analysis. We will continue our collaborations with the IEO to compare results between the Gulf of Mexico, the Western Caribbean and the Mediterranean Sea.

Last year's survey (NF1602) is 75% sorted and all larval bluefin tuna and other species of interest have been identified. For the trophodynamics sub-project, frozen samples of mesozooplankton and microzooplankton were shipped to IEO personnel for processing. For the ageing project, 138 bluefin tuna otoliths have been aged from the Gulf of Mexico's 2014 survey and at least 100 otoliths from the eastern spawning grounds (Balearic Islands) will be analyzed and compared from the same year. Finally, we will examine temporal and spatial differences between bluefin tuna growth rates and investigate whether variability among growth rates is linked to water mass types found in the spawning grounds.

Understanding spatiotemporal dynamics of Atlantic Bluefin tuna spawning

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

NOAA Collaborators: J. Lamkin, T. Gerard and W. Ingram (NOAA/SEFSC)

Other Collaborators: D. Alvarez-Berastegui (Balearic Islands Coastal Observing and Forecasting System, SOCIB); P. Reglero, R. Balbin, E. Blanco, M. Hidalgo, F. Alemany, A. Ortega, F. Abascal and D. de la Gandara (Instituto Espanol de Oceanografia, IEO); A. Medina (University of Cadiz, UCA); O. Fiksen (University of Bergen, UB)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To identify potential unknown bluefin tuna spawning grounds and understand how spawning is influenced by the environment.

***Strategy*:** To use remote sensed environmental data, field observations of larvae and laboratory experiments on larvae to develop an omnibus habitat model.

CIMAS Research Theme:

***Theme 5*:** Ecosystem Modeling and Forecasting *(Primary)*
Theme 3: Sustained Ocean and Coastal Observations *(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/SEFSC
NOAA Technical Contact: Theo Brainerd

Research Summary:

Atlantic bluefin tuna populations spawn at different locations and times of the year. In this project we are constructing a model to identify unknown spawning grounds with the goal to incorporate field and laboratory observations to test the model and obtain a better understanding the timing of bluefin spawning.

Recent studies suggest that bluefin tuna spawning may not be restricted to just the Gulf of Mexico and Mediterranean like previously believed. The implications of spawning occurring outside of just these two spawning areas has profound impacts on stock productivity. We predicted unknown spawning areas by developing habitat models. We used historical larval collection data from the Gulf of Mexico and Mediterranean to parameterize the model. Environmental data were derived from the global HYCOM model to allow for common predictions throughout the Atlantic. Best fit models suggests that change in temperature, geostrophic velocity, chlorophyll and salinity best define spawning grounds. We used these data and predicted spawning events every 8 days from 2003-2014. The model predictions predict the unknown spawning grounds that have been recently observed and suggest there may be additional spawning grounds in the north Atlantic (Fig. 1). These results suggest spawning is not restricted to just the Gulf of Mexico and Mediterranean.

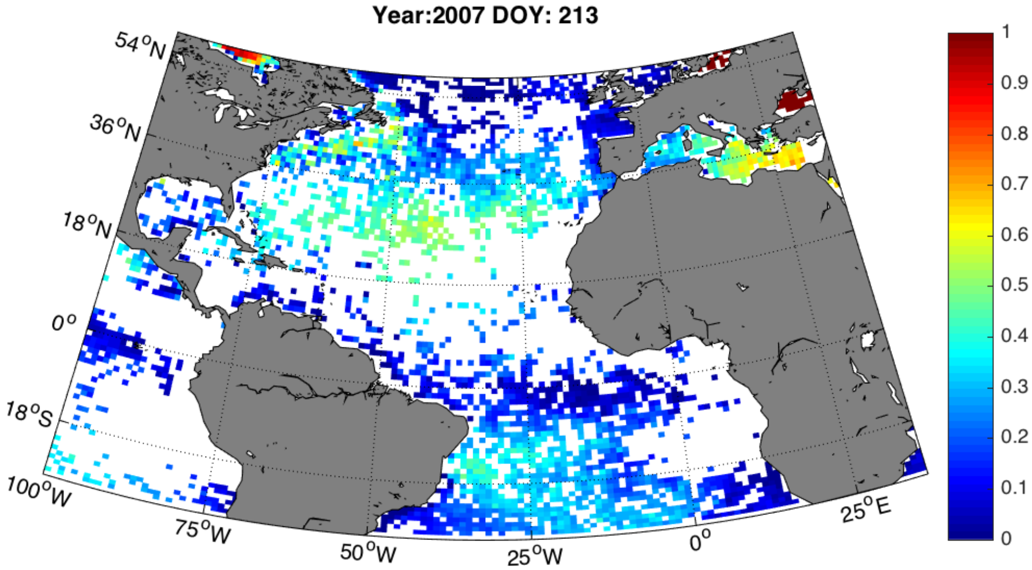

Figure 1: Preliminary habitat model that predicts bluefin tuna spawning grounds in the North Atlantic Ocean. Scale shows probability of positive habitat suitable for spawning from 0-1, with 1 being 100% probability.

Research Performance Measure: The model has been created and the predictions generated. We are in the process of analyzing the outputs. The project is on track. A peer reviewed publication is currently being prepared.

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 and C. Langwiser (UM/CIMAS)
NOAA Collaborators: J. Bohnsack, M. Johnson and L. Grove (NOAA/SEFSC); L. Maclaughlin (NOAA/FKNMS)
Other Collaborators: M. Feeley (NPS); A. Acosta (FWRI); K. Kilfoyle (NSUOC)

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, habitat composition and coral demographics 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 hardbottom 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 research also allows us to assess domain wide benthic composition as well as coral colony density and community structure. This longitudinal monitoring approach is a vital component enabling us to detect annual and decadal reef fish population and benthic composition changes across the Florida coral ecosystem.

To accomplish a large-scale monitoring protocol, however, a multi-agency cooperation is needed. 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 saw continued effort along the northern reef tract and 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 to inform management decisions.

Research Performance Measure: Divers conducted photo-documentation, stationary point counts for fish, line point intercept and coral demographic surveys for habitat assessments along the Florida reef tract. 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, 4596 individual dives (Figure 1) were needed to complete the 2016 mission to track biological trends on Florida's coral reef tract. Data are used to assess three main conditions including 1) coral diversity, distribution, abundance, colony size and condition, 2) habitat composition, complexity and key species and 3) reef-related fish diversity, distribution, abundance and size structure. All field related and QAQC milestones were met and objectives completed.

Additionally, this research and monitoring effort is now completely aligned with the National Coral Reef Monitoring Program (NCRMP). NCRMP is a federal program for conducting sustained and standardized observations of biological, climatic and socioeconomic indicators in all U.S. states and territories. Resulting biological trends from this research were successfully used in the development of a National 'report card' on the status and health of U.S. coral reefs.

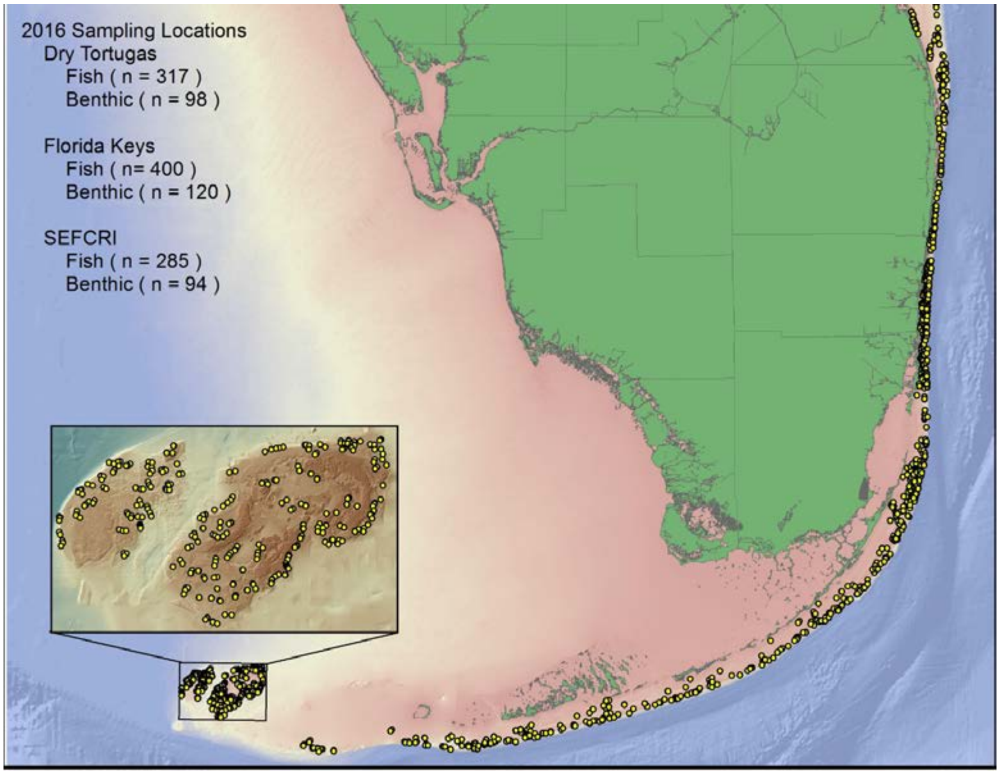

Figure1: Sampling site locations for 2016 in the Florida domain

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Ecology of Forage Fish in the Arctic Nearshore

Project Personnel: K. Boswell (FIU)
NOAA Collaborators: R. Heintz and J. Vollenweider (NMFS/AKFSC/ABL)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** The goal of this project was to develop a detailed characterization of nearshore Arctic fish communities and their habitats in order to better understand the ecological function of the coastal habitats fringing the Arctic Large Marine Ecosystem. Our approach was to characterize Arctic fish communities in nearshore habitats by observing seasonal changes in the communities in a variety of habitats near Pt. Barrow, Alaska and relating those changes in local environmental conditions.

***Strategy*:** Through a series of weekly surveys during the ice free periods in 2013 and 2014, we characterized the nearshore fish community structure and demographic patterns among dominant species, examined the feeding ecology and energetics of nearshore fish species, used stable isotopes to elucidate food web interactions, characterized the shallow water habitats with an autonomous vessel and examined the meteorological and oceanographic forcing between the Elson Lagoon and Beaufort Sea water masses. In general, the occupants of the nearshore habitats of the Arctic, near Barrow, are strongly influenced by the physical and meteorological processes that dominate this region. The regulation of sea ice in the nearshore and overall climatic forcing during the ice-free period appear to play a deterministic role in the species present, their energetic content, prey

availability and food-web interactions. As expected there was a direct linkage between the meteorological conditions (i.e., wind speed, direction and pressure) and the magnitude and direction of the flow between the Lagoon and Beaufort Sea habitats. Reversals in meteorological condition yielded rapid reversals in flow between water masses.

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: AKFSC
NOAA Technical Contact: Ron Heintz

Research Summary:

As Arctic climate change continues and anthropogenic pressures increase it is imperative that a detailed baseline is established of the state of Arctic marine ecosystems before the impacts of these threats manifest further. To date, little is known about the functionality and structure of nearshore habitats and the communities within them. A multi-faceted approach was used to investigate the nearshore ecosystems around Point Barrow in order to gain a better understanding of how these imminent threats may affect the Arctic nearshore.

Building on the work of Johnson and Thedinga (2012), we established 12 sampling stations along the shorelines of the Chukchi Sea (n = 5), Beaufort Sea (n = 3), and Elson Lagoon (n = 4). These sampling stations were sampled by means of beach seines every week for 6 weeks during the shift from ice-covered to open-water at the beginning of summer (July 14th – August 23rd). Fish were enumerated and processed for stable isotope analysis. A multivariate and multiscaled approach were used to identify patterns that can function as a baseline for future monitoring efforts.

Feeding Experiment

In order to use appropriate SIA models to represent trophodynamics of the Arctic nearshore, we first performed a lab-based feeding experiment to determine the tissue turnover rates and Trophic discrimination factors of a common Arctic nearshore species (Arctic sculpin – *Myoxocephalus scorpioides*). Juvenile Arctic sculpin were collected with the methods described above, and transported to a temperature controlled holding facility at Florida International University. They were fed ground krill during a 36 day acclimation period, until the diet of half of the sculpin were abruptly switched to a ground fish diet, the remaining sculpin were maintained on the krill diet. Using methods described by Madigan et al. (2012) we calculated the time it took for each of three tissues (fin, liver, and muscle) to reach a new isotopic equilibrium after the diet switch. This time is known as the tissue turnover rate (TTR) and can be used to identify dietary shifts that have occurred over their respective time scales. Furthermore, the difference between dietary isotope ratios and the equilibrium state isotope ratios of each tissue were calculated. This value is known as a trophic discrimination factor, and can be used to represent trophic linkages between predators and prey within a community.

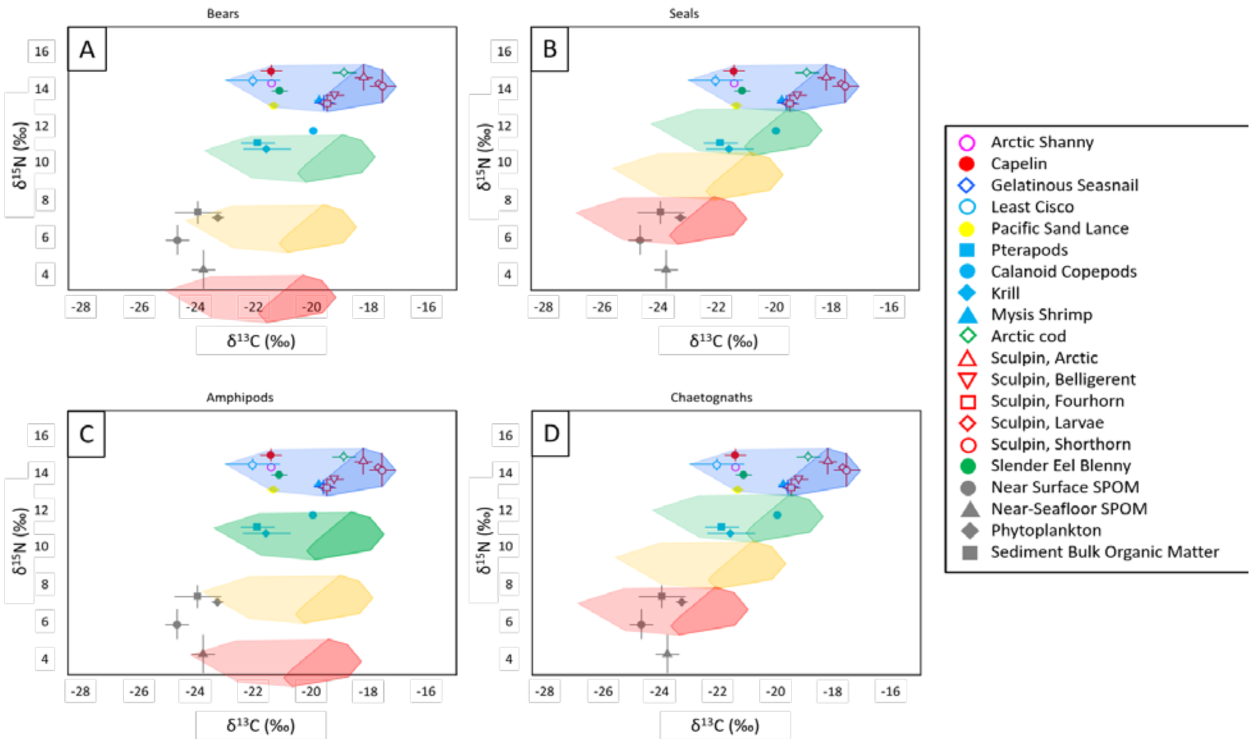

Figure 1: The isotopic niche space of Arctic nearshore fish (blue polygon) was used to predict the isotopic niche space of lower trophic levels (green, yellow, red) and overlayed over the isotopic ratios of known prey resources of Arctic nearshore fish. Predicted niche space were determined using a linear model with the slope of $\Delta^{15}N/\Delta^{13}C$ as determined for Polar bears (*Ursus maritimus*; A), Harp Seals (*Pagophilus groenlandicus*; B), Amphipods (*Ampelisca macrocephala*; C), and Chaetognaths (*Parasagitta elegans*; D).

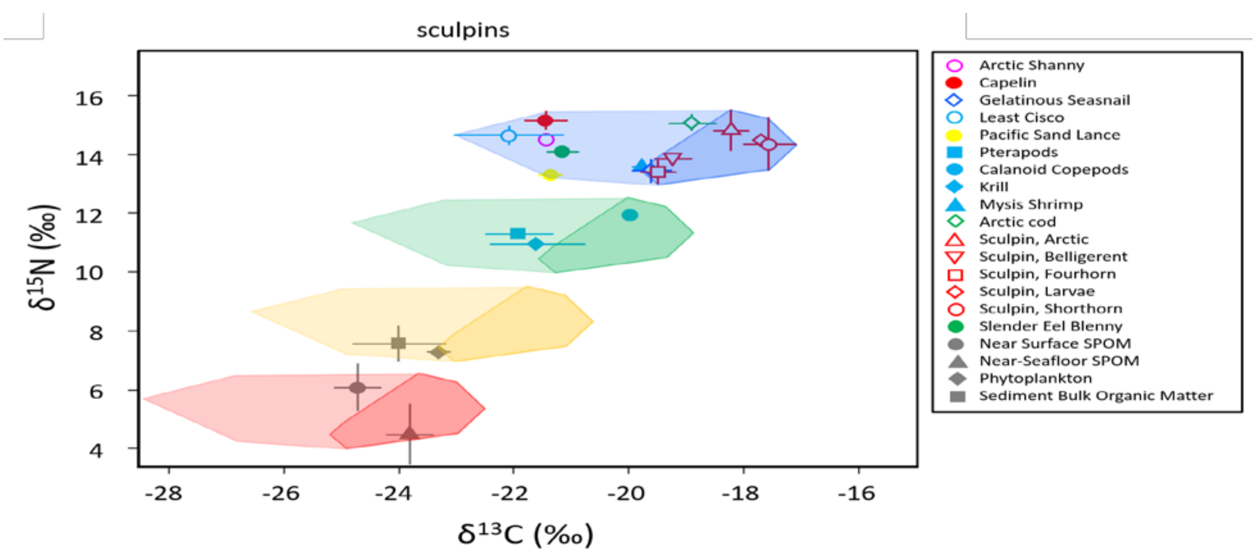

Figure 2: The isotopic niche space of Arctic nearshore fish (blue polygon) was used to predict the isotopic niche space of lower trophic levels (green, yellow, red) and overlayed over the isotopic ratios of known prey resources of Arctic nearshore fish. Predicted niche space were determined using a linear model with the slope of $\Delta^{15}N/\Delta^{13}C$ as determined for Arctic sculpin (*Myoxocephalus scorpioides*).

Research Performance Measure: The objectives were:

(1) To understand the abundance and distributions of communities in the three habitats that were sampled. We examined community structures across multiple spatial and temporal scales to identify patterns and limitations in fish distribution.

(2) To understand what physical and environmental variables drive changes in community structure. We used multivariate Canonical Correspondence Analysis (CCA) models in variance partitioning to identify the variables that explain most of the variation in community composition.

(3) To establish the viability of using Arctic sculpin as a biomonitor for environmental changes to Arctic nearshore habitats. A lab-based controlled feeding experiment was use to determine the tissue turnover rates of Arctic sculpin (*Myoxocephalus scorpioides*) to be used in further analyses.

(4) To establish appropriate parameters for stable isotope models to represent food web structures of lower trophic levels of the Arctic nearshore communities. A lab-based controlled feeding experiment was use to determine the trophic discrimination factors of Arctic sculpin (*Myoxocephalus scorpioides*) to be used in further analyses.

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Examining the status and distribution of reef fish spawning aggregations in the Southeast Florida Coral Reef Initiative (SEFCRI) Region

Project Personnel: K. Boswell (FIU); D. Burkepile (University of California Santa Barbara)

NOAA Collaborators: C. Taylor (NOS/NCCOS/CCFHR/AERRB); T. Kellison (NMFS/SEFSC/BL); K. Gregg (NMFS/SER/SERO/HCD/AB)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** Locate and assess Fish Spawning Aggregations (FSAs) in the South East Florida Coral Reef Initiative (SEFCRI) region to inform and guide the development of a regional resource management plans by the State of Florida Fish & Wildlife Conservation Commission (FWC), South Atlantic Fisheries Management Councils, and NOAA Fisheries.

***Strategy*:** To address our objective we have engaged with local fishers and divers to collect historical and anecdotal reports of recreationally and commercially important FSAs in the targeted region. Using those reports a field survey incorporating hydroacoustics, divers, and stationary video camera deployments was developed to investigate the reported spawning locations. Field observations and compiled reports have been assembled into a comprehensive geospatial database and Geographic Information System (GIS) for visualization that can be used by state and federal management agencies for policy development and amendment.

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: CRCP

NOAA Technical Contact: Theo Brainerd

Research Summary:
Reef fish spawning aggregations (FSAs) are a vital part of the life cycle of many reef fishes, yet the act of aggregating makes this an attractive and lucrative target for exploitation. Additionally, knowledge of FSA locations in South Florida is predominately limited to commercial and experienced recreational anglers, leaving these resources vulnerable to overexploitation. Thus our research integrates the considerable knowledge of local fisherman and community members with fisheries research techniques to investigate the spatial, temporal, and ecological aspects of FSAs in the South Florida region.

During the 2014/2015 research year 12 reef fish aggregations from 7 species were identified by resource users, extracted from the existing literature, and working relationships were built with local recreational users and commercial fisherman in the area (Figure 1 – Map). Our evaluation of the literature revealed that very little is known about the spatial aspects of aggregations in South Florida, but research from the greater Caribbean identified peak reproductive periods for a range of species, providing important insight into the seasonality of FSA formation (Table 1 - Calendar).

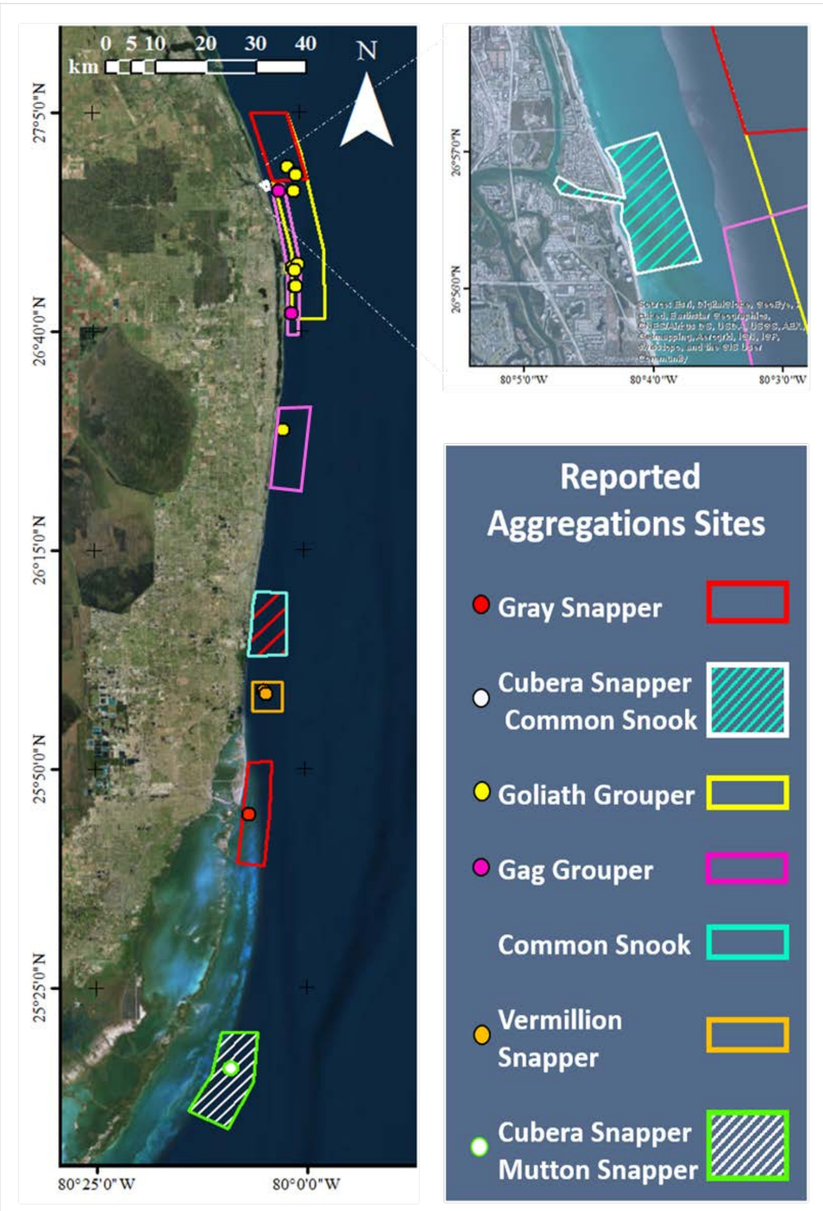

Figure 1: Reported aggregation sites were presented to the SEFCRI-TAC for the development of their regional resource management plan and Marine Spatial Planner (http://ourfloridareefs.org/tool/). Polygons are representative of a generalized aggregation area, while points relate to specifically identified aggregation locations.

