Cooperative Institute for Marine and Atmospheric Studies

CIMAS

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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, and 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 $24.86 M. Task I which includes not only Administration but also Research Infrastructure (ship-time, computing resource access etc.) and Education and Outreach was ca. $3.3M. The University of Miami contributed an additional $.27 M towards Administration. Task II, which supports CIMAS employees conducting closely collaborative research off-campus was ca. $ 14.9M.

Individual research project funding (Tasks III and IV) totaled ca. $6.64M. The largest portions were the research projects within Theme 3 (Sustained Ocean and Coastal Observations) which accounts for 61%. Themes 1, 4, 6 and 7(Climate Research and Impact, Ocean Modeling, Ecosystem Management and Protection and Restoration of Resources) accounts for 34%. The smallest portions were in Themes 2 and 5 (Tropical Weather 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 this same time-period under prior agreements or awards.

During this reporting period a total of 170 individuals at UM were directly provided salary support through CIMAS. Of these, 136 received over 50%; 7 received less than 50% of their support through CIMAS. Of the 143 research employees who received over NOAA support, 83 worked at AOML, 40 at SEFSC, 2 at RSMAS, 1 at NHC, 5 at the University of Puerto Rico, 1 at the University of Virgin Islands, 1 at SWFSC, 1 at NCWCP and 11 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 45% female leading to a 1% increase compared to last year. Foreign-born individuals make up 48% of the total, same as last year. The largest foreign sub-groups are Hispanics (22%), and Asian and Pacific Islanders (10%). 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 40.4. 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 78 peer-reviewed publications and another 22 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

Are Eastern Tropical Pacific Coral Reefs Becoming More Resilient to ENSO?
This proposal addresses the long-term resilience of coral reefs to climate change, using the eastern tropical Pacific as a case study. This is relevant to society because reefs are critically threatened worldwide, but eastern Pacific reefs are arguably the best-studied reefs anywhere in the world in terms of their response to long-term repeated severe coral “bleaching” events. We are studying why these reefs actually seem to be becoming more resilient to thermal stress over time, and are studying the adaptive processes that might explain this. This is ultimately important to better understanding the fate of coral reefs worldwide in an era of climate change.

The Ocean, Coastal, and Estuarine Network for Ocean Acidification monitoring
Our ocean acidification (OA) observing system is used to determine patterns and trends in key indicators of OA. Our data are used to evaluate changes in marine ecosystems and to develop management and mitigation strategies under ocean acidification conditions. We specifically focus our research in the Gulf of Mexico and East coast of the US. OA conditions are evaluated through surface measurements obtained from autonomous systems on 2 ships of opportunity (SOOP-OA), dedicated research cruises (the GOMECC-3 cruise in 2017, the ECOA-2 cruise in 2018) and by the continued development of the observing system.

Ocean acidification is a consequence of the increase of CO_2 concentration in the water due to the burning of fossil fuels, cement production, deforestation etc. and it can have significant impacts on shell fisheries and coral reef ecosystems. On GOMECC-3 we performed the first Gulf-wide survey of coastal OA conditions, including Mexican and Cuban waters, the Yucatan channel and the Florida Straits. We established a successful collaboration with the National Parks Service to include 4 of their parks in our survey and also collected data at two National Marine Sanctuaries to establish baseline OA conditions. Using data from this and preceding projects on the ships of opportunity of the Royal Caribbean Cruise Lines, we have established algorithms to map ocean acidification in the Caribbean on a monthly basis. The 16-year data record shows strong and unexpected multi-annual trends in surface pH in the region.

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 June 2018, 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. Major progress with the instrument over last year includes that the sampling capacity was increased from five on-board samples to a 60-sample cartridge. This prototype instrument showed 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.

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.

Dimensions: Analysis of Microbiomes from Three Coral Species

Little is known about the different microbiomes of various coral reef species, and the surrounding waters. The microbiome may have influence over coral resilience to disease, bleaching and other concerns. Previous studies have observed that there is often a decrease in microbiome biodiversity and shifts in microbial population community structures in stressed and diseased coral reef communities.

This project works to measure the exposure of coral microbiome communities to land-based microbial contaminants and to characterize the microbiome community biodiversity and population composition of the coral species Orbicella faveolata, Siderastrea sidera, and Acropora cervicornis at six sentinel reefs within the Florida Keys National Marine Sanctuary in combination with the ongoing Marine Biodiversity Observing Network to provide better understanding of the health, status, biodiversity, function, and response to stressors of these critical coral reef habitats.

Environmental Microbiology: Characterization of marine microbiomes and molecular source tracking of microbial contaminants

Microbiomes are critical components of marine habitats such as coral reefs, and these microbial populations are vital for the healthy functioning and ecosystem services of these habitats. Changes in microbiome structure, biodiversity, and activity can often herald the influence of habitat stressors, onset of disease, and changes in health status of marine habitats. In addition, these native marine microbiomes and their hosts can themselves be greatly impacted by contaminating microbes associated with land-based sources of pollution. This project has used a combination of molecular genetic techniques such as next-generation-sequencing of microbiome populations and qPCR-based microbial source tracking of microbial contaminants such as fecal-associated bacteria to better understand the influence and exposure patterns of pollution on marine microbiomes, to investigate the status, biodiversity, and function of habitats such as coral reefs, and improve understanding of public health exposure patterns and risks from LBSP microbial contaminants in coastal waters, beaches, and tidal floodwaters. In addition, this project has provided training and resources to transition this molecular microbial source tracking technology to operations by other agencies, resource managers, researchers, and the private sector, thus helping to make its utility and benefit more widespread.

Ocean technology development: bottom drifter development

Our novel observation platform addresses the lack of instruments able to investigate near bottom environments over an area of interest rather than a fixed point. 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. The science deployment on the northern shelf of the Gulf of Mexico (offshore of Louisiana) will allow us to address the interaction between large-scale circulation on the shelf, bottom flows and turbulence. In addition, mechanisms that control vertical and lateral mixing as well as stratification, low oxygen and hypoxic zones are investigated. Two platforms were deployed on the shelf, in the region where hypoxic conditions are dominant throughout most of the summer. Here the data measured by the platforms will allow us to determine Reynolds, and Richardson or Froude 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 an extended space and 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 these goals. 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.

Length-based assessment and harvest control rules for severely data-limited fisheries of the South Atlantic, Gulf of Mexico, and U.S. Caribbean

The goal of this project is to develop harvest control rules that link severely data-poor stock assessment outputs to catch limits. This work pertains to the Magnuson-Stevens Act requirement of establishing annual catch limits for all stocks, including those that lack stock assessments. The need for annual catch limits is particularly challenging for fisheries that are considered to be data limited. We are addressing this issue through management strategy evaluation, which enables the efficacy of various data-limited management options to be examined through simulation modeling. Thus, this work holds significance because it may enable data-limited annual catch limits to be established as per federal fisheries management regulations.

Effects of Nitrogen sources and plankton food-web dynamics on habitat quality for the larvae of Atlantic bluefin tuna in the Gulf of Mexico.

Our work continues to improve the understanding of larval bluefin tuna distribution and ecology in the Gulf of Mexico and western Atlantic. The NF1802 research cruise aboard the NOAA Ship Nancy Foster was completed at the end of May 2018 for year-two of field sampling in support of our project supported by the NOAA RESTORE Act Science program. Using stable isotopes, this project examines linkages between ecosystem biogeochemistry in the Gulf of Mexico and planktonic trophic dynamics with larval Atlantic bluefin tuna as the top predator as the focus of the food-web's trophic positions. Similar to year-1, during the 2018 research survey, we utilized products generated by collaborators at NOAA AOML, Coastwatch and from the University of Southern Mississippi to guide us in examining the oceanographic environment as we targeted likely spawning habitat ultimately maximizing valuable ship time.

Our interdisciplinary collaboration spans from as far east as the University of Hawaii at Manoa and as far west as Spain's Instituto Español de Oceanografia en Malaga. Scientists from UM's CIMAS, Scripps Institute of Oceanography, and Florida State University participated in surveys and sample processing for this ongoing research project that is the first to link larval distributions, feeding, gut content, growth and trophic interactions simultaneously for the region. Results will facilitate better management of bluefin tuna, by enhancing knowledge of spawning behaviors and recruitment mechanisms.

Examining the status and distribution of reef fish spawning aggregations in the Southeast Florida Coral Reef Initiative (SEFCRI) Region

The goal of this project was to 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 plan. In our efforts to attain that goal we have developed the first centralized repository for FSA reports in the South Florida region, and these data have also been included in an interactive Marine Spatial Planner (http://ourfloridareefs.org/tool/). To further enhance the utility of the web tool, we have also developed extensive species profiles to provide managers with additional, more accessible background information related to the aggregating species of interest that will aid in informing their decisions.

In addition to centralizing the local spawning aggregation reports for use by the SEFCRI working groups and sharing our work with others around the region, a comprehensive review of our work in the SEFCRI region is being compiled for publication in the spring of 2019. Additionally, data from field efforts in Jupiter, Florida are being used to prepare three manuscripts highlighting a link between water management strategies and the local reef fish communities, fish community association with FSAs, and the relationship between acoustic target strength and fish length. Findings from the first two manuscripts provide important insight into fish population dynamics associated with FSA formation, and their response to changes in environmental conditions. The third manuscript fills in an important gap in knowledge related to acoustic survey methods and data analysis for large reef fish, and will be exceptionally useful in future FSA research.

Trophic Interactions and Habitat Requirements of Gulf of Mexico Bryde's Whales
The main goal of this research project is to develop a comprehensive ecological understanding of Gulf of Mexico Bryde's whales. The project also assess critical habitats and the ecological role of Bryde's whale in Gulf of Mexico marine food webs. The scientific team assessed the habitat, spatial distribution, and foraging ecology of Gulf of Mexico Bryde's whales using a multi-faceted approach that integrates visual and acoustic monitoring, environmental sampling, trawling, biopsy sampling for genetic, stable isotope and pollutant analyses, and deployment of animal-borne tags sampling at fine and coarse scales as well as models to identify the key features. Limited baseline information is available on the ecology and behavior of Bryde's whales, particularly on their foraging ecology, habitat requirements and full distributional range. Obtaining these crucial data will support effective conservation actions that will promote the recovery of this species and restoration of injuries from the DWH event.

Applying Bio-physical Monitoring and Capacity Assessments to Mesoamerican Reef Marine Protected Areas
This multi-year research focuses on monitoring larval and post-larval fish populations in the Mesoamerican region that are recruiting into MPAs. The goal is to fill data gaps and examine how these fishes are distributed and eventually develop comparisons between them. This barrier reef is the second largest in the world and houses ecologically and economically important species as well as increased anthropogenic pressures. The numerous marine protected areas and NGOs that conserve and manage the region are directly involved in the monitoring (via the ECOMEs) of their own areas which enriches the existing human capacity as well as generates a baseline for the development of a time series in a data pour region already vulnerable to a rapidly changing climate.

Evaluation of ESA listed Acropora spp. Status and Actions for Management and Recovery
Elkhorn coral, Acropora palmata, was listed for protection under the US Endangered Species Act as a threatened species in 2006 prompting the need for a better understanding of threats and potential recovery actions. Elkhorn coral are fast growing and structurally complex corals which provide coastal protection and habitat needed for several other economically important species. This ongoing project aims to document the long-term population trajectory (decline or recovery) of the remaining Elkhorn populations in Florida, identify the cause(s) associated with these changes, and to explore strategies to foster recovery. These issues are addressed by focal, demographic monitoring of a subsample of the population and strategic outplanting of nursery

raised fragments. In September 2017, Hurricane Irma caused considerable damage to the Florida Keys reef tract, after suffering major losses from mass bleaching events associated with thermal stress in 2014 and 2015. Our long-term monitoring projects allowed for evaluation of the impacts of these events. Natural recovery from stress events by the Acropora spp. of the Florida Keys is outpaced by increasing frequency and severity of stress events indicating an urgent need for restoration.

A dynamic decision support tool for management
The successful integration of stock assessment science into fisheries management decision making is critical to the goal of achieving optimal sustainable harvest rates. In many coastal states a large proportion of the economy is driven by fishery and marine tourism related activities. It is therefore imperative that maximum coordination between stock assessment scientists and fishery managers is achieved. This project is working to eliminate a major bottleneck in the assessment to management process by allowing managers to directly obtain stock assessment forecasts, based on proposed management interventions, in real time. Thereby, enabling them to increase allocations in a sustainable fashion and maximize the economic productivity of their fisheries.

Nearshore salinity and juvenile pink shrimp (Farfantepenaeus duorarum): Integrating field observations, laboratory trials, and habitat suitability simulations
The Comprehensive Everglades Restoration Plan (CERP) is the world's largest ecological restoration. Careful ecological monitoring before, during, and after CERP implementation is necessary to determine impacts of its implementation. Pink shrimp, a commercially fished species and important ecological linkage between primary consumers and higher trophic levels, was previously identified as a bioindicator of CERP implementation. Along Biscayne Bay's southwestern shoreline, restoration of historic salinity regimes was predicted to increase pink shrimp densities. Quantile regression of 10 years of monitoring data revealed that pink shrimp density is limited by salinities <8 ppt; further, pink shrimp spatial density patterns revealed by clustering identified low density associations with areas the southwestern Biscayne Bay shoreline that are greatly impacted by present canal discharges. Habitat suitability modeling indicates that reduction of salinity conditions would negatively impact pink shrimp density in this area. These findings are important within the context of adaptive management and provide insight on potential impacts of CERP implementation. Negative impacts would not likely result in substantial impacts on pink shrimp productivity within Biscayne Bay as the spatial extent of restored-salinity areas is small relative to the size of the bay.

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

Natural variability versus climate change influence on U.S. heat waves
In this study, we address the relative role of natural variability versus Anthropogenic (i.e., human-induced) Climate Change (ACC) in the modulation of U.S. heat waves into the 21st Century. This is relevant to society because heat waves are the leading cause of weather related deaths in the U.S. and the number and severity of heat waves is projected to increase into the 21st Century. Specifically, we assessed the regional dependence of future projections of heat waves, the timeframe for which the ACC signal will emerge on top of the natural variability (i.e., time of

emergence or ToE) with respect to heat waves, and physical mechanisms controlling different ToE for different heat wave regions. This was done by analyzing observations and model simulations under present and future anthropogenic forcing to assess how natural variability and ACC modulate US heat waves. We clustered extreme heat events by their spatial distribution. This allowed us to identify four dominant heat wave patters (i.e., Western, Northern Plains, Southern Plains, and Great Lakes patterns). We show that ACC dominates heat wave occurrence over the Western and Great Lakes regions, with ToE occurring as early as in 2020s 2030s, respectively. In contrast, internal variability governs heat waves in the Northern and Southern Great Plains, where ToE occurs in the 2050s and 2070s; this later ToE is found to be a result of a projected increase in circulation variability, namely the Great Plain low-level jet. Thus, greater mitigation and adaptation efforts are needed in the Great Lakes and western US regions. These results have significant scientific/societal implications because it hints at the need for caution in attributing heat extremes to ACC. Also, our study emphasizes that the consequences of increased heat wave amplitude and frequency in the Great Lakes and Western US could be further exacerbated by the large population and rapid population increase in these regions, highlighting the regions where mitigation and adaptation efforts are most required. In contrast, the late ToE of the ACC signal in the Great Plains suggests that future projection of heat extremes in this region is more uncertain and masked by large internal variability, calling for the need to understand these natural processes in order for better predictions.

Development & Research Activities for the Basin-Scale Hurricane Weather Research and Forecasting (HWRF-B) Model

<u>Experimental Model Produces Better Track Forecasts than HWRF & GFS</u>
The Basin-Scale HWRF is an experimental version of the HWRF modeling system that serves as a testbed for model-based hurricane research. In 2017, Basin-Scale HWRF produced ~5% better track forecasts than the operational HWRF and the GFS in the 3-5-day range. This positive result was at least partly fueled by advanced configuration options within the Basin-Scale HWRF: (i) large outermost domain that covers and Atlantic and Northeast Pacific hurricane basins and (ii) multiple movable multi-level nests that follow individual storms around the large domain. This research supports the notion that a better representation of multi-scale interactions and the environment can improve tropical cyclone track predictions.

<u>Cycled Data Assimilation System for HWRF Developed</u>
Data assimilation improvements are vital to the overall reduction of track and intensity errors for tropical cyclones. For the first time, the outermost domain of Basin-Scale HWRF was cycled every 6 hours for the 2017 hurricane season. This cycled system provides a clear pathway for the operational HWRF system to perform its own outer domain data assimilation in the future. Because the data assimilation system uses bias information from the HWRF forecast itself, these analyses are believed to be the best representation of initial conditions for that model. This system can help to identify model deficiencies and to improve model physics.

<u>Experimental HWRF Produced Realistic Rainfall Totals for Hurricane Harvey</u>
Rainfall poses a dangerous hazard during hurricane landfalls that requires more attention in our numerical weather prediction model research. Rainfall forecasts from Basin-Scale HWRF were compared with the Stage IV observations for a 5-day period during Hurricane Harvey's landfall. Overall, Basin-Scale HWRF reproduced the areal coverage of the rainfall, especially the >8"

contour, with good accuracy. Although the forecasted rainfall maximum was underpredicted, the location of the rainfall maximum (Houston to Port Arthur) was captured well. This highlights the need for more tropical cyclone rainfall evaluations from high-resolution regional models.

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.

Composite Impact of NASA Global Hawk Unmanned Aircraft Dropwindsonde Observations on Tropical Cyclone Analyses and Forecasts

Improving intensity prediction (particularly prediction of rapid intensity change) of tropical cyclones (TCs) continues to be a high priority for both research and operations. Experiments conducted using NOAA/AOML/HRD's vortex-scale ensemble DA system (Hurricane Ensemble Data Assimilation System, HEDAS) and NOAA's operational Hurricane Weather Research and Forecasting (HWRF) model suggest that the high-altitude dropsondes have great value for TC analyses and forecasts, particularly for TCs that undergo large intensity changes ($\geq$ 20 kt $(24\ h)^{-1}$). Beyond the case studies, the merits of high-altitude dropsonde assimilation are further demonstrated in a composite study. Greater improvements in the absence of data from crewed reconnaissance aircraft reveal the strengths of long-endurance UAS platforms to sample TCs that traditional crewed aircraft cannot reach due to range limitations.

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.

Global Observing System Experiments (OSEs) and Observing System Simulation Experiments (OSSEs)

Observing System Experiments (OSEs) can show us the impacts of current satellites already in orbit and operationally assimilated. Observing System Simulation Experiments (OSSEs), on the other hand, 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. Global OSEs and OSSEs were performed to evaluate and test the impact of current and future satellite platforms, including radio occultation, microwave and infrared satellites, atmospheric motion vectors, as well as a proposed new constellation of infrared hyper-spectral sounders. Initial evaluation with current satellite platforms indicate the benefit of microwave, infrared, radio occultation, and atmospheric motion vectors on global forecast skill. In particular, microwave, radio occultation, and atmospheric motion vector observations have large impacts to hurricane track and intensity forecasts. A reported has been prepared to summarize these OSE results. OSSEs assessing the impact of a five-satellite constellation (Geostationary Hyperspectral Sounders, or GeoHSS), in accordance with House Bill 353 (2017), have been mostly completed. Results show positive improvements in global atmospheric analyses with these new observations. Forecast results are more mixed, with positive impacts noted in the Northern Hemisphere and slightly negative impacts noted in the Southern Hemisphere.