Predicted Spawning Season

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Grouper												
Black	■	■	■									
Gag	■	■	■	■								
Goliath							■	■	■	■	■	
Snapper												
Cubera					■	■	■	■	■			
Gray						■	■	■				
Mutton				■	■	■	■					

Table 2: The species presented are historically known to aggregate and spawn during the highlighted months. The highest level of spawning activity is known to exist near the center of the highlighted regions, associated with peak (new or full) moon phases.

In the 2015/2016 period, additional reports were gathered from various sources and several of the reported aggregations were investigated further. Hydroacoustic surveys, along with 360 degree Remote Underwater Video surveys (360 RUV's), and diver visual surveys were performed at eight goliath grouper spawning sites in the Jupiter,Fl region to characterize the temporal and spatial nature of goliath aggregation behavior, and the reef fish community response to aggregation activity between July and November 2015. To address reports of a cubera snapper aggregation in the Homestead, Fl region, trip reports consisting of landings, fishing pressure, and reproductive organ state were gathered from a collaborating commercial charter fisherman between July and September. Additionally, hydroacoustic and 360 RUV's were performed at a historically recognized gag grouper aggregation site in the Boynton Beach, Fl region to assess the status of the reported aggregation between January and March 2016.

In the most recent funding year (2016/2017) we continued to develop relationships with a few key resource users and sought to build new partnerships with experienced commercial users. A continued investigation into the dynamics of goliath aggregation activity was carried out with supplementary support from experienced colleagues, with a new emphasis on movement patterns and fine scale temporal activity (using acoustic telemetry). In the winter of 2016/17 additional reports were gathered to determine the level of activity on historically recognized gag grouper aggregation sites in the Boynton area. Unfortunately, based on all evidence provided by reputable resource users that frequent the identified aggregation sites, gag grouper again failed to aggregate in the 2016/17 winter months. Currently an extensive compilation of species profiles related to those that are suspected to aggregate in the SEFCRI region is being developed to assist in regional management initiatives. The profiles will be supplied to the "Our Florida Reefs" IT specialist for display on the SEFCRI Technical Advisory Council Marine Spatial Planner (a web based Geographic Information System); and will include distribution, life history, known spawning information, historical susceptibility to fishing, known status of the fishery, and a list of references related to the species in question. (Figure 2)

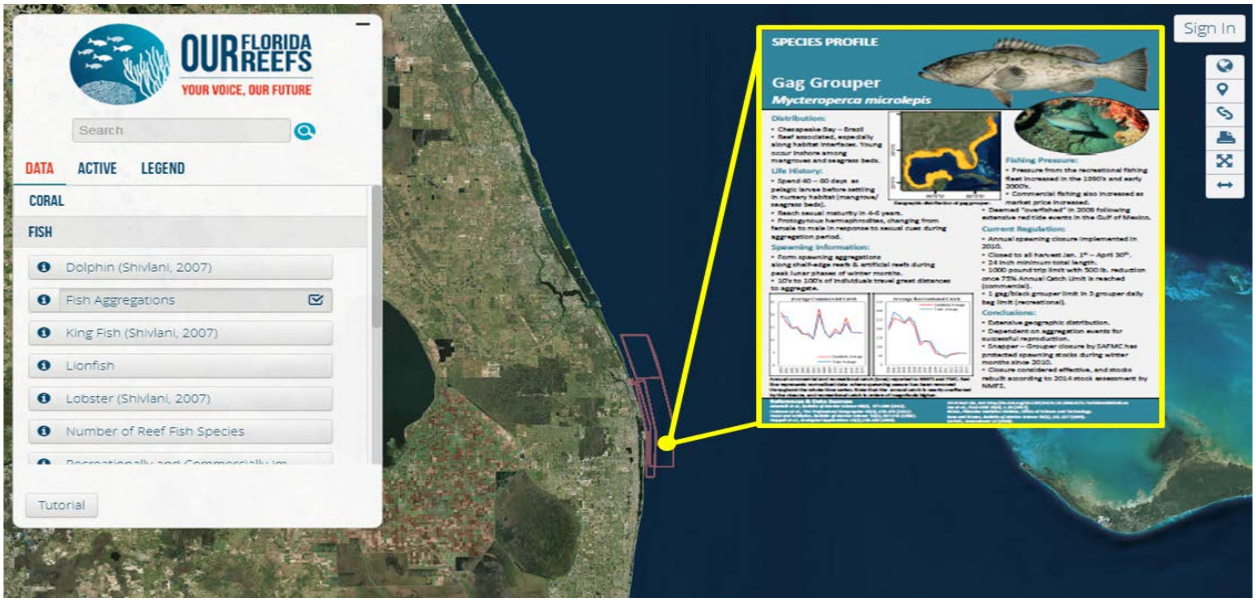

Figure 2: An example of the web based Geographic Information System being provided to SEFCRI and NOAA that will include; distribution, life history, known spawning information, historical susceptibility to fishing, known status of the fishery regulations, and a list of references related to the commercially and recreationally fish species that aggregate to spawn in South Florida.

While the task of implementing dedicated field efforts to survey every reported aggregation is logistically infeasible, collaborating resource users can offer a wealth of knowledge and act as agents in the field to relay real-time information to researchers. Based on real-time information from resource users, a directed field effort can then be implemented to characterize and assess the status of the identified aggregations. This process of gathering information and developing a response program ensures the most effective use of resources, and is essential to future FSA research.

Research Performance Measure: The objectives were to (1) locate and assess FSAs in the SEFCRI region; and (2) provide policy-makers with information to assist in the development of a regional resource management plan. To address these objectives we have compiled a geospatial database consisting of 13 reef fish aggregations from 7 species that have been identified by resource users, reported in the scientific literature or documented and confirmed in the field; and relayed this information to the SEFCRI working groups for the development of their regional management plan and Marine Spatial Planner (http://ourfloridareefs.org/tool/) (Figure 1 & 2 – Map & Webpage Ex). Currently, the Marine Spatial Planner is being updated with extensive species profiles to provide managers with additional, more accessible background information related to the aggregating species of interest to better inform their decisions.

Additionally, a manuscript related to the effect of heavy rainfall and outflow from the St. Lucie Estuary on nearshore fish communities (specifically aggregating goliath grouper) is currently being internally reviewed for publication and has been presented at several symposiums around the region. We attended the 2017 Coral Reef Conservation Commission Winter Learning Exchange among other regional scientists, the 69th Gulf and Caribbean Fisheries Institute conference in Grand Cayman, and will be attending the 147th American Fisheries Society National Meeting in Tampa this August.

Pelagic Observer Program

Project Personnel: S. Davies (UM/CIMAS)
NOAA Collaborators: L. Beerkircher and S. Cushner (NOAA/SEFSC)
Other Collaborators: T. Morrell and D. Tricarico (Riverside Technologies)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To collect data aboard the Atlantic and Gulf of Mexico pelagic longline fleet in an effort to learn more about targeted and non-targeted pelagic species and the interactions between this commercial fishery and these species. This data is an instrument of scientific discovery in terms of increasing understanding of population levels, migration, behavior, and frequency of interactions of marketable target species and protected by-catch species and the pelagic longline fleet. The data is also an instrument of public policy in terms of gathering information needed to set sustainable federal fisheries regulations of Highly Migratory Species regarding this commercial fishery.

***Strategy*:** To place trained scientific observers aboard pelagic longline vessels at a level of 8% coverage of all longline fishing efforts aboard the Atlantic and Gulf of Mexico pelagic longline fleet. Observers document vessel information, fishing gear information, where and how the gear is deployed, and all species interactions with the longline gear. Additionally, observers collect biological samples of some protected species and targeted catch.

CIMAS Research Theme:

Theme 6: Ecosystem Management (*Primary*)
Theme 7: Protection and Restoration of Resources (*Secondary*)
Theme 3: Sustained Ocean and Coastal Observations *(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:

How is the Atlantic and Gulf of Mexico pelagic longline fleet fishing and what are the impacts to pelagic species? The research places trained observers aboard pelagic longline vessels in order to collect data regarding the gear being used to fish for targeted species, how the gear is deployed, the targeted species being captured, and the non-targeted by-catch interactions with the gear. This information can help determine population levels, migration, behavior, and how pelagic species interact with longline gear. The desired level of coverage is 8% of fishing effort, or longline sets made in the Atlantic and Gulf of Mexico. Observers also collect biological samples of protected species and targeted species, and in some cases tag animals that are released alive in an effort to track or collect future data from them. This program works closely with commercial fishermen, and occasionally with law enforcement when observer data supports investigations of fisheries violations.

This research and data is collected by observers, then subjected to quality control during a debriefing with the observer in which all aspects of the trip and data are discussed. The end users

of the data are scientists who study pelagic species, lawmakers who use this data for policy guidance, and occasionally law enforcement.

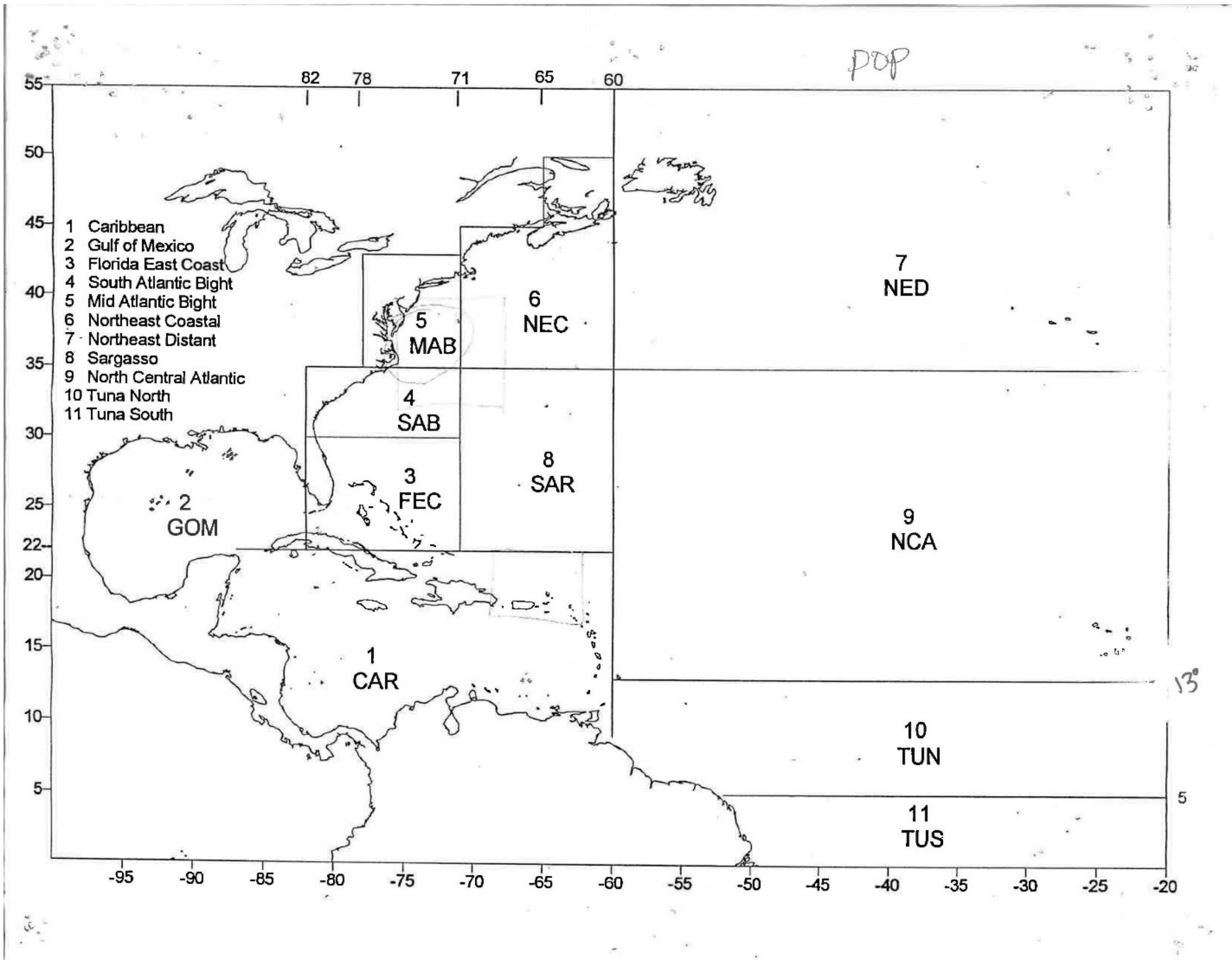

Figure 1: Geographic range of pelagic longline fleet and observer coverage

Research Performance Measure: At the end of Quarter 2, 2017, the targeted goals of the program are being met.

Survey of Boat Ramp-Based Non-Commercial Fishing on U.S. Virgin Islands (Phase II)

Project Personnel: D. Die (UM/CIMAS)
NOAA Collaborators: S. Crosson, M. McPherson and B. Stoffle (NOAA/SEFSC)
Other Collaborators: T. Gedamke (MER C. LLC)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives: The study will provide an initial estimate of recreational harvest for the US Virgin Islands which may be used to inform future management actions and improve monitoring of the island fisheries.

Strategy: The study will focus on the public boat ramps (although based on the results of the pilot study, some sampling of marinas or public docks may be required). Field samplers will count and measure the species of recreationally-caught fish that are landed at specific boat ramps, and gather economic and social information from the intercepted anglers. Information from this study will be used to develop a permanent sampling strategy for the territory's recreational fisheries catch.

CIMAS Research Theme:

Theme 6: Ecosystem Management

Link to NOAA Strategic Goals:

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

Goal 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:

Sampling has progressed in both St Croix, and St Thomas and close to 100 trips have been intercepted by port samplers. Most were commercial fishing trip in St Croix whereas in St Thomas they were mostly sport charters. About 50 individual demographic surveys have been completed from the two islands. Whereas in St Croix recreational and commercial fishers land in the same port in St Thomas landing sites are exclusively of one type of stakeholder. Spot checks in selected landing sites are providing indicators of total fishing effort.

Research Performance Measure: The planned fishermen surveys are for the most part being conducted according to plan. The individual in St. Thomas who began refusing the survey at the beginning of the study continues to do so, but is polite and considerate with our samplers and we maintain a good rapport.

Figure 1: Sampled catch of commercial landing trip in St. Thomas Virgin islands.

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Gulf of Mexico Integrated Ecosystem Assessment

Project Personnel: A. Gruss, K. Kearney, W. Harford, C. Quenée, N. Trifonova, S. Martin and S. Blake (UM/CIMAS)

NOAA Collaborators: C. Kelble (NOAA/AOML); M. Karnauskas, M. Schirripa and M. McPherson (NOAA/SEFSC); M. Jepson (NOAA/SERO)

Other Collaborators: P. Fletcher (NOAA/Florida Sea Grant); S. Regan and A. Freitag (NCCOS)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives**:** To develop scientific products and analytical tools required for integrated ecosystem assessments within the Gulf of Mexico large marine ecosystem.

Strategy**:** To accomplish these objectives we are conducting integrated ecosystem-level risk assessments, developing network-based methods for exploring trade-offs in complex multi-sector systems, and informing resource management decision-making to minimize risk to ecosystem services provisioning while bettering the resilience and sustainability of coastal communities.

CIMAS Research Theme:

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

Link to NOAA Strategic Goals:

Goal 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 nations coastal wetlands. However the footprint of the GoM extends well beyond the coastal waters of Texas, Louisiana, Mississippi, Alabama, and Florida. Through its upstream linkages it impacts and is impacted by 31 of the 50 states comprising the greater Gulf of Mexico watershed. Clearly, sustaining the resilience of this marine ecosystem and the services it provides is vital to our nation and its economy.

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: Socioecological conceptual model of the Gulf of Mexico region. Integrates biophysical components with human dimensions for the region.

Figure 2: Conceptual model (in development) for the Mid-Barataria Sediment Diversions project in southeastern Louisiana.

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.

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. We have also published an update to the Gulf of Mexico Ecosystem Status Report which was well received in the region. We are also conducting a case study in the Barataria Bay are of southeastern Louisiana to study the impacts of proposed sediment diversions.

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

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

Long Term Research Objectives & Strategy to Achieve Them:

***Objectives*:** To establish research priorities in the Mesoamerican and Caribbean region in order to provide baseline data (oceanographic and larval fish distributions) to support connectivity and fisheries management decisions in the region.

***Strategy*:** Carry out larval and oceanographic collections to assess larval transport & recruitment pathways in the Mesoamerican reef system. In addition, to enhance international capacity for the topic of connectivity as it relates to research and management with local and regional practitioners in the Mesoamerican Reef.

CIMAS Research Theme:

***Theme 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:

Connectivity research has become an ambitious focus through the study of physical and meteorological processes in the ocean that strongly impact biological and ecological populations and communities living in marine and coastal habitats. We utilized existing regional capacity-building collaborations (El Colegio de la Frontera Sur, Healthy Reefs Initiative and the Mesoamerican Reef Fund) in order to carry out capacity building training and subject-geared- workshops focusing on connectivity in the Mesoamerican Reef System.

The "3rd Workshop in Connectivity" took place in Cancun, Mexico July 12 and 13, 2016. Representatives from each of the four countries attended and collecting equipment was distributed to each MPA practitioner. In addition, the activity titled Connectivity Exercises or "ECOME 6" was executed during the new moon of September, 2016. During this event, another MPA was added to the Connectivity network that monitors the recruitment of juvenile fishes into the Mesoamerican Reef habitats. At least 40 people representing now 11 MPAs from the 4 countries in Mesoamerican Reef region have participated in the field exercises.

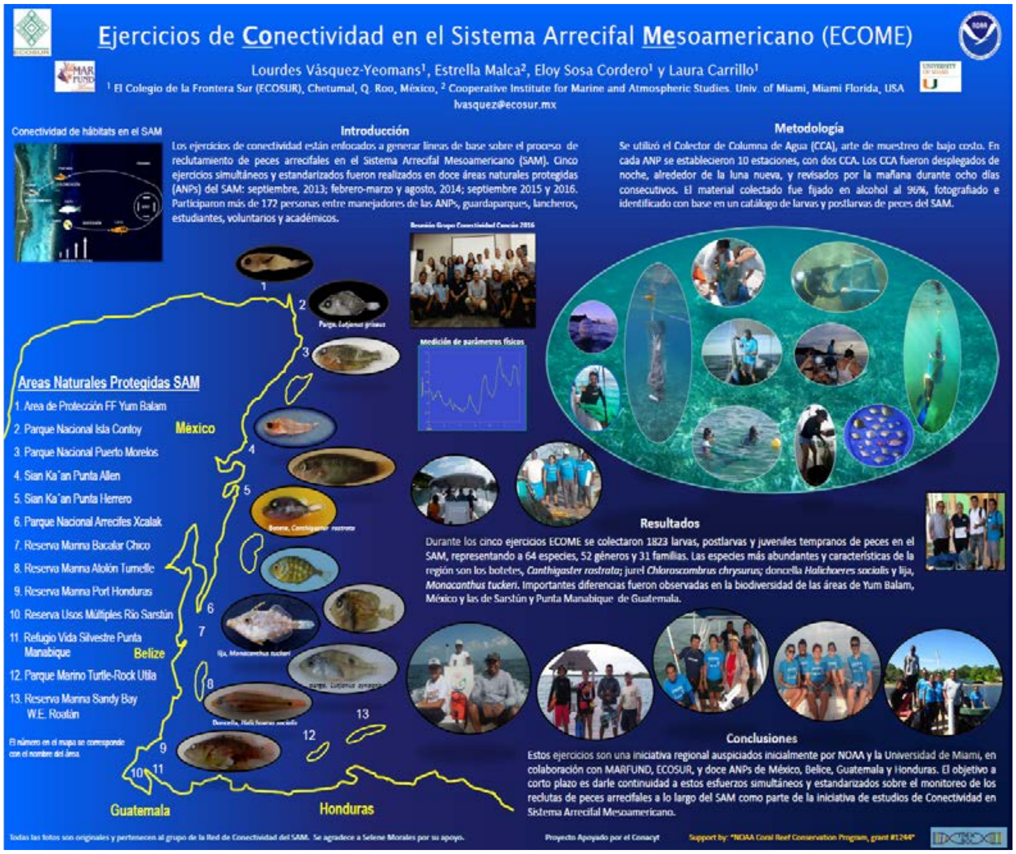

Figure 1: Exercises in Connectivity (ECOME) in the mesoamerican reef system.

Research Performance Measure:
Through our collaborative work, several manuscripts were developed and published that added new information about the ecosystem and also synthesized some of the oceanographic processes using examples in the Atlantic-Caribbean region. Despite funding limitations, the program has been proceeding as a result of multiple contributions and outreach activities sponsored by all partners involved in this project. During the year, members of the "Connectivity Network" carried out several informal training events within the region to augment additional monitoring sites for the ECOME exercises including increasing capacity of the SACD team during the Xcalak ECOME event. On-site training was provided by L. Vasquez Yeomans in Belize at the Sarteneja Alliance for Conservation and Development (SACD) to include light traps and plankton nets in their ongoing monitoring efforts. Ms. E. Vidotto from the Bay Islands Conservation Association (BICA) in Honduras was trained to train other BICA staff to process plankton and ichthyoplankton specimens at the Larval Fish Lab under the supervision of L. Vasquez Yeomans. In addition, Ms. S. Morales was funded to process the specimens collected in ECOME 5. These fish were processed, measured, identified and a subset were prepared for genetic identification.
Results from the Connectivity Exercises (ECOME) were presented to local and regional managers during replenish or outfit new collecting equipment as well as temperature sensors to continue monitoring the region.

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Caribbean Reef Ecosystem Research, USVI Larval Distribution and Supply

Project Personnel: E. Malca, L. Rasmuson, K. Shulzitski, S. Privoznik, A. Jugovich, A. Shiroza and J. Mostowy (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, June 2016, and April 2017. 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 cruises: 2007-2011, and 2015-2016. Oceanographic cruise data has been collected and processed for 2007-2011, 2015, and 2016. In addition, the taxonomic family identification has been completed for 2007, 2008, 2009, and 2010, with species of interest identified from 2011, 2015, and 2016. The most recent cruise was successfully completed from 14 – 25 April 2017, replicating collections at some historical stations and adding additional sampling techniques. We completed a total of 106 stations, yielding 116 plankton samples (40 subsurface Neuston, 40 100m-Bongo, 36 MOCNESS), of which sorting will soon begin.

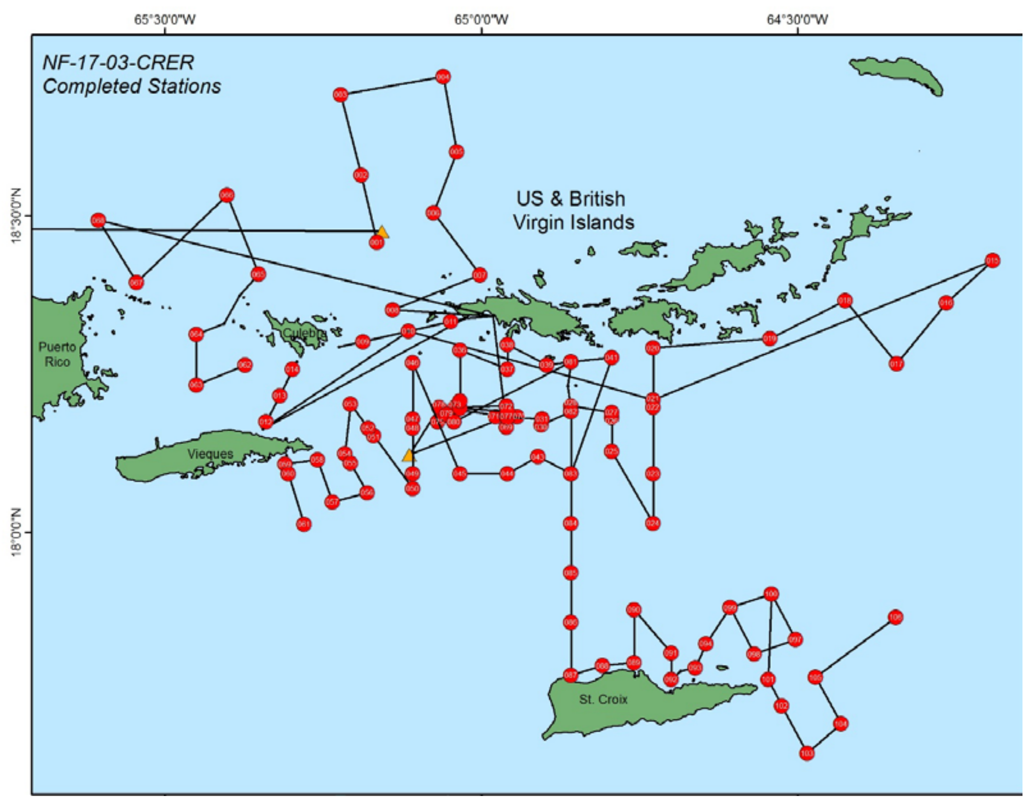

Figure 1: Cruise track showing sampling locations in 2017.