A Twenty One-Year Tropical Cyclone Global Positioning System Dropwindsonde Dataset

A comprehensive dropwindsonde data archive is updated annually to provide high quality observational data to the research community. This archive is used to increase understanding of tropical cyclones and make improvements to numerical forecast models in order to better protect lives and property. The 2017 Atlantic Hurricane season was particularly busy and a large number of data were collected in tropical cyclones which had major impact on the United States and its territories. The post processing of these data allow for the accurate assessment of the hazards encountered and improve the use of the observations for operational forecasts. The archive, including the 2017 data is available via the AOML web page and ftp server.

An Observing System Experiment for the Hurricane Imaging Radiometer

Surface wind speed observations from the HIRAD instrument were successfully assimilated into the HWRF model improving the initial analysis of the surface wind structure. Improved wind analyses provide forecasters a better estimate of the strength and extent of damaging winds, helping them to inform the public. With adjustments to the data assimilation parameters, the observations were also able to have a positive impact on the forecast of the tropical cyclone path and intensity. The experiments represent the first step towards demonstrating the potential value of this instrument for future deployments, in addition to, or eventually as a replacement for SFMR. The results found here may be applicable to other surface wind observations which are typically not assimilated.

Validation of Tropical Cyclone Precipitation in HWRF using Satellite Observations

One of the most important pathways towards more accurate forecasts of hurricane intensification is to improve the model representation of mesoscale processes, such as the organization of precipitation within the inner core region. One of the first steps towards achieving that improvement is to understand what model precipitation biases currently exist. This project quantifies those biases by validating precipitation in Hurricane Weather Research and Forecasting (HWRF) forecasts against satellite observations. Comparisons between the satellite observed and CRTM-simulated passive microwave brightness temperatures for operational HWRF forecasts during the intensification of Hurricane Edouard (2014) reveals that HWRF is biased towards having too much coverage of intense, deep convection within the inner rain band and eyewall, as well as broadly more precipitating area on the storm scale. This bias likely affects how well HWRF represents precipitation processes and the subsequent vortex (structure and intensity) response.

Ocean OSSE System Development and Applications for QOSAP

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. This project will provide methods to optimize the ocean observing system to reduce costs. Specific scientific issues include understanding how ocean data assimilation reduces errors in ocean analyses and increases predictability time scales in ocean forecasts, either standalone or in coupled hurricane forecasts. The ocean OSSE system was developed to address these issues. 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 level changes, 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.

A recent study (Smeed et al., 2018) show that the AMOC has been in a state of reduced overturning since 2008 as compared to 2004-2008. This change of AMOC state is concurrent with other changes in the North Atlantic such as a northward shift and broadening of the Gulf Stream and altered patterns of heat content and sea surface temperature. These changes resemble the response to a declining AMOC predicted by coupled climate models. Concurrent changes in air-sea fluxes close to the western boundary reveal that the changes in ocean heat transport and sea surface temperature have altered the pattern of ocean-atmosphere heat exchange over the North Atlantic. These results provide strong observational evidence that the AMOC is a major factor in decadal-scale variability of North Atlantic climate.

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.

Variations in the MOC have been documented to covary with important societal environmental conditions such as precipitation patterns, sea level changes, surface air temperatures, and hurricane intensification. Observations of the MOC have now been collected and analyzed over the period 2009-2017, allowing for the first time a direct estimate of seasonal to interannual MOC variability at 34.5°S using daily in situ data (Meinen et al. 2018). The SAM PIs and their partners demonstrated the longitudinal complexity of the MOC flows at 34.5°S, and illustrated the necessity of direct measurements of the barotropic and baroclinic components of the flow, as well as the Ekman flow, in order to properly characterize the MOC variability at this latitude.

South Atlantic-North Atlantic Meridional Overturning Circulation (MOC) Linkages: Analysis of the Upper and Lower Limbs With In Situ Instruments

This project helps refine our current understanding of the AMOC pathways in the North and South Atlantic Ocean, and how they influence AMOC variability in both basins. Improved understanding of AMOC variability will lead to improvements in weather and seasonal-to-interannual climate forecasts, which have major implications for agriculture, commerce, and coastal community resilience. A major research effort this year was to study the seasonal to interannual variability of the AMOC volume transports in the South Atlantic using observations from the 34.5°S moored arrays over the period 2009-2017. In the resulting publication, Meinen et al. (2018), the Project PIs, postdoc, and their partners demonstrated that the baroclinic (density-driven) and barotropic (bottom pressure-driven) changes at both boundaries are clearly important at seasonal time scale, which is a surprising difference from 26.5°N where only variations at the eastern boundary are thought to be influential at seasonal time scales. These observations demonstrated unequivocally the need to observe the dynamics on both sides of the basin as the MOC flows at 34.5°S are more broadly spread across the basin than at 26.5°N.

Hourly near-surface oceanic velocity and temperature from surface drifters

Understanding the cascade of energy in the ocean from large-scale forcing by winds and tides to small-scale high-frequency currents, sea level variability, and associated mixing processes remains one of the outstanding issues in physical oceanography. This understanding is crucial to accurately predict large-scale and regional oceanic circulations and global climate, including global mean sea level and its continuing rise, one of the greatest challenges our society currently faces. RSMAS, CIMAS, and AOML scientists are continuously producing a quality-controlled global dataset of surface drifter positions and velocities at an hourly and spatial resolution, freely available to the global research community.

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

The surface current is a critical variable for transport of buoyant pollutants and biota, as well as accurate calculation of air-sea fluxes. There are few if any observations of ocean velocity within a few centimeters of the sea surface, as most surface current observations are from tens of centimeters to several meters depth. A new low-cost surface drifter was developed with technological innovations that allow it to have a very small (a cylinder <5 cm tall and < 15 cm diameter) hull geometry and transmit regardless of its orientation, as a drifter with this geometry flips under wave action. This instrument can have applications including real-time tracking of oil spills, scientific investigations of the near surface velocity structure, and ground-truthing of new remote sensing technologies.

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

The broad scientific issue addressed by our work is air-sea CO_2 fluxes. The oceans absorb an estimated 25% of the anthropogenic CO_2 that would otherwise be stored in the atmosphere, thus increasing atmospheric levels of CO_2, which is why it is very important to be able to accurately determine the ocean-atmosphere exchanges. Our program contributes to the goal of creating regional flux maps on seasonal timescales to quantify uptake of anthropogenic CO_2 by the ocean and short-term changes thereof. We do this by providing 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). This collaborative program (led by Dr. Pierrot) of investigators at the NOAA laboratories AOML and PMEL, Columbia University, the University of Miami, and the Bermuda Institute of Ocean Sciences is the largest project of its kind in the world.

This is a critical component of constraining the global carbon cycle which is of paramount importance for verification of climate frameworks such as proposed in COP-21.

PIRATA Northeast Extension

A new tropical Atlantic data set was released that includes several enhancements to measurements from 17 PIRATA buoys in order to improve data accuracy and continuity. The original PIRATA data are corrected for instrumental biases, temporal gaps are filled using supplementary datasets, and the subsurface temperature and salinity time series are mapped to a uniform 5-m vertical grid. The new data set is called enhanced PIRATA, or ePIRATA, and provides continuous daily records of upper-ocean temperature, salinity, and currents, together with meteorological data such as winds, humidity, and solar radiation. ePIRATA should prove valuable in better analyzing ocean and atmospheric processes in the tropical Atlantic, which affect hurricane activity and rainfall over South America and Africa.

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 Fellowship 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 fellows' 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 fellow, 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 four 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.

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 176 persons were associated with CIMAS in various capacities. Of these, 136 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, 83 are located at AOML, 40 at SEFSC, 2 at RSMAS, 1 at NHC, 9 work at distant NOAA facilities, 5 at UPR, 1 at UVI, 1 at SWFSC and 1 at NCWCP.

Table 1: CIMAS Research Personnel 2017 – 2018

Category	Number	BS	MS	Ph.D
Research Associate/Scientist	86	15	38	33
Part Time Research Associate/Scientist	7	2	3	2
Other Research Professional Category	5	2	2	
Postdoctoral Fellow	13			13
Research Support Staff	32			
Total (> 50% NOAA support)	**143**	**19**	**43**	**48**
Full Time Administrative Staff	5			
Task I Undergraduate Students	8			
Task I Graduate Students	14			
Visiting Scientist	6			
NOAA Association	83 - AOML			
	40 - SEFSC			
	2 - RSMAS			
	18 - (1) NHC, (5) UPR, (1) UVI, (1) SWFSC, (1) NCWCP (9) Other locations			
Obtained NOAA employment within the last year	1			

CIMAS Research Associates/Scientists are hired into a well-delineated series of categories that allow for professional advancement in the research ranks. There is a sequence of five positions targeted for advanced technical or scientific staff conducting University research. Advancement is not automatic with time-in-grade. Additional education, continuing professional achievement, and/or increased responsibility are the basis for advancement to higher-level positions. The progression order is: Research Associate, Senior Research Associate, Assistant Scientist, Associate Scientist, and Scientist. The "Scientist" ranks (Assistant Scientist, Associate Scientist and Scientist) are designed to closely parallel in pay, prestige and description the Research Faculty track at the University (i.e., Assistant Research Professor, Associate Research Professor and Research Professor). Over the last twelve months, there were in addition a total of 13 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). Presently, there are five 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. 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,
2. Preparing and providing briefing documents and workshops for relevant NOAA personnel (advisors and administrators) regarding UM Human Resources policies, practices and regulations.
3. 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 one employee was transitioned to Federal position.

Demographics of CIMAS Employees

The CIMAS population is 55% male, this represents a 1% decrease from last year. Foreign-born individuals make up 48% of the personnel; of these Hispanics make up 22% of the ranks; Asian and Pacific Islanders, 10%. Only 2% continue to be 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 40.4. The largest age decade is that between 30 and 40, for a total of 77. 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 14 UM/RSMAS graduate students supported through CIMAS Task I for this reporting period. Many others are supported on Task III projects and in other capacities (see *Section X* for the full list). In addition 8 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. $24.8M 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
Year 3	3,318,077	14,902,770	5,366,060	456,605	817,760	24,861,272
TOTALS	**7,567,320**	**37,223,820**	**20,039,654**	**4,319,769**	**2,643,327**	**71,793,890**

The sources of NOAA funding are shown in Table 2. The major source of NOAA funding continues to be OAR which provided 54% of the total. NMFS and NESDIS contributed at 25%, and 12% respectively. "Other" accounts for 2%, the source of funding include awards from NOS. This table does not include funding from other federal agencies (NASA, NSF) and private industry as well as sub-contractual awards from Florida International University, Purdue University, Ocean Foundation, Nature Conservancy, and University of Wisconsin - Madison to CIMAS investigators.

Table 2: Funding by Source

1 July 2017 - 30 June 2018		
Source	**Funding $M**	**% Total**
NESDIS	2.90	12%
NMFS/SEFSC	6.00	25%
OAR/AOML	14.10	50%
OAR/CPO	0.51	2%
OAR-Other	0.53	2%
GRAND TOTAL	**24.04**	**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 $ 3.31M, of which $0.57M was for the Administration component (that sum did not 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. Under the category of “Administration”, 15% covers a portion of the salary of CIMAS staff including its Director and Associate Director. Under the category of "Other", 25% includes: travel for students, visiting scientists and temporary staff in support of research activities, consulting agreements, other supplies (minor equipment, peripherals, etc.). Research ship-time accounts for 14% of the total. Temporary Staff accounts for 20% which covers persons hired on a temporary basis to support specific research projects. Outreach accounts for 2%, Other research infrastructure access (e.g. supercomputing access, capital equipment) accounts for 15% and student stipends another 8%.

Task I: General

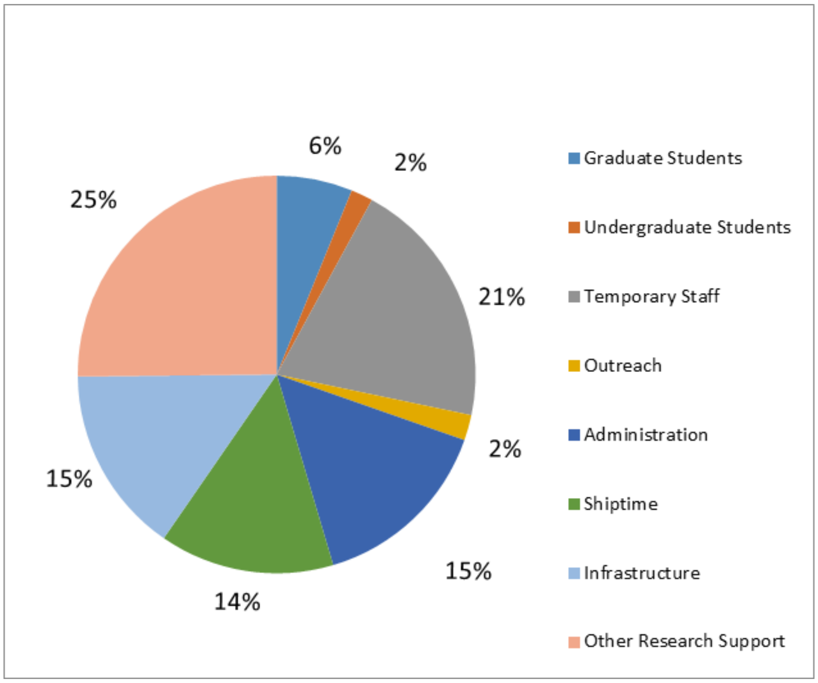


Figure 1: Distribution of Task 1 Funding

The funding provided for Task II employees totaled $14.9M over the past twelve months. The distribution of these funds by employee category is depicted in Figure 2.

Task II: Employees by Category

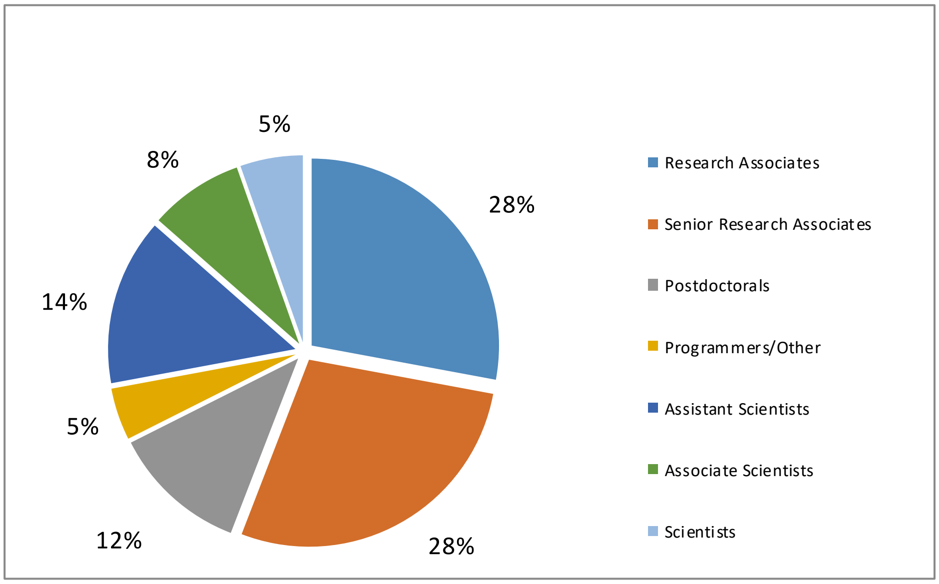


Figure 2: Distribution of Task 2: Funds by Employee Category

Funding By Theme

Project-specific research funding (Tasks III and IV) under the new CA totaled ca. $6.64M 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 61%. The smallest portions of funding were in Theme 2: Tropical Weather– 2% and Theme 5: Ecosystem Modeling and Forecasting – 3%.

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

Research Funding by Theme

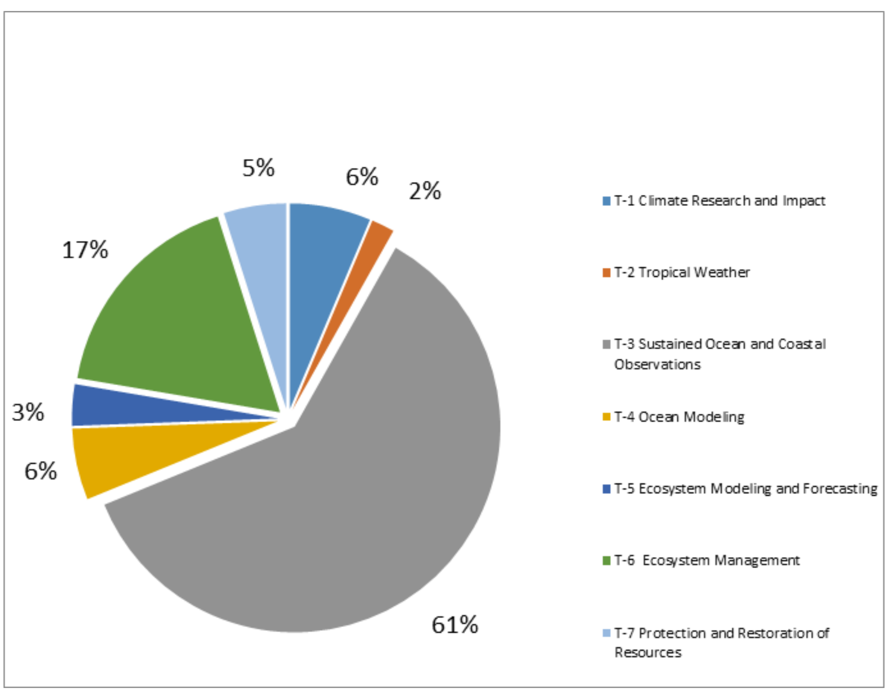


Figure 3: Percentage of Task 3 and Task 4 (Individual Research Project) funding per Theme

Table 3 below tabulates NOAA funding linked to CIMAS under the present Cooperative Agreement (CA). Marked with asterisk we indicate still one ongoing awards under the Disaster Relief Appropriation Act of 2013 related to Hurricane Sandy.

Table 3: NOAA Projects with Individual Award Numbers

NOAA Award #	Principal Investigator	Award Period	Award Amount	Project Title
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 - 06/30/19	$ 139,145	Sub-Seasonal Prediction with CCSM4
NA16OAR4310141	Kirtman, B	07/01/16 - 06/30/19	$ 149,126	Developing a Real-Time Multi-Model Sub-Seasonal Predictive Capability
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
NA17NMF4630010	Lirman, D	01/01/17 - 12/31/18	$ 521,920	Building Coastal Resilience Through Coral Reef Restoration
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
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 - 08/31/18	$ 46,789	Improvement to the Tropical Cyclone Genesis Index (TCGI)
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 - 08/31/18	$ 398,812	Evaluation of Gulf of Mexico oceanographic observation networks, impact assessment on ecosystem management and recommendation
NA15OAR4590203	Nolan, D	09/01/15 - 08/31/18	$ 75,772	Guidance on Observational Understanding Over the Tropical Cyclone Lifecycle
NA13OAR4310131	Lehenaff, M	09/01/13 - 08/31/18	$ 222,723	South Atlantic Meridional Overturning Circulation: Pathways and Modes of Variability
NA14NWS4680028	Zhang, Jun	08/01/14 - 07/31/18	$ 389,332	Addressing Deficiencies in Forecasting Tropical Cyclone Rapid Intensification in HWRF
*** Award under the Disaster Relief Appropriation Act of 2013.**				

Funding distributed through CIMAS to the Partner Universities during the present reporting period was $ 1.32M or 25% of Task III. The funding to the Partner Universities increased by .42M 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	12/20/17 - 09/30/18	FIU	FPHL Model Operation & Maintenance & Model Upgrades
Annane, B	04/14/14 - 12/31/17	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 - 06/30/18	FAU	Integration & Deployment of PCO2/PH Sensors on a ROV
Dunion, J	09/01/17 - 06/30/18	U of Wisconsin	An Observational and Numerical Investigation of Energy Exchange Between a Tropical Cyclone and its Environment at the Outflow Level
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
Enochs, I	08/31/17 - 05/31/18	FDEP	Cheeca Rock Disease Mosaics
Enochs, I	03/26/18 - 06/30/18	FDEP	Ultraviolet Deactivation of Coral Disease Lesions
Goes, M	09/15/15 - 08/31/19	NSF	The Interannual Variability of the Brazil Current
Harford, W	03/20/18 - 03/19/19	TNC	Updated Red Abalone Management Strategy Evaluation
Kirtman, B	09/15/16 - 08/31/19	NSF-Perez	NSF Collaborative Research: Extratropical Triggering of ENSO Events Through the Trade-Wind Charging Mechanism
Lehenaff, M	04/1018 - 04/09/18	NASA	Combining Coastal Altimetry and in Situ Observations to Improve Meridional Overturning Circulation Estimates in the South Atlantic
Lehenaff, M	04/10/18 - 04/09/21	NASA	Combining coastal Altimetry and in Situ Observations to Improve Meridional Overturning Circulation Estimates in the South Atlantic
Lehenaff, M	04/18/14 - 11/30/18	NASA	Variability of the South Atlantic Subtropical Gyre
Leighton, H	03/14/17 - 03/13/20	NASA	Using NASA Observations to Advance the Understanding and Determine the Predictability Limits Regarding Tropical Cyclone Rapid Intensification and Cyclogenesis Processes
Pierrot, D	06/11/18 - 06/10/19	Ocean Foundation	Ocean Foundation Observing Network's (GOA-ON) Pier 2 Pier Program
Volkov, D	08/05/13 - 08/04/18	NASA	The Mediterranean & Black Sea: Analysis of Large Scale Sea level
Volkov, D	07/01/14 - 06/30/19	NASA	Investigating the Processes Contributing to the Salinity Differences Between Aquarius and In Situ Measurements
Zhang, J	07/03/14 - 07/02/19	U of W	Calculating tropical Cyclone Inflow and Boundary Layer Proce
Zhang, J	06/01/17 - 08/21/18	FIU	Improving HWRFS Ability to Predict Raspid Change in the Tropical
Zhang, J	12/01/15 - 07/31/17	FIU-NOAA	Understanding the Impcat of Sub-Grid Scale Physics in HWRF
Zhang, J	04/01/18 - 03/31/20	NSF	Collaborative Research: EAGER: Effects of Eddy Forcing Induced by Eyewall and Rainband Convection on Tropical Cyclone Rapid Intensification
Zhang, J	03/15/15 - 02/28/19	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. Appendix I lists the amendments received during this reporting period (July 1, 2017 through June 30, 2018).

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

Coral Health and Monitoring Program (CHAMP)

Project Personnel: C. Aguilar, N. Amornthammarong, L. Chomiak, E. Dutra, I. Enochs, N. Formel, M. Gidley, L. Gramer, R. van Hooidonk, M. Jankulak, G. Kolodziej and J. Morris (UM/CIMAS)

NOAA Collaborators: J. Hendee, D. Manzello, C. Kelble, C. Sinigalliano and J. Stamates (NOAA/AOML); B. van Dine (NOAA Corps)

Other Collaborators: A. Jones (5Cs); P. Fletcher (SeaGrant); J. Halas (EMI)

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 oceanography and air-sea interaction to improved understanding and conservation of both coral reef and pelagic *Sargassum* 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; apply existing geophysical models to improve understanding of the near-surface ocean transport processes which affect pelagic Sargassum; 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) accomplished several coral-related research efforts by CIMAS personnel along with NOAA collaborators. Last year, CHAMP's Coral Reef Early Warning System (CREWS) continued an international collaboration with the Caribbean Community Climate Change Centre (5Cs) and with local communities in South Florida. Dr. Natchanon Amornthammarong (OCED/CIMAS), Joe Bishop, Dr. Jim Hendee (OCED/NOAA), Dr. Pamela Fletcher (Sea Grant), John Halas (Environmental Moorings Inc.) and Albert Jones (5Cs) have successfully installed 3 CREWS buoys in Antigua, St. Kitts & Nevis and St. Lucia. Outreach and engagement efforts with local managers and stakeholders were led by Dr. Fletcher, including discussion of management applications for buoy data, as well as information on the maintenance aspects of buoys. At AOML, Mike Jankulak (OCED/CIMAS) oversaw the posting of buoy data and maintenance and other meta-data to a special open-access blog, and Lew Gramer (OCED/CIMAS) together with Madison Soden (student intern, OCED/CIMAS) oversaw formulation and implementation of ecological forecasts. Data are available in near real-time through the CHAMP Portal data query website (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 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.

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

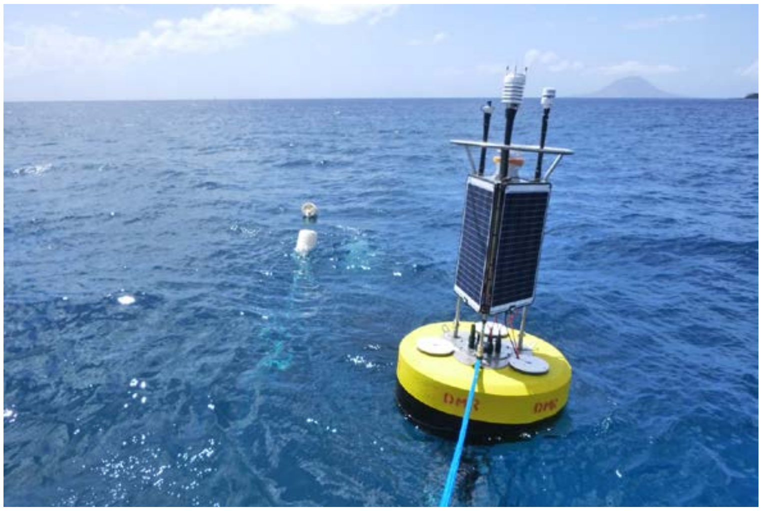


Figure 1: A new CREWS station was deployed at St. Kitts & Nevis.

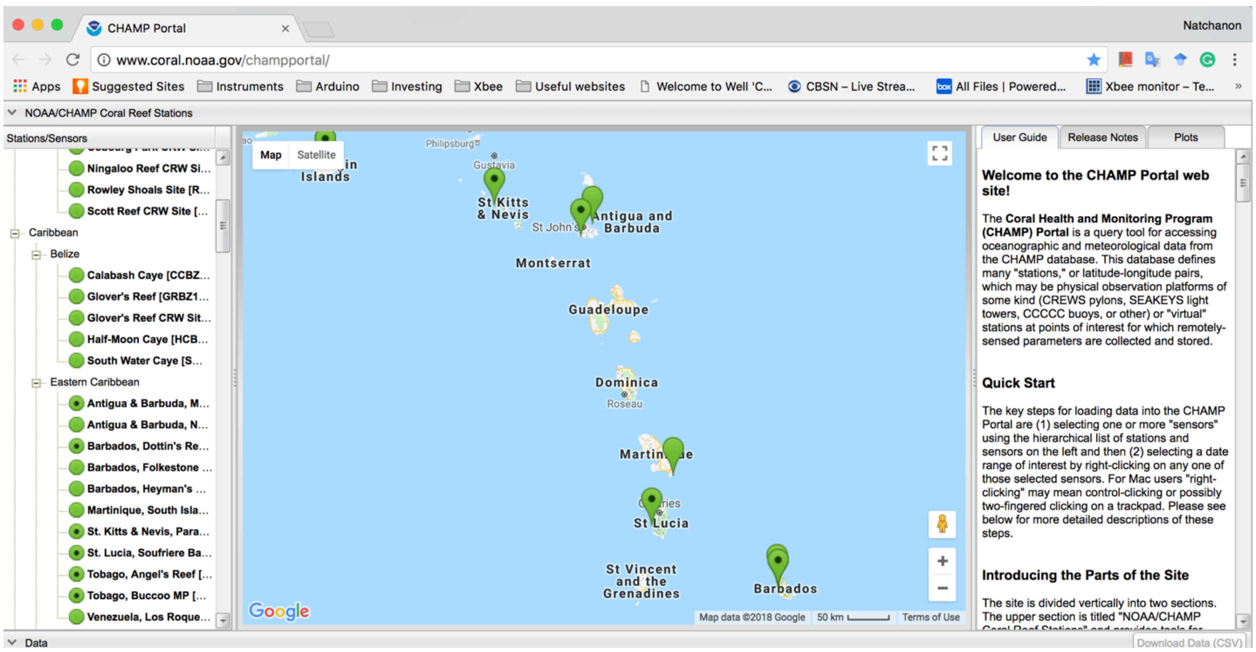


Figure 2: Near real-time data are available on the CHAMP Portal website (http://www.coral.noaa.gov/champportal).

This year, ACCRETE/CIMAS personnel, Ian Enochs, Mike Jankulak, Elizabeth Dutra, Graham Kolodziej, Nathan Formel, John Morris, and Leah Chomiak 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. Thomas and St. John, as well as 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 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, Liz Dutra, Leah Chomiak, 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. Formel, Morris, and Enochs assessed the benthic composition and water chemistry of a previously undescribed CO_2 vent in Mayreau, Grenadines. Additional collaborations included work in the Panama, where upwelling in the southern gulf locally raises pCO_2 and impacts reef permanence. In the Florida Keys and across the Florida Reef Tract, ACCRETE continued ongoing work with NOAA investigators, as well as CIMAS scientists Kelly Montenero and Charline Quenee, to analyze carbonate chemistry from water samples taken on the RSMAS ship, the RV Walton Smith.

In the CIMAS Experimental Reef Lab (ERL), experiments were run to examine the impacts of carbonate chemistry variability on the growth of *Acropora cervicornis*. Several genotypes of the threatened coral species were grown in variable and static pH treatments, with mean values representing present-day and future ocean acidification scenarios. Diel pH variability was found to enhance coral calcification in present day conditions. Another ERL study was conducted to better understand the molecular mechanisms of the coral *Orbicella faveolata*'s resilience to environmental change. For this, *O. faveolata* fragments were exposed to different temperature conditions (30-33ºC). The photosynthetic yield of these fragments was measured every week and showed that fragments from inshore colonies had higher yield than the offshore colonies during the high temperature treatment, which correlates with field observations (Figure 3). Samples for transcriptomics analysis were taken after 1 and 4 weeks of exposure and sent for RNA sequencing at the Duke Center of Genomic and Computational Biology. The transcriptomic analysis shows that some of the gene modules have differential responses to high temperature treatments, when compared across inshore and offshore genotypes.

Figure 3: Fragments of *Orbicella faveolata* experimentally subjected to high temperature in the Experimental Reef Lab (ERL). Rows reflect different genotypes and differences in the paling response highlight genetic resilience to thermal stress.

Formel and Enochs designed and created Subsurface Automatic Samplers (SAS) that are automated devices for collecting seawater when environmental conditions, timing, or funding otherwise restrict fieldwork (Figure 4). The low cost instruments are completely open source and can be produced using widely available 3D printing technologies. Each SAS unit is field programmable, with an IR remote and OLED display. They have low power consumption and are deployable for months at depths up to 150 feet.

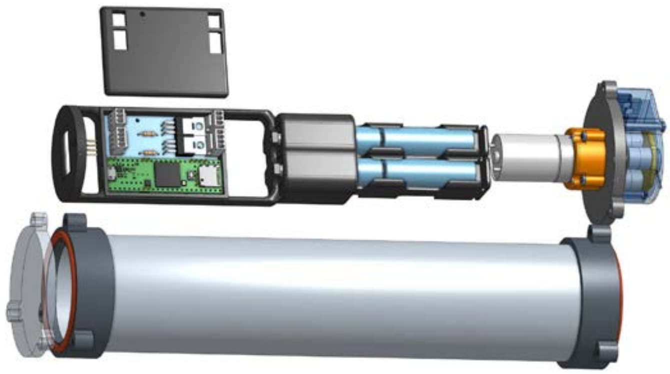


Figure 4: CAD model of the Subsurface Automatic Samplers designed and built by Formel and Enochs.

Ocean Acidification Product Suite

Dr. van Hooidonk updated 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. Several significant improvements have been made to the existing OAPS. Specific algorithms describing TA-SSS/SST relationships have been introduced for the Mississippi out flow region and Galveston area. A newer version of SST data was used that eliminated many of the artifacts seen in the previous iteration. All the data for 2014-2017 has been reprocessed.

A similar effort has been completed to monitor OA on the USA East coast, for five regions specific algorithms were implemented to derive surface partial pressure CO2 based on Chlorophyll-a, SST and SSS. Total alkalinity was estimated using different TA-SST-SSS relationships based on SSS.

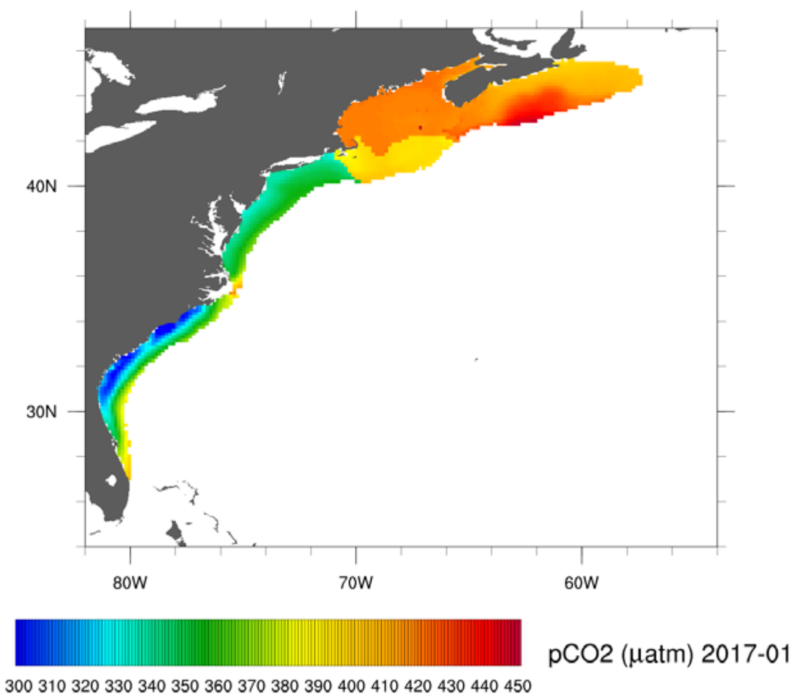


Figure 5: The computed surface partial pressure of CO2 (µatm) near the US East coast in January 2017.

Climate and resilience-based decision-support tools to maximize coral transplant survivorship and reef recovery in Florida.

Out-planting is the very last part of the significant investment in growing corals in nurseries. This last step carries a low cost relative to nursery maintenance but is the most important step for achieving nursery goals. The overarching goal of the Florida nurseries is to maximize the survivorship of out-planted corals. Only corals that survive can aid impacted reefs to recover, and can contribute to the replenishment and ongoing persistence of *A. cervicornis* in Florida reef habitats.

Dr. van Hooidonk has collaboratively (with nursery operators and managers) developed a new scheme for identifying and ranking candidate out-planting sites based on compilation of spatially explicit data on at least these variables: depth, substrate type, proximity to seagrass beds, ecological resilience potential, and projections of ocean acidification and coral bleaching conditions.

Dr. Lew Gramer wrapped up two collaborative projects and moved three others toward publication during this CIMAS fiscal year. The project to study upwelling on the Southeast Florida shelf saw its final data set and NOAA technical memo put out during this FY, as did the project to combine remote sensing of turbidity in South Florida with modeled waves. A peer reviewed publication on the upwelling study is now in preparation with partners from Nova Southeastern University and the Florida Department of Environmental Protection. Gramer also submitted a manuscript for publication on ecological forecasting of pelagic *Sargassum* in the Caribbean with partners from private industry, the NOAA AOML Physical Oceanography Division, and University of South Florida. He presented preliminary results at two international scientific symposia on two other ongoing interdisciplinary projects: modeling coral connectivity in the Florida reef tract (Gramer and Putman), and quantifying the effect of oceanographic habitat characteristics on coral microbiome diversity and make-up (Rosales, Gramer, et al., Figure 6). Finally, his research on mapping fine scale sea temperature and wave-action variability to predict success of coral outplants continues, with two proposals for additional funding submitted during the fiscal year and a manuscript in preparation (see Figure 7).

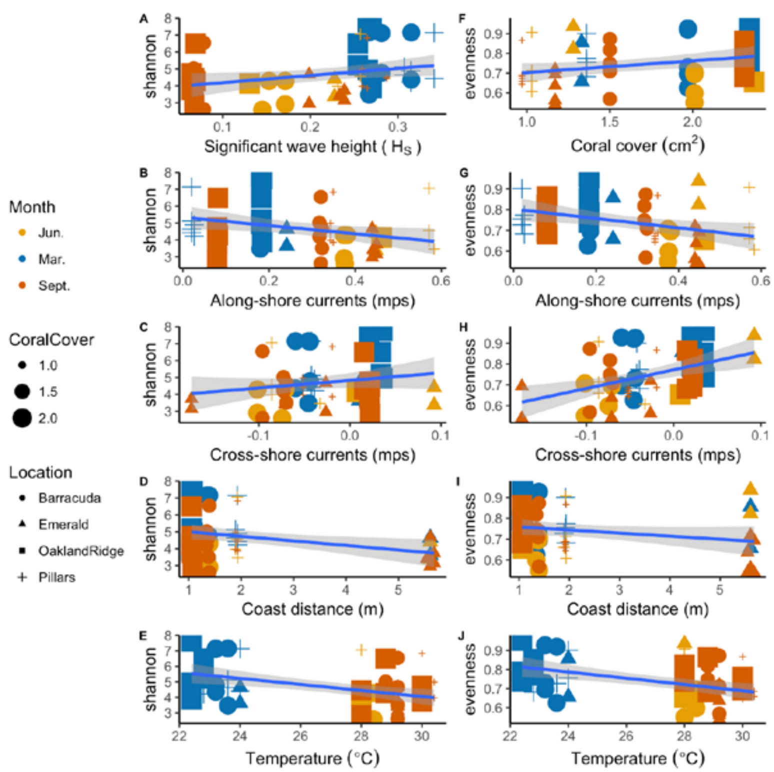


Figure 6: Statistical relationships between two measures of coral microbiome diversity (evenness and Shannon index) and oceanographic habitat variables: modeled significant wave height, modeled along-shore and cross-shore current velocity (Gulf of Mexico HYCOM), distance from coast (NGDC 30 m-resolution bathymetry), diver-measured near-bottom sea temperature, diver-estimated coral cover. Data are from the CGON study of four reefs on the southeast Florida shelf (region of the South East Florida Coral Reef Initiative), by Rosales, Gramer, Sinigalliano, Gidley, Jones, van Dine.