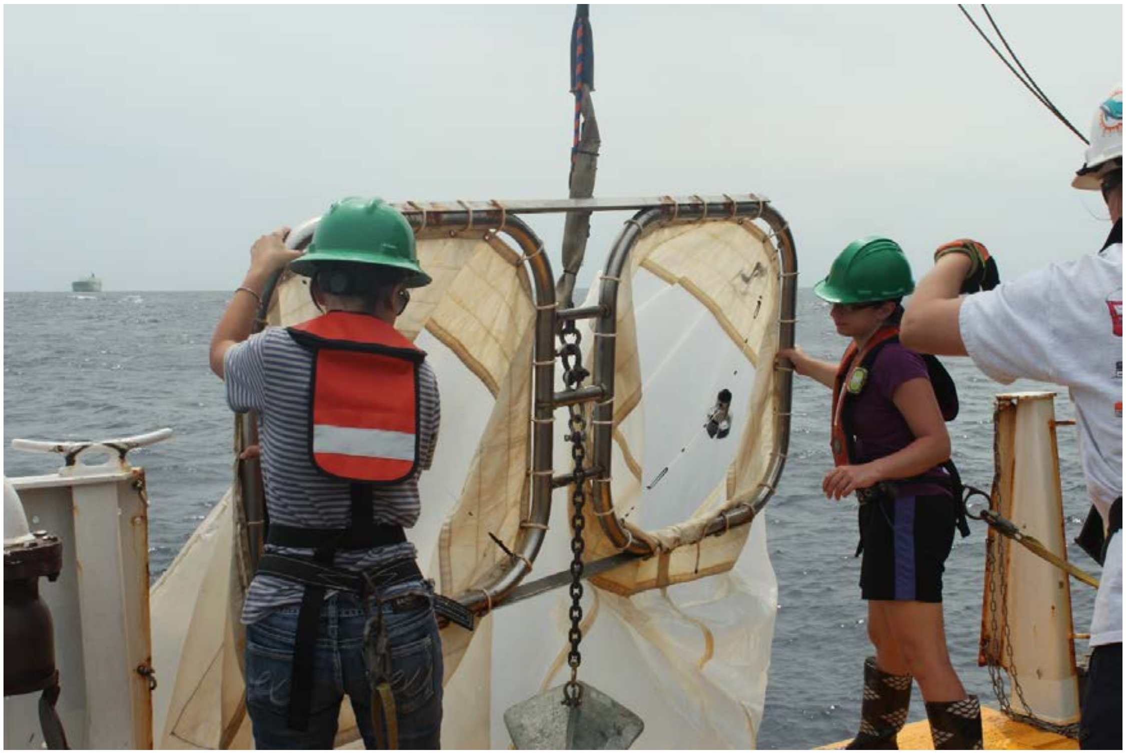

Figure 2: Undergraduate students from City University of New York retrieve the Bongo net on NOAA Ship *Nancy Foster*.

Figure 3: High school students from AZ Academy visit the wetlab on NOAA Ship *Nancy Foster* and view plankton samples under the microscope.

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:

The contractor has created software to generate automated reports that summarize various commercial fishery segments of the Gulf of Mexico and the South Atlantic; equations to estimate net revenues for these segments are built. Multiple user groups have been provided the output for comments and are awaiting feedback. Preliminary research has been completed and presented which evaluates the economic benefits of catch share management in the Gulf of Mexico reef fish fishery. Additionally, the contractor played a critical role in the design and roll out of the automated generation of an economic panel data set within the data warehouse.

Research Performance Measure: The economic analysis of economically and statistically meaningful sub-populations of the SE federal fin-fisheries (including at the trip- and annual/vessel-levels) is almost complete and the reporting design is in progress. The overall response rate and quality of the data collection has improved. The migration of the economic panel data set to the data warehouse is complete. A manuscript is being planned on the economic benefits of catch share management in the Gulf of Mexico reef fish fisheries.

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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 the University of South Florida College of Marine Science (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 below under the "MRA Core Courses" heading. The MRA program has succeeded in involving NOAA instructors in the design and execution of key coursework, specifically the *Fish Population Dynamics* course, which was team-taught by highly experienced NOAA personnel upon execution of the present agreement in August 2010 and has been taught since then by Dr. Cameron Ainsworth, a former NOAA fisheries biologist and modeler (contracted by NMFS NWFSC, Seattle). Dr. Ainsworth recently offered an

Ecosystem Modeling course that was remotely attended by 18 fisheries professionals from ten different NMFS labs on the east and west coasts of the US. Dr. Christopher Stallings, who is another faculty member recruited to USF under the NOAA-sponsored MRA program, continues as the lead instructor for *Fish Biology*.

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

There are currently 27 fulltime USF-CMS students participating in the MRA program, with 10 being Master's students and 17 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 (see *2014-15 Awards & Honors* below).

Research Performance Measure: The MRA-related coursework supported by the present agreement has been successful at attracting career-minded students in the area of MRA. Participation in the MRA Area of Concentration is a popular request among prospective students; hundreds of qualified prospective students have applied to the program, but the number that is accepted has become limited by available resources (Fig. 1). MRA students currently represent >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.

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.

The MRA program has produced 21 graduates to date. As intended, most MRA graduates are employed in the living-resource management field after graduation (57%) or pursue an academic position (38%; see *MRA Graduates* below). 5% have left the field.

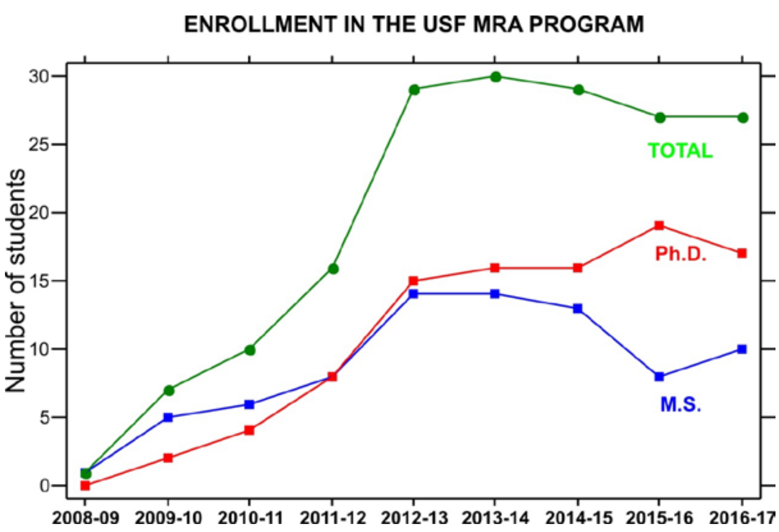


Figure 1: Enrollment in the USF-CMS Marine Resource Assessment (MRA) program by type of student and academic year.

Figure 2. Student on the R/V *Weatherbird II* with a fish caught during longlining surveys of Mexican and Cuban waters. The surveys were conducted during 2016-17 by students and faculty of the USF-CMS Marine Resource Assessment program.

Figure 3: Reef fish collected by students of the USF-CMS Marine Resource Assessment program for an egg-production study.

Figure 4: Students of the USF-CMS Marine Resource Assessment program working at the NMFS Panama City lab to prepare red snappers for fecundity analysis.

Annual Catch Limit (ACL) Monitoring Program

Project Personnel: A. Shideler (UM/CIMAS)
NOAA Collaborators: D. Gloeckner, M. Judge and K. Dettloff (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, gear type, 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). New modeling methods incorporating estimation of landings by non-federally permitted dealers and implementing confidence limits are being developed. We notify SERO within two weeks 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), coordination with local partners and additional outreach measures, such as sharing compliance summaries with stakeholders, should improve reporting in the future.

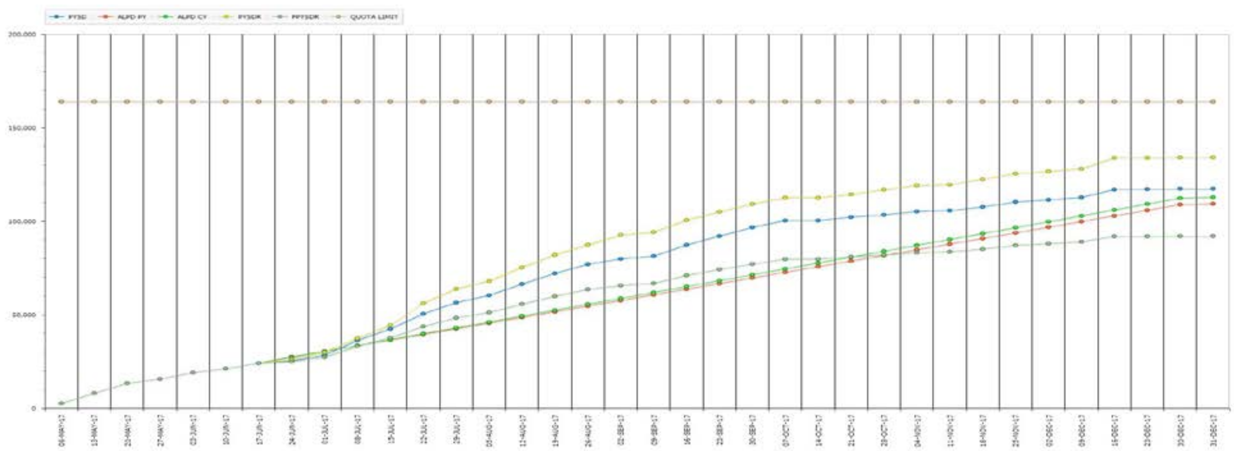


Figure 1: Landings of South Atlantic Red Porgy through June 17, 2017, with projected landings using different estimation methods for dates after June 17, 2017. The tan horizontal dotted line represents the quota limit, or Annual Catch Limit (ACL). Estimation methods are: Prior Year Same Day (PYSD, blue symbol, the dealer-based landings on the same day of the season the prior season), Average Landings Per Day Prior Year (ALPD_PY, red symbol, the dealer-based average landings per day for the prior season), Average Landings Per Day Current Year (ALPD_CY, light 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, dark green 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).

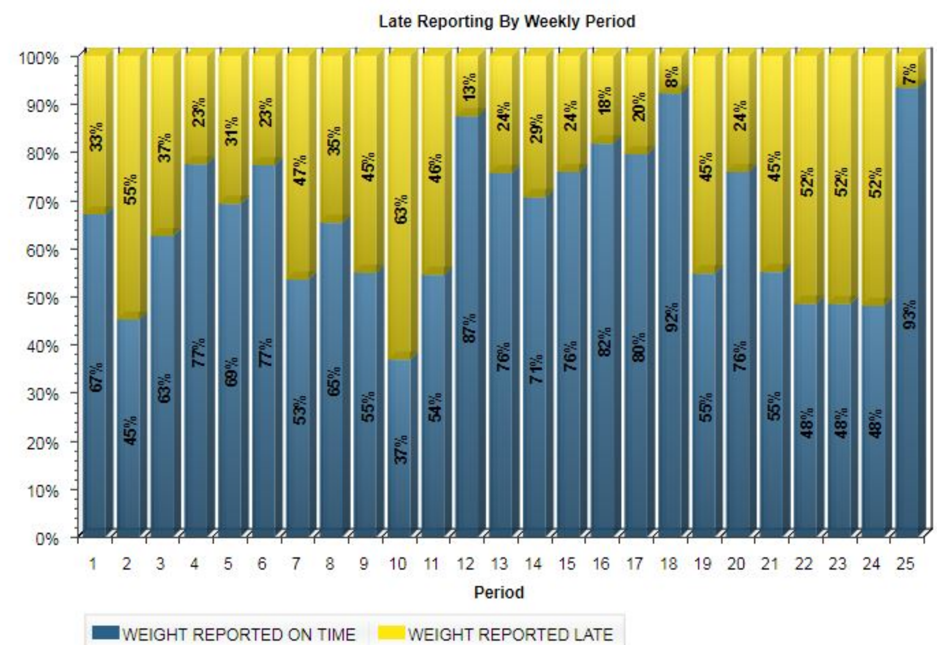


Figure 2: Percent of weight reported by dealers on time (blue) versus late (yellow) by weekly reporting period for the South Atlantic Gray Triggerfish Annual Catch Limit (ACL).

Research Performance Measure: Since 1 July 2016, 5510 emails or letters have been sent to 424 distinct dealers informing them of one or more periods of reporting non-compliance.

Since 1 July 2016, we advised for the closure of 18 quotas based on projected landings meeting or exceeding the ACL.

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).

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 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.

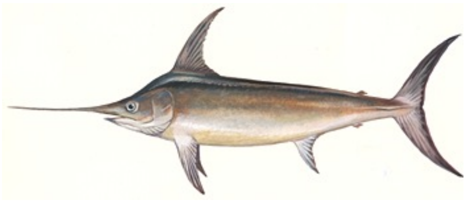
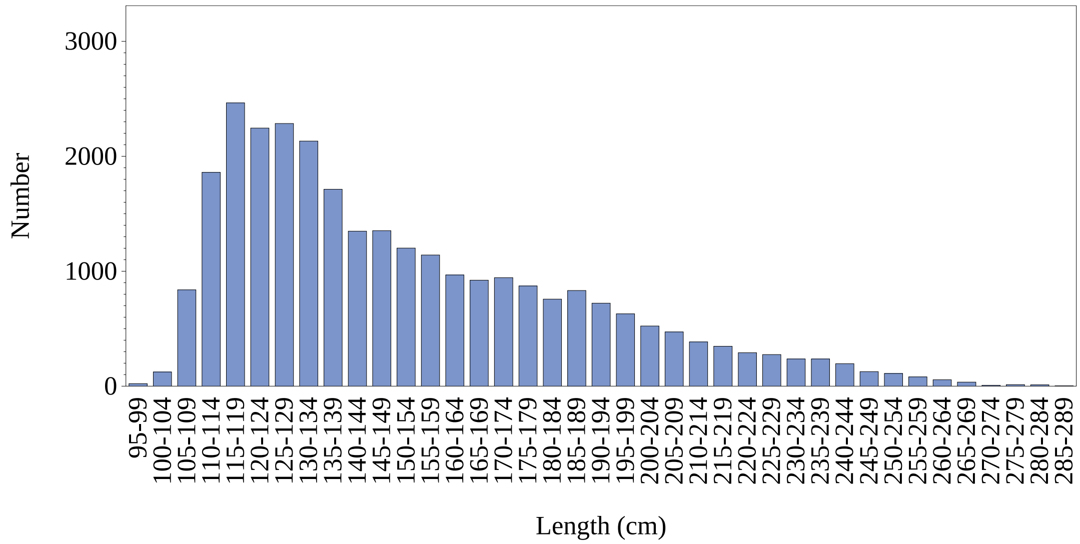


Figure 1: *Xiphias gladius*, the swordfish (www.safmc.net**)**

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

A)



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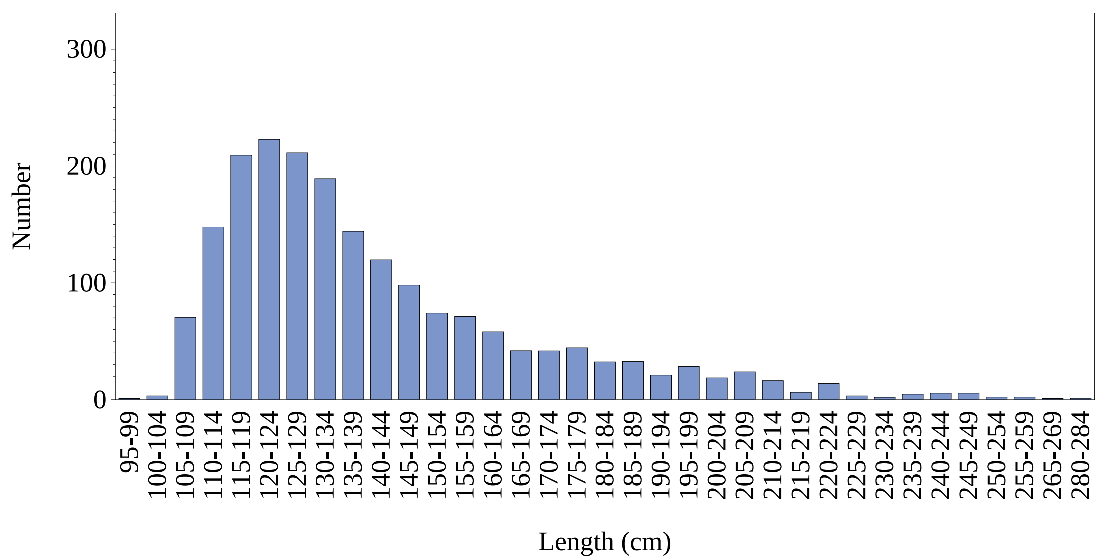

Figure 3: Length frequency (lower jaw fork length, in cm) of swordfish caught in commercial (A) longline and (B) hand gear fisheries obtained from catch as size (CAS) data reported to the Pelagic Longline program for 2015.

Research Performance Measure: One hundred thirty-nine validations designed to improve logbook data quality have been integrated into UDP. This includes 10 new validations added in the past year to improve quality of protected species bycatch data and automate corrections of data entry errors.

One hundred four vessels have been contacted about missing or invalid information submitted on logbooks for 373 distinct trips between 1 July 2016 and 30 June 2017, decreasing from 125 vessels contacted regarding issues on 483 trips during the same time period last year. This decrease indicates that correspondence regarding logbook reporting errors may be helping train stakeholders to properly complete their reporting requirements.

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National Marine Sanctuaries as Sentinel Sites for a Demonstration Marine Biodiversity Observation Network (MBON)

Project Personnel: K. Shulzitski (UM/CIMAS)
NOAA Collaborator: T. Gerard and J. Lamkin (NOAA/SEFSC)
Other Collaborators: F. Mueller-Karger, M. Hepner and D. Otis (USF)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives To develop a demonstration Marine Biodiversity Observation Network (MBON) aimed at monitoring changes in marine biodiversity within the Florida Keys National Marine Sanctuary (FKNMS).

***Strategy*:** To analyze geographically integrated time-series data in order to 1) describe patterns in oceanography as well as fish diversity and abundance through time in the FKNMS, 2) examine the relationship between oceanography and fish distributions, 3) elucidate underlying mechanisms driving patterns in fish diversity, and 4) contribute products to the operational phase of the MBON.

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 Marine Biodiversity Observation Network is a growing global initiative composed of regional networks of scientists, resource managers, and end-users working to integrate data from existing long-term programs to improve our understanding of changes and connections between marine biodiversity and ecosystem functions. Our work in MBON is part of this much larger initiative that encompasses participants from around the globe and that focuses on additional National Marine Sanctuaries across the United States.

As our contribution we are collecting novel time series data on oceanographic conditions adjacent to the FKNMS. Specifically, we are using satellite data (i.e., ocean color) to identify and track mesoscale and submesoscale eddies propagating through the Straits of Florida. These data will be used to examine

relationships between oceanography and fish distributions in the FKNMS. Patterns in fish distribution and diversity are being described using Reef Visual Census (RVC) data that extend from 1999 to the present. This dataset includes information on benthic variables. These benthic variables will be included in analyses to investigate mechanisms driving patterns in fish distribution and diversity and to specifically compare contributions of oceanographic versus benthic variables as key mechanisms.

Research Performance Measure: In collaboration with Megan Hepner, the RVC data have been used to calculate five metrics of reef fish distribution and diversity across space (i.e., habitat types with the FKNMS) and time (i.e., time series of RVC dataset; see Figure 1). The five metrics are biomass and abundance, and three measures of diversity: species richness, the Shannon entropy index, and the Gini-Simpson index. Temporal and spatial patterns are being used to determine the operational metrics produced for end users of this MBON dataset (e.g., infographic, map).

In collaboration with Dan Otis, ocean color images for oceanographic time series analysis have been obtained and cataloged (Figure 2). Metrics for quantification have been determined. Semi-automated methods for analysis of images are currently being implemented. Analysis of images is planned to begin August 2017 and to be completed January 2018.

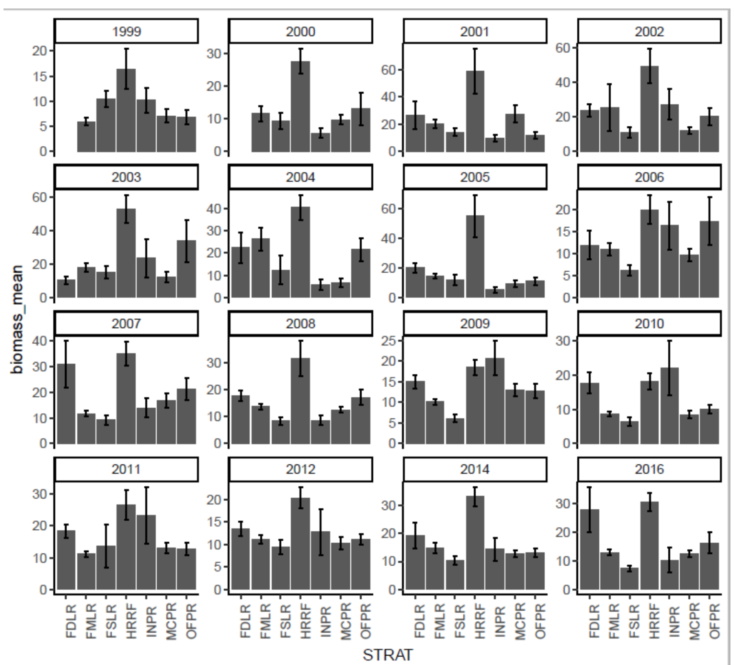


Figure 1: Mean (+/- SE) fish biomass by year and across habitat types in the Florida Keys National Marine Sanctuary.

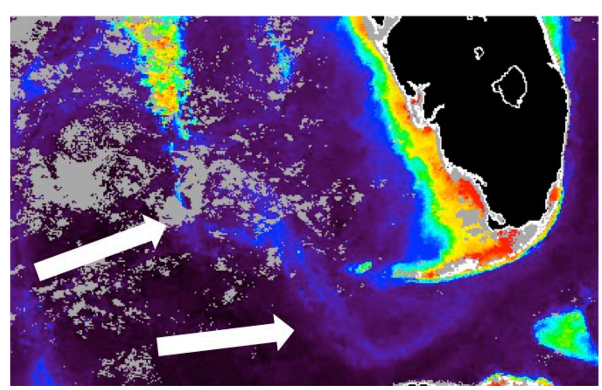


Figure 2: Ocean color image showing chlorophyll a data as a 7-day composite (processed by USF).

Monitoring and Prediction of Phytoplankton Dynamics in Biscayne Bay, Card Sound and Barnes Sound

Project Personnel: A. Wachnicka (FIU)
NOAA Collaborator: T. Jackson and J. Browder (NOAA/SEFSC); C. Kelble (NOAA/AOML)
Other Collaborators: L. Visser (UM/CIMAS); K. Kulpa (UM/RSMAS)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To assess hydro-ecological conditions in nearshore areas of Biscayne Bay based on spatial distribution of epiphytic and planktonic algae at 29 locations along N-S transect near western shoreline and at the major drainage canals.

Strategy: 1) To differentiate major algal taxa in the phytoplankton using HPLC analysis; 2) To quantify species composition of diatom taxa of seagrass epiphytes using cell counts; 3) Measure water quality parameters (nitrogen, phosphorus, silica).

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 (Secondary)*

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

Research Summary:

Biscayne Bay is a shallow lagoonal estuary adjacent to a large metropolitan Miami, coastal wetlands and farmlands to the west and barrier islands to the east. A highly structured system of canals operated by South Florida Water Management District (SFWMD) controls the flow paths of water delivered to coastal wetlands and the nearshore areas of Biscayne Bay.

Characterization of algal communities and water quality conducted in this study was done at 29 locations along the N-S transect and from the mouth to the most inland location in the major drainage canals that could be reached by the boat (Figs. 1, 2). These locations are experiencing significant inter- and intra-annual changes in freshwater quantity and quality due to changes in discharges from the major drainage canals, storm water runoff and groundwater. These western nearshore areas will be most affected by the Biscayne Bay Coastal Wetlands Project (BBCWP).

Physical and chemical measurements provide quantitative data on the presence and levels of aquatic pollution and degradation, but these parameters do not reflect the extent of environmental stress reaching the living organisms or the subsequent effects of this stress. Our ability to protect key biological resources such as seagrass beds depends on our ability to quickly identify and predict the effects of human actions on biological systems. Unlike other biological indicators, algae have a long history of successful use in restoration and ecological assessment projects in freshwater and marine systems. This is due to their ability to respond quickly to environmental perturbations, which makes them a powerful tool in the early detection of deteriorating environmental conditions. Early warning is critical for formulation

of appropriate management actions in time to prevent serious ecosystem damage to valued ecosystem components like seagrass. Many investigators showed that algae-based indices of water give the most precise data compared to chemical and zoological assessments, which was also evident in this study.

Algae are powerful indicators of environmental change in aquatic systems as many taxa have distinct ecological requirements and narrow tolerances to different water quality parameters, which makes them ideal organisms for early detection of deteriorating water quality conditions that could result from the restoration efforts or increased freshwater inflows. This survey was conducted as part of a longer effort to characterize spatial and temporal differences in algal communities along salinity and nutrient gradients.

The major goal of this project was to assess hydro-ecological conditions in nearshore areas of Biscayne Bay based on spatial distribution of epiphytic and planktonic algae at 29 locations along N-S transect and the major drainage canals. A total of 29 sites were selected along the Biscayne Bay shore and the major drainage canals (Figs. 1, 2) to encompass the gradients of salinity and nutrients availability in this area. Environmental conditions at the locations are driven by precipitation, groundwater discharge and surface water from canals, natural creeks, and overland flow. Nearshore areas have degraded water quality due to release of pollution from a nearby municipal landfill; nutrients and heavy metals from agricultural and urban areas; and sewage, solid wastes, fuel and oil pollution from local marinas. The distribution and dominance of benthic and planktonic microorganisms and vegetation are strongly influenced by freshwater. Our study sites captured the nearshore gradients in water quality.

Samples for measuring physico-chemical conditions, phytoplankton biomass and composition were collected at 29 stations Central and South Biscayne Bay, Manatee Bay, Barnes Sound and Card Sound (Fig. 1) in December 2016. At each station, surface water samples (~0.3-0.5 meter) were collected for nutrient, phytopigment and phytoplankton composition analyses using a marine bilge pump (pumping time was recorded and used for calculations of the total volume of water pumped via the 10 µm phytoplankton net used for phytoplankton compositional analysis). Water & phytoplankton samples were placed in coolers to maintain dark, in situ temperature conditions for the duration of each sampling trip. Samples for microscopic phytoplankton analysis were preserved with Lugol solution immediately after collection. YIS 6600 was used to measure salinity, temperature, pH. At each site, water depth was measured using a depth sounder. Additionally, 100- 150 ml of water was filtered through Whitman Glass microfiber filters (Grade GF/F) for Chlorophyll a analysis and 2000 ml of water was collected for chemotaxonomic algae analysis with HPLC. These samples were immediately stored in a -80C freezer after filtration through 47 mm GF/F filters in the lab, until HLPC analysis. Furthermore, 55 ml of water was filtered through 0.2 um Whatman PTFE syringe filters, stored frozen and later analyzed for water NO3, NO2, NH4, Si03, and P04.

In a lab, the 500 ml plankton samples were concentrated to 100 ml by allowing the material in the glass beakers to settle down under a fume hood for at least 24 hours and carefully vacuuming water out from the top using a syringe. A 10 ml subsample of slurry was obtained from each of the sample algal observations and photo-documentation. Samples for Chlorophyll *a* were analyzed within 2-3 weeks (they were kept in -80C freezer until analysis). Chlorophyll *a* was measured spectrophotometrically using a TD-700 Turner fluorimeter at NOAA Atlantic Oceanographic and Meteorological Laboratory (NOAA AOML). Concentrations of nutrients in water were determined by gas-segmented continuous flow colorimetric analysis on the Seal analytical autoanalyzer AA3 using the EPA methods 349.0 for NH4; 366.0 for SiO3; 353.4 for NO3 and NO2; 365.5 for PO4 at NOAA AOML. The relative concentrations of taxa-specific indicator pigments (chlorophyll a, chlorophyll b, fucoxanthin, and zeaxanthin) was measured at FAU using HPLC.

Figure 1: Map showing phytoplankton sampling locations in Biscayne Bay (Florida, U.S.A.). Nearshore locations marked with letters JP, A or LB. Sites in major canals marked as C or G: Coral Gables Canal (G1-G10); Snapper Creek Canal (C7,C8); Cutler Channel (C9,C10); Princeton Canal (C11,C12); Military Canal (C13, C14); Mowry Canal (C15, C16); Convoy Point (C17, C18); Deering Estate (J6), canal S of Turkey Point (C19, C20); C-111 Canal (B1, C21); Barnes Sound (LB12); Card Sound (LB10);

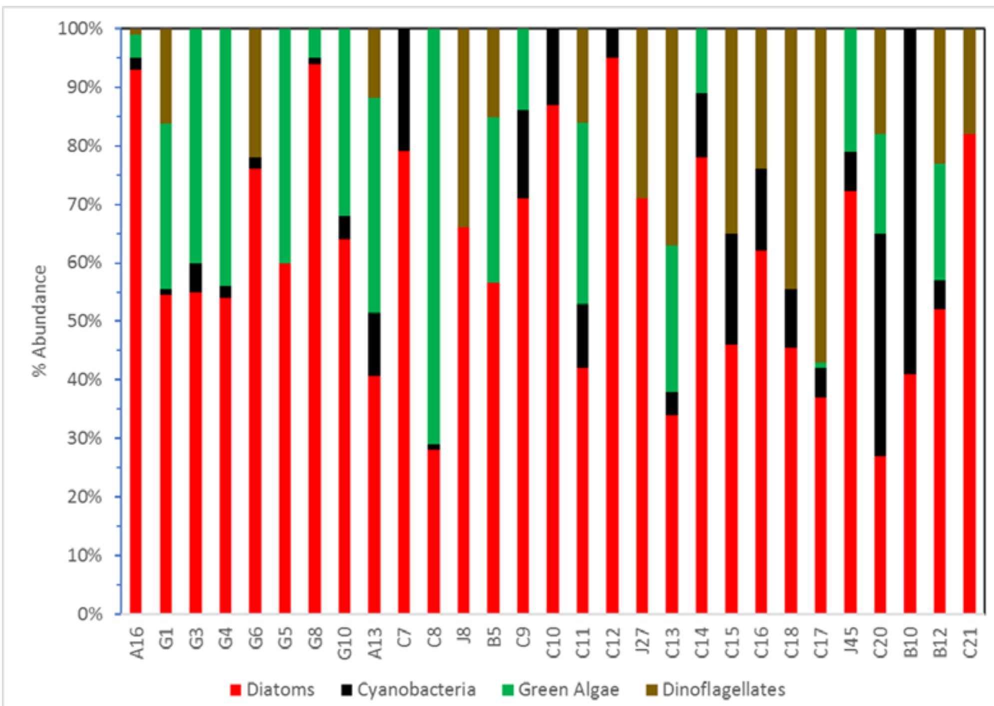


Figure 2: Changes in relative abundance of the major phytoplankton groups along at nearshore locations in Biscayne Bay.

Project findings were as follows:

- Phycotaxonomic analysis with HPLC revealed that diatoms were the most abundant algae at most samplingof locations. Increase abundace of cyanobacteria was recorded in Manatee Bay and Barnes-Card Sound region. Green algae were abundant in the Coral Gables and Snapper Creek canals while dinoflagellates in canals near Convoy Point and Mowry Canal (Figs. 2)
- Algal biomass (concentration of chlorophyll *a*) was highest at northernmost locations, especially in the Coral Gables canal and near Coral Gables waterway (Figs. 3,4). The maximum value (3.01 µg/L) was recorded at the most inland location in the Coral Gables canal (G10) and the lowest (0.06 µg/L) south of Princeton Canal (J27). Seventy five percent of all recorded chlorophyll a

values were equal to or below 0.5 μg/L. The sites with highest algal biomass concetration also had elevated levels of phosphorus and silica.

- Sites could be grouped into 4 major clusters and 3 subclusters based on similarity in water quality. The Snapper Creek (Cluster A), Princeton Canal (cluster B), and the middle Coral Gables canals (Cluster C) had significantly different water quality compared to the remaining sites (Cluster D). Water quality also differed among Cutler Channel (subcluster D1), sites in the lower Coral Gables Canal and Card-Bernes Sound region (subcluster D2), and remaining canals (subcluster D3).
- Salinity was significantly lower in the Coral Gables canal, Snapper Creek and Princeton Canal. Silica was was highest in the Coral Gables and Princeton canals. Princeton Canal also had the higherst PO4 levels. Water in Snapper Creek had the higherst NO2 and NO3 concetration levels and the lowest pH, while water in Cutler Channel was the coldest and had the highest concentration of NH4.

The following work is in progress:

- Development of algal prediction models based on the results of chemotaxonomic analysis of phytoplankton.
- Improvement of predictive abilities of algae biomass prediction models developed in the previous annual report in this project.
- Phycologic analysis of epiphytic assemblages from dry season 2016.

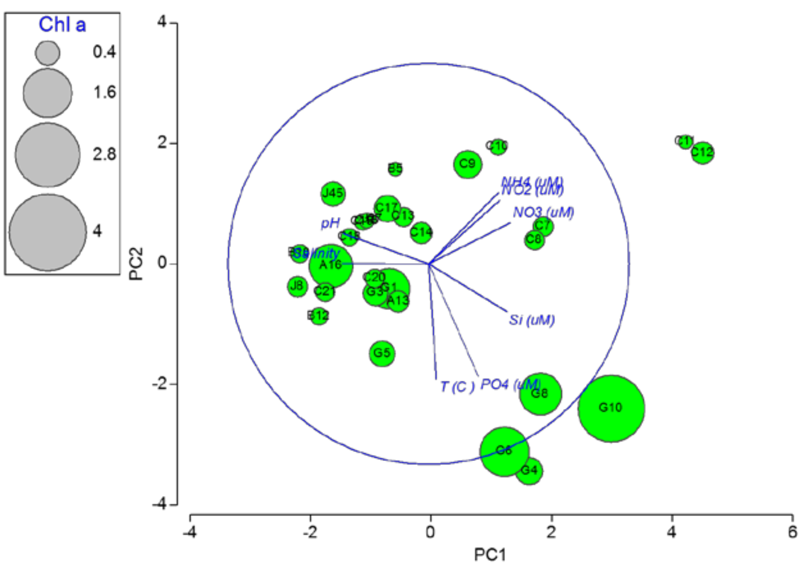
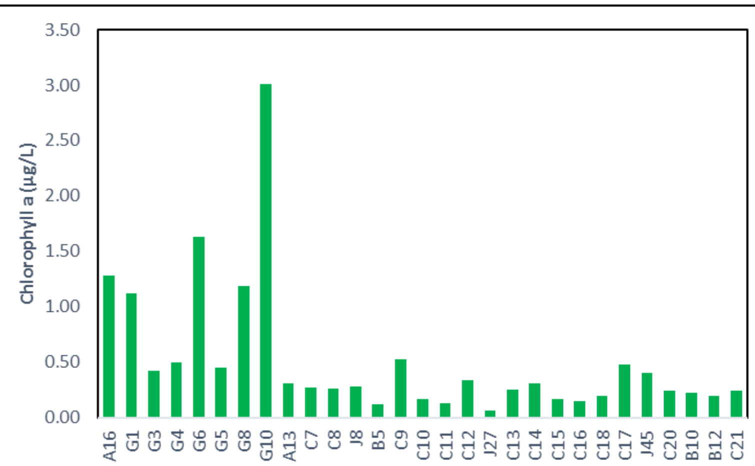


Figure 3: Similarity among sites based on algal biomass (concentration of chlorophyll a) and water quality.

Figure 4: Concentration of chlorophyll a at the the sampling locations



Research Performance Measure: The following research performance measures are being developed by this project to assess the health of western nearshore Biscayne Bay:

1. Proportions higher taxonomic classes (diatoms, chlorophytes, dinoflagellates, and cyanobacteria) of phytoplankton (as determined by pigment analysis using HPLC techniques.
2. Species composition and relative species abundance in the diatom community of the phytoplankton (as determined by strategic counting of cells under a microscope).

Change in either measure indicates a response of the ecosystem to changing conditions. Furthermore, with algal-based measures, substantial information resides in the specific type of change. For example, an increase in cyanobacteria (PM1) suggests degrading conditions. An increase in the diatom genus *Chaetoceras* suggests emerging potentially harmful conditions for filter-feeding fish and the food webs they support. In addition, certain diatom species are indicators of a specific change in environmental conditions (e.g., decreasing salinity or a change in the balance of nutrients, with specific nutrients).

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

Project Personnel: D. Williams, A. Bright and R. Pausch (UM/CIMAS)
NOAA Collaborator: M. 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 undertake hypothesis-driven field experiments evaluating *Acropora* spp. restoration strategies.

***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) To plant nursery raised *A. palmata* fragments in a variety of configurations to determine the effect of genotypic diversity on the longterm ability to form thickets.

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 ongoing long term monitoring component of this project has entered its thirteenth year and is the longest existing record of *Acropora palmata* (elkhorn coral) population trends. In that time period the study has documented major losses associated with episodic events including tropical storms and bleaching events along with more chronic threats including disease and predation. Since 2004 the population (in terms of tissue abundance has declined by over 50%. This study tracks demographic data

for the upper Florida Keys population by monitoring fixed study plots at 7 reefs off Key Largo. Study plots (150 m^2) are surveyed annually to document growth, recruitment and mortality and three times a year a subset of the colonies are assessed for threats such as disease and predation. In 2016 we established monitoring plots at an additional site to be monitored annually. Live cover of *A. palmata* declined by 50% as a result of the 2005 hurricane season, the population showed a very modest trend towards recovery until two unprecedented back to back bleaching events in 2014 and 2015. These events combined resulted in a loss of nearly 1/3rd of the live tissue cover at the monitoring sites. In 2016 a slight decline was observed as colonies that were stressed by the 2015 bleaching event continued to die.

The recovery plan for *Acropora palmata* specifically addresses the restoration of thickets as a criteria for recovery of the species. Additionally, in the monitoring component of this project we have observed that higher density stands may be more resistant to some stressors. Based on these concepts, an experiment was designed to examine the effectiveness of outplanted elkhorn coral in developing high density thicket structures important for habitat. Experimental treatments include genotypic diversity and interspersion of genets within outplanted plots. This experiment was initiated in summer 2016 and was surveyed in Nov 2016 and May 2017 (including counts of fish and invertebrate use of the outplanted coral plots). Semi-annual surveys are expected to continue through 2020.

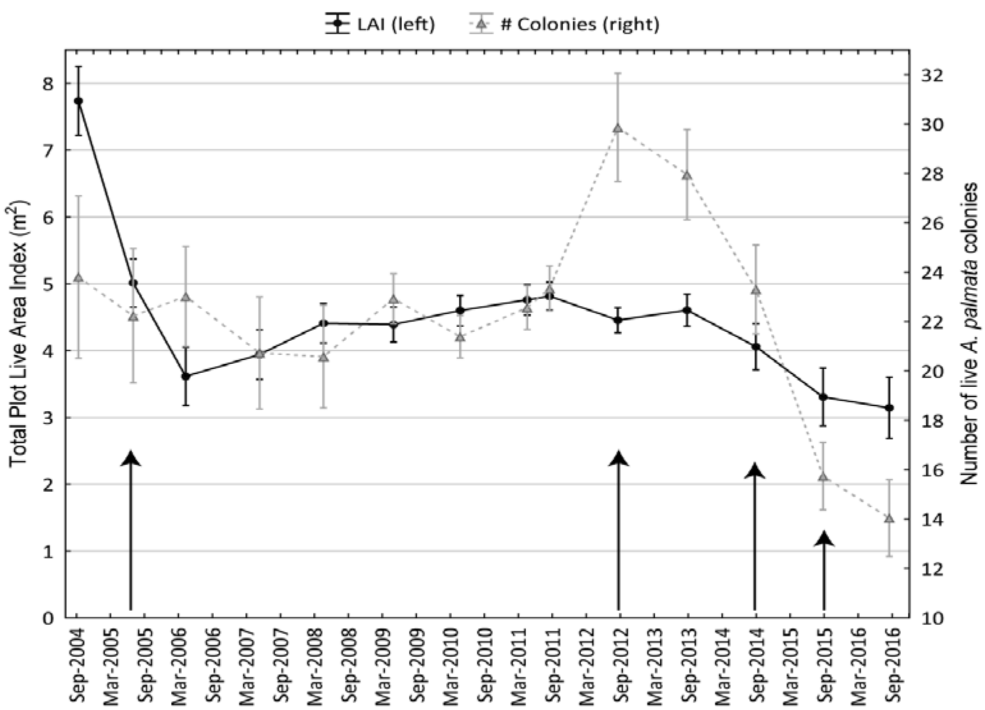


Figure 1: Abundance of Acropora palmata in the upper Florida Keys expressed as Live Area Index (a measure of tissue cover) and the number of colonies in a 150m^2 plot. Error bars are standard error. Arrows indicate timing of tropical storms (2005 and 2012), and bleaching events (2014 and 2015).

Research Performance Measure: All planned monitoring surveys of the Florida Keys demographic sites were conducted as scheduled in spite of challenging weather and substantial resource limitations (limited boat access). Findings from the monitoring component (2010 to 2016) are presented in a peer-reviewed publication that is in press. The outplant field experiment was successfully setup in Summer 2016 and is being monitored as planned.

Support of t.he 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 DOI OIA)

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

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

NOAA Funding Unit: NOAA/CRCP
NOAA Technical Contact: John Tomczuk

Research Summary:

In the last year, NSU the seven coral management assistants for all seven jurisdictions – American Samoa, CNMI, Florida, Guam, Hawaii, Puerto Rico and USVI have continued to work toward completion of their work plans, which were developed in collaboration with NOAA and the jurisdictional agencies.

The Hawaii coral assistant left the position in February 2017 for a full time coral monitoring position with the local agency. While he left the position sooner than hoped, this outcome is viewed as a success as the assistantship led to full-time employment with the agency, working to build local capacity. The CNMI coral assistant vacated early in November 2016, for personal reasons, but was replaced with a very qualified candidate, who started in February 2017.

In March 2017, all six coral assistants, along with NOAA CRCP and NSU staff met for a Year 2 training orientation in Kona, HI, where they worked with meeting facilitator Kevin Doyle, to present their work plan progress and receive further professional development training. The training also included site visits to local priority watersheds, where the assistants learned about management strategies.

NSU and NOAA staff have monthly check-in calls with the seven coral assistants, which at times also include the local agency POC/supervisor. There is also interaction on a regular basis with NOAA CRCP jurisdictional liaisons.

All six have also planned their professional development training for 2017, which they will complete between July and September 2017.

Research Performance Measure: The assistants met all goals for the program this year. While the Hawaii assistant did depart early, the other six continue to work toward completing their workplans by the end of their assistantship in January 2018. All six assistants are working successfully in their respective local jurisdictional agency and continue to have regular contact via scheduled calls with NSU and NOAA.

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.

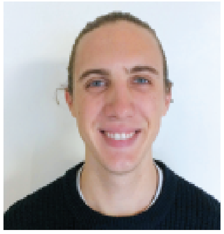
As Puerto Rico's fellow, León-Pérez is working under the Puerto Rico Coral Reef Conservation and Management Program (PRCRMP) at the Department of Natural and Environmental Resources. Her efforts are centered on conducting an assessment of PRCRMP's Coral Reef Monitoring Program and providing recommendations 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) • Malcolm Johnson



Raised in Northern Virginia, Malcolm Johnson received his B.A. in Environmental Sociology from Wichita State University and his M.A. in Ocean and Coastal Resource Management from the Middlebury Institute of International Studies in Monterey.

As the fellow in the CNMI, Johnson is working on the Luta/Talakhaya Revegetation Project, located on the island of Rota. The overall goal of his project is to improve the health of the Talakhaya watershed, including its streams and adjacent coral reef habitat, from land-based sources of pollution. His 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.

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.

02-007-17MCP

RESEARCH REPORTS

THEME 7: Protection and Restoration of Resources

Develop a Computer System to facilitate researchers to do their tasks. Data Request Tracking System (DRT) and Fisheries Trip Matching System (FTM)

Project Personnel: S. Aguilar and A. Shideler (UM/CIMAS)
NOAA Collaborators: D. Gloeckner, S. Turner and J. Hall (NOAA/SEFSC)
Other Collaborators: O. Rodriguez (Jamison Professional Services)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** Develop a system that helps to the data managers to track the data requests (DRT system) and keep maintaining FTM (Trip Matching System) system checking that new data is up to date.

***Strategy*:** DRT: SEFSC currently was a Data Request form on paper. The form will be filled out in the system and allows to the manager to assign the request to the data manger and allows to keep track of the progress. FTM: We are constantly monitoring the different data sets are updated and jobs are being run to find new matching trips.

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: DRT: Developed in Oracle-Application Express (APEX). The interface was designed based on the user needs. Allows to the administrator to assig a data request and also allows to keep track of how the request is progressing.

FTM: Continuously run a new jobs to create new matches and keep monitoring of the data updates. Also gives support the users of the system.

Research Performance Measure: DRT: Currently in testing phase; FTM: Operational.

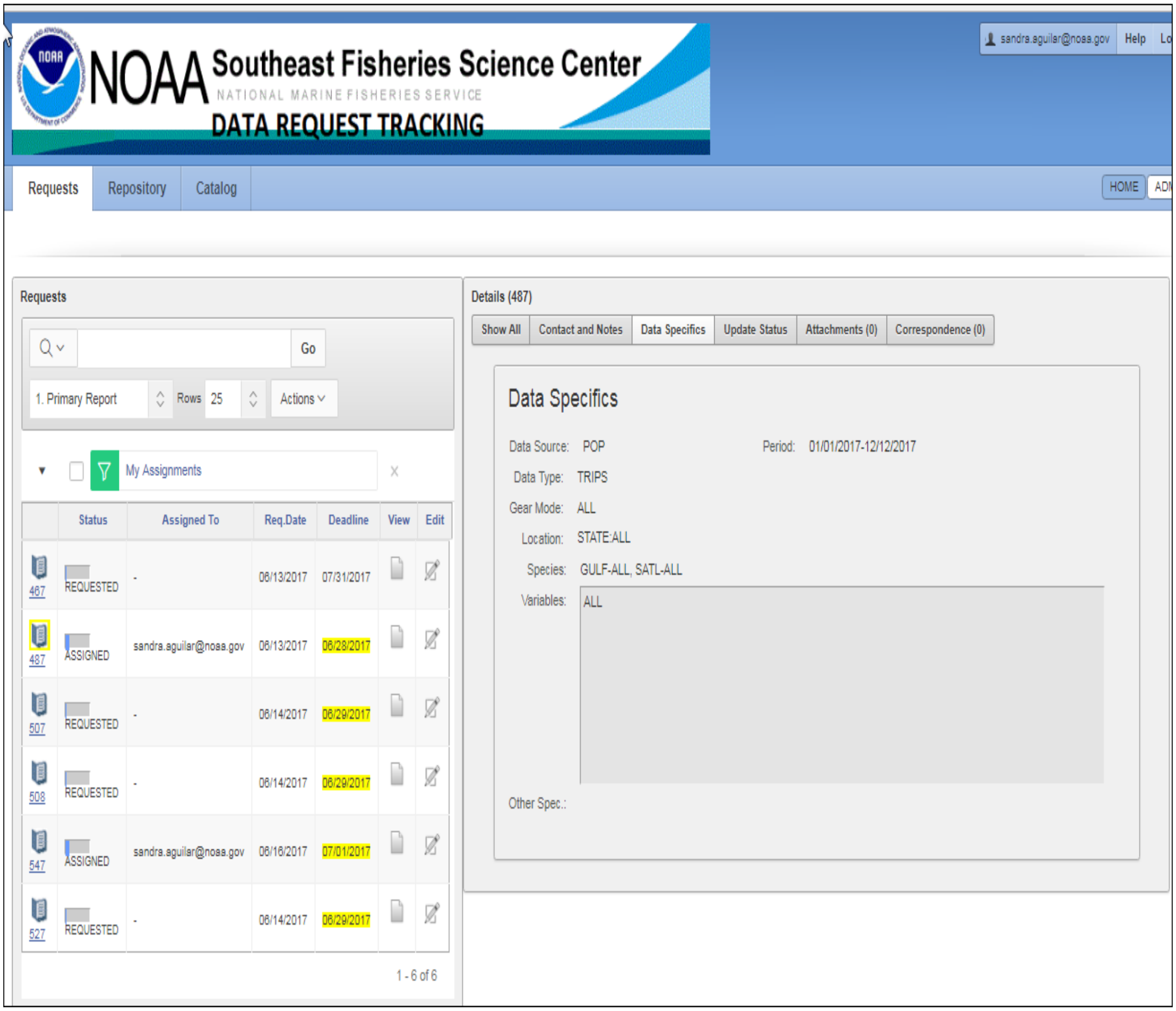


Figure 1: Data Request Tracking

Marine Mammal Research

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

Long Term Research Objectives and Strategy to Achieve Them:

Objectives To collect and manage cetacean data from the Atlantic and Gulf of Mexico marine assessment programs for protected species. To support the National Oceanic and Atmospheric Administration (NOAA) and the Southeast Fisheries Science Center (SEFSC) missions in management of protected species.

Strategy: To explore options for the development of a comprehensive geodatabase for historical and future survey data; To collect broad-scale data over multiple years on the seasonal distribution and abundance of cetaceans using direct aerial and shipboard surveys of coastal U.S. Atlantic Ocean and Gulf of Mexico waters; To manage the data originating from the aerial and shipboard research surveys; To assist in writing technical reports and scientific publications; To respond and coordinate response actions during cetacean strandings dead or alive in the US Southeast Region. 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:

As a conclusion of the Offshore Marine Mammal Injury Assessment studies originating from the Deepwater Horizon (DWH) oil spill, co-authors and I published a peer-reviewed article on the documentation at least 11 cetacean species swimming through oil and sheen or with oil adhered to their skin following the DWH oil spill (see Figure 1 and publication below).