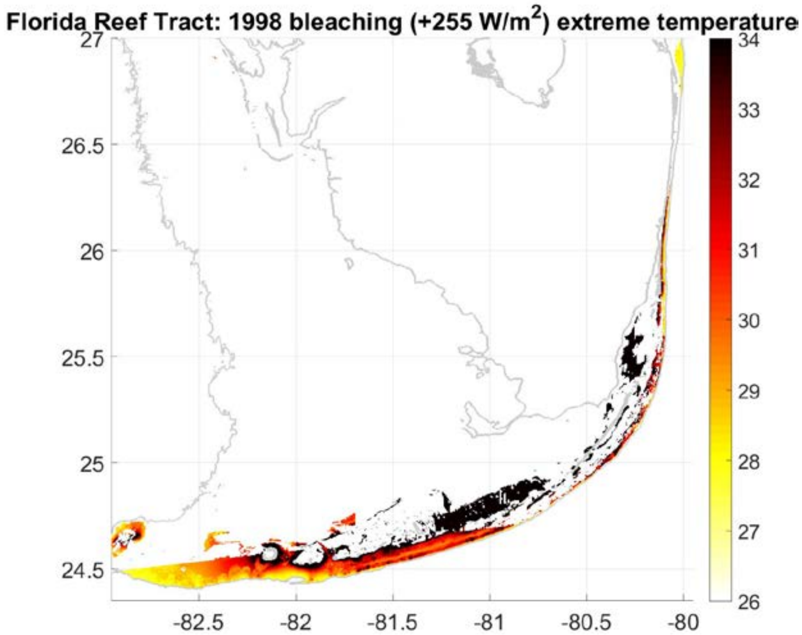


Figure 7: Map of southern Florida coastline and ocean shelf, showing high-resolution modeling of sea temperature in response to ocean warming during a major coral bleaching year (1998). Maps like this that take into account the true patchiness of wave breaking, horizontal convection, and turbidity may be critical for guiding current and planned efforts at coral reef restoration.

Dr. Amornthammarong has built more than 250 underwater temperature data loggers that has an accuracy of +/-0.05 C, can remain submerged for over four months without a change of its AA batteries, and costs less than $15 in parts. This low-cost temperature 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 and AOML scientist Jack Stamates, 30 temperature sensors were deployed on southeast Florida shelf on August 14th and retrieved on November 22nd, to observe gradients in sea temperature across and along shore and high-frequency variability, including possible summer upwelling. These data were analyzed by NOAA-CREST Fellow Andrea Gomez 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.

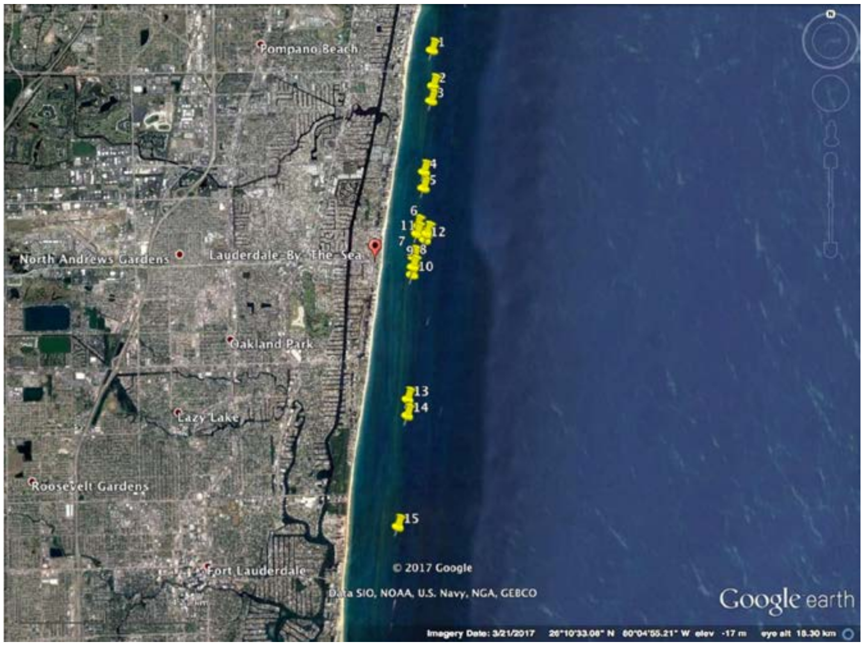
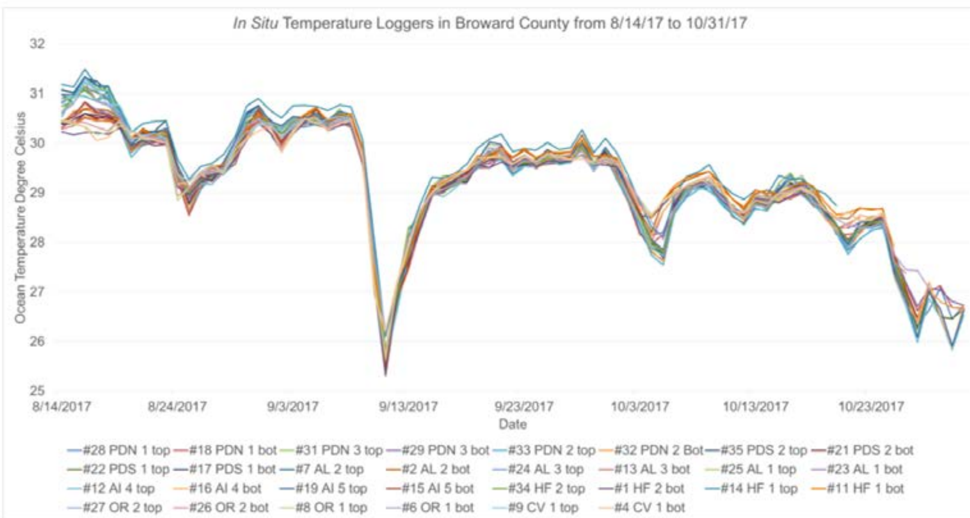


Figure 8: Map showing the 15 *in-situ* temperature logger deployment sites in Broward County.

The *in-situ* data of the deployment was compiled into daily, night-time only measurement to match up with the satellite daily, night-time only measurements as shown in Figure 9. The data clearly shows a significant decrease of temperature when hurricane Irma hit Miami on 9/13/17.



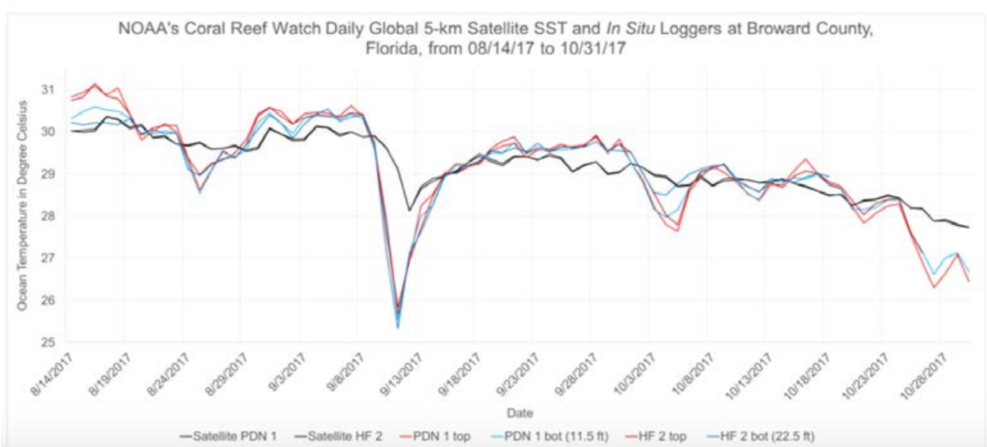


Figure 9: Data of the deployed temperature loggers are compared with NOAA's Coral Reef Watch Daily Global 5-km Satellite SST at Broward County, Florida from 08/14/17 to 10/31/17.

Research Performance Measure: The CHAMP project addressed and met the defined objectives during 2017-2018 through a suite of research components that included ongoing data gathering as well as maintenance, data processing and data delivery of new and existing CREWS stations throughout the Caribbean and Pacific, and a variety of peer-reviewed publications, technical memoranda, and accessioned data sets.

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Western Boundary Time Series Project

Project Personnel: Z. Barton, G. Berberian, S. Dolk, R. Domingues, R. Garcia, S. Garzoli, J. Hooper, G. Rawson, R. Roddy, T. Sevilla, D. Ugaz and D. Volkov (UM/CIMAS)

NOAA Collaborators: M. Baringer, Y-H. Daneshzadeh, S. Dong, C. Meinen, P. Peña, 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).

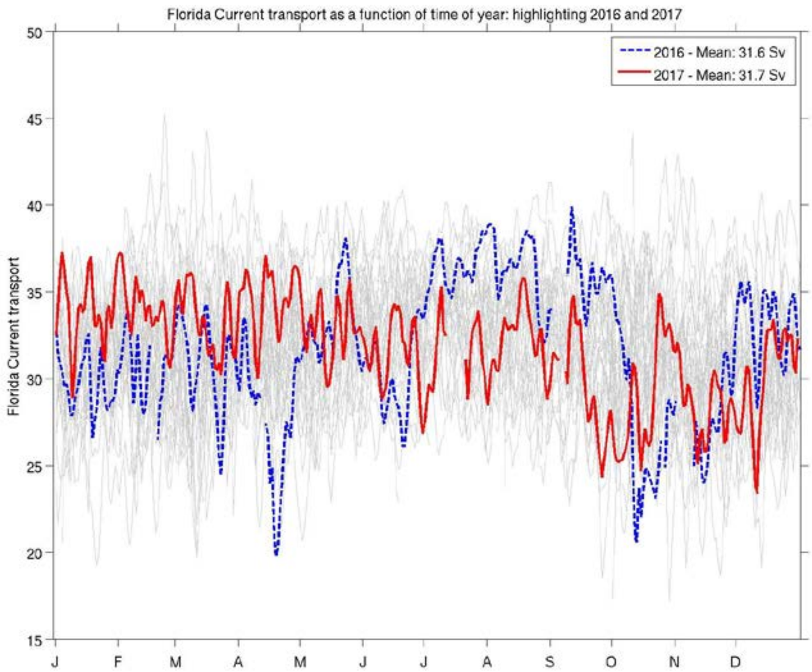

Figure 1: Volume transport of the Florida Current at 27ºN. The two most recent years are highlighted in color.

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 Florida Current observations are sustained 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.

Research Performance Measure: Most research goals were met during the 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. During this period one research cruise was conducted (February 2018) to collect hydrographic (CTD) data and to maintain the array of pressure-equipped inverted echo sounder (PIES) moorings. The data collected during these cruises was processed and quality-controlled after the cruise.

Analysis of kinetic energy and structure functions from along-track and crossover altimeter data

Project Personnel: D. Chambers, B. Galperin and X. Liang (USF)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** 1) To examine low-frequency changes in kinetic energy derived from surface geostrophic currents computed from satellite altimeter data. 2) To quantify climate-related drivers of the observed changes. 3) To perform a novel analysis employing structure functions, which are averaged velocity differences between points along a separation trajectory. From the structure functions, one can estimate spectral energy transfer, ε, and determine whether the geostrophic flow harbors a direct (ε>0, energy flows from large to small scales) or inverse (ε<0, energy flows upscale, from small to large scales) energy cascade.

***Strategy*:** The more than 24-year record from TOPEX/POSEIDON, Jason-1, Jason-2, and Jason-3 along-track, 1 Hz data will be primarily used, to determine velocities perpendicular to the groundtrack and both zonal and meridional currents at crossover points. Gridded altimetry products will also be examined and compared to the along-track data. A high-resolution state estimate will also be sampled in order to quantify if the altimeter sampling is sufficient to quantify the full variability of kinetic energy.

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: NESDIS
NOAA Technical Contact: Eric Leuliette

Research Summary:

In the first year of this project, we created databases for new altimetry products (Jason-3 data, TOPEX/Poseidon, Jason-1, and Jason-2 Tandem Missions) and computed geostrophic velocities from the along-track data. These are currently being used to compute structure functions.

We used the computed velocities to study kinetic energy in the Antarctic Circumpolar Current (ACC). We demonstrated that kinetic energy (KE) forms an envelope of enhanced power around fronts in the Southern Ocean (Figure 1). By determining the half-power point of these envelopes over successive three-year periods, we tested whether the hypothesis that fronts in the Southern Ocean have moved south throughout the Southern Ocean is valid. This has been assumed true by many recent papers, based on a single study looking at shifts in isolines of dynamic topography and the results of some large-scale climate models. However, isolines will also shift south as sea level rises. We demonstrated that the envelopes of KE did not have any significant southward shift (Figure 2), but instead had large interannual variability. This result does not support a southward movement of ACC fronts. The results were published in the journal *Ocean Science*.

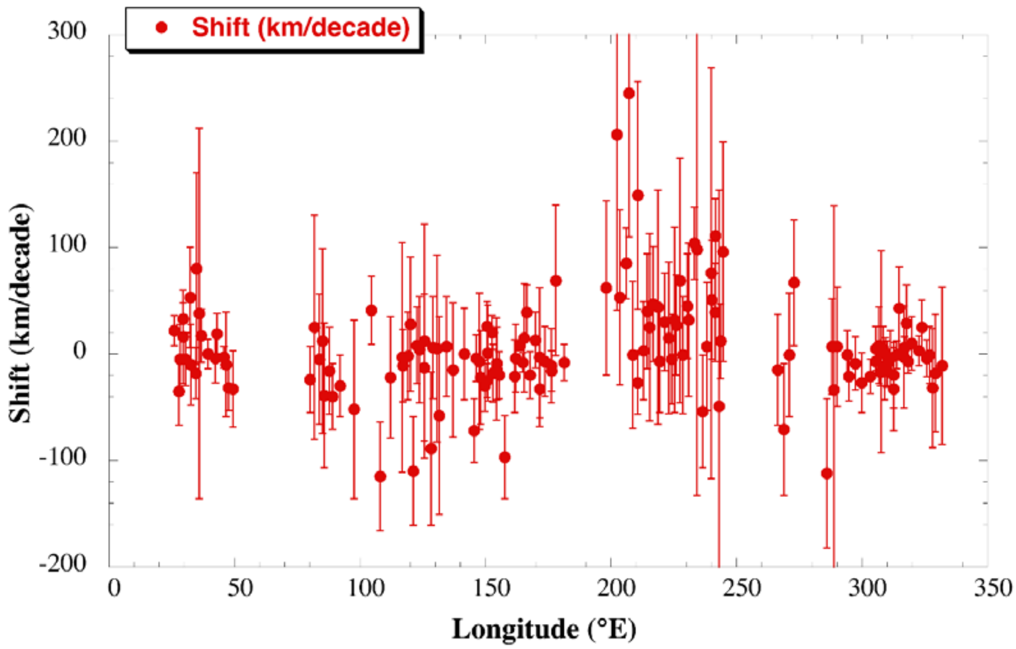

Figure 1: An example profile of mean cross-track kinetic energy (CKE) averaged between 1993-2016 along a ground track in the southern Indian Ocean, demonstrating the location of the half-power point and the locations of the southern and northern boundaries of the enhanced CKE envelope.

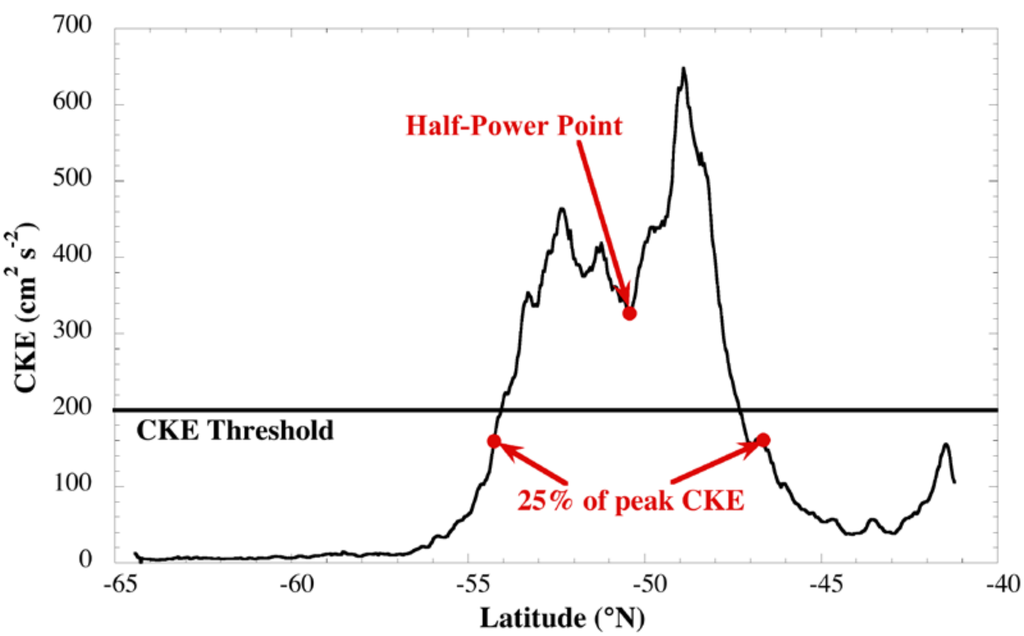

Figure 2. Estimated trend in the half-power point of CKE as a function of longitude. Error bars represent the 90% confidence interval.

Research Performance Measure: We accomplished the majority of the Year 1 goals. The only item we did not accomplish is computation of structure functions, but we are in the process of doing that.

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Global Drifter Program

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

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*: :** To maintain a global 5x5 degree array of 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.

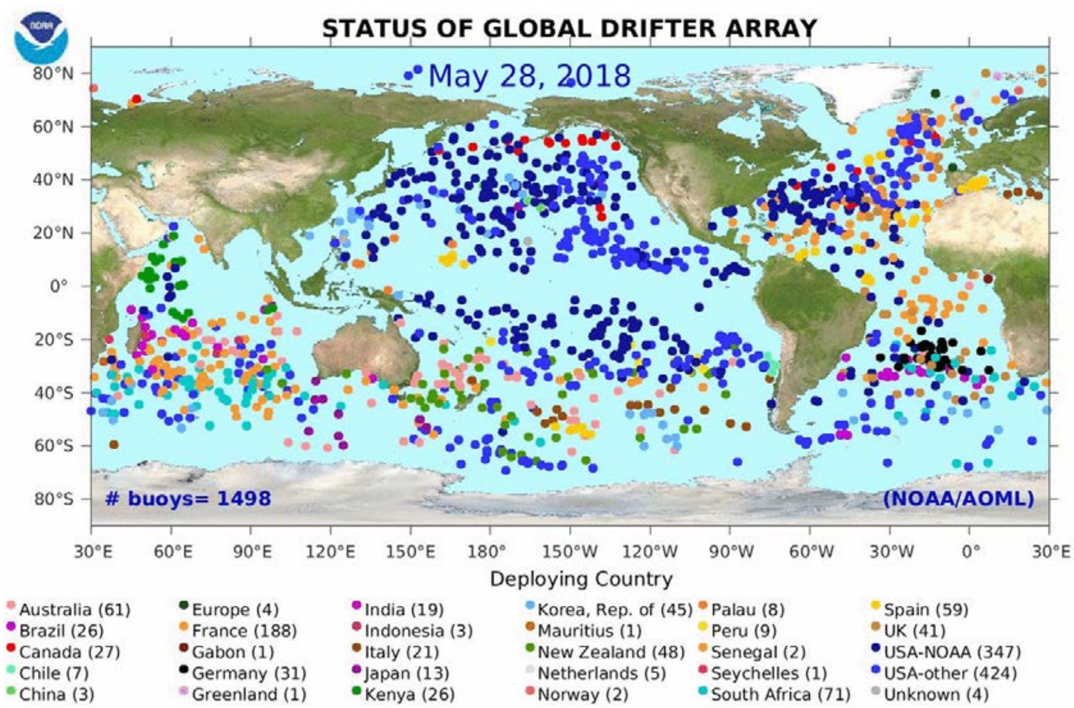

Figure 1: Status of the Global Drifter Array (updated weekly)

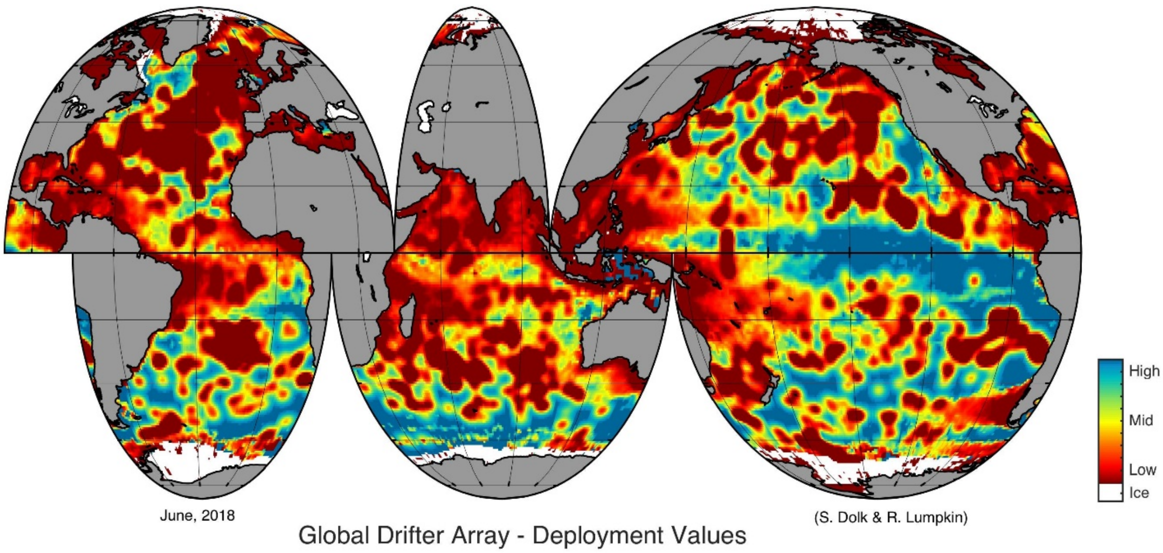

Figure 2: Deployment Value Map(s) (updated monthly)

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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Southwest Atlantic Meridional Overturning Circulation ("SAM") Project

Project Personnel: R. Garcia and S. Garzoli (UM/CIMAS)
NOAA Collaborators: S. Dong, C. Meinen, P. Peña, R. Perez, U. Rivero and R. Smith (NOAA/AOML)
Other Collaborators: I. Ansorge and T. Lamont (University of Cape Town, South Africa); E. Campos and O. Sato (University of Sao Paulo, Brazil); M. 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, sea level, and hurricane intensification in the Atlantic. These changes have strong societal impacts both in the region and around the globe. Observations and modeling studies have also indicated that water mass transformations occurring in the South Atlantic alter the waters circulating in the global MOC resulting in changes to the global circulation system. NOAA has maintained a crucial long-term array measuring the western boundary components of the MOC in the South Atlantic near 34.5°S since 2009 via the 'Southwest Atlantic MOC', or 'SAM', project. The SAM project represents a collaborative effort with partners in Argentina, Brazil, France, and South Africa to monitor the MOC-related flows in the South Atlantic and to improve our understanding of the key processes that cause this variability. The NOAA component of this international effort is focused on the western boundary currents, specifically the Brazil Current in the upper layer and the Deep Western Boundary Current (DWBC) at depth. Study of the DWBC is of particular interest because it is believed to carry a significant percentage of the lower limb of the MOC, and prior to the SAM project, observations were insufficient to constrain its mean and variability in this region. Long-term observations of these key flows will be required to understand the mechanisms leading to changes in the MOC system in the South Atlantic, and the impact of those MOC changes on the global climate. The goal of the NOAA SAM program, and the international collaborating programs, is to measure the MOC in the South Atlantic with a trans-basin array from South America to South Africa along 34.5°S (Figure 1). With eight moorings on the western side of the basin (in May 2018) and ten moorings on the eastern side of the basin (in July 2017), this trans-basin array ("SAMBA") has achieved a new milestone of collecting multi-year daily trans-basin MOC measurements. Note that the number of total moorings deployed has varied from year to year 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: During this year, two research cruises were conducted (October 2017 and April-May 2018) to collect data and/or to maintain the array of pressure-equipped inverted echo sounder (PIES) moorings. The data collected during these cruises was processed and quality-controlled after each cruise. Project PIs led and/or participated in a peer-reviewed paper on the MOC variability at 34.5°S that was published this year (Meinen et al. 2018). 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 collaborating on an analysis of the eastern boundary currents observed by French CPIES and South African tall moorings together with international PIs and a CIMAS postdoctoral fellow (Kersalé). 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 IAPSO-IAMAS-IAGA
Joint Assembly in Cape Town, South Africa in August-September, 2017, at the SAMOC VII workshop in Cape Town, South Africa in September 2017, and during a special South Atlantic MOC session at the Ocean Sciences meeting in Portland, OR in February 2018.

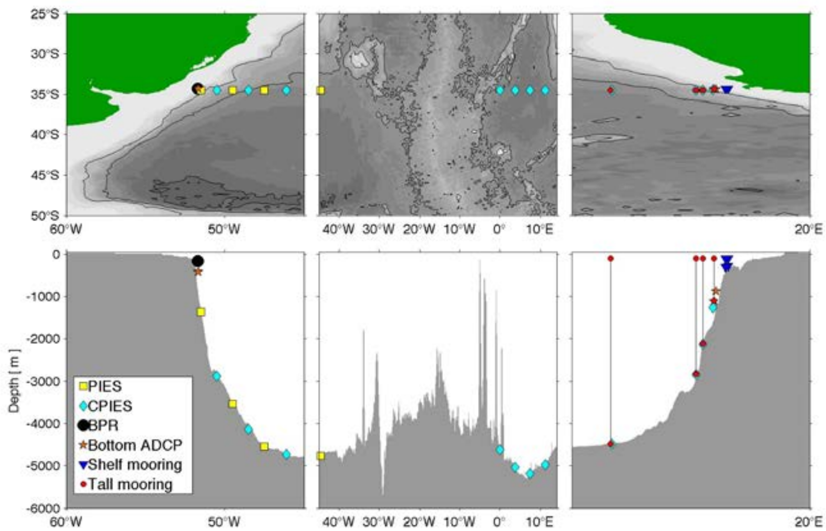

Figure 1: Map indicating the location (top panel) and the vertical distribution (bottom panel) of the four NOAA PIES making up the SAM array at 34.5°S; also shown are the Brazilian CPIES deployed in December 2012, the Brazilian coastal moorings deployed in December 2013, the French CPIES deployed in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

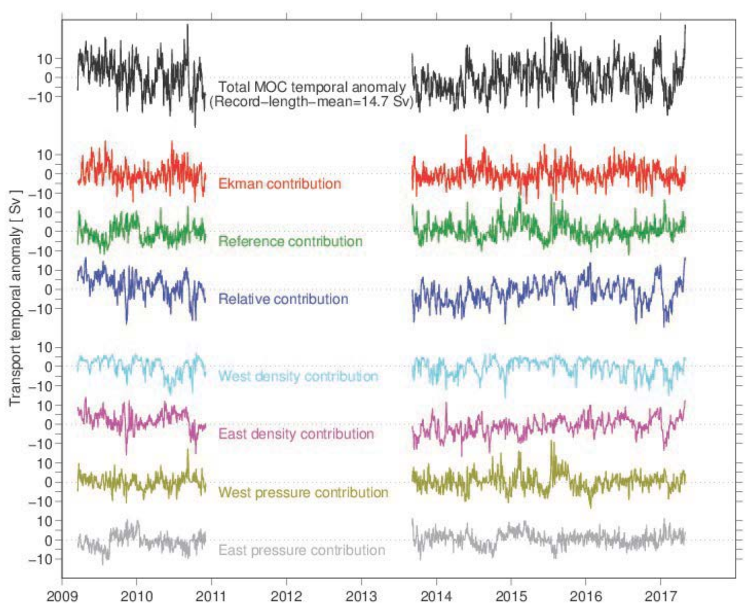

Figure 2: Time series (temporal anomaly relative to the record-length mean) of the basin-wide MOC volume transport across 34.5°S. The total (net) transport anomaly is shown in black. The record-length mean total MOC value that has been removed to create the anomaly is noted on the figure. Also shown are the contributions of Ekman, geostrophic reference flow, and geostrophic relative flow components; the geostrophic relative and reference flow components are further broken down into the contributions from variations in the western and eastern density or pressure contributions, respectively. For all components, the “contribution” is estimated as the difference between the total MOC (black line) and the MOC calculated while holding the term in question constant (i.e., the reference contribution is the difference between the total MOC and the MOC that was calculated holding the bottom pressure values on both sides of the basin constant). From Meinen et al. (2018).

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 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 Atlantic Meridional Overturning Circulation (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, large freshwater input 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 considering uncertainties due to wind stress forcing and the magnitude of both atmospheric dust loading and freshwater hosing. For this we developed a parameterization to simulate the dust radiative effects in an intermediate complexity model (Figure 1). 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. 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 (Figure 2). We conclude that dust-climate feedbacks may provide an amplification to Heinrich cooling by further weakening AMOC and increasing North Atlantic sea ice coverage.

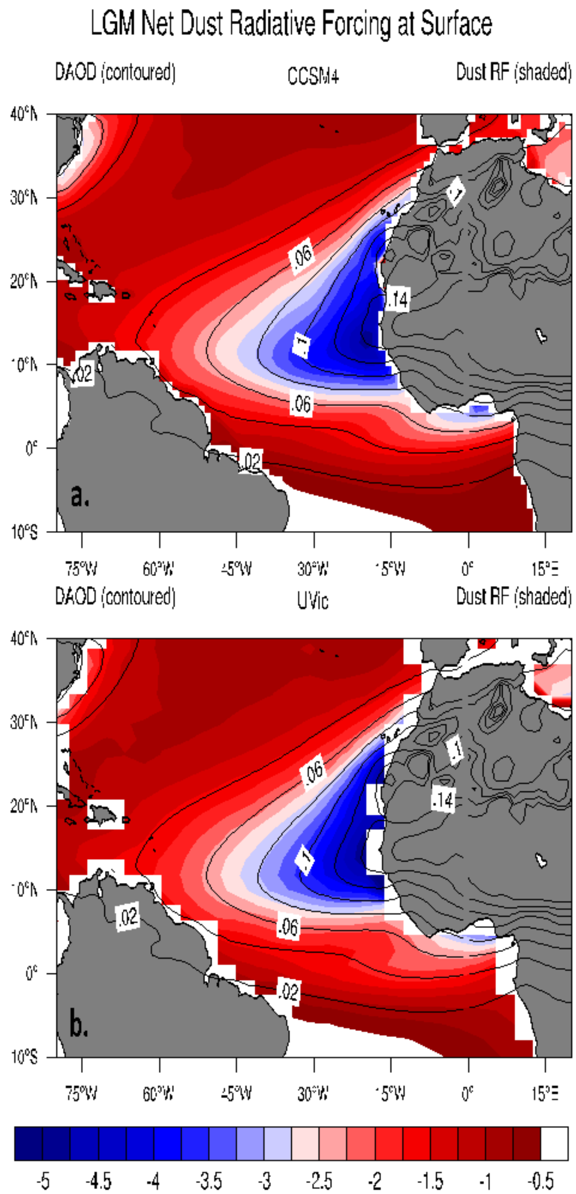

Figure 1: The annual mean net dust radiative effect (W m^{-2}) at the surface due to LGM dust loading in CCSM4 (a) and parameterized in UVic (b) (shaded). The total CCSM4 LGM dust aerosol optical depth (DAOD) (contoured) in overlaid on each panel.

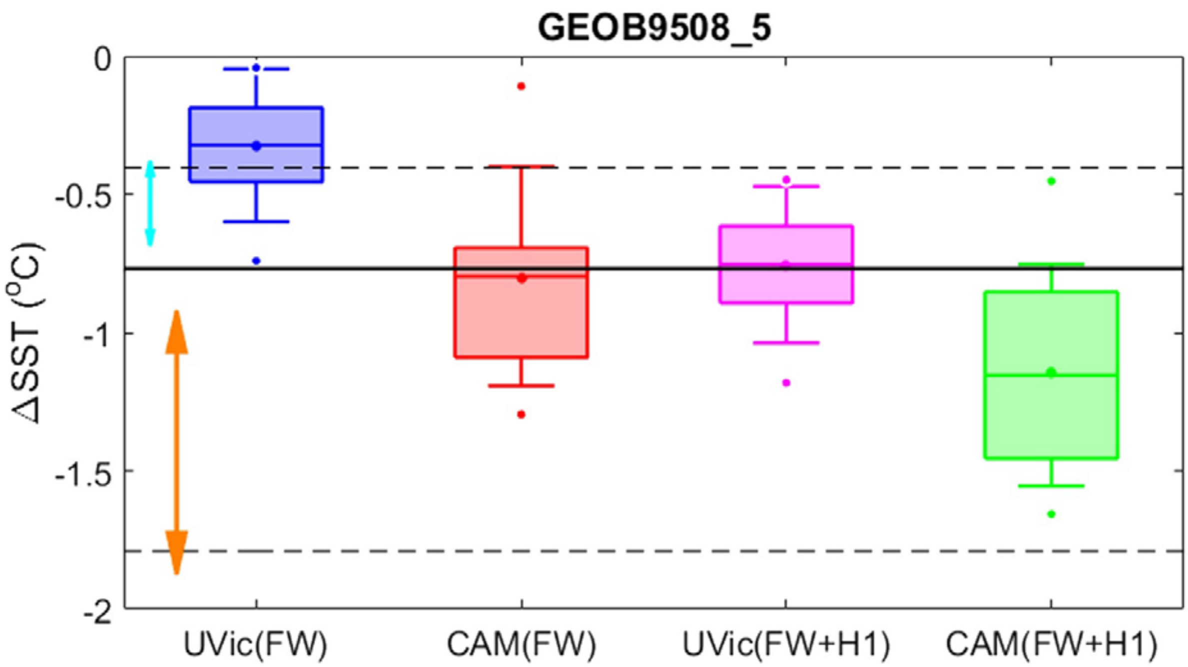

Figure 2: The black lines show the median HS1-LGM temperature anomaly (solid) and confidence interval (dashed; CI = 1st and 99th percentiles) at the GeoB9508-5 core. The temperature anomaly is calculated using the temperature over the HS1 interval (18–15 ka) minus the temperature over the LGM interval (21ka±2ka). The arrows (dots) show the CI (median) of the individual alkenone (orange) and Mg/Ca (light blue) proxies. The box and whisker plots are the probability density functions (PDFs) based on the range of values of temperature difference between our FW experiments with and without H1 dust and the control LGM experiment. The boxes show the 25th to 75th percentiles with the median at the center; the whiskers give the 5th and 95th percentiles, and the dots give the 1st and 99th percentiles based on the derived PDFs.

Research Performance Measure: All research goals were met during this year with respect to the investigation of the AMOC and 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) Revised and published the paper : The Role of African dust in the weakening of AMOC during Heinrich events.
2) New ensemble of simulations with the UVic are under development to understand the effect of wind and vertical ocean mixing on the stability of the AMOC and North Atlantic sea surface temperature. These results will be presented at the joint USAMOC/RAPID meeting in Miami (July 2018).
3) Initial spinup and control simulations with the robust diagnostic feature have been produced, and analysis of their outputs are underway.

Interannual-to Decadal Variability of the South Atlantic MOC

Project Personnel: A. Gronholz and H. Lopez (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 Ocean Heat Content (SAOHC) variability and to explore the impact of mesoscale eddies on SAOHC variability on interannual to decadal time scales.
Strategy: To use a combination of high- and low-resolution coupled CESM model simulations and ocean model experiments to study the variability of SAOHC and the effect of an eddy-permitting resolution and to define larger-scale driving mechanisms, e.g. the role of Southern Hemisphere westerlies or the Indian ocean windstress curl on SAOHC variability.

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: Molly Baringer

Research Summary:
Recent studies suggest that changes in the South Atlantic ocean heat content induced by variations in the South Atlantic Meridional Heat Transport (MHT) could play an important role in global monsoons and extreme weather events.

The conventional view is that the Atlantic Meridional Overturning Circulation and the associated Atlantic 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. In this project, we aim to quantify the impact of the northern versus southern origin of the South Atlantic Ocean Heat Content (SAOHC) variability. We analyze and compare results from low- and high-resolution fully-coupled climate model simulations to better understand the main driver of the SAOHC variability. We show that in both low- and high resolution simulations ocean heat advection processes dominate and lead SAOHC variability while surface fluxes play a minor role and respond to SAOHC changes. However, there is a marked difference between the two simulations in term of where the ocean heat advection anomalies originate from. In the non-eddy-resolving (i.e., low-resolution) case, heat advection from the northern boundary at 8S largely determines the SAOHC variability. In the eddy-resolving (i.e., high-resolution) case, on the other other hand, the SAOHC variability is largely dominated by ocean heat advection from the southern boundary. Further analysis shows that South Atlantic MHT variability and thus SAOHC variability is dominated by both Ekman as well as geostrophic heat transport in the low-resolution simulation while Ekman heat transport plays a minor role in the high-resolution simulation, suggesting a larger role played by geostrophic components.

To further understand the different driving mechanisms and underlying dynamics we currently investigate the impact of Southern Hemisphere westerlies, Indian ocean windstress curl, El Nino, the Southern

Annular Mode and others on the MHT as well as on SAOHC variability in the eddy-resolving and the non-eddy-resolving simulation.

An additional approach to understand the relationship between Southern Hemisphere westerlies and the SAOHC as well as South Atlantic Meridional Overturning Circulation is the application of model simulations for several wind stress scenarios. To achieve this goal we are currently configuring the Modular Ocean Model (MOM) version 6, developed at GFDL. We plan to conduct several sensitivity simulations using different modifications of Southern Hemisphere westerlies to investigate their roles in the MHT and SAOHC variability.