In the summer of 2016, I participated in the Atlantic Marine Assessment Program for Protected Species (AMAPPS) research cruise onboard the NOAA Ship *Gordon Gunter* in the east coast of the United States. The main goal of this survey was to collect data on cetacean distribution and abundance in the Atlantic Ocean. During this cruise, I conducted marine mammal observations and performed management of data and samples collected from dolphins and whales observed throughout the survey. Once back from the survey, I continued managing the data and assisted in writing technical reports and scientific summaries.

Another research activity I participated was the long-term monitoring of bottlenose dolphins (*Tursiops truncatus*) in Biscayne Bay. By means of photo-identification (photo-ID), the SEFSC has been monitoring this wild dolphin population since the 90's and has a catalog of more than 200 resident animals. During field efforts in October 2016, I worked as a photographer and off-season, I assisted in project planning and writing of technical reports. Similarly, in January 2017, I assisted during the Timbalier-Terrebonne bottlenose dolphin photo-ID project in Louisiana.

During the spring semester of 2017 I enrolled in the Data Management in the Research Environment class at the Rosenstiel School of Marine and Atmospheric Science (RSMAS) campus. The main focus of this class was to introduce several practical tools for digital scholarship, encouraging early adoption of best practices in research data management. This class was instrumental in further developing my skills and insights into data management standards and processes and in the onset of development of the comprehensive geospatial database for cetacean sighting data.

In May 2017 I participated as an observer in the AMAPPS aerial survey, which main goal was to collect data on the distribution and abundance of cetaceans and sea turtles in the US Atlantic waters. This survey was flown between New Jersey and Florida aboard a NOAA Twin Otter aircraft.

Research Performance Measure: all objectives were completed on time.

- Senior authored a peer-reviewed article as part of the Offshore Marine Mammal Injury Assessment studies following the DWH oil spill in the Gulf of Mexico.
- Worked as a marine mammal observer and managed data and samples collected during the 2016 AMAPPS research cruise in the Atlantic Ocean.
- Assisted in project planning and development for the Biscayne Bay Photo-ID project also working as a photographer during the field season.
- Assisted in field work during the Timbalier-Terrebonne bottlenose dolphin photo-ID project in Louisiana.
- Attended the Data Management in the Research Environment class at the Rosenstiel School of Marine and Atmospheric Science (RSMAS).
- Worked as a marine mammal observer during the 2017 AMAPPS aerial survey in the Atlantic Ocean.
- Assisted in writing scientific publications and technical reports for the SEFSC.
- Trainings accomplished: 8-hour Hazardous Waste Operations and Emergency Response (HAZWOPER); Department of Transportation/ International Air Transport Association Hazardous Material Shipping (DOT/IATA); First aid, cardiopulmonary resuscitation (CPR) and automated external defibrillator (AED).

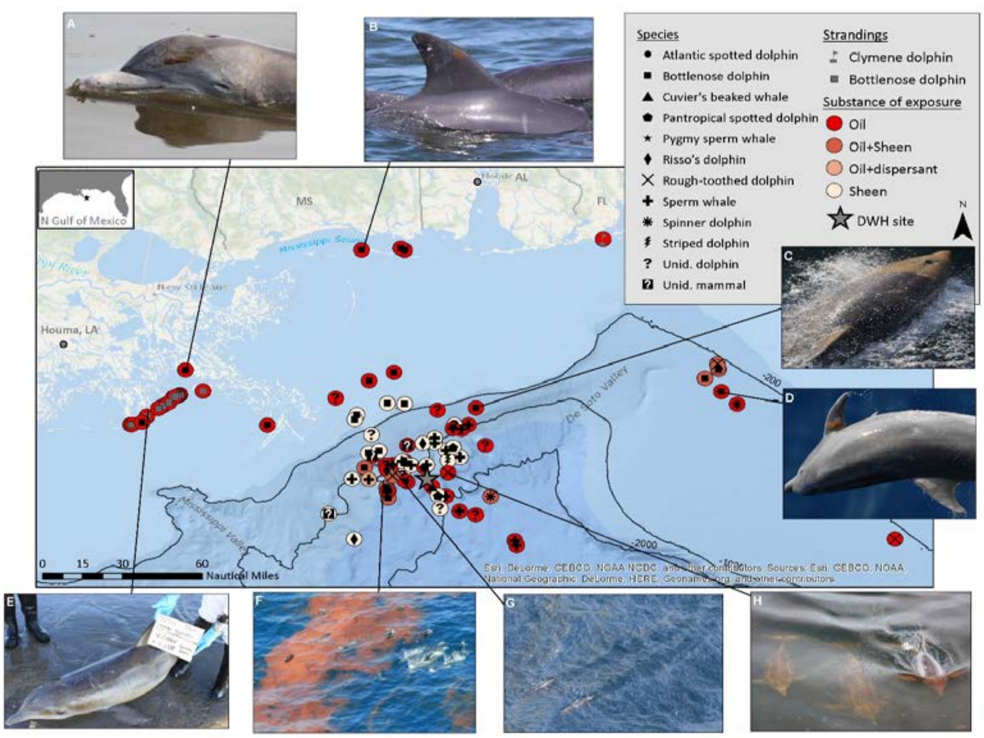


Figure 1: Map with photos of cetaceans with direct exposure to oil.

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:

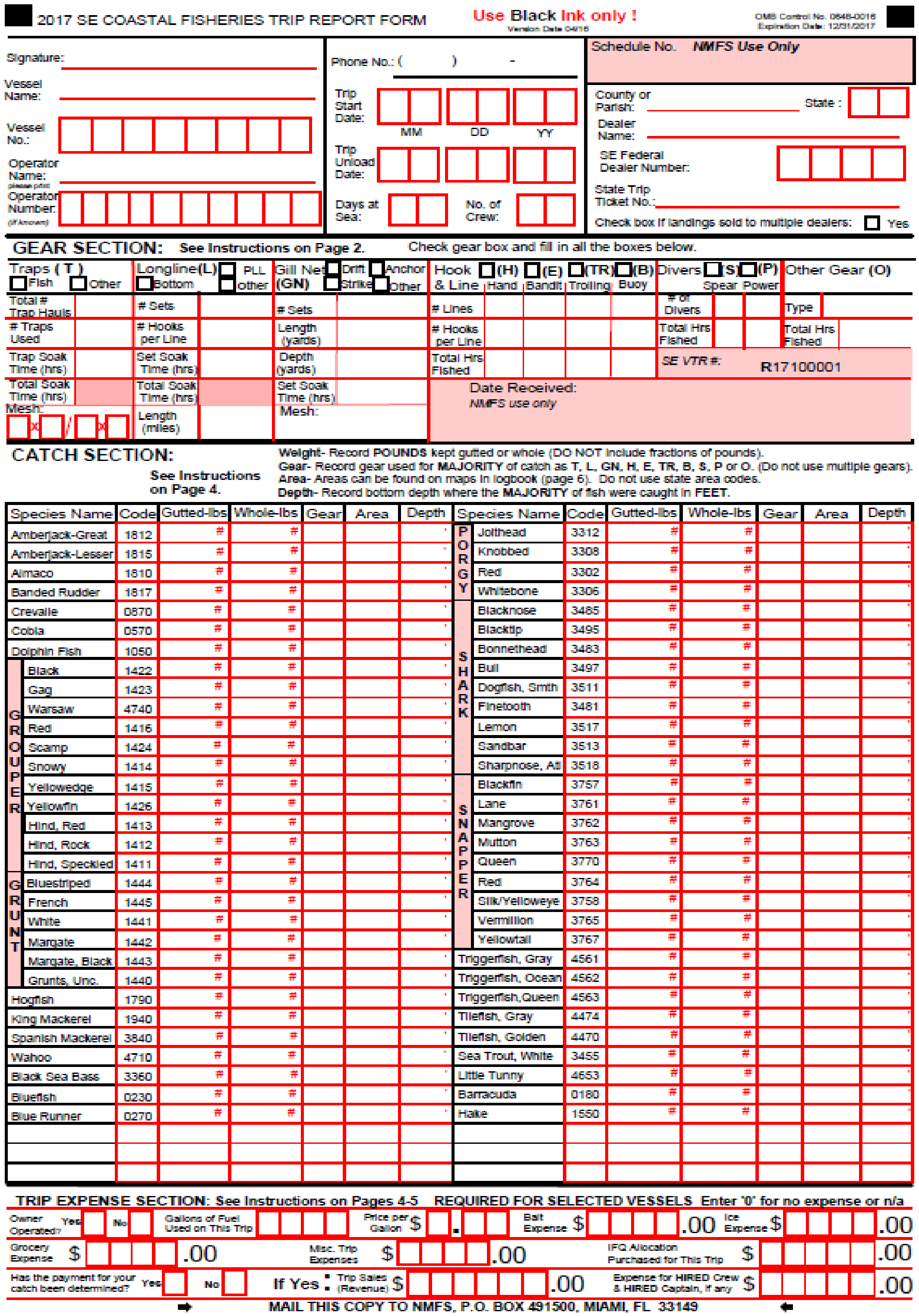
***Goal 1*:** Healthy Oceans - *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems*

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.



2017 SE COASTAL FISHERIES TRIP REPORT FORM

Use Black Ink only !

Version Date 04/16

OMB Control No. 0648-0016
Expiration Date: 12/31/2017

Signature:

Vessel Name:

Vessel No.:

Operator Name: (please print)

Operator Number: (if known)

Phone No.: (   )   -

Trip Start Date: MM DD YY

Trip Unload Date:

Days at Sea:

No. of Crew:

Schedule No. *NMFS Use Only*

County or Parish:

State :

Dealer Name:

SE Federal Dealer Number:

State Trip Ticket No.:

Check box if landings sold to multiple dealers: ☐ Yes

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

Traps (T) ☐ Fish ☐ Other		Longline(L) ☐ Bottom ☐ PLL ☐ other		Gill Net (GN) ☐ Drift ☐ Strike ☐ Anchor ☐ 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 #:*	R17100001		
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 4.

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	#	#					Knobbed	3308	#	#			
	Almaco	1810	#	#					Red	3302	#	#			
	Banded Rudder	1817	#	#					Whitebone	3306	#	#			
	Crevalle	0870	#	#				SHARK	Blacknose	3485	#	#			
	Cobia	0570	#	#					Blacktip	3495	#	#			
	Dolphin Fish	1050	#	#					Bonnethead	3483	#	#			
GROUPER	Black	1422	#	#					Bull	3497	#	#			
	Gag	1423	#	#					Dogfish, Smth	3511	#	#			
	Warsaw	4740	#	#					Finetooth	3481	#	#			
	Red	1416	#	#					Lemon	3517	#	#			
	Scamp	1424	#	#					Sandbar	3513	#	#			
	Snowy	1414	#	#					Sharpnose, Atl	3518	#	#			
	Yellowedge	1415	#	#				SNAPPER	Blackfin	3757	#	#			
	Yellowfin	1426	#	#					Lane	3761	#	#			
	Hind, Red	1413	#	#					Mangrove	3762	#	#			
	Hind, Rock	1412	#	#					Mutton	3763	#	#			
	Hind, Speckled	1411	#	#					Queen	3770	#	#			
GRUNT	Bluestriped	1444	#	#					Red	3764	#	#			
	French	1445	#	#					Silk/Yelloweye	3758	#	#			
	White	1441	#	#					Vermillion	3765	#	#			
	Margate	1442	#	#					Yellowtail	3767	#	#			
	Margate, Black	1443	#	#					Triggerfish, Gray	4561	#	#			
	Grunts, Unc.	1440	#	#					Triggerfish, Ocean	4562	#	#			
	Hogfish	1790	#	#					Triggerfish, Queen	4563	#	#			
	King Mackerel	1940	#	#					Tilefish, Gray	4474	#	#			
	Spanish Mackerel	3840	#	#					Tilefish, Golden	4470	#	#			
	Wahoo	4710	#	#					Sea Trout, White	3455	#	#			
	Black Sea Bass	3360	#	#					Little Tunny	4653	#	#			
	Bluefish	0230	#	#					Barracuda	0180	#	#			
	Blue Runner	0270	#	#					Hake	1550	#	#			

TRIP EXPENSE SECTION: See Instructions on Pages 4-5 **REQUIRED FOR SELECTED VESSELS** Enter '0' for no expense or n/a

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 : Trip Sales (Revenue) $ .00 | Expense for HIRED Crew & HIRED Captain, if any $ .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.

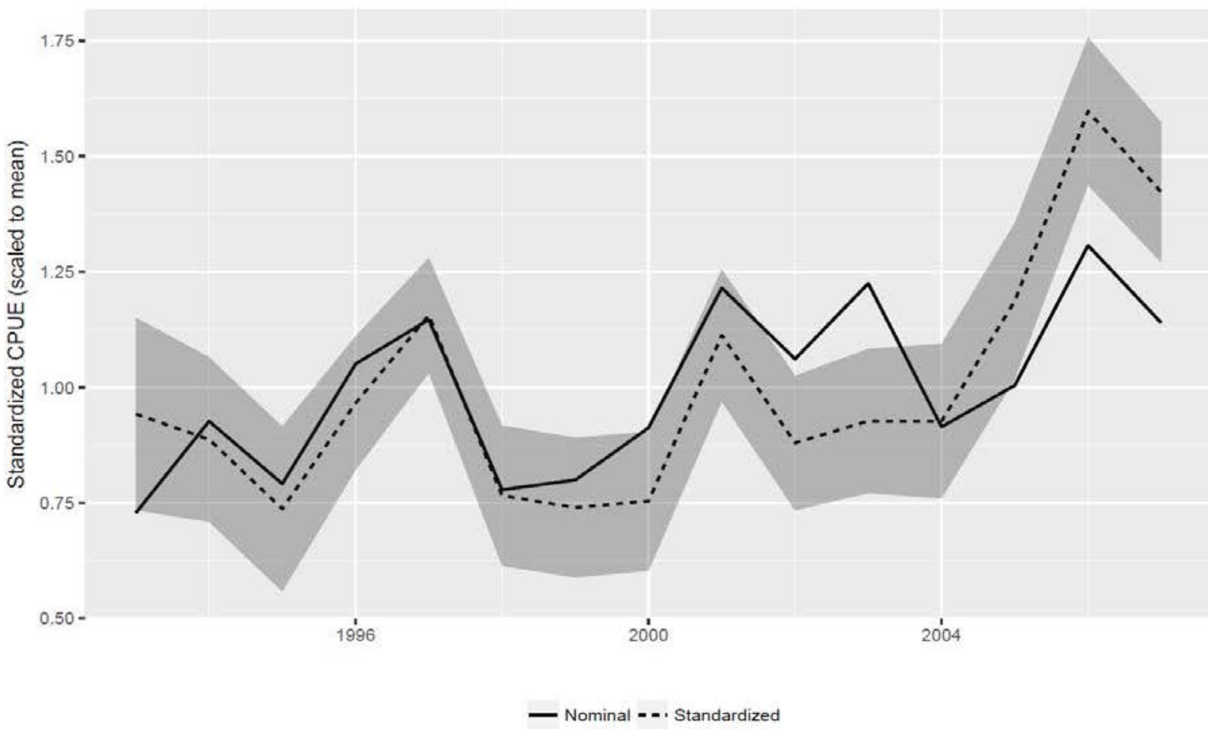


Figure 2: The recent SEDAR50 utilized a standardized commercial logbook catch per unit effort in the US Atlantic blueline tilefish fishery. Figure 2 shows the standardized catch-per-unit effort (CPUE) for the commercial handline fishery in the Atlantic blueline fishery.

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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
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 then, the system hosted at AOML has received and processed over **11,500** MSR reports from approximately **2,000** distinct commercial vessels. 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.

Research Performance Measure: All planned goals were met during this year. During the period between July 1, 2016 and June 30, 2017, the MSR system hosted at AOML has received and processed more than **3,200** 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.

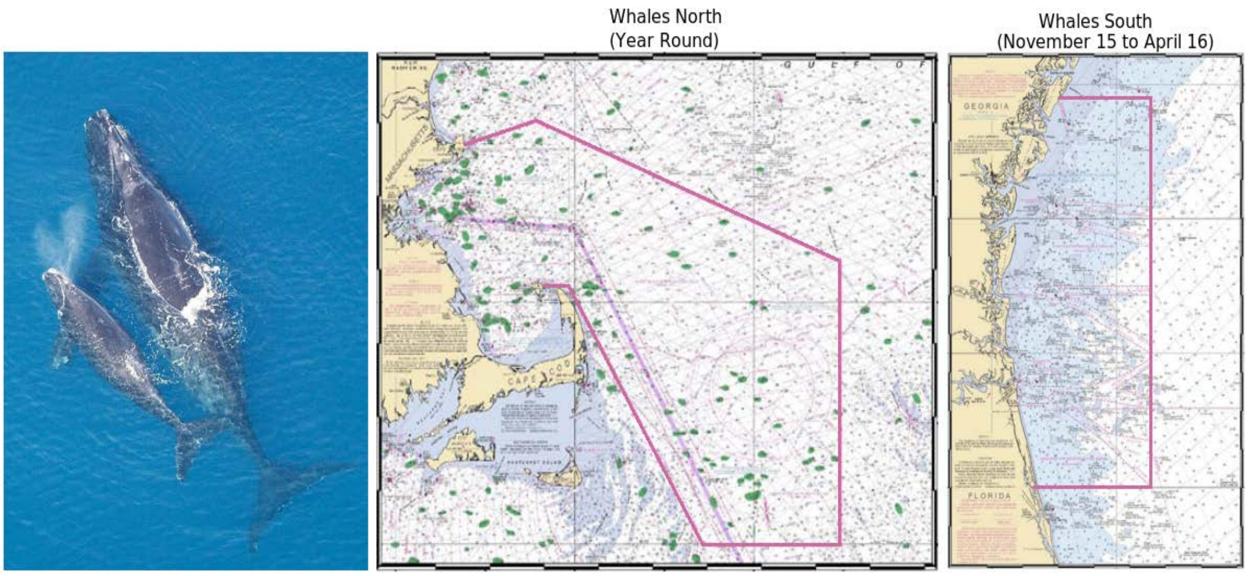

Figure 1: (left) North Atlantic right whale with calf. The (center) Whales North and (right) Whales South reporting areas along the east coast of United States within the Mandatory Ship Reporting system. The reporting requirements for each area are emphasized above the maps.

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Evaluation of Methods of Incorporating Oceanographic Indicators into Indices of Abundance for Stock Assessment

Project Personnel: F. 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 is designed around catchability of Atlantic blue marlin and 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.

Research Performance Measure: The research program is on schedule.

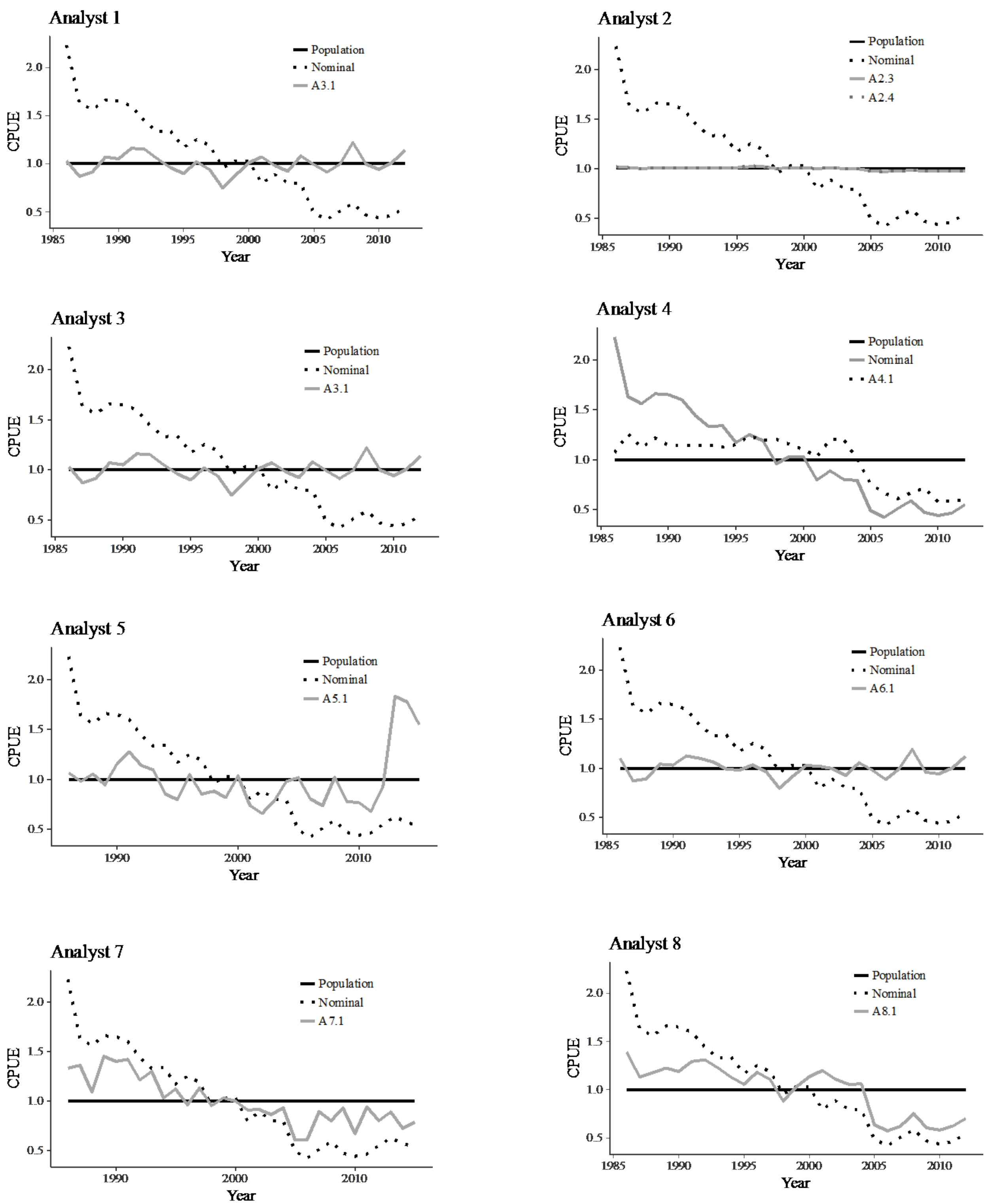

Figure 1: Standardized trends using environmental variables as explanatory variables from all analysts. Solid black line is true population within longline simulator, the solid grey line is the nominal CPUE output from the longline simulator and the dotted lines are the standardized trends obtained from the analysts.

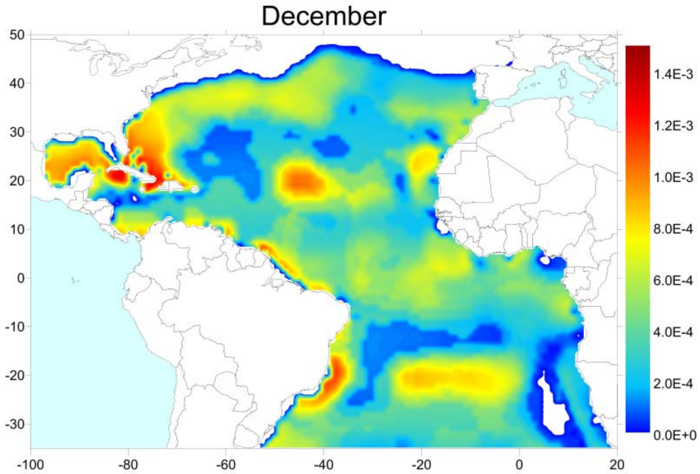

Figure 2: Distribution of swordfish from initial habitat suitability model predictions based on the combination of oxygen, temperature and chlorophyll preference curves.

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Coral Restoration and Recovery

Project Personnel: R. Pausch, A. Bright and D. Williams (UM/CIMAS)
NOAA Collaborators: M. Miller (NOAA/SEFSC)
Other Collaborators: FKNMS, FIU, Mote Marine Lab, Coral Restoration Foundation

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*). Both species spawned reasonably well in 2016, but the larval performance was poor, particularly for *O. faveolata*. Very high rates of larval mortality, presumably due to acute heat stress affecting the parental population the prior two years, compromised experiments to characterize larval longevity and settlement competence. We completed pilot experiments, in

collaboration with FIU, examining settlement in different algal turf and sediment-laden habitat types. These experiments are intended to be repeated in 2017.

A second component evaluated performance of nursery-cultured elkhorn coral (*Acropora plamata*) outplanted to natural reef habitat. Experiments examining the effects of fragment size, genotype, and habitat on restored coral success (survivorship, growth, and bleaching) have been completed and results submitted for publication (Pausch et al. In Review).