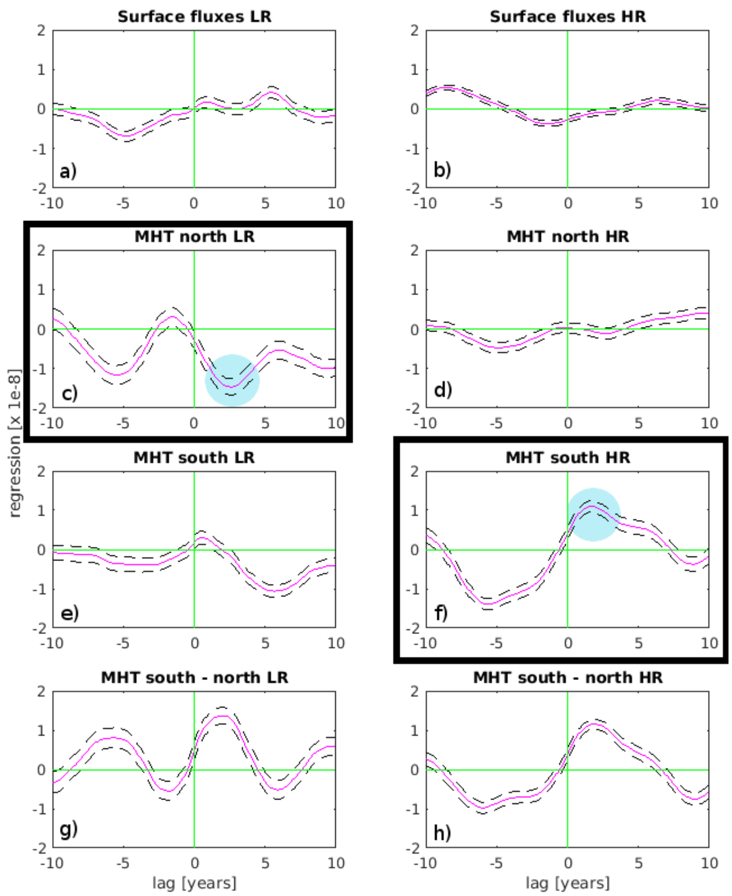

Figure 1: Regression coefficients of (a) Q_net, (c) MHT_North, (e) MHT_South, and (g) oceanic heat convergence to SAOHC from low-resolution simulations. (b), (d), (f), and (h) are similar to (a), (c), (e), and (g), respectively, but from high-resolution simulation. Positive lags indicate that the corresponding process (Q_net, MHT, etc) leads the SAOHC.

Research Performance Measure: The manuscript for the first part of the project focusing on CESM data analysis is currently under internal review and will be submitted soon.

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

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.

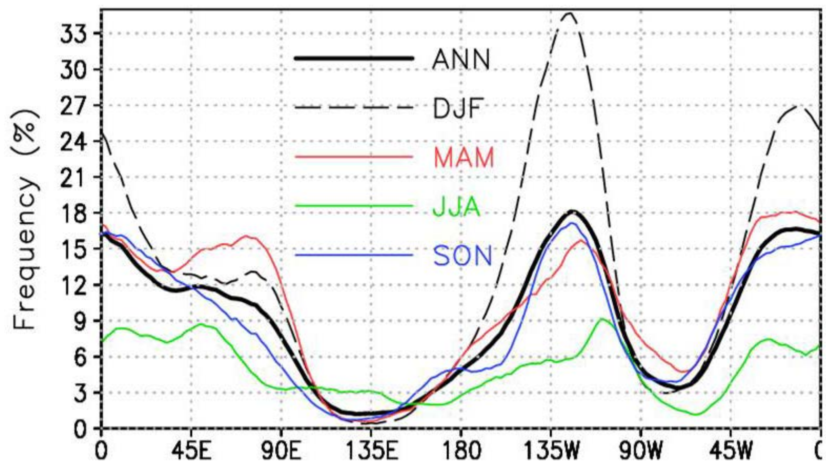

Figure 1: Annual frequency distribution for the impact grid points of the tracked PMZ events be-tween 1979-2015 for annual (solid black), seasonal DJF (black dashed), MAM (red), JJA (green), and SON (blue) averaged between 40°, 50°, and 60°N.

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The North American Multi-Model Ensemble (NMME) Operational Phase

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

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

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 (Primary)*

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

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
- 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 Atlantic

Accurate seasonal forecasts of wind and waves in the North Atlantic will provide benefits to coastal land management, marine vessel routing, renewable energy and oil and gas activities. The variability of the winter North Atlantic wind-wave climate is dominated by a small number of modes. Previous studies have shown the North Atlantic Oscillation (NAO) to have the dominant effect on wind-wave variability, and to a lesser degree the East Atlantic Pattern. The NAO is the term given to the variability of the latitude of the North Atlantic mid-latitude storm-track, which is most prominent in winter. It is traditionally measured using mean sea-level pressure (mslp) fluctuations between Iceland and the Azores. During the NAO positive (negative) phase the storm-track takes more of a northerly (southerly) track.

Despite seasonal forecasts often struggling in the extra-tropics due to a low signal-to-noise ratio, recent studies have found the NAO to be predictable on seasonal time-scales. This is in part due to the drivers of seasonal NAO variability being predictable on seasonal time-scales. For example, tropical Pacific SSTs are often at the crux of a skillful seasonal forecast and its impact on the NAO is captured in the GloSea5 model which has good skill at forecasting the NAO. Atlantic SST has also shown to be predictable on seasonal time-scales, such as in the north Atlantic sub-polar gyre. While it is important to understand and predict the physical mechanisms forcing the NAO, the role of ensembles and multi-model forecasts increase the skill of forecasting the NAO. It has been shown that increasing the number of ensembles increases the correlation of the ensemble-mean forecast with the observed NAO. This skill limit is determined by the quotient of how well the ensemble members correlate with the observations over the correlation between pairs of ensembles members.

Multi-model forecasts have shown their benefit over a single model forecast in recent years (Kirtman et al. 2014), especially in their superiority of probabilistic verification metrics. The skill increase in multi-model forecasts comes from error cancellation of model biases. In this study we make use of a Grand Multi-Model Ensemble (GMME) to investigate the skill of seasonal forecast of wind and waves in the North Atlantic. The GMME is a comprehensive multi-model study using models in the North American Multi-Model ensemble (NMME) and models in EUROSIP. While, previous studies have focused on seasonal forecasting of surface winds, to our knowledge, this is the first study looking at seasonal ocean wave forecasts using a multi-model ensemble. These results are reported in Bell and Kirtman (2018b) and are briefly summarized below.

The 10-m winds from the seasonal forecast models are used to force Wave Watch III experiments. The 4.18 version is used with wind input and dissipation source terms. The experiments are integrated over a large Atlantic domain (100W-30E, 70S-80N) to ensure swell waves are captured. ETOPO1 is used for the bathymetry and islands smaller than 1 degree are included at obstruction points. In this study the wave variables of significant wave height (Hs) and mean wave period (T01).

The spatial pattern of variability of winter Hs and T01 in the North Atlantic is largely explained by the first Empirical Orthogonal Function (EOF1). EOF1 accounts for 44% of the variance of Hs and 55% of the variance of T01. The spatial pattern of EOF1 for Hs and T01 resembles that of the NAO: a dipole in the north-east North Atlantic (not shown). It is therefore likely that the forecast skill of the models NAO has a large impact on the forecast skill of the waves. Figure 1 shows how well each model and the GMME are able to forecast the NAO. In this case the NAO is defined as the first Principal component (PC1) of North Atlantic ocean-only mslp in the spatial domain 100W-30E, 0N- 80N using the years 1993-2010. The black line in all the panels show the observed PC1. The red line in Fig. 1a-g are ensemble-mean forecast PC1 for the individual models using December initial conditions. Supplementary information about the models PC1 is given in the text in the top-left corner of the panel. Figure 1h is the GMME PC1 forecast. The correlation coefficient, p-value of the correlation coefficient and mean absolute error is given in the top-right corner for all panels. The absolute error for each year is given below the panel. The NAO is well predicted in CFSv2 and GloSea5, with correlation coefficient values of 0.74 and 0.64, respectively. CCSM4 is shown to predict the NAO well with a correlation coefficient value of 0.64, however, wave forecast skill in CCSM4 is limited to the north-east North Atlantic, where the NAO is most dominant. The GMME forecast has a correlation coefficient of 0.69 and is only behind CFSv2.

Figure. 2a presents the observed correlation coefficient of mslp PC1 (the black line in Fig. 1) with SST. Significant points at the 99-percentile value are shown as stippling. There is a strong dipole in the North Atlantic which has a large influence on the NAO. There are however dipoles outside of the North Atlantic which are correlated with the NAO. For example, the region in the sub-tropical North Pacific and the South Atlantic. Figure 2b shows the same relationship using the GMME forecast and Fig. 2c is GMME minus the observations. The GMME captures the large-scale spatial relationship between SST and the NAO, however there some regional differences. For example, the GMME has a larger correlation with eastern tropical Pacific SSTs, whereas this relationship is more noisy in ERA-Interim. The GMME forecast correlation pattern in the North Atlantic is slightly weaker than observed and few points are statistically significant.

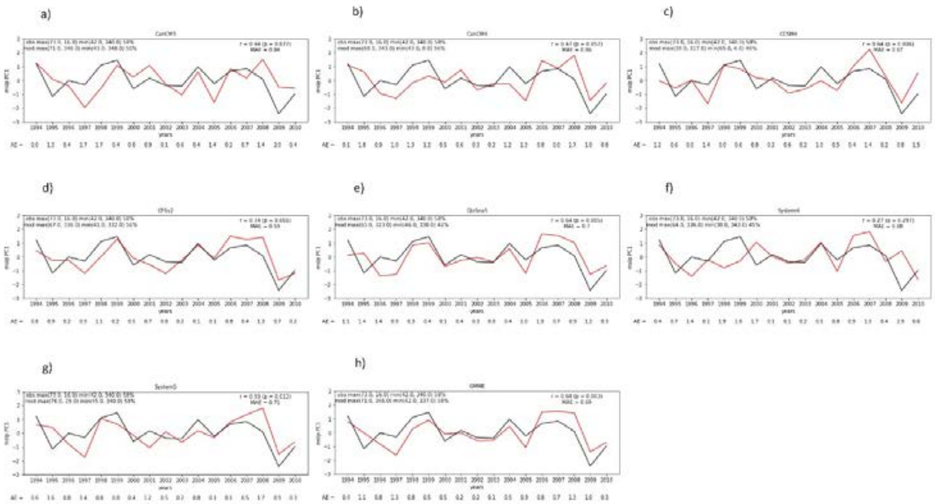

Figure 1: The black line in all the panels is the mean sea-level pressure DJF principal component one, expressed as covariance, in the spatial domain 100W-30E, 0N-80N, for the years 1994-2010. The East Pacific and land points have been masked out of the calculation. The red line is the model forecast using December initial conditions for a) CanCM3; b) CanCM4; c) CCSM4; d) CFSV2; e) GloSea5; f) System4; g) System5; h) Grand multi-model ensemble. The correlation coefficient, p-value and mean absolute error are given in the text in the top right-hand corner for each model. The absolute error for each year is given below the x-axis for each model. The location of the maximum and minimum of empirical orthogonal function (EOF) one is shown in the top left along the variance explained by the EOF.

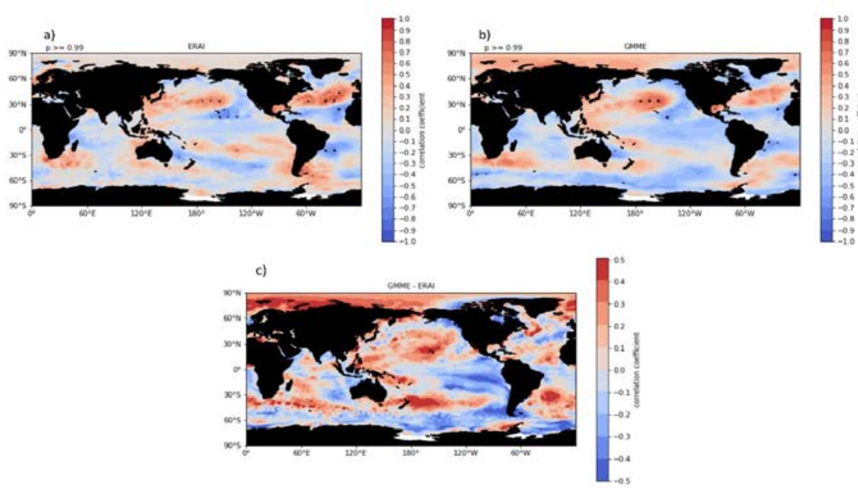

Figure 2: a) Observed correlation coefficient of DJF sea-surface temperature and mean sea-level pressure PC1 (see Fig. 1). b) Grand Multi-Model Ensemble mean forecast of DJF sea-surface temperature and mean sea-level pressure PC1 correlation coefficients using December initial conditions. Stippling shows points significant at the 95-percent level calculated using a one-sided t-test for positive values and calculated using the survival function for negative values.

The observed correlation of mslp PC1 with *Z*500 is presented in Fig. 3a. There is a clear NAO pattern in the North Atlantic. This pattern is far reaching and extends over the continental US. The physical mechanisms explaining the correlation of the NAO with mid-level blocking in Russia as well as low-pressure over Antarctica are unclear and may be artifacts of the correlation. The GMME forecast correlation of mslp PC1 with *Z*500 is very good in the North Atlantic (Fig. 3b). Outside of the North Atlantic, the relationship is stronger in GMME that observed (Fig. 3c) as the GMME forecasts a broad hemispheric oscillation in both hemispheres.

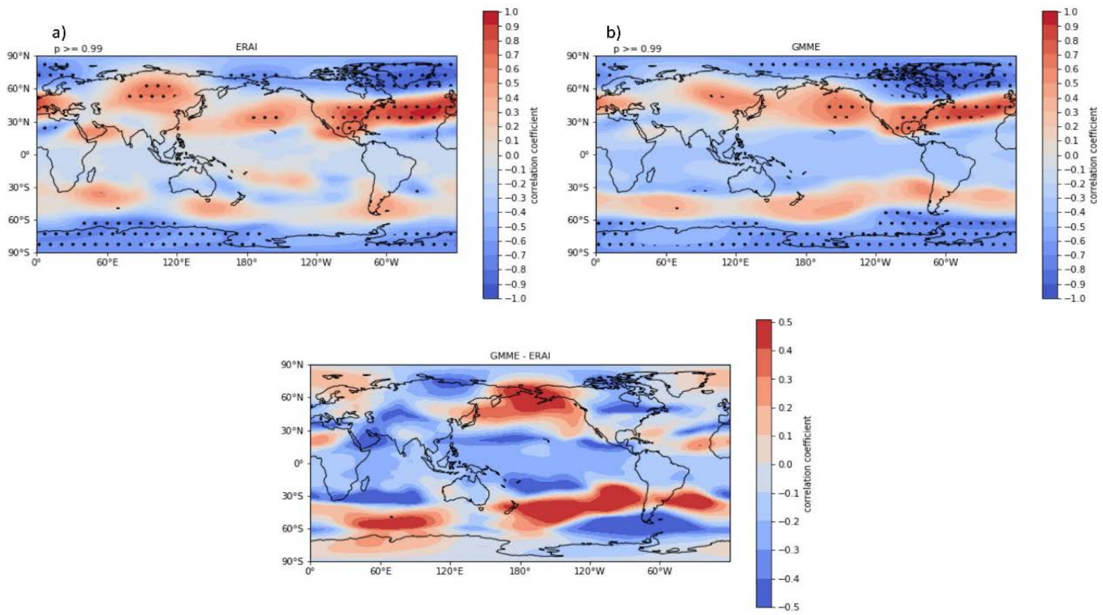

Figure 3: Same as Figure 2, but for geopotential height at 500 mb.

Finally, we ask the question of how many models are required. Here we use Rank Probability Skill Score (RPSS) as the metric to make this assessment. The RPSS of all possible model combinations averaged over the North Atlantic region is given in Fig. 15 for 10-m wind speed (a), Hs (b), T01 (c) and mslp (d). The maximum number of model combinations with seven models is 35 using two and three model combinations and these are shown in the box and whisker. For all parameters the median skill for two models, denoted by the orange line, is double that of the median skill of the single models. The RPSS for the seven model combination is marginally less than that of the best model (GloSea5) for 10-m wind speed (0.2 and 0.21). However, removing CanCM3 - the only model with RPSS less than zero - gives a RPSS greater than any individual model, 0.215. The best forecast is given by combining CCSM4, CFSv2, GloSea5. The relationship is similar for Hs and T01. The best forecast for Hs is obtained by combining CFSv2 and GloSea5, whereas the best forecast for T01 is obtained by combining CanCM4, CFSv2 and GloSea5. The relationship for mslp is different. The seven model combination is better than any individual models. A combination of CCSM4, CFSv2, GloSea5 and System5 provide the best forecast.

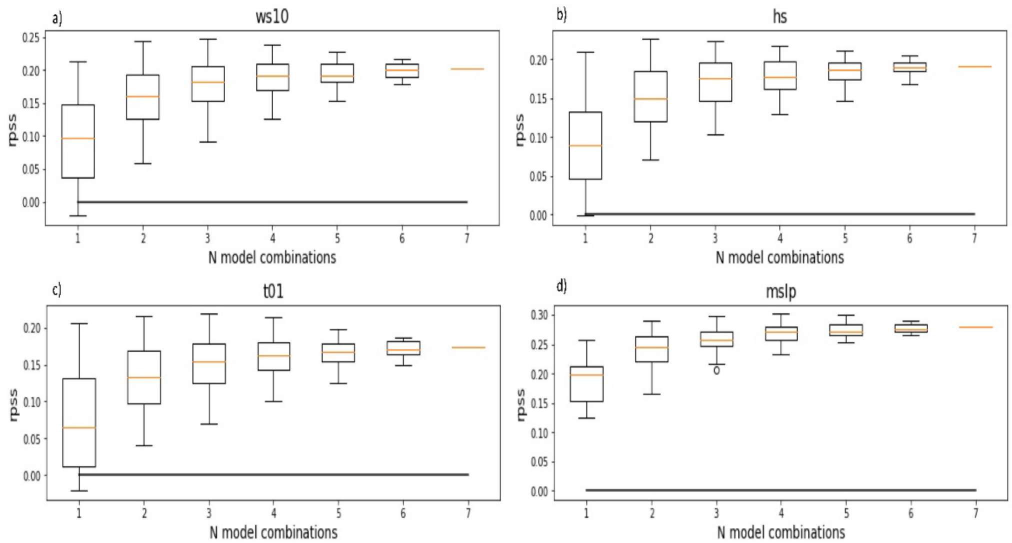

Figure 4: Rank Probability Skill Score for DJF forecast of a)10-m wind speed, b) significant wave height using, c) mean wave period and d) mean sea-level pressure using December initial conditions with all possible multi-model combinations. The box and whiskers display the multi-model combinations with: the box outlining the lower to upper quartile and the orange line as the median. The whiskers extend to the first datum less (greater) than the first quantile minus (add) 1.5 multiplied by the inter-quartile range. The black line in all panels is the zero line which is the rank probability skill score for a climatological forecast.