A new component of this project, initiated this year (summer 2016), aimed at documenting potential genotypic disease resistance in *Acropora* spp. being cultured for restoration. Disease is an ongoing and dire threat to species recovery, but previous research from Panama indicated that ~ 6% of genotypes of *A. cervicornis* showed innate disease resistance. We developed and published a standardized field protocol (Miller and Williams 2016) intended for use by other nursery operators to screen stocks across the region. Then, in partnership with two local coral nurseries, we initiated screening stocks of both *A. cervicornis* (16 genotypes) and *A. palmata* (6 genotypes). We indeed detected moderate to strong disease resistance in several of the tested genotypes. This information is pre-requisite to better mechanistic research to understand how resistance is accomplished and can be applied in the design of more resilient restored coral populations. In the coming year, this project component will continue screening additional genotypes and initiate collaboration (Serrano CIMAS, and Traylor-Knowles, MBE) to compare gene expression patterns between resistant and susceptible genotypes.

Research Performance Measure: Intensive field work is involved with each project component. We were successful in implementing the genotypic disease resistance experiment as planned (June 2016). Unfortunately, our larval experiments in 2016 were compromised by poor fitness of larvae, particularly of *O. faveolata*, likely due to carryover effects of severe heat stress experienced in the previous two summers.

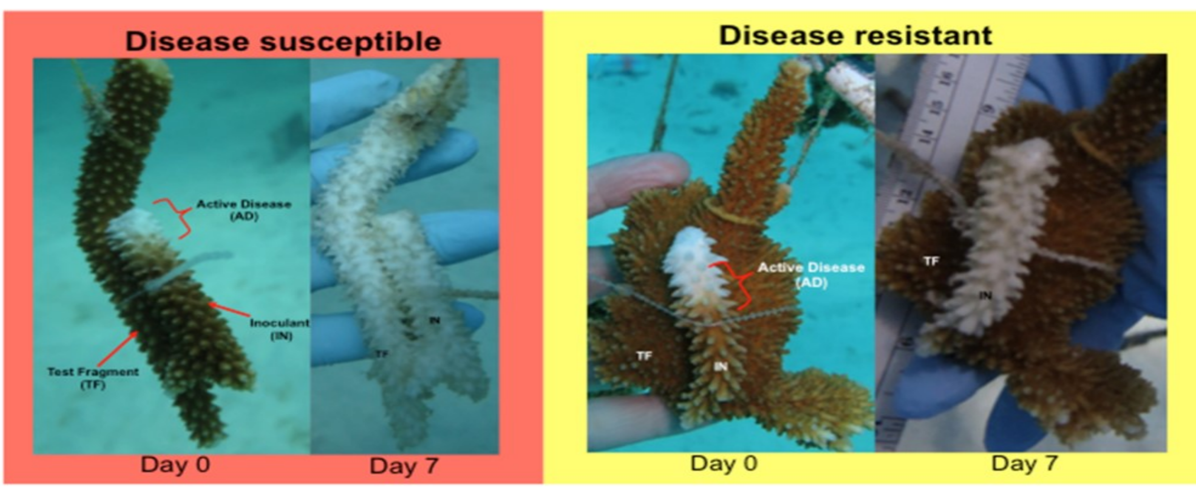

Figure 1: Illustration of outcomes for the standardized, 7-day field disease resistance assay. A diseased inoculant fragment is attached to the healthy fragment to be screened. The assays are monitored every other day to document the initiation of transmission (tissue loss) and the rate of tissue loss (disease severity) in transmitted fragments. Replicate (n=7-10) fragments of each genotype were assayed so genotypes can be ranked according to their relative resistance (% of replicates in which transmission was observed). One of six A. palmata genotypes and two of 16 A. cervicornis genotypes screened in summer 2016 were resistant, showing no transmission in n=7-10 replicates.

Marine Mammal Genetics Research

Project Personnel: C. Sprehn (UM/CIMAS)
NOAA Collaborators: P. 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 assist with the assessment population structure and genetic differentiation of *T. truncatus* in the north central GOMx. 3) To support general lab functionality and data and sample management.

***Strategy*:** 1)To sequence and genotype biopsies collected in Terrebonne and Timablier Bays in Louisiana and compare with existing data from neighboring regions. 2) To genotype biopsies and live captures collected in coastal waters of the western North Atlantic. 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. Genetic data collected from biopsies provides a basis to examine stock structure. Examining fine-scale structure can help improve the biological accuracy of stock delineations, which can increase the efficacy of conservation and management efforts.

Biopsy efforts in the Terrebonne and Timbalier bays of Louisiana in 2016 resulted in 54 biopsy samples from common bottlenose dolphins. I extracted genomic DNA, determined sex, and generated genetic data through mitochondrial DNA control region sequencing and genotyping at 44 loci for each biopsied animal. These data were then compared with existing data from neighboring Barataria Bay and coastal waters to examine genetic differentiation among the regions. We found evidence of fine-scale partitioning, suggesting the possibility of independent populations both between and within the bays. These animals were severely impacted by the *Deepwater Horizon* oil spill, so increasing our understanding of their structure within this region will help inform future conservation efforts as well as stock assignments.

I also completed a quality control effort to ensure correct genotypes were assigned to all genotyped samples at two loci that were suspected of having null alleles. I was responsible for quality assurance and database management for these 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 (Tursiops truncatus). Photo credit: NOAA SEFSC under permit*

Research Performance Measure: all objectives were completed on time or are ongoing.

- Processing samples (including DNA extraction, sexing, mtDNA sequencing, and genotyping) from Terrebonne and Timbalier biopsies and completing appropriate data analysis.
- Identifying samples of interest in the coastal western North Atlantic and genotyping as needed.
- Organizing and verifying data entry for samples in archival storage and database management for tissue samples.
- Helping maintain stocks of laboratory reagents.
- Trainings accomplished: Hazard Communication, Safety Data Sheets, Records Management

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Gulf of Mexico Marine Mammal Stranding Database – data diplomat position (FL)

Project Personnel: S. Stevens (UM/CIMAS),

NOAA Collaborators: J. Litz (NOAA/SEFSC); E. Fougères (NOAA/SERO); T. Rowles and J. Adams (NOAA/OPR)

Other Collaborators: National Fish and Wildlife Foundation, AL and FL Gulf Coast Marine Mammal Stranding Network and Marine Mammal Commission

Long Term Research Objectives and Strategy to Achieve Them:

Objectives**:** To expand and standardize marine mammal stranding health data to make the information more comprehensive and accessible for research and management purposes. Having access to those data in a searchable database that is appropriately maintained (QA/QC'd) will enable real time detection of trends in morbidity or mortality and emerging threats to marine mammals. This project will assists future restoration actions for marine mammals in the Gulf of Mexico following the Deepwater Horizon (DWH) oil spill.

***Strategy*:** To consult with database programmers on the development of a database for the marine mammal stranding network recipients who received Gulf Environmental Benefit Funds (GEBF). To provide support, training, and auditing of the database to ensure timely entry and data accuracy.

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:

NOAA authorizes and coordinates with marine mammal stranding network agencies to responded to and collect data from cetacean and pinniped strandings. Data collected from strandings are useful to detect and investigate emerging threats to marine mammals and unusual mortality events. Marine mammals in the northern Gulf of Mexico were impacted by the Deepwater Horizon (DWH) spill. Pooling the stranding data results from the northern gulf was critical in assessing the injury to marine mammals. Typically, following a stranding event, only the basic stranding data (Level A) is available to NOAA through the national stranding database; however, the GulfMAP database, under development, plans to include additional data not normally compiled in the national stranding database including necropsy data (Level B and C). Such a dataset will assist managers with identifying new threats to already impacted marine mammals in the Gulf of Mexico; become a valuable tool to monitor future DWH restoration projects; and be useful in long term monitoring of protected marine mammals in the Gulf of Mexico.

The current project includes a data diplomat (Stevens) who works with the database developers to design and test the various database modules. The first module of GulfMAP has been released and plans to continue expanding the database have been drafted. Future modules will include samples, sample tracking, and results from tissues and necropsies. Plans also involve moving the current access database into a web-based system that will be capable of visualizing data for users, managers, and some data will be publicly accessible.

A training plan and database manual were created to introduce marine mammal stranding agencies to GulfMAP and users from nine agencies were trained on how to use the database in late 2016 and early 2017. Stevens documented and assisted with troubleshooting database issues as well. This project will standardize necropsy data and samples collected and analyzed by providing network agencies with a common sampling outline of the types of samples and tests requested. The goal of this sample list is to detect morbillivirus, Brucella, and biotoxins; document freshwater exposure; and determine background levels of other pathogens and toxins in cetacean samples.

Since November of 2016, 233 cetacean strandings were entered and audited in GulfMAP. Two mass stranding events occurred, 33 pilot whales stranded in November 2016 and 99 false killer whales stranded in January 2017. Seventeen strandings had signs of human interaction. Of the stranding cases where life stage was determined, 32 were sexually immature and 24 were sexually mature. Necropsies were completed on 73 strandings, 42 were complete necropsies and 31 were limited necropsies.

Research Performance Measure:
Objectives were met. 1. All stranding network agencies were trained on GulfMAP. 2. The GulfMAP manual was created and updated. 3. Each month the agencies submitted their data and data were audited within a month from submission, often sooner. 4. Stevens served as the help desk for participants using GulfMAP. 5. Stevens participated in multiple developmental planning meetings of future GulfMAP modules.

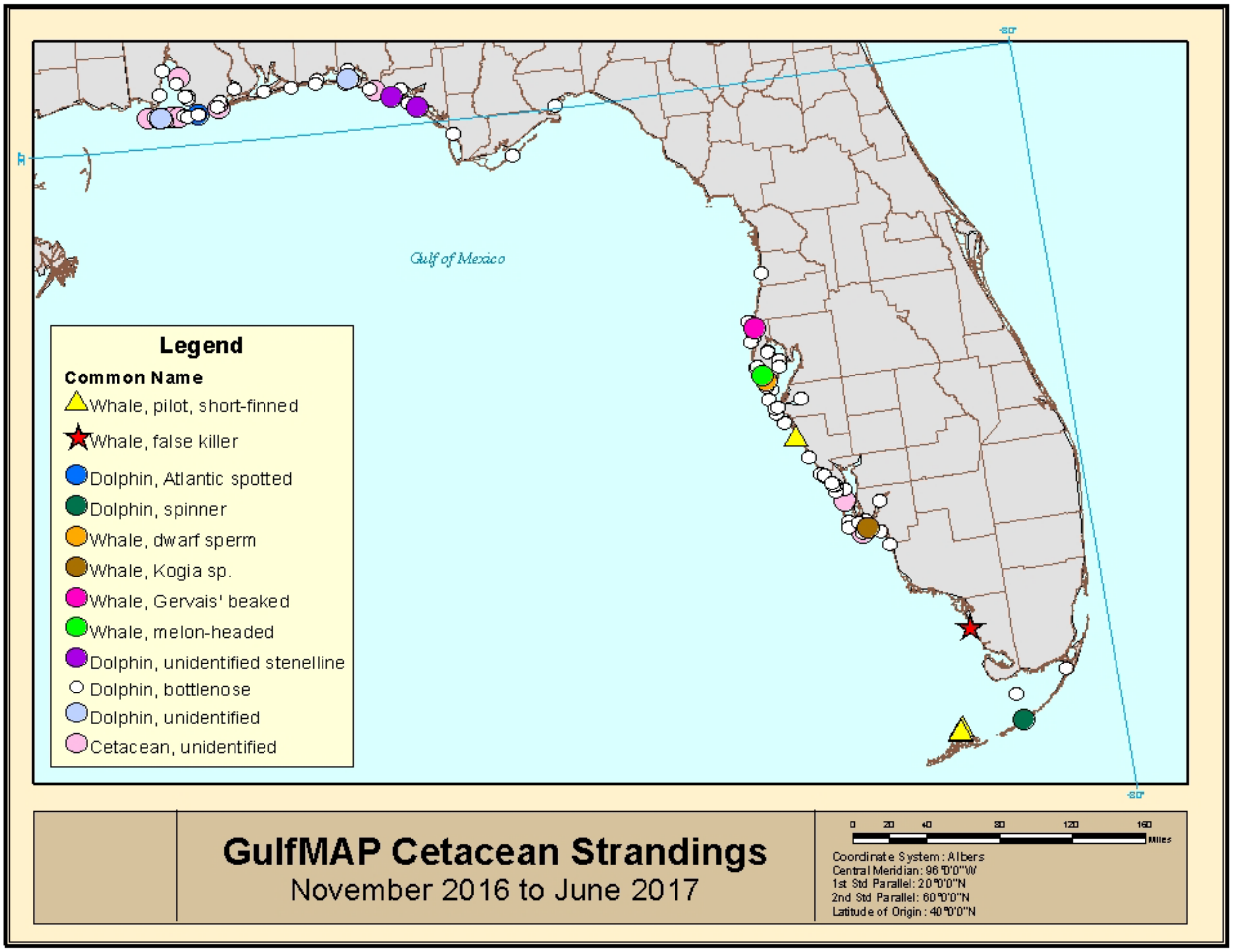

Figure 1: Location of cetacean strandings entered into GulfMAP from November 2016 to June 2017. Common name of cetaceans are represented by different colors. The red star and yellow triangle represent the two mass stranding events.

A dynamic decision support tool for management

Project Personnel: N. Vaughan (UM/CIMAS),
NOAA Collaborators: J. Walter, S. Sagarese and M. Karnauskas (NOAA/SEFSC); N. Farmer (NOAA/NMFS/SERO)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To develop a user-friendly decision support tool that empowers NOAA regional offices to investigate the impact of alternative management strategies in maximizing sustainable ACL's. This will provide regional offices with dynamic feedback during the management planning stage and eliminate the bottleneck of requesting assessment updates from SEFSC scientists.

***Strategy*:** To achieve this goal a cloud based graphical tool is being developed in R shiny to interface with stock synthesis assessment results and allow users to dynamically investigate the impacts of management action on forecast allocation quotas.

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:

In the Southeast Region, the Gulf, Caribbean, and South Atlantic Fishery Management Councils' Scientific and Statistical Committees review stock assessments and provide Acceptable Biological Catch (ABC) recommendations. By law, the Councils cannot exceed these ABC recommendations when implementing annual catch limits (ACLs); however, the Councils frequently consider management actions that could change fishery selectivity and alter the ABC upon which the ACL is based. These actions include, but are not limited to, modifications to size limits, bag limits, seasons, and sector re-allocation. The disconnect between management actions and the assessment ABC could result in forgone yield or allow overharvesting. Examples of management actions where projected ABC would be impacted by a change in selectivity patterns due to size limit or sector allocation changes include: (1) Reef Fish Amend. 28 will re-allocate red snapper quota between the commercial and recreational sectors; (2) Reef Fish Amend. 39 may allow states to set their own management measures for red snapper, including different minimum size limits; (3) Reef Fish Amend. 41 considers development of a charter boat catch share program for red snapper ; and, (4) Reef Fish Amend. 42 considers development of a headboat catch share program for multiple reef fish species. A tool is desperately needed that dynamically considers the implications of proposed management measures upon projected ABC.

This is especially critical for stocks managed in catch share programs or subject to increasingly shortened recreational seasons, such as red snapper, red grouper, and gag grouper. The objective of this project is to build a decision-support tool that represents a dynamic link between stock assessment models and management- in essence a bridge between the assessment products of the Southeast Fisheries Science Center (SEFSC) and the management decision tools produced by the Southeast Regional Office (SERO). This will incorporate the aspects of the current SERO decision support tools into a user-friendly interface

with the actual stock assessment model adopted for any individual species. By manipulating sliders on the user-interface to select potential management measures, a researcher will be able to change the assessment specifications, run model projections in the background, and evaluate the impacts of actions such as altering size limits, selectivity or allocations on benchmark quantities and projected yields.

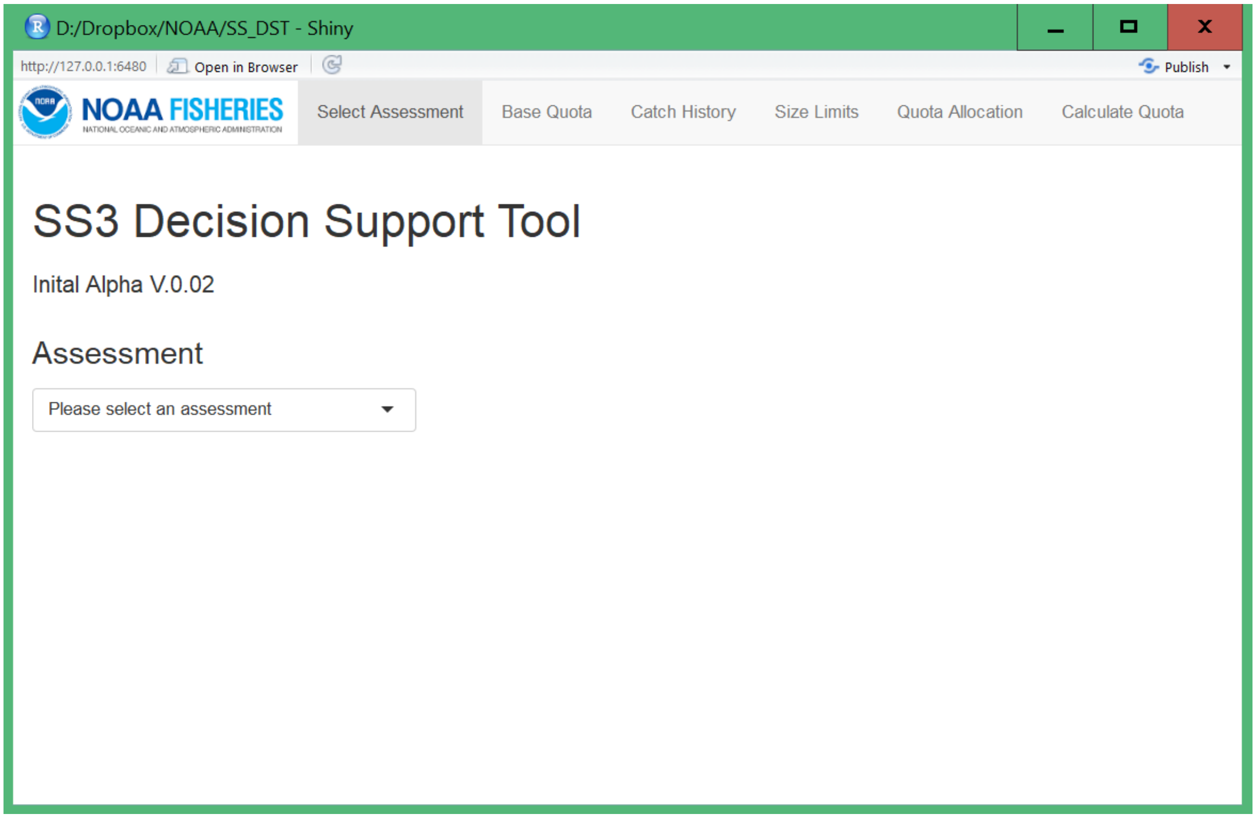

Figure 1: Graphic of the assessment selection title pane in the decision support tool. The contents of the following panels will be developed dynamically depending on the structure of the specific assessment chosen.

Research Performance Measure: The project is currently on track with a beta version of the graphical interface nearing completion. Specific achievements to date have been: The development of an R package to read and write stock synthesis (SS) control and parameter files; and the development of R functions to update group quota allocations and historic catch values in the SS forecast file. The achievements provide the basis for continuing GUI development.

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. 2) lead surveys within the Southeast Atlantic Marine Mammal Assessment Program and collect data on the abundance, habitat, and spatial distribution of cetaceans within U.S. waters. 3)support the Atlantic Marine Assessment Program for Protected Species (AMAPPS) Cruise by collecting biopsy samples, photographic data, acoustic data and visual data. 4) To assist on the Biscayne Bay's bottlenose dolphin population long term photo-identification study.

CIMAS Research Theme:

***Theme 7*:** Protection and Restoration of Resources (*Primary*)
***Theme 3*:** Regional Coastal Ecosystem Processes (*Secondary*)

Link to NOAA Strategic Goals:

***Goal 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 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 509 marine mammal sightings, 19 biopsy samples, and 5,381 (km) of visual survey effort. The summer 2016 Atlantic Marine Assessment Program for Protected Species (AMAPPS) cruise assessed the abundance, habitat and spatial distribution of marine mammals through visual and passive acoustic monitoring, and biopsy sampling.

Research Performance Measure: all objectives were completed on time.

- Conducted Pre and Post cruise planning and supported the development of procedures and protocols for marine mammal research cruises with a focus on passive acoustic and photographic data collection and management.
- Served as a small boat coxswain onboard NOAA ship Gordon Gunter during the marine mammal large vessel survey during the summer of 2016.
- Assisted in the development of cruise plans and lead survey teams while in the field.
- Maintained and verified data quality, interacting with principal investigators to effectively execute scientific methodology during the cruises.
- Managed and updated the Biscayne Bay Photo ID Database and continued to import historical data into FinBase database
- Assist in NOAA small boat field work through SE United States.
- Aerial observer for AMAPPS onboard a NOAA Twin Otter plane off the eastern seaboard winter of 2017.

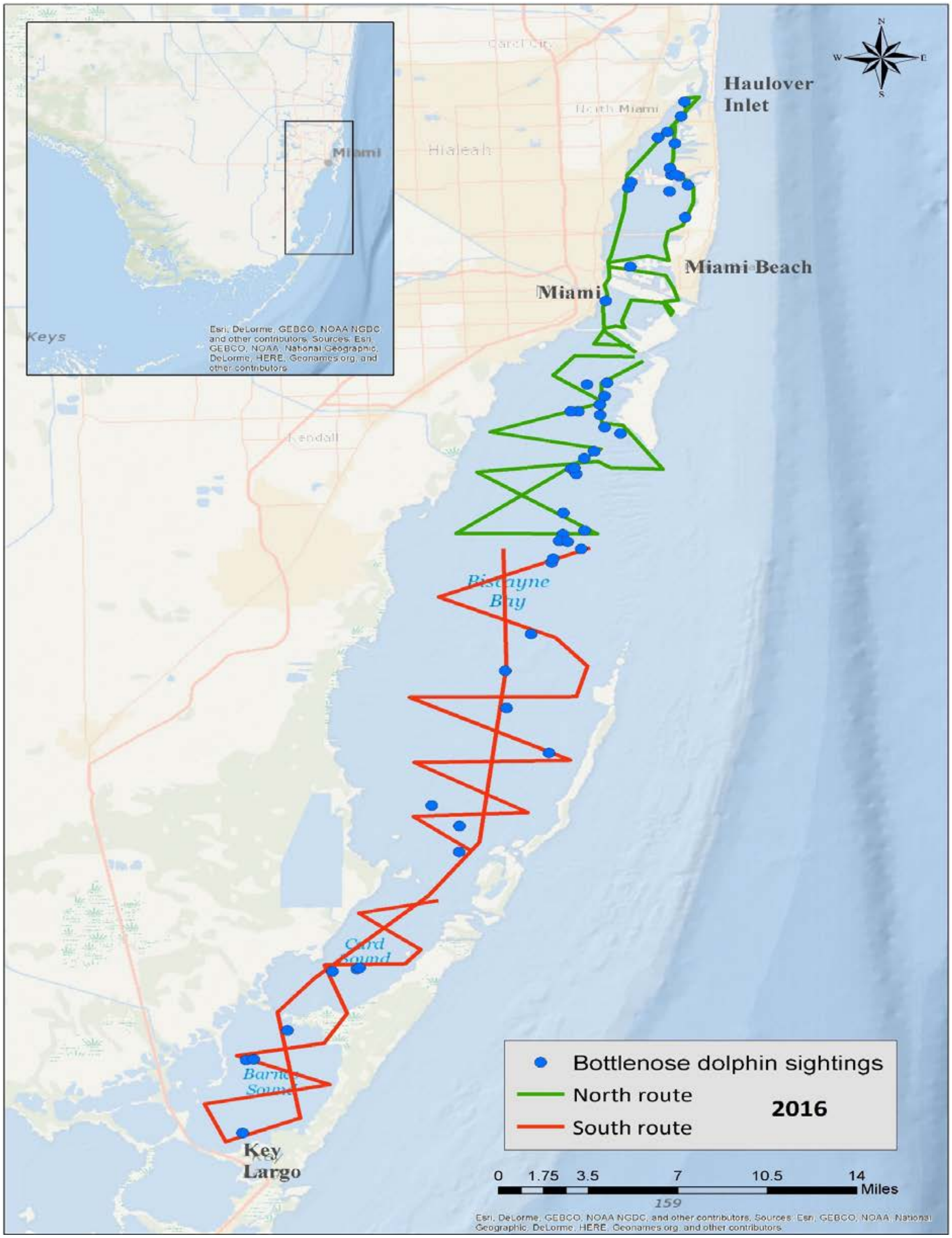

Figure 1: Dolphin Sightings, 2016.