Research Performance Measure: The project has been extended until July 2020, key performance measures are continued operational CCSM4 prediction, and prediction and predictability research with CCSM4.

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South Atlantic-North Atlantic Meridional Overturning Circulation (MOC) Linkages: Analysis of Upper and Lower Limbs With In Situ Instruments

Project Personnel: M. Le Hénaff, M. Kersalé, S. Majumder, R. Garcia and S. Garzoli (UM/CIMAS)
NOAA Collaborators: C. Meinen, R. Perez and S. Dong (NOAA/AOML)
Other Collaborators: R. Matano (OSU); S. Speich (ENS, France); E. Campos and O. Sato (U. Sao Paulo, Brazil); A. Piola and M. Chidichimo (SHN/UBA, Argentina); T. Lamont (DEA, S. Africa); I. Ansorge (U. Cape Town, S. Africa).

Long Term Research Objectives and Strategy to Achieve Them:

Objectives**:** To advance our understanding of the temporal variability and meridional coherence of the upper and lower components of the Atlantic Meridional Overturning Circulation (AMOC) limb pathways in the South and North Atlantic, and to thereby achieve a more holistic view of AMOC.

Strategy**:** To use *in situ* observations from moored arrays along 34.5°S in the South Atlantic and along 26.5°N in the North Atlantic collected in collaboration with national and international partners to study the variability of the flows in the upper and lower limb of the AMOC.

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: Sandy Lucas

Research Summary:

The Meridional Overturning Circulation (MOC) plays a crucial role in redistributing heat and salt throughout the global ocean system. MOC slowdowns, shutdowns, and/or changes in the amount of heat and salt carried by the Atlantic component of the MOC (AMOC) in both the South and North Atlantic are thought to have pronounced impacts on a variety of socially important climate and weather phenomena (e.g. coastal inundation, hurricane intensification, droughts, heat waves). Quantifying and understanding how the AMOC changes over time in both hemispheres is therefore crucial for improving our knowledge of how the climate system functions. This project helps refine our current understanding of the AMOC pathways in the North and South Atlantic Ocean, and how they influence AMOC variability in both basins. To address this goal, we are analyzing in situ observations from moored arrays along 34.5°S in the South Atlantic (including NOAA's Southwest Atlantic MOC – SAM – project) and along 26.5°N in the North Atlantic (including NOAA's Western Boundary Time Series – WBTS – project). We are also working with data from the national and international partners at both latitudes (Argentina, Brazil, France, and South Africa at 34.5°S, and the University of Miami and the United Kingdom at 26.5°N). This proposed research effort is being led by the project PIs, C. Meinen, R. Perez, and M. Le Hénaff, who work together with a postdoctoral researcher, M. Kersalé, supported by this proposal.

Research Performance Measure:

Project PIs worked with R. Garcia and other colleagues to extend the SAM and WBTS daily bottom pressure and travel time moored along 34.5°S and 26.5°N, respectively. During this year multiple cruises were conducted for the two arrays to collect data and maintain the moored instruments. These extended records have been processed and quality controlled. Along 34.5°S, SAM data have been used in conjunction with data from a French moored instrument in the Eastern South Atlantic, to extend the daily AMOC volume transport measurements. Project PIs, the project postdoc, and national and international partners worked together and analyzed the variability of this extended time-series, from 2009 to 2017. Results were recently published in a peer-reviewed Geophysical Research Letters paper (Meinen et al., 2018). The results demonstrate that signals at both boundaries cause significant transport variations at seasonal time scales (Figure 1), as well as variations at both shorter and longer time scales. Project PIs and the project postdoc are also leading and co-authoring manuscripts including a paper describing the mesoscale dynamics in the Eastern Atlantic observed by French and South African moored instruments (Kersalé et al., 2017), a paper describing water mass variations in the SAM region that is under review (Valla et al., 2018), and a paper studying the time variability of the Brazil Current that is in preparation (Chidichimo et al., 2018). Project PIs and the project postdoc are collaborating with national and international researchers on several additional AMOC-related publications that are at earlier stages of preparation. Results from several analyses involving the project PIs and postdoc were presented at the IAPSO-IAMAS-IAGA Joint Assembly and the SAMOC VII workshop both in Cape Town, South Africa (August-September, 2017), and during the Ocean Sciences meeting in Portland, OR (SAMOC session, February 2018).

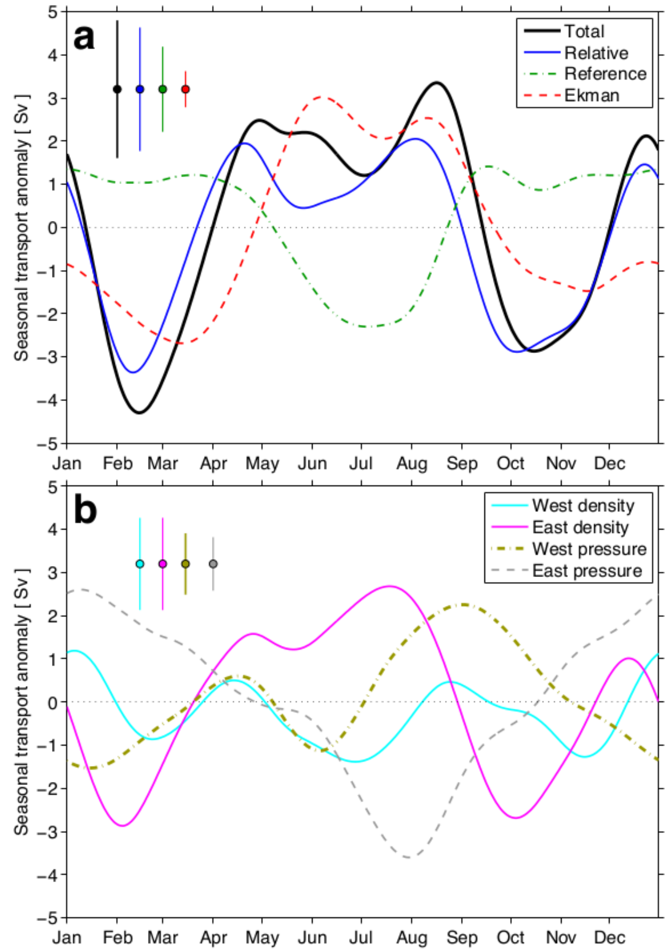

Figure 1: (a) Seasonal anomaly of the MOC volume transport time series. The seasonal anomaly of the total, geostrophic relative, geostrophic reference, and Ekman transports are shown. (b) Seasonal anomalies resulting from variations on either end of the basin for the relative component (density) and the reference component (pressure). Error bars indicated in the upper left of each panel represent plus/minus one standard error, with colors matching the corresponding time series. Reproduced from Meinen et al. (2018).

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Natural Variability versus Climate Change Influences on U.S. Heat Waves

Project Personnel: H. Lopez (UM/CIMAS); B. Kirtman (UM/RSMAS)
NOAA Collaborators: G. Goni, S. Dong, S.-K. Lee and R. Atlas (NOAA/AOML)
Other Collaborators: R. West (FSU)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To characterize the most common heat wave patterns over the US and to assess the regional dependence of future projections of these extreme events.

***Strategy*:** Perform cluster analysis on atmospheric reanalysis products, as well as on large ensemble of 20th and 21st Century Climate simulations from a fully coupled general circulation model, and from several CMIP5 models. Use this clustering technique in order to identify extreme heat events in the

U.S. by their spatial distribution. Then, for each cluster or pattern, perform an attribution analysis to obtain the time frame when human-induced climate change would overtake natural variability as the dominant cause of heat waves.

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: NOAA/OAR

NOAA Technical Contact: Molly Baringer

Research Summary:

The number and severity of heat waves have increased in recent decades and is projected to continue increasing into the 21st Century. Population growth coupled to the fact that extreme heat is the leading weather-related cause of death in the US call for the need to identify the relative roles of internal variability and Anthropogenic Climate Change (ACC) on these extremes. Therefore, knowledge on the Time of Emergence of the ACC signal (i.e., time frame for which ACC will overtake natural variability as the dominant factor) with respect to heat waves and its regional dependence is crucial for better adaptation efforts.

In this study, we start by characterizing the most common heat wave patterns over the US by the use of clustering of extreme events by their spatial distribution. This allowed us to identify four dominant heat wave patters (i.e., Great Lakes, Northern Plains, Southern Plains, and Western patterns) as shown in Fig. 1 (left-column). Using reanalysis products, statistical Markov models, a large ensemble of 20th and 21st Century Climate simulations from a fully coupled general circulation model, and from several CMIP5 models, we show that the signal-to-noise ratio (where the signal is taken as the amplitude of the ACC signal and noise is defined by the amplitude of natural variability) of heat waves days for the 21st Century (i.e., 2020-2100) is significantly smaller for the Great Plains regions (Figs. 1d and f) compared to the Great Lakes and Western regions (Figs. 1b and h), indicating that future projection of heat waves over the Great Plains is more uncertain due to large natural variability there.

We also show that natural variability will dominate heat wave occurrence over the Great Plains with ToE occurring in the 2050s (2070s) for the Northern (Southern) Plains shown in Fig. 2a and 2d respectively. In contrast, ACC forcing will dominate over the Great Lakes and (Western) region with ToE occurring as early as in the 2030s (2020s) as shown in Fig. 2b and 2c respectively, suggesting caution in attributing heat extremes to external forcing due to their regional dependence. The later ToE of ACC signal in the Great Plains is a result of projected increase of the Great Plain low-level jet and moisture transport, attenuating the surface warming due to ACC there. In contrast, a projected reduction in eddy activity (i.e., storminess) and strong negative correlation between surface temperature and storminess over the Western and Great Lakes regions increases the possibility of heat waves there, exacerbating the ACC mean temperature shift and producing earlier ToE.

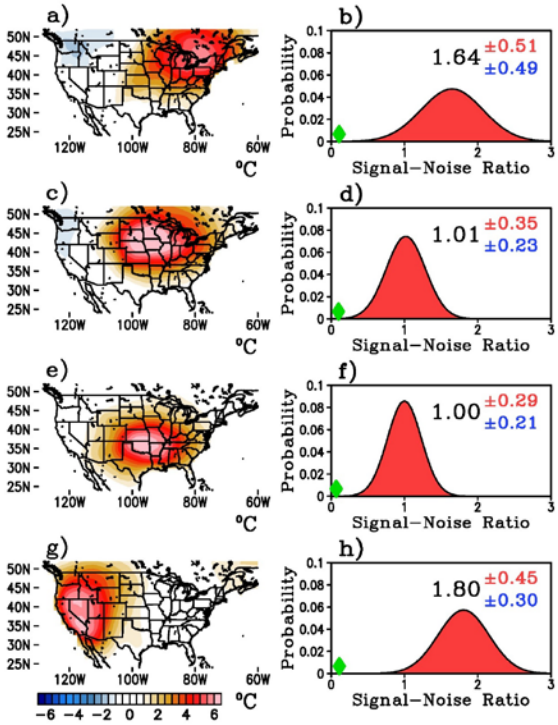

Figure 1: Geographic distribution of heat waves. a) 20th Century 2m temperature anomaly and b) 21st Century probability density function (PDF) of the signal-to-noise ratio (SNR) of heat wave events for the Great Lakes cluster. Similarly, c) and d) for the Northern Plains, e) and f) Southern Plains, and g) and h) Western heat wave clusters from the ensemble mean of CMIP5 models. The SNR PDF is obtained by randomly selecting eight models (ensembles) 1000 times from the CMIP5 (CESM1-LE) simulations. The mean SNR is shown in black and 95% confidence interval in red (blue) from the CMIP5 (CESM-LE). The 20th Century SNR is shown by green diamond.

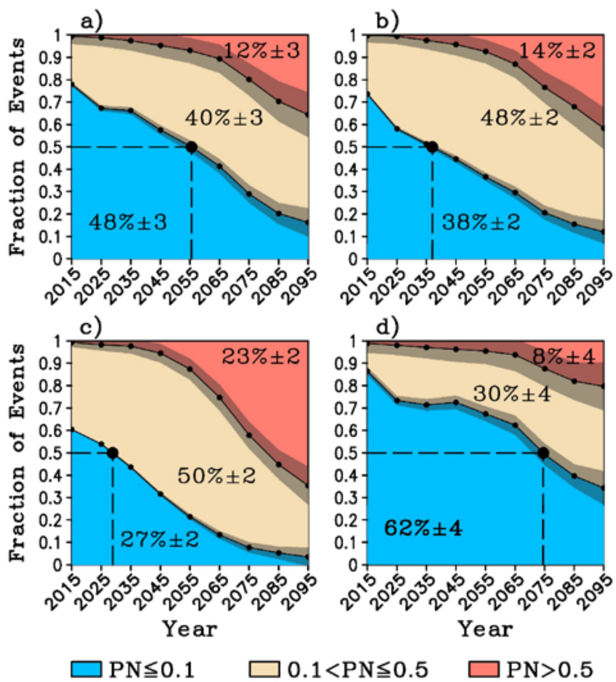

Figure 2: Probability of necessary causation (PN) of heat waves, a) Northern Plains, b) Great Lakes, c) Western, and d) Southern Plains regions. PN values are binned into: PN ≤0.1 (blue region, e.g., ACC is not a necessary condition for heat waves), 0.1<PN≤0.5 (yellow, ACC is somewhat important) and PN>0.5 (red, ACC is a necessary condition for heat waves). The intersection of the dashed lines denotes when ACC becomes a major contributor to heat extremes (e.g., a measure of the time of emergence). The percentage values indicate the fraction of heat extremes attributed to each category. The plus/minus value and the gray shading indicates 95% confidence interval by randomly selecting 20 ensemble members 500 times.

Research Performance Measure: the research objectives were met based on the primary objective: to quantify the relative role of natural variability versus ACC in modulating heat waves and to identify regional patters of heat waves in the U.S. The high mortality and economic losses associated with heat wave events calls for the need to understand how these events might change in the future under ACC forcing. This should help decision makers in improving mitigation and adaptation efforts.

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).

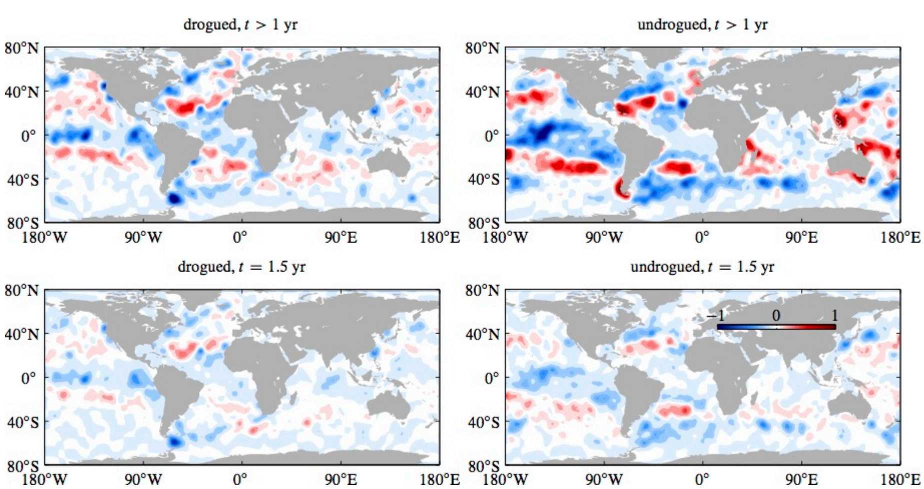

Figure 1: Expressed as a signed number per degree squared, density difference with respect to initial locations of (left column) drogued and (right column) undrogued drifters from the NOAA Global Drifter Program over 1979–2015 after at (top row) least 1 year or exactly (bottom row) 1.5 years past the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

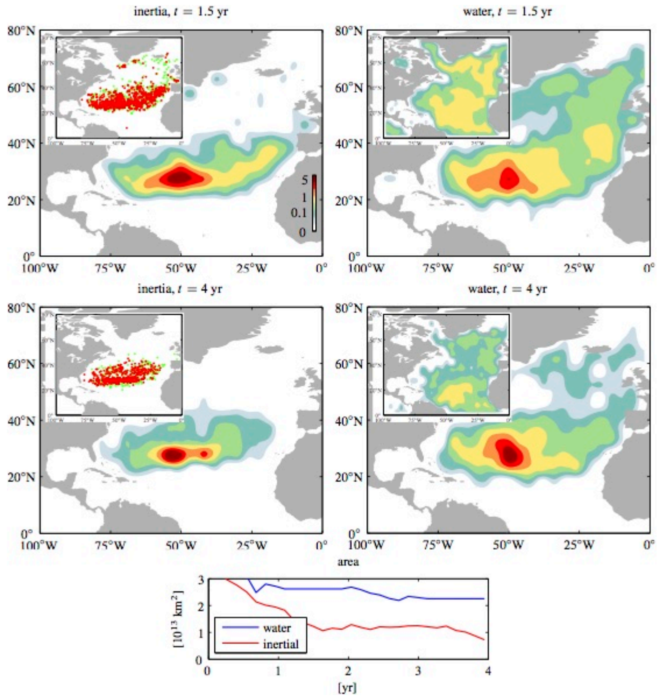

Figure 2: Density of particles after (top row) 1.5 and 4 (middle row) years of integration of the (left column) inertial (i.e., reduced slow-manifold Maxey-Riley) equation and of (right column) advection by water velocity normalized by density in the initially uniform distribution of particles. Insets 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.

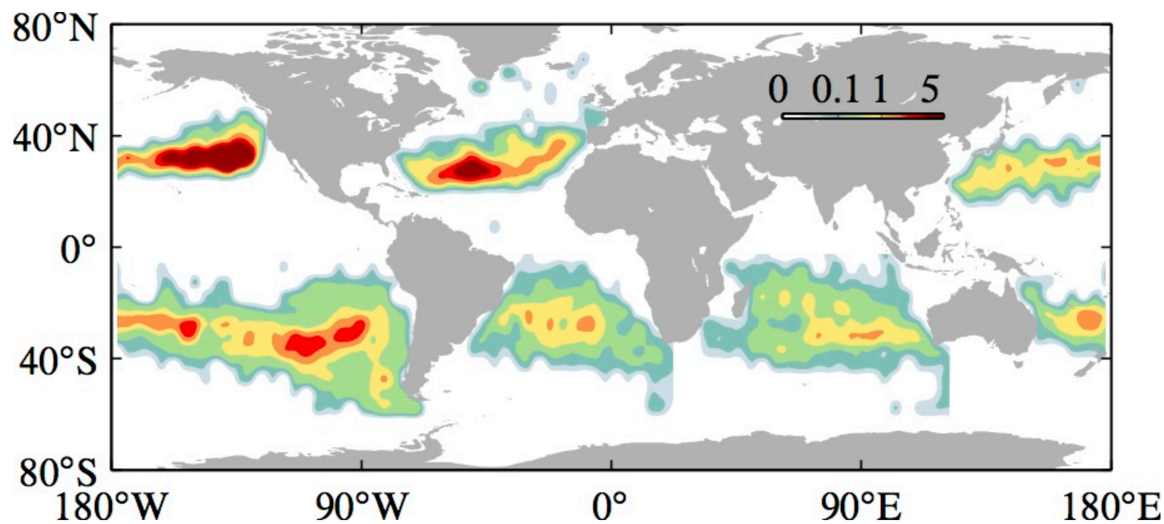

Figure 3: Expressed as number per degree squared, density of particles after 1.5 yr of integration of the inertial equation (5) normalized by density in the initially uniform distribution of particles over each global ocean basin. Water velocity is given by surface ocean velocity from the 1/12° Global 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).

RESEARCH REPORTS

THEME 2: Tropical Weather

Development & Research Activities for the Basin-Scale Hurricane Weather Research and Forecasting (HWRF-B) Model

Project Personnel: G. Alaka, X. Zhang, M.-C. Ko and R. St. Fleur (UM/CIMAS); J. Poterjoy (NRC)
NOAA Collaborators: S. Gopalakrishnan, F. Marks and J. Sippel (NOAA/AOML); A. Mehra, B. Liu, Z. Zhang and H. Winterbottom (NOAA/NCEP/EMC)
Other Collaborators: E. Kalina and J. Frimel (NCAR/DTC)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To improve the performance of tropical cyclone forecasts through development and research on the Basin-Scale HWRF
***Strategy*:** *1*- To develop a version of Basin-Scale HWRF with self-cycled data assimilation to bridge the gap with next generation numerical weather prediction efforts within NOAA; *2*- To evaluate Basin-Scale HWRF forecasts, including verification against other models (global/regional/statistical) to identify model strengths and weaknesses.

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:

We successfully ran the Basin-Scale HWRF in near-real-time for the 2017 hurricane season under the support of the Hurricane Forecast Improvement Project (HFIP). For the first time, NOAA aircraft observations were assimilated into the Basin-Scale HWRF in real-time, demonstrating the advancing readiness level of this modeling system. Further, good organization and timely communication between the Project Personnel led to the delivery of model products to our web site (http://storm.aoml.noaa.gov/basin) with enough lead time to be useful in the NOAA Hurricane Field Program and HRD Map Discussions (Fig. 1). Upon completion of the 2017 hurricane season, Basin-Scale HWRF produced better track forecasts than the Operational HWRF and the Global Forecast System (GFS) (Fig. 2). In 2017, NRC Postdoc Dr. Poterjoy cycled the outer domain of the Basin-Scale HWRF (that spans ¼ of the globe) for several consecutive months in an HFIP real-time demo. In recent months, Dr. Alaka has worked closely with Dr. Poterjoy to develop a cycled data assimilation (DA) system for the Basin-Scale HWRF. The DA system was re-configured to produce initial conditions for Basin-Scale HWRF forecasts. In addition, coupling to the Princeton Ocean Model (POM) has been added for the outermost domain.

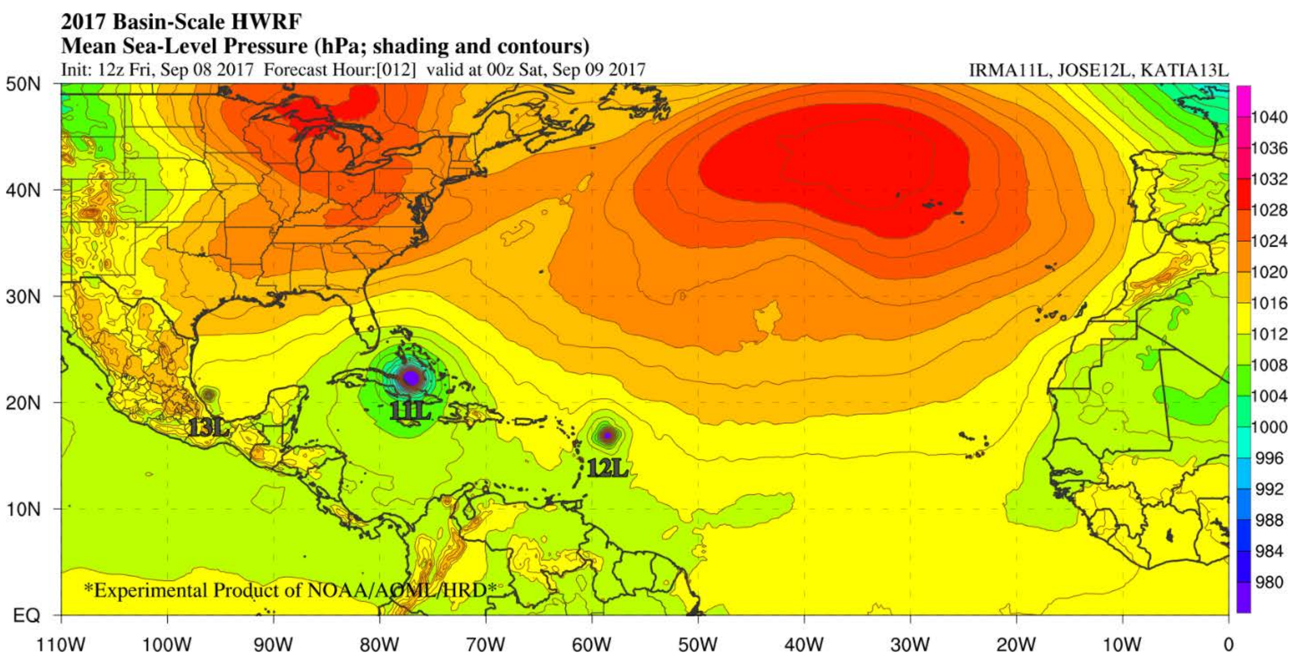

Figure 1: An example of real-time guidance produced from Basin-Scale HWRF output in 2017. Here, a 12-h forecast of mean sea-level pressure is shown from a forecast initialized at 12Z 08 Sept 2017. Three hurricanes were simultaneously present at this time: Hurricane Irma ('11L'), Hurricane Jose ('12L') and Hurricane Katia ('13L').

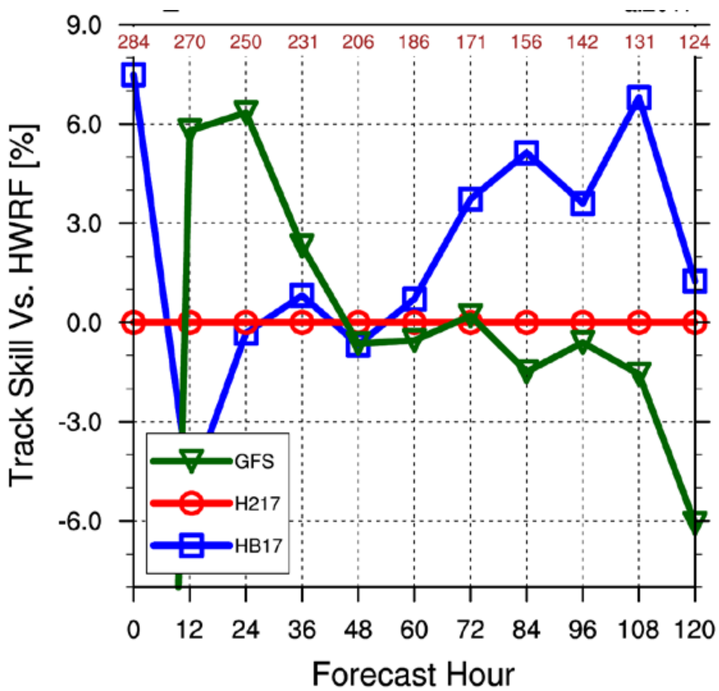

Figure 2: Track forecast skills (e.g., % improvement/degradation) are shown for the 2017 Basin-Scale HWRF (HB17; blue), the 2017 Operational HWRF (H217; red), and the Global Forecast System (GFS; green) are shown for various forecast hours for the 2017 Atlantic hurricane season. Case numbers are provided at the top of each column.

Basin-Scale HWRF was also utilized to conduct important tropical cyclone research. For one, Dr. Alaka has evaluated the relationship between the vortex and the environment in determining track forecast spread in ensemble prediction systems. Using Basin-Scale HWRF, Dr. Alaka showed the dominance of initial perturbations to the environment for the case of Hurricane Joaquin and developed new metrics to evaluate ensemble track performance. These results have been written in a manuscript, which has been reviewed by HRD and is currently being prepared for submission to a peer-reviewed journal. Additionally, Ms. Ko has focused on rainfall evaluations of Basin-Scale HWRF forecasts, where great promise was shown in the ability to reproduce the high rainfall totals in Hurricane Harvey (Fig. 3). She submitted an extended abstract on this topic to the AMS 33rd Conference on Hurricanes and Tropical Meteorology and is currently preparing a manuscript with Dr. Alaka and others. The group also studied tropical cyclogenesis in real-time forecasts made by Basin-Scale HWRF in 2017 using the GFDL tracker in “genesis” mode.

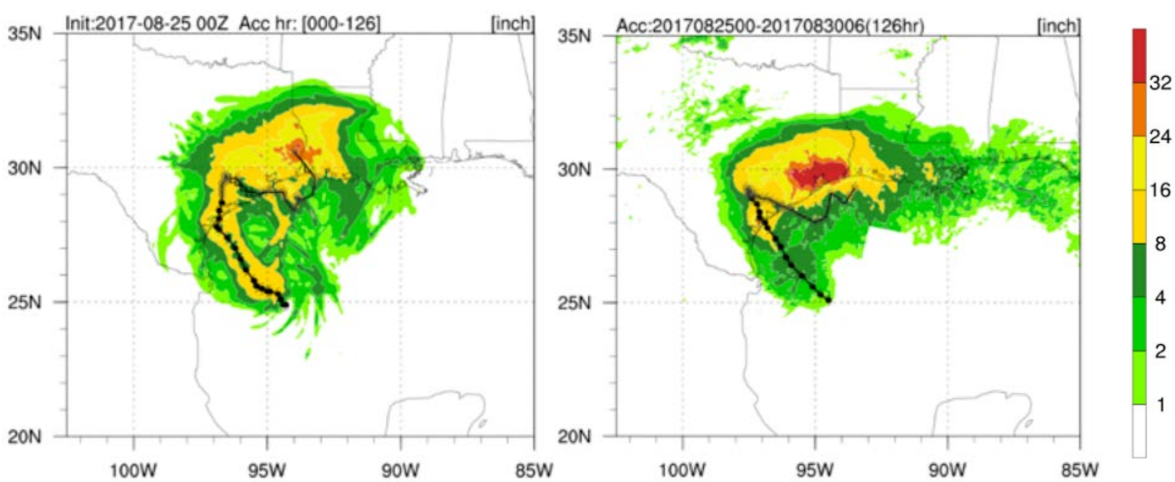

Figure 3: Rainfall evaluation comparing 126-h total rainfall from the Basin-Scale HWRF (left) with observations from the Stage IV analysis (right) for a Hurricane Harvey forecast initialized at 00Z 25 Aug 2017. The forecast track (left) and the actual track (right) are also provided

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

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

Project Personnel: B. Annane and R. Hoffman (UM/CIMAS); B. McNoldy (UM/RSMAS)
NOAA Collaborators: R. Atlas and S. Murillo (NOAA/AOML)
Other Collaborators: 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:

The NASA Cyclone Global Navigation Satellite System (CYGNSS) is a new constellation of mini-satellites that observe the reflections of the GPS signals from the ocean surface. Scattering of these signals depends on the ocean surface roughness and hence on the winds and to some extent the waves. CYGNSS observations should improve the specification of the ocean surface wind field globally, including in tropical cyclones (TCs) since the GPS signals penetrate clouds and precipitation.

During the first half of the reporting period, in preparation for the launch of 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. CYGNSS winds were assimilated as scalar wind speeds and as wind vectors determined by a Variational Analysis Method (VAM). (VAM is the variational analysis method that combines the CYGNSS wind speeds and the background vector winds into an analysis of vector winds that is then used to assign directions to the CYGNSS wind speeds.) 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. Two papers (Bachir et al. 2018, Leidner et al. 2018) are now in press on these experiments.

Work during the second half of the reporting period began experiments parallel to the simulation experiments, but with the real CYGNSS data. A number of experiments have been conducted but are considered very preliminary since the real CYGNSS data sets available until just now have had major quality issues. Even the latest version has some quality issues and we have studies various approaches to quality controlling the data. Because the data for mature TCs has greater quality issues, our current approach is to experiment during the development stage of TCs.

The design of our observing system experiments (OSEs), which is similar to the approach taken in simulation reported in the journal articles is the following: Except for different data, the experiments all share the NCEP operational HWRF analysis and forecast system. The atmospheric forecast model is the 2017 NCEP operational HWRF, denoted H217. The data assimilation system used is the hybrid 3d-

Variational/Ensemble Kalman Filter data assimilation system in the Gridpoint Statistical Interpolation (GSI) framework We conduct experiments using different treatments of CYGNSS data: (a) Wind speed as SSMI wind speed is used in HWRF operational configuration; and (b) VAM CYGNSS wind vectors as ASCAT wind vectors are used in the HWRF operational configuration. The OSEs focus on cases of sparsely observed periods of the TCs early lifecycles, when wind speeds are not too strong, and cases when the operational HWRF forecasts had relatively high intensity error. These cases include hurricanes Harvey, Irma, Katia, and Maria. Based on the simulation results, we focus on the 1-2 day forecasts of hurricane intensity.

Research Performance Measure: The research program is on schedule.

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A Uniformly-High Resolution Nature Run for Hurricane OSSEs

Project Personnel: L. Bucci, K. Ryan, J. Delgado 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:

An Observing System Simulation Experiment (OSSE) is a technique to study and quantify the impacts of a proposed observing system in a numerical forecast model. The *nature run* (NR) is the integral part of an OSSE. It is a long deterministic forecast that realistically represents atmospheric features created by a research quality, high-resolution numerical model. A validated NR should contain atmospheric features that compare well to real world corollaries. The goal of this project is to run 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)

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, followed by a 2 km forecast, as reported last year. This year, we achieved a 1.5 km forecast. Figure 1 shows the intensity comparison between the G5NR, 2km BSNR, and 1.5km BSNR. 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.

We have continued the evaluation of our 2 km nature run. Various fields, including evolution of environmental shear, deep-layer mean steering, and simulated reflectivities were analyzed. We are continuing our in-depth analysis and compiling the results into a manuscript. Figure 2 shows a comparison of the pressure-wind relationship through the life-cycle of the G5NR storm (Storm #8) and its equivalent in the BSNR. Our analysis includes evaluating how realistic our storm of interest is and all results thus far have demonstrated that it is.

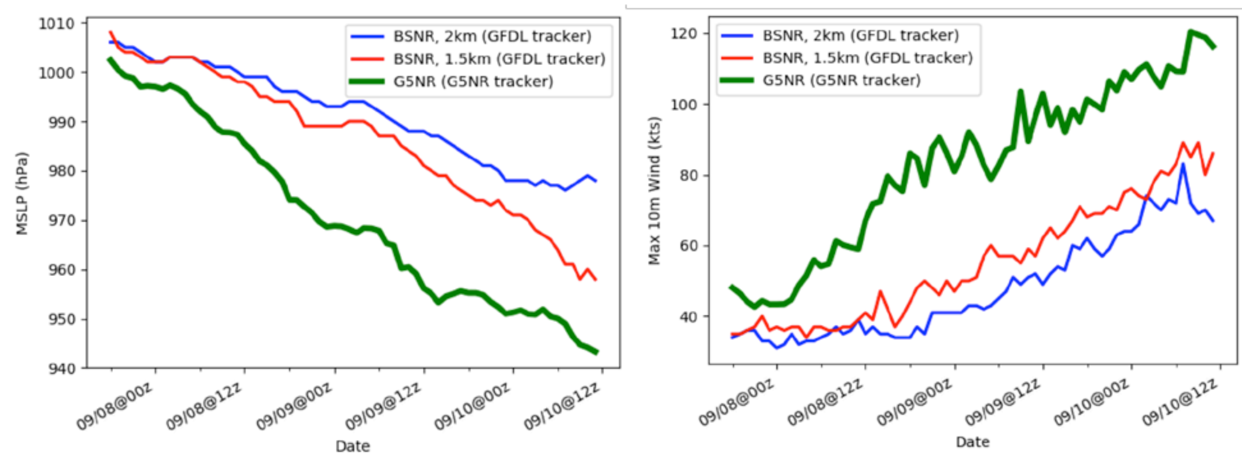

Figure 1: Hurricane Intensity Comparison – Comparison of the G5NR (green), 2km BSNR (blue), and 1.5km BSNR (red) minimum sea level pressure and maximum 10m wind speed.

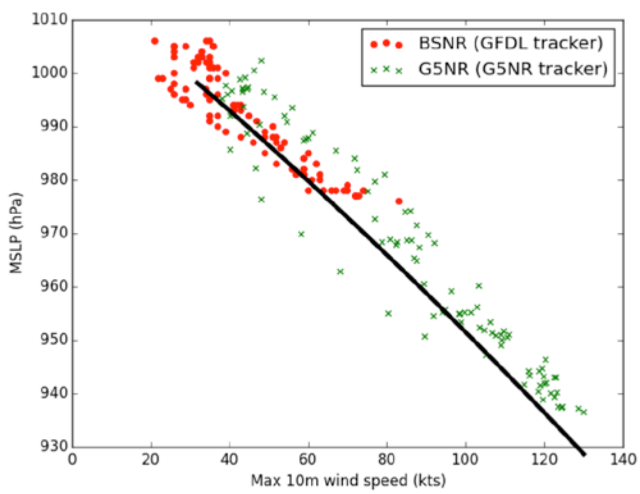

Figure 2: Pressure-Wind Relationship – Pressure-Wind relationship of the BSNR (red dots) and the G5NR (green plus)

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 and a 1.5km 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.

Composite Impact of NASA Global Hawk Unmanned Aircraft Dropwindsonde Observations on Tropical Cyclone Analyses and Forecasts

Project Personnel: H. Christophersen, A. Aksoy, J. Dunion, K. Sellwood and B. Dahl (UM/CIMAS)
NOAA Collaborators: S. Aberson, R. Atlas and S. Murillo (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To evaluate the impacts of NASA Global Hawk dropwindsondes on tropical cyclone analyses and forecasts as part of NOAA's Sensing Hazards with Operational Unmanned Technology (SHOUT) Project.

***Strategy*:** Conduct Observing System Experiments (OSE) using data from Global Hawk field missions and utilizing NOAA/AOML/HRD's in-house data assimilation system - 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 UAS Program
NOAA Technical Contact: Phillip Hall

Research Summary:

Results from a detailed composite study to investigate Global Hawk (GH) dropsondes impacts on TC analyses and forecasts in NOAA/AOML/HRD's vortex-scale ensemble DA system (Hurricane Ensemble Data Assimilation System, HEDAS) and the HWRF model are presented. Innovation statistics of assimilated dropsondes are evaluated to ensure that data are properly assimilated. The probability distribution functions of dropsonde temperature, wind, and humidity innovations indicate less bias and smaller root-mean-square error after DA.

Since reconnaissance data from crewed aircraft missions have shown a large impact on accurately defining TC structure and the resulting forecasts (e.g., Christophersen et al. 2017), GH dropsonde data denial experiments are performed in two sets: a baseline set with crewed aircraft data and one without. The majority of the composite analyses are evaluated using the samples without crewed aircraft data. In this scenario, experiments with GH dropsondes are generally associated with smaller position and intensity errors and a better wind-pressure relationship in the final mean analyses. Better TC structures are also inferred from smaller integrated kinetic energy (IKE) errors in the final mean analyses when GH