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 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 4 agency employees – 14% 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, Garrett Miller, Morganne Morrison, Tiffany Nicholson, Michael Sipes, Susan Snyder, Lindsey Sorg, Kara Wall, Lena Wray
Florida FWC students: Oscar Ayala, Benjamin Kurth, Leo Meirose
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)

This course was taught for the fourth time during Fall 2016 by Cameron Ainsworth of USF-CMS (8 students - 0% agency)

USF students: Jeremy Browning, Meaghan Faletti**, Greta Helmueller, Megan Hepner, Alexander Ilich, Michelle Masi, Elizabeth Simpson**, Kelly Vasbinder, Julie Vecchio
Florida FWC students: none
NOAA students: none

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

This course was taught for the fifth time during Spring 2017 by David Jones of USF-CMS (7 students; 1 agency employee – 14% agency)

USF students: Jeremy Browning, Megan Ferguson, Alexander Ilich, Laurinda McEachern, Christopher Moore, Jonathan Sharp

Florida FWC students: Leo Meirose

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, Brianna 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 Ainsworthof USF-CMS (8 students, including 3 agency employees – 38% agency).
USF students: **E**lizabeth 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.

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

This course was taught for the third time during Fall 2016 by David Jones of USF-CMS (10 students – 0% agency)

USF students: Shahd Aljandal, Jeremy Browning, Alexandria Creasy, Megan Ferguson, Alexander Ilich, Selena Johnson, Loraine Martell-Bonet, Brenna Meath, Natalie Sawaya, Susan Snyder
Florida FWC students: none
NOAA students: none

R Coding Clinic, taught Spring 2017 by Cameron Ainsworth and Chris Stallings of USF-CMS (25 students, including one agency employee – 4% agency)

USF students: Dinorah Chacin, Sarah Grasty, Matthew Hommeyer, Edmund Hughes, Enrique Montes Herrera, Digna Rueda Roa, Erin Symonds, Kara Wall, Alyssa Andres, Imogen Browne, Emily Chancellor**, Marcy Cockrell**, Alexandria Creasy, Meaghan Faletti**, Megan Hepner, Elizabeth Herdter, Alexander Ilich, Brittany Leigh, Brianna Michaud, Dana Nieuwkerk, Natalie Sawaya, Susan Snyder, Kara Vadman, Kelly Vasbinder
Florida FWC students: Ryan Moyer
NOAA students: none

MRA Graduates (All Years)

Claire Crowley (M.S., Spring 2012); employed by FWC FWRI
Catherine (Bruger) Hayslip (M.S., Fall 2013); employed by USF-CMS
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-Scharf (M.S., Summer 2014); employed as Sea Grant Agent, Hernando County, Florida
Holly Rolls (Ph.D., Summer 2014); left the field (ecotourism guide and paddling instructor)
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 as science officer at Pew Charitable Trusts
Michelle Masi (Ph.D., Fall 2016); employed as stock assessment scientist at National Institute of Water and Atmospheric Research (NIWA), New Zealand
Maria Vega-Rodriguez (Ph.D. Fall 2016); looking for post-doc or other academic position
Joseph Curtis (M.S., Fall 2016); employed as Laboratory Technician at UC Santa Barbara
Benjamin Kurth (M.S., Fall 2016); employed by FWC FWRI
Brianna Michaud (M.S., Fall 2016); continuing in MRA program as Ph.D. student

RESEARCH HIGHLIGHTS – MRA FELLOWSHIP RECIPIENTS:

During the past year, five doctoral students were supported by fellowships under the present award. Below are highlights of former and present recipient's research projects during 2016-17.

Emily Chancellor (advisor: Dr. Steve Murawski): Emily Chancellor is a second-year Ph.D. student working on early life history assessments of Gulf of Mexico fish communities. Using the SEAMAP ichthyoplankton data, she has been characterizing the density, community structure, timing and spatial distribution of fish larvae in the northern Gulf of Mexico. In particular, she is working on indices of population connectivity, spatial overlap with past and potential oil spills (simulation studies), and linking population connectivity to surface-flow scenarios. These studies have considerable application to understanding the resilience of fish populations in the wider Gulf of Mexico to chronic and acute stressors, including fishing, hurricanes, oil spills and climate change.

Marcy Cockrell (advisor: Dr. Steve Murawski): Development of a decision-support framework for implementing marine protected areas on the West Florida Shelf.
Former MRA Fellowship recipient Marcy Cockrell is continuing her work at USF-CMS 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.

Michael Drexler (advisor: Dr. Cameron Ainsworth): An Atlantis model for the Gulf of Mexico (Atlantis-GoM):

Former MRA Fellowship recipient Michael Drexler has taken a full-time position as a Fisheries Scientist with the Ocean Conservancy in St. Petersburg. FL.

Meaghan Faletti (advisor: Dr. Chris Stallings): Investigating Hogfish (*Lachnolaimus maximus*) movement and habitat connectivity using eye-lens stable isotopes

Meaghan is using stable-isotope analysis of eye lenses to retrospectively trace ontogenetic movement through the life of an economically important finfish, the Hogfish (*Lachnolaimus maximus*). The first objective of this study is to characterize habitat use and migration patterns of Hogfish in the eastern Gulf of Mexico (eGOM). The second objective is to determine the locations and relative importance of juvenile habitat to the adult eGOM Hogfish population, and use this information to potentially define specific nursery habitats. This information can be used to aid in conservation and management of this species and its essential habitats. So far, Meaghan has collected eye lenses and muscle tissue samples from >150 Hogfish and has begun the eye lens stable-isotope analysis on 5 individual specimens.

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.

Elizabeth Simpson (advisor: Dr. Cameron Ainsworth): Fishing effects on succession patterns on natural and artificial reefs in the northern Gulf of Mexico.

Elizabeth Simpson started the Marine Resource Assessment PhD program in January 2015 and has made very good progress. She was able to transfer some academic credits from her previous Master's degree at another institution, which has allowed her to put more emphasis

on her dissertation. She subsequently has fulfilled all course requirements for the MRA Program. She is scheduled to take the Integrated Marine Science Exam (IMSE) in Sept 2017, and will write her comprehensive exam in Fall 2018 for admission to PhD Candidacy. To date, she has had two meetings with her academic committee, and has a well-formulated plan for her dissertation. Elizabeth is studying succession patterns on natural and artificial reefs in the northern Gulf of Mexico. Her interests are to determine how natural and artificial reefs relate in their succession dynamics, climax communities, and response to fishing. Her study has relevance to NOAA's priorities since it will elucidate how well artificial reefs can serve as a repository of biomass and biodiversity to supplement exploited species and maintain healthy ecosystem functioning. As part of this project, she is working closely with Will Patterson at the University of Florida to analyze ROV survey data. She is developing two models to study succession dynamics: a Markov state transition matrix model and an Ecospace numerical trophodynamic model. We expect her first publication in 2018 describing reef complex biodiversity using a hierarchical clustering method. This effort supports the definition of Markov transition states. Graduation is expected in Spring of 2019.

Orian Tzadik (advisor: Dr. Christopher Stallings): Non-lethal alternatives to otoliths for application to juvenile groupers.

Former MRA Fellowship recipient Orian Tzadik has graduated and taken a full-time position as a Science Officer at Pew Charitable Trusts in Rincon, Puerto Rico.

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* and 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. An Interdisciplinary, cross-departmental program in Meteorology and Physical Oceanography remains as a well populated graduate program. Currently there are close to 185 students enrolled in the RSMAS Ph.D and MSc programs, 73% of whom are in the Ph.D programs.

CIMAS has also started a graduate studies assistantship. The intent of this prestigious CIMAS Ph. D. graduate fellowship is to foster collaborative research between scientists at either AOML or SEFSC and UM-RSMAS, and includes 5-years funding for a highly competitive graduate stipend, health insurance, full 5-years of tuition expenses and

professional travel. CIMAS Ph.D. graduate assistants are co-advised by scientists at AOML or SEFSC and RSMAS, and will work on a research problem that is of interest to both of the co-advisors. As such, the applicant is expected to identify potential co-advisors. For example, the applicant could identify a researcher at one of the NOAA facilities that is working in the student's area of interest. The applicant would then contact that researcher and establish a dialogue to help identify a potential co-advisor at UM/RSMAS. Alternatively, the applicant could identify a UM/RSMAS faculty member that is working in the student's area of interest. The applicant would then contact that faculty member and establish a dialogue to help identify a potential co-advisor at one of the NOAA facilities. Both co-advisors should be identified and agree to serve as part of the application process. This academic year the CIMAS assistantship was awarded to Olivia Williams who is studying coral reef health.

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. For example, last year CIMAS hosted the meeting of the ICCAT small tunas working group and gave fifteen selected RSMAS graduate students the ability to attend. Other individual RSMAS students and post-docs funded through CIMAS attended selected ICCAT working group meetings at the ICCAT HQ in Madrid. These experiences provide youg scientists a professional experience on how international scientific working groups conduct their collaborative research and also allow them to enrich their personal network of professional contacts.

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. For example, two CIMAS students, joined NOAA last year: Dr. Mark Fitchett was hired by the Fisheries Research and Monitoring Division of NMFS in Hawaii and Dr. Kristin Klesiner by the North East Fishery Science Center of NMFS. Other graduates joined last year research institutes associated with NOAA, for example Dr. Michelle Sculley joined JIMAR in Hawaii. 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.). 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 116 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 2016-2017, 380 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.

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 academic year.

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

In order to advance CIMAS science to a non-scientific audience, we have established a collaboration with the Climate Leadership Engagement Opportunities (CLEO) institute. The collaboration with the CLEO institute allows CIMAS scientists to engage underserved individuals in vulnerable communities to:

- improve their climate science scholarship and understand what NOAA does;
- make connections between the causes and effects of climate change;
- better recognize the broad scope climate vulnerability;
- understand multiple approaches to addressing solutions; and

These engagement events include presentations by CIMAS scientists described basic climate science, but also the specifics of their own research projects on level that is accessible to non-experts. To date CIMAS scientists have participated in four such events.

Directed by Dr. Neil Hammerschlag, the Predator Ecology Lab and Shark Research & Conservation Program (SRC) at the University of Miami conducts science centered broadly on food-web dynamics and the behavioral ecology, conservation biology and movement ecology of marine predators. Research projects currently underway are primarily focused on the ecology, movement and conservation of sharks. A core component of our work is to foster scientific literacy and environmental ethic in youth and the public by providing exciting hands-on field research experiences in marine conservation biology. Opportunities are especially made available for under-served populations in the sciences. To impact a global, we employ online outreach tools, including webinars, curricula, videos, blogs, and social media. Focusing primarily on the study and conservation of sharks, we employ a full-immersion educational approach that allows students to actively grow as future scientists.

Our work is composed of four overlapping focal areas:

Science – Education – Conservation – Technology

The core tenet is the science, with the others branching out and building upon it.

From a broader educational perspective, the SRC Program address two major needs in the United States and abroad: (1) a lack of engaging science education opportunities that inspire youth to learn STEM (Science, Technology, Engineering and Math) skills and adopt conservation attitudes and behaviors, and (2) a lack of knowledge and awareness about marine ecology and conservation, particularly in relation to shark species. To meet these challenges and bring about the desired change, SRC engages in numerous activities including community outreach, marine-based field, lab, and virtual research experiences and online educational activities.

The Shark Research & Conservation Program and the Deering Estate at Cutler have teamed up to create an interactive, educational and exciting curriculum for you and your students! The Marine Conservation Science & Policy Service Learning Program provides practical, hands-on marine science education and self-initiated research project opportunities for high school, undergraduate and graduate students in the marine science field. The MCS&P Curriculum will expose students and teachers from across the globe to the importance of oceans in their daily lives. Students will learn about the threats facing our waters and adjacent coasts, and explore the solutions for conservation

In addition, CIMAS projects have their own specific outreach components, listed in the section below according to project names:

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.
- R. C. Perez co-mentored a NOAA Hollings Scholar and a MAST High School teacher in 2016. R. C. Perez is also involved in the MPOWIR (Mentoring Physical Oceanography Women to Increase Retention) organization.
- R. Perez, E. Valdes, R. Lumpkin, and M. Pazos participated in Bring Your Child to Work Day.

Coral Health and Monitoring Program (CHAMP)

- Enochs participated in question and answer sessions at public screenings of a PBS show covering ACCRETE research at Maug, CNMI. He gave a public talk as part of the Nerd Nite lecture series, participated in a "Skype with a scientist" session with students at MacArthur Beach State Park, and taught a class to students as part of the Frost Science Center's IMPACT program. Finally, Enochs gave an invited talk for NOAA's Science Days and was a guest lecturer at the University of Oregon.
- Dr. Amornthammarong and AOML/Sea Grant scientist Pamela Fletcher are leading a citizen-science group collaboration with local communities and county partners in Broward County to deploy an array of the underwater temperature data loggers on the southeast Florida shelf.

Southwest Atlantic Meridional Overturning Circulation ("SAM") Project

- R. Perez was the guest editor for the 2017 spring edition of the US CLIVAR Variations newsletter, which focused on present and future observing of the deep ocean. R. Perez also co-mentored a NOAA Hollings Scholar and a MAST high school teacher in Summer 2016. R. Perez has begun mentoring a postdoctoral fellow (Marion Kersale) in June 2017 under support from a related NOAA Climate Variability & Predictability (CVP) proposal. S. Garzoli and R. Perez are involved in the MPOWIR (Mentoring Physical Oceanography Women to Increase Retention) organization.

Interannual-to-Decadal Variability of the South Atlantic MOC

To increase public awareness the following project websites were created:

- http://www.aoml.noaa.gov/phod/research/moc/moc_monsoons/index.php
- http://www.aoml.noaa.gov/phod/SAMOC_international/index.php

Additionally, research results were presented at the following meetings:

- EGU meeting, April 2017:
- "Altimetry-derived South Atlantic Meridional Overturning Circulation between 20°S and 35°S Since 1993".
- US AMOC meeting, May 2017:
  "Impact of Eddies on South Atlantic Meridional Overturning Circulation"

The North American Multi-Model Ensemble (NMME) Operational Phase

- The results of the NMME project being served in graphical form only by CPC (http://www.cpc.ncep.noaa.gov/products/NMME/), and the digital data are being served at the IRI (http://iridl.ldeo.columbia.edu/SOURCES/.Models/.NMME/) and by NCAR ESG. The CPC site primarily serves the real-time needs of the project, and the IRI site, along with the analysis tools that are being developed at the IRI (http://iridl.ldeo.columbia.edu/home/.tippett/.NMME/.Verification/), primarily serves research needs in terms of assessing the prediction skill and predictability limits associated with phase-I and in terms of designing the phase-II experimental protocol. While the phase-I data is limited to monthly mean data, it is a research tool (or test-bed) that is proving extremely useful in supporting the basic prediction and predictability research needs of the project participants. This database also serves as "quick look" easy access data that is the external face of the NMME experiment to the research community.

The Southward Returning Pathways of the AMOC and their Impacts on Global Sea Surface Temperature

- M. Goes presented our work "Role of African dust in the Atlantic meridional overturning circulation during Heinrich events" through a webinar on February 23, 2017 to the CLIVAR USAMOC TT3.
- On Saturday, March 18, M. Goes in an Open House event jointly hosted by the National Hurricane Center (NHC) and Miami-South Florida Forecast Office of the National Weather Service. The public was invited to tour the facility located on the grounds of Florida International University to learn how forecasters track and predict tropical weather systems.
- M. Goes and other AOML and UM/CIMAS colleagues manned a table that highlighted oceanographic and meteorological research that supports weather forecasts and NOAA's goal of building a weather-ready nation. Throughout the 4-hour event, they interacted with hundreds of people, many of them school-age children, explaining AOML's role in the sciences and the community.
- On May 12 the 2017 Hurricane Awareness Tour wrapped up at Opa Locka airport. The Coast Guard Air Station hosted the NOAA P3 and two USAF C-130 Hurricane Hunter planes. M. Goes and AOML/CIMAS colleagues had a table there featuring our hurricane research and physical oceanographic efforts.

Global Assessment of Looping Drifter Trajectories

- Career day at La Salle—Immaculata Haigh School, Miami, FL, March 2017 (Olascoaga and Beron-Vera)
- Invited outreach presentation on flotsam transport at Splash Trash, Florida Keys Eco Discovery Center, Key West, March 2017 (Olascoaga)
- Published peer-reviewed paper covered by San Diego Tribune, Miami Herald among others (Beron-Vera et al., 2016).
- Two-week-long graduate course on dynamical systems applied to Lagrangian ocean transport at Universidad de Buenos Aires, Argentina, December 2016 (Beron-Vera).

Autonomous Marine Sampling Technology Testbed: Integrating advanced biomedical sensor technologies with advances in drop probe

- Public awareness of all our OceanScope activities (including this one) is through and in collaboration with RCCL. A video has been made available to their passengers and were in the process of designing realtime data displays available to passengers through the shipboard closed circuit TV system.

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

- Delgado, S., 2017: The Atlantic hurricane database reanalysis project. Tropical Cyclone Reanalysis Workshop, May 22-23, 2017, in Asheville, NC.

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

- Article published in AOML's Newsletter, Issue March-April 2017, Vol. 21(2): http://www.aoml.noaa.gov/keynotes/PDF-Files/Mar-Apr%202017.pdf
- 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.

Improvement to the Tropical Cyclone Genesis Index (TCGI)

- Guest Speaker, Marlborough Elementary School 3rd grade, Marlborough, CT (June 2016)
- Guest Speaker, NASA-NOAA student event: Federal STEM Careers in the Emerging Unmanned Aircraft Systems (UAS) in the Aerospace Industry (September 2016)
- Featured Presentation, National Science Teachers Association, Columbus, OH (December 2016): Hurricanes: What Makes Them Tick and How Do We Track Them?
- Guest Speaker, Marlborough Elementary School 3rd grade, Marlborough, CT (June 2017)

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

- Guest Speaker, Marlborough Elementary School 3rd grade, Marlborough, CT (June 2016)

- Guest Speaker, NASA-NOAA student event: Federal STEM Careers in the Emerging Unmanned Aircraft Systems (UAS) in the Aerospace Industry (September 2016)
- Featured Presentation, National Science Teachers Association, Columbus, OH (December 2016): Hurricanes: What Makes Them Tick and How Do We Track Them?
- Guest Speaker, Marlborough Elementary School 3rd grade, Marlborough, CT (June 2017)

Rainfall Evaluation for Developments in the High-Impact Weather Prediction Project
- NOAA/AOML/HRD Science Meeting (13 April 2017)
- Local AMS Miami Chapter (26 April 2017)

Development of the Basin-Scale HWRF Modeling System
- Xuejin Zhang participated in activities organized by the Greater Miami AMS Chapter

The GO-SHIP Repeat Hydrography Program
- Pierrot, Baringer, Wanninkhof, and Langdon are actively involved in the international coordination and data quality control of efforts such as GO-SHIP repeat hydrography.
- Zhang is actively involved in the Joint IOC-ICES Study Group on Nutrient Standards (SGONS)

PIRATA Northeast Extension
- 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. R. C. Perez, E. Valdes, and R. Lumpkin participated in Bring Your Child to Work Day.
- G. Foltz and R.C. Perez mentored a Hollings Undergraduate Scholar, Dylan Gates, from May 2016 to July 2016 to analyze Atlantic zonal and meridional mode variability. G. Foltz hosted Saliou Faye, a visiting scientist from the Oceanographic Research Center in Dakar, Senegal during April 24 - May 5, 2017. Saliou learned techniques for calculating the mixed layer heat budget using data from a joint French-Senegalese buoy maintained off the coast of Senegal. The results will be published in a peer-reviewed article and compared to those obtained from the 11.5°N, 23°W PNE mooring, located at a similar latitude but in the open ocean.
- G. Foltz mentored a high school student, Steve Marrero, from MAST Academy during June-August (M. Goes in CIMAS is a co-mentor). The topic of the internship is the Atlantic Equatorial Undercurrent, the ability to estimate its transport using satellite altimetry and XBT.

Remote Sensing and In-Situ Observations for Operational Climate Applications
- OceanTeacher Global Academy-Invemar Training course: "From Measurement to Mean Fields: Aggregating Oceanographic Data for Science using World Ocean Database and World Ocean Atlas tools" 21 - 23 November 2016, Santa Marta , Colombia. Lecturers: Tim Boyer (NOAA/NCEI) and Joaquin Trinanes. The course incorporated sections on remote sensing, database management and on using R for time series processing.

- Between Nov 16-19, Joaquin Trinanes participated in the GOSUD and GTSPP meeting in Osstend, Belgium. One of his presentations was about interoperability and involved CoastWatch/OceanWatch activities.
- During the week of Mar 20-24, Gustavo Goni and Joaquin Trinanes attended the NOAA XBT/TSG Operations Meeting at NOAA/AOML.
- Between Mar 27-31, Gustavo and Joaquin participated in the 9th Session of the Ship Observations Team (SOT-9), held at the International Maritime Organization headquarters in London,UK where they discussed and presented research work related to BUFR, NETCDF4 and data management & tracking.

Calibration/Validation Support for NPP VIIRS Data Product Continuity

- SaWS has been used by many stakeholders, including governmental agencies, environmental groups, researchers, and the general public.

Development of New Drifter Technology for Observing Currents at the Ocean Surface

- The new technology and scientific results developed under this study were presented to the general public at two events: the 2017 COAPS Open House held conjunction with the National High Magnetic Field Laboratory Open House (Tallahassee, FL, estimated 8,000 visitors) and the bi-annual FSU Coastal and Marine Laboratory Open House, themed "Coastal Literacy – Connecting Marine Science to Society" (St. Teresa, FL, estimated 2,000 visitors).
- The work was also showcased to state lawmakers and staff at "FSU Day" at the Florida Capitol Building. In addition, this project included a "citizen science" component, in which self-addressed drift cards were deployed with the surface drifters. These drift cards, when found by members of the public along the shore, directed the public to an informative website where they could learn about the technology and scientific experiment, as well as report the drift cards' locations.
- Finally, a website was developed under this project to not only facilitate reporting of drift cards, but also to disseminate in real-time the progress of the drifter field experiment (drifters.ocean.fsu.edu). This work was highlighted in two online news stories (http://coaps.fsu.edu/experiment-testing-new-drifter-design-underway-in-the-gulf-of-mexico and http://news.fsu.edu/news/university-news/2017/03/13/fsu-technology-tracks-ocean-current-device-aids-tracking-pollutants-water/).

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 2016 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.

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

- AOML Open house in May 2016 where we set up a station to explain ocean acidification to students from local schools, boy and girl scouts and general audience.

Ocean technology development: bottom drifter development

- Presentation and public display of the Bottom Drifter at the annual research-to-market inventions 'sneak-peak' event and the Open House of the Center of Ocean-Atmospheric Predictions Studies at FSU.

- Poster presentation of the Bottom Drifter at the 50 year Geophysical Fluid Dynamics Institute of FSU.

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
- Presentation at Doral High School K-12 students

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.

Larval Bluefin tuna ecology in the Gulf of Mexico and Caribbean

- We held an open house in Progreso, Yucatán on May 20, 2017. This event explained the scientific research activities that were carried out in the Gulf of Mexico. Several academic and government officials attended: Dr. Mario González Espinosa, Director of ECOSUR; Dr. Magda Estela Domínguez Machín, Assistant Director of Fisheries Resources in the Atlantic of INAPESCA and Dr. Josefina del Carmen Santos Valencia, Chief of CRIP Yucalpetén. Dr. Alvaro Hernández Flores, Professor-Researcher at MARISTA University together with students of the Doctorate in Fisheries and Aquaculture Bioeconomics of the university. The students of the Marine Biology (UADY) students, led by Dr. Alfonso Aguilar Perera, Professor-Researcher of the Faculty of Marine Biology of the UADY were present as well as Mr. Manuel Sánchez González, President of the Union of Shipowners of Yucatán.
- The research survey had the participation of undergraduate and graduate students from the University of Miami's RSMAS, Florida State University, and University of California Santa Barbara participated in the project in research cruises, sample and laboratory processing.
- During the year, three undergraduate students provided valuable research support in the FORCES Lab in various projects and facilitated technical assistance while having the opportunity for hands-on learning

Understanding spatiotemporal dynamics of Atlantic Bluefin tuna spawning

- IEO article highlighting the collaboration between the NOAA and the IEO Labs published on June 1, 2017: http://www.ba.ieo.es/es/rokstories/1931-un-nuevo-metodo-para-evaluar-el-estado-de-las-poblaciones-de-atun-rojo-podria-mejorar-su-gestion-sostenible--

Survey of Boat Ramp-Based Non-Commercial Fishing on U.S. Virgin Islands (Phase II)

- K-12: The project has been successful in engaging local fishers, who by now are familiar with and interested in the project. As a result fishers look forward to interacting with our samplers. We believe that this project is an excellent means of maintaining an open

relationship and dialogue with fishers, as well as laying the foundation for buy-in with commercial port sampling.

Gulf of Mexico Integrated Ecosystem Assessment

- 2015 Review Panel for NOAA Ernest F. Hollings and Educational Partnership Program Undergraduate Scholarship Programs.

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

- An oral and a poster presentation highlighting this project was presented at the Annual "Semana de Intercambio Academico" at the Chetumal campus, ECOSUR
- Graduate and undergraduate students utilized samples collected from this project as either part of their thesis or used training from their
- Websites were created and updated quarterly to promote public awareness and provide a venue for communication and exchanges: http://www.marfund.org/en/new_projects/second_connectivity_regional_workshop.html, http://ocean-ecosur.com/index.php/vinculacion/12-vinculacion/5-workshop-1

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 2017, graduate students from the University of Virgin Islands, University of Puerto Rico-Mayaguez, City University of New York also participated in the sampling effort. Two separate open house events took place aboard the Nancy Foster in St. Croix, USVI. The first group was comprised of high school ladies from the AZ Academy who are involved in the "Diving for Debris" community transfer program, part of the UVI "Pride in Our Seas, Pride in Ourselves" project and funded by the NOAA Marine Debris Program. The second group of middle and high school students traveled from the St. Croix 7th Day Adventist School in Christiansted, St. Croix. During these events, cruise participants demonstrated laboratory and research capabilities, as well as provided a tour of the research vessel.
- During these cruises, an informal blog was updated with educational information regarding the project and research survey: http://nfchroniclesnoaa.blogspot.com/

Net Revenues of the Federal Fin-Fish Commercial Fisheries in the Gulf of Mexico

- Presentations:
    - SEFSC Social Science Research Group Seminar, August 3, 2016, Miami, FL., A Discussion on the Economic Component of the Southeast Coastal Fisheries Trip Report Form
    - NAAFE (North American Association of Fishery Economists) 2017 conference, March 22-24 2017, La Paz, Mexico, Evaluating the Economic Benefits of Catch Share Management in the Northern Gulf of Mexico Reef Fish Fishery: Preliminary Results

- Poster:
    - SEFSC Social Science Research Group Panel Review, May 16-18, 2017, Miami, FL., Evaluating the Economic Benefits of Catch Share Management in the Northern Gulf of Mexico Reef Fish Fishery: Preliminary Results)

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

- Presentation of Acropora survey methods at the Workshop To Advance The Science & Practice of Caribbean Coral Restoration Nov 15-17, Fort Lauderdale, Florida

Support of the National Coral Reef Management Assistantship Program

- **American Samoa:** Through classroom visits and in-school rain garden installations, the assistant has reached more than 150 level 7 students, more than 150 level 8 students, about 60 level 6 students, 50 high school students, and 10 community college students. About 220 children (between the ages of 5 and 18) attending summer camps, the American Samoa STEM Summit, and AS-DOC's Coast Weeks Festival have received watershed and stormwater lessons. Through these youth-oriented events, as well as agency-oriented trainings, the assistant has reached around 50 adults.
- **CNMI:** Since February 2017, when the new CNMI assistant started, he has conducted an environmental expo for 100 students grades K-5 about the value of the watershed. He also met with 50+ community members in informal settings for public outreach and disbursement of outreach materials and established relationship with high school teachers to begin drafting lesson plans associated with the watershed.
- **Florida:** The Florida assistant has staffed and run outreach booths with the FL DEP at the Fairchild Ramble in the Garden, Miami in November 2016. She presented on the Southeast Florida Action Network (SEAFAN) to the Hallandale Green Team, July 2016, Bug Fest Fort Lauderdale, Changing Seas screening at NSU, St. Lucie Sailing Club, West Marine Fort Lauderdale, Miami Beach Senior High School, Jupiter Drift Divers, Coral Gables High School, Active Divers Association, RSMAS Scientific Dive Class, Hollywood Hills Saltwater Fishing and Science Social Club, and South Beach Divers June 2017. She updated and redesigned a reporting web based survey to be mobile friendly, including photos and outreach, hosted on the Florida DEP SEAFAN website. She also wrote and designed fact sheets for the general public about 13 types of marine incidents, which will be disseminated via the Florida DEP SEAFAN website. With a NOAA CRCP, she wrote a spotlight piece on the Coral Management Assistantship for distribution by environmental publications and is creating a newsletter about the assistantship, which will be distributed on the NOAA and NSU assistantship web pages.
- **Guam:** During the past year, the Guam coral assistant has assisted with ten outreach sessions for the Eyes of the Reef Marianas (EOR) program, training a total of 103 participants to identify coral reef impacts – such as coral bleaching and invasive species – and report them online. This program is a crucial component of Guam's early warning system, allowing local managers and scientists to detect acute reef impacts and respond

as quickly as possible. Additionally, the she developed underwater field guides for identification of coral reef impacts to be distributed as outreach materials to EOR participants. In September 2016, the Guam coral assistant presented on coral reef biology and the efforts of the EOR program at the Save Our Reefs: Reef Safe Tour Operator Workshop for individuals involved in tourism and water activity industries. She also presented on basic coral biology, the causes and impacts of coral bleaching, and the work of Guam's Coral Reef Response Team at Science Sunday, a monthly public event hosted by the National Park Service and the Guam Community Coral Reef Monitoring Program. In May 2017, the Guam assistant assisted NOAA's Ms. Val Brown with a "Training the Trainers" session for EOR at the Bureau of Environmental and Coastal Quality in Saipan, CNMI. In June, she wrote a press release and public service announcement related to the 2017 coral bleaching outlook for Guam and interviewed with local media regarding the end of the global coral bleaching event, Guam's continued bleaching risk, and the EOR program. In April 2017, the Guam coral assistant assisted the Bureau of Statistics and Plans (BSP) with development of a request for proposal and scope of work for the Guam Comprehensive Outreach and Education Strategy. Additionally, she delivered an oral presentation "Coral damage and disease along human use gradients in Tumon Bay, Guam" at the 8th Regional Island Sustainability Conference hosted by the Center for Island Sustainability. In June, she represented BSP during an interview with the US Navy for the Pacific News Center to highlight interagency collaboration in restoration efforts after a vessel grounding. Following the second leg of the NOAA Mariana Archipelago Reef Assessment and Monitoring Program cruise in May 2017, the Guam Assistant coordinated a post-cruise briefing for local agencies, scientists, and other stakeholders. NOAA's Climate Change Team Leader, Dr. Tom Oliver, presented at the meeting, which was attended by 28 individuals representing BSP, Guam EPA, Guam Department of Agriculture, the Micronesia Conservation Coalition (NGO), The Nature Conservancy, the Western Pacific Fishery Council, the University of Guam, Guam Sea Grant, NOAA (NMFS, CRCP, and NWS), USFWS, National Park Service, NAVFAC Marianas (Navy), and US Air Force.

- **Puerto Rico:** During the Coral Reef Week in September 2016, several activities were coordinated by the PR's Coral Reef Conservation Program to educate about the coral reefs conservation. The Coral assistant assisted in the coordination of a series of presentations given by coral reef monitoring experts held at the Department of Natural and Environmental Resources. She also assisted in developing a set of three posters about corals, herbivores fish and threats to coral reefs that were used by reserve managers to give short talks at the reserves during that week. In Spring 2017, the coral assistant participated in three meetings to review the PR's Coral Reef Conservation Program priorities, in where she conducted a short informative presentation about the importance of coral reef ecosystems in Puerto Rico.
- **USVI:** The USVI assistant offered four guest lectures (total) at the University of the Virgin Islands' Biology 100 Fall 2016 and spring 2017 classes. She organized a turtle monitoring program with local volunteers, and offered informal talks to describe the program to two local homeowner associations. She led a turtle etiquette campaign for local businesses, shoreline homeowners, and island visitors with information about how to be respectful and responsible on the beaches during turtle nesting season, and organized a new bayside sign campaign for the East End Marine Park to remind beach-goers of no-take fishery zones and to remove trash from the beach.

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
- 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

- Invited public presentation for Coral Restoration Foundation's Ocean Conservation Seminar. 2 Apr 2017, Key Largo FL http://www.coralrestoration.org/speaker-series/
- Presentation on larval culture at the Workshop To Advance The Science & Practice of Caribbean Coral Restoration Nov 15-17, Fort Lauderdale, FL

VIII. CIMAS FELLOWS AND EXECUTIVE ADVISORY BOARD

The Fellows provide guidance to the Director on matters concerning the ongoing activities and future direction of CIMAS. 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
Dr. Marguerite Koch	Florida Atlantic University
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

The Southward Returning Pathways of the AMOC and their impacts on global sea surface temperature

- The paper Lee et al. (2017) was selected as Journal of Geophysical Research (JGR) Editors' Highlight. http://agupubs.onlinelibrary.wiley.com/hub/article/10.1002/2016JC012416/editor-highlight/

Coral Health and Monitoring Program (CHAMP)

- Ian Enochs, Graham Kolodziej, and Lauren Valentino received US DOC AOML Certificate of Appreciation.

The South Atlantic Overturning Circulation and Monsoons

- NOAA/AOML best paper award for the publication:
- Lopez, H., S. Dong, S.-K. Lee, and E. Campos (August 16, 2016): Remote influence of Interdecadal Pacific Oscillation on the South Atlantic meridional overturning circulation variability, *Geophysical Research Letter.*, **43**, 8250–8258, doi:10.1002/2016GL069067.

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

- Recipient: 2016 Best Paper Award, NOAA Atlantic Oceanographic and Meteorological Laboratory: Dunion et al. 2014, The Tropical Cyclone Diurnal Cycle of Mature Hurricanes.
- Recipient (2017): NASA Group Achievement Award for "outstanding achievements of the Hurricane and Severe Storms Sentinel (HS3) airborne mission to investigate the factors influencing hurricane intensity change".

Improvement to the Tropical Cyclone Genesis Index (TCGI)

- Recipient: 2016 Best Paper Award, NOAA Atlantic Oceanographic and Meteorological Laboratory: Dunion et al. 2014, *The Tropical Cyclone Diurnal Cycle of Mature Hurricanes*.
- Recipient (2017): NASA Group Achievement Award for "outstanding achievements of the Hurricane and Severe Storms Sentinel (HS3) airborne mission to investigate the factors influencing hurricane intensity change".

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.

Addressing Deficiencies in in Forecasting Tropical Cyclone Rapid Intensification in HWRF

- Jun Zhang won CIMAS Gold Medal award which is equivalent to NOAA gold medal.

Near-automation of real-time airborne radar analysis onboard NOAA aircraft

- Sonia Otero was recognized by AOC for her software engineering leadership during the development of the Airborne Atmospheric Measurement and Profiling System (AAMPS), the principal aircraft data system used on the NOAA G-IV and WP-3D aircraft, from 2007-2016.

Ship of Opportunity Program

- Caridad Ibis Gonzalez was selected as NOAA's Team Member of the Month for the month of April 2016 for leading the efforts to develop software to improve how ocean temperature data from eXpendable Bathy Thermographs are transmitted by shifting to the Iridium satellite network.

Calibration/Validation Support for NPP VIIRS Data Product Continuity

- USF Global Achievement Group Award

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

- Jim Hendee, Libby Johns, Chris Kelble, Chris Sinigalliano, and Lindsey Visser were awarded the 2016 Excellence in Partnering Award from the National Oceanographic Partnership Program.

Dimensions: Analysis of Microbiomes from Three Coral Species

- Chris Sinigalliano, along with Jim Hendee, Libby Johns, Chris Kelble of NOAA/AOML, and Lindsey Visser of UM/CIMAS, were awarded the 2016 Excellence in Partnering Award from the National Oceanographic Partnership Program for their cooperative work with the Florida Keys Nation Marine Sanctuary.

Gulf of Mexico Integrated Ecosystem Assessment

- Kelble (NOAA/AOML), Karnauskas (NOAA/SEFSC) and Schirripa (NOAA/SEFSC) were awarded the 2015 NOAA Bronze Medal for Karnauskas et al (2015) peer-reviewed publication – highest honor award bestowed by the Under Secretary of Commerce for Oceans and Atmosphere

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

- Alexander Ilich – William and Elsie Knight Endowed Fellowship Fund for Marine Science (this is the top fellowship at USF-CMS)
- Meaghan Faletti – George Lorton Fellowship in Marine Science (USF-CMS)
- Jen Granneman – 1st Place, poster competition, Florida Restore Act Centers of Excellence Annual Meeting, October 27-28, 2016, St. Pete Beach, FL

- Amy Wallace – 2nd Place, poster competition, Florida Restore Act Centers of Excellence Annual Meeting, October 27-28, 2016, St. Pete Beach, FL
- Julie Vecchio – 3rd Place, poster competition, Florida Restore Act Centers of Excellence Annual Meeting, St. Pete Beach, FL

National Marine Sanctuaries as Sentinel Sites for a Demonstration Marine Biodiversity Observation Network (MBON)

- NOPP Excellence in Partnering Award 2016

Mandatory Ship Reporting System

- Ricardo Domingues was selected as NOAA's Team Member of the Month for the month of February 2015 for his work in developing the Mandatory Ship Reporting system.

X. POSTDOCTORAL FELLOWS AND GRADUATE STUDENTS

CIMAS-Supported Postdoctoral Fellows and Graduate Students

Postdoctoral Fellows

Aguilar, Catalina
Council, Elizabeth
Dong, Jili
Forrestal, Francesca
Gronholz, Alexandra
Gruss, Arnaud
Jones, Paul
Kersale, Marion
Liu, Yanyun
Majumder, Sudip
Putman, Nathan
Rasmuson, Leif
Serrano, Xaymara
Trifonova, Neda
Vaughan, Nathan

Graduate Students, Task I

Bouck, David
Denson, Latrese
Drury, Crawford
Groves, Carolyn
Hoenig, Daniel
Komisarjevsky, Nicholas
Pacini, Chiara
Pontes, Emma
Sarkis, Sierra
Savoia, Caitlyn
Sculley, Michelle
Zink, Ian

Task II *Employees*

Domingues, Ricardo
Jugovich, Amelia

Other Participants in CIMAS Projects

Postdoctoral Fellows

Barnes, Brian
Ghosh, Tirthankar
Hancock, C
He, Bain
Hu, Wenting
Min, Dughong
Perryman, Holly
Shulze, Lena
Speer, K
Tao, Cheng

Other Participants in CIMAS Projects Cont'd

Graduate Students

Barton, Mark
Binder, Benjamin
Collier, Melissa
Cortezi, Matheus
Ewen, Kristen
Fisch, Jay
Fisco, Dana
Garcia, Ailen
Grasso, Peter
Groves, Sarah
Hansen, Kurt
Heindmann, Sarah
Helms, Charles
Henderson, Paige
Hepner, Megan
Infanti, Johnna
Jensen, Brittany
Jermain, Robert
Knowles, Morgan
Larson, Sarah
Lee, Hyo Won
Long, Jacki
Olinger, Lauren
Patranella, Allison
Peebles, Kelly
Peter, Szandra
Pomales, Luis
Seijo, Giovanni
Sinnickson, Dylan
Sukhdeo, Raymond
Sun, Shaojie
Valla, Daniel
Vandine, Benjamin
Vollmer, Alicia
Wickes, Marissa
Xia, Qiong
Zavadoff, Breanna

XI. RESEARCH STAFF

Aguilar, Sandra	Senior Research Associate III
Aguilar Hurtado, Catalina	Postdoctoral Associate
Aichinger Dias, Laura	Research Associate III
Aksoy, Altug	Scientist
Alaka, Ghassan	Assistant Scientist
Amornthammarong, Natchanon	Assistant Scientist
Annane, Bachir	Senior Research Associate III
Atluri, Charita	Senior Research Associate I
Barbero Munoz, Leticia	Assistant Scientist
Barton, Zachary	Research Associate II
Berberian, George	Research Associate II (PT)
Blake, Suzana	Senior Research Associate I
Blondeau, Jeremiah	Senior Research Associate III
Boyd, Albert	Research Laboratory Technician
Bright, Allan	Senior Research Associate I
Bucci, Lisa	Senior Research Associate I
Carollo, Cristina	Assistant Scientist
Casey, Sean	Associate Scientist
Christophersen, Hui	Assistant Scientist
Christophersen, Johnathan	Research Associate II
Councill, Elizabeth	Postdoctoral Associate
Dahl, Brittany	Research Associate I
Davies, Stephen	Research Associate II
Delgado, Javier	Senior Research Associate II
Delgado, Sandy	Research Associate II
Diaz, Jose	Research Associate III
Diaz, Steven	Senior Research Associate I
Dolk, Shaun	Senior Research Associate I
Domingues, Ricardo	Research Associate III
Dong, Jili	Postdoctoral Associate
Dunion, Jason	Associate Scientist
Ehrbar, Elizabeth	Programmer, Intermediate
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	Senior Research Associate III
Garzoli, Silvia	Scientist (PT)
Gidley, Maribeth	Assistant Scientist
Goes, Marlos	Assistant Scientist
Gonzalez, Caridad	Research Associate III
Gramer, Lewis	Assistant Scientist
Gronholz, Alexandra	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.	Sr. Systems Administrator
Jones, Paul	Postdoctoral Associate
Jugovich, Amelia	Research Associate I
Kersale, Marion	Postdoctoral Associate
Klotz, Bradley	Senior Research Associate II
Ko, Mu-Chieh	Senior Research Associate I
Kolodziej, Graham	Research Associate II
Langwiser, Caitlin	Research Associate I
Le Henaff, Matthieu	Assistant Scientist
Leighton, Hua	Assistant Scientist
Liu, Yanyun	Postdoctoral Associate
Lopez, Hosmay	Assistant Scientist
Majumder, Sudip	Postdoctoral Associate
Malca, Estrella	Senior Research Associate I
Martin, Shannon	Associate Scientist
Mears, Patrick	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
Pierrot, Denis	Associate Scientist
Privoznik, Sarah	Research Associate II
Putman, Nathan	Postdoctoral Associate
Quenee, Charline	Research Associate I
Rasmuson, Leif	Postdoctoral Associate
Rawson, Grant	Research Associate III
Roddy, Robert	Research Associate III (PT)
Ryan, Kelly	Senior Research Associate II
Sabina, Reyna	Research Associate III (PT)
Sellwood, Kathryn	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	Senior Research Associate III
Teare, Paul	Research Associate II
Trifonova, Neda	Postdoctoral Associate
Valdes, Erik	Research Associate III
Valentino, Lauren	Senior Research Associate I
van Hooidonk, Ruben	Assistant Scientist
Vaughan, Nathan	Postdoctoral Associate
Visser, Lindsey	Research Associate III
Volkov, Denis	Associate Scientist
Wicker, Jesse	Research Associate III
Williams, Dana	Associate Scientist
Zhang, Jun	Scientist
Zhang, Xuejin	Scientist

XII. VISITING SCIENTISTS

Dr. Nancy Maynard – October 1, 2012 (to continue through December 2017)
NASA Emeritus
NASA Goddard Space Flight Center
Greenbelt, MD

Dr. Sachiko Yoshida – February 27 - March 2, 2017
Woods Hole Oceanographic Institute
Woods Hole, MA

1 March, 2017 – "Tacking Fukushima radionuclide signals in the North Pacific Ocean"

Dr. Soumi Chakravorty – April 09 - 14, 2017
Indian Institute of Science Education and Research
Pune, India

11 April, 2017 – "*El Nino Southern Oscillation discharge and recharge mechanisms using numerical simulations of the global oceans"*

Dr. Saliou Faye – April 22 - May 7, 2017
Dakar-Thiaroye Oceanographic Research Center
Dakar, Senegal

26 April, 2017 – "*Variability of sea surface temperature and circulation in the northeastern tropical Atlantic upwelling system"*

Dr. Shyama Mohanty – May 1, 2017 (4 months)
School of Earth Ocean and Climate Sciences
Indian Institute of Technology Bhubaneswar
Odisha, India

XIII. PUBLICATIONS

Table 1: Publication Record 2016-2017 for Cooperative Agreement NA15OAR4320064

	Institute Lead Author	NOAA Lead Author	Other Lead Author
	2016-2017	**2016-2017**	**2016-2017**
Peer Reviewed	47	18	52
Non-Peer Reviewed	24	4	6

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.*, 144, 3321-31, doi: 10.1175/MWR-D-15-0421.1.

Aichinger Dias, L., J. Litz, L. Garrison, A. Martinez, K. Barry, and T. Speakman (2017), Exposure of cetaceans to petroleum products following the Deepwater Horizon oil spill in the Gulf of Mexico, *Endangered Species Research*, 33, 119–125, doi: 10.3354/esr00770.

Alaka, G.J., X. Zhang, S.G. Gopalakrishnan, S.B. Goldenberg, and F.D. Marks (2017), Performance of Basin-Scale HWRF Tropical Cyclone Track Forecasts, *Wea. Forecasting*, 32, 1253–1271, doi: 10.1175/WAF-D-16-0150.1.

Androulidakis, Y., V. Kourafalou, G.R. Halliwell, M. Le Hénaff, H. Kang, M. Mehari, and R. Atlas (2016), Hurricane interaction with the upper ocean in the Amazon-Orinoco plume region, *Ocean Dynamics*, 66, 1559-1588, doi: 10.1007/s10236-016-0997-0.

Baker-Austin, C., J. Trinanes, N. Gonzalez-Escalona, and J. Martinez-Urtaza (2017), Non-cholera vibrios: The microbial barometer of climate change, *Trends in Microbiology*, 25, 76-84, doi: 10.1016/j.tim.2016.09.008.

Bakker, D.C.E., B. Pfeil, C.S. Landa, N. Metz, 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. Ibánhez, T. Johannessen, R. Keeling, V. Kitidis, A. Körtzinger, A. Kozyr, E. Krasakopoulou, A. Kuwata, P. Landschützer, S.K. Lauvset, N. Lefèvre, 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,* 8, 2, 383-413, doi:10.5194/ESSD-8-383-2016.

Baringer, M.O., M. Lankhorst, D. Volkov, S. Garzoli, S. Dong, U. Send, and C.S. Meinen (2016), Meridional overturning circulation observations in the North Atlantic Ocean [in "State of the Climate in 2015"], *Bull. Amer. Meteor. Soc.*, 97, 8, S84-S87, doi:10.1175/2017BAMSStateoftheClimate.1.

Barros, N.H.C., A.A. de Souza, E.B. Peebles, and S. Chellappa (2017), Dynamics of sex reversal in the marbled swamp eel (*Synbranchus marmoratus* Bloch, 1795), a diandric hermaphrodite from Marechal Dutra Reservoir, northeastern Brazil, *J. Applied Ichthyology*, 33, 3, 443-449, doi: 10.1111/jai.13273.

Beron-Vera, F.J., M.J. Olascoaga, and R. Lumpkin (2016), Inertia-induced accumulation of flotsam in the subtropical gyres, *Geophys. Res. Lett.*, 43, 12228–33, doi:10.1002/2016GL071443.

Boer, G., J. Douglas, M. Smith, C. Cassou, F. Doblas-Reyes, G. Danabasoglu, B. Kirtman, Y. Kushnir, M. Kimoto, G. Meehl, R. Msadek, W. Mueller, K. Taylor, F. Zwiers, M. Rixen, Y. Ruprich-Robert, R. Eade (2016), The Decadal Climate Prediction Project (DCPP) contribution to CMIP6, *Geoscientific Model Development*, 9, 3751, doi: 1-.5194/gmd-9-3751-2016.

Boukabara, S.A., I. Moradi, R. Atlas, S.P.F. Casey, L. Cucurull, R.N. Hoffman, K. Ide, V.K. Kumar, R. Li, Z. Li, M. Masutani, N. Shadroudi, J. Woollen, and Y. Zhou (2016), Community global observing system simulation experiment (OSSE) package: CGOP. Description and usage, *J. Atmos. Oceanic Technol.*, 33, 8, 1759–1777, doi:10.1175/JTECH-D-16-0012.1.

Boukabara, S.A., T. Zhu, H.L. Tolman, S. Lord, S. Goodman, R. Atlas, M. Goldberg, T. Auligne, B. Pierce, L. Cucurull, M. Zupanski, M. Zhang, I. Moradi, J. Otkin, D. Santek, B. Hoover, Z. Pu, X. Zhan, C. Hain, E. Kalnay, D. Hotta, S. Nolin, E. Bayler, A. Mehra, S.P.F. Casey, D. Lindsey, L. Grasso, V.K. Kumar, A. Powell, J. Xu, T. Greenwald, J. Zajic, J. Li, J. Li, B. Li, J. Liu, L. Fang, P. Wang, and T.-C. Chen (2016), S4: an O2R/R2O infrastructure for optimizing satellite data utilization in NOAA numerical modeling systems: A step toward bridging the gap between research and operations, *Bull. Amer. Meteor. Soc.*, 97, 12, 2359 – 2378, doi: 10.1175/BAMS-D-14-00188.1.

Burgman, R.J., B.P. Kirtman, A.C. Clement, and H. Vazquez (2017), Model evidence for low-level cloud feedback driving persistent changes in atmospheric circulation and regional hydroclimate, *Geophys. Res. Lett.*, 44, 428–437, doi: 10.1002/2016GL071978.

Cheng, Y., D. Putrasahan, L. Beal, and B.P. Kirtman (2016), Quantifying Agulhas leakage in a high-resolution climate model, *J. Climate*, 29, 6881-6892, doi: 10.1175/JCLI-D-15-0568.1

Christophersen, H., A. Aksoy, J. Dunion, and K.J. Sellwood (2017), The Impact of NASA Global Hawk Unmanned Aircraft Dropwindsonde Observations on Tropical Cyclone

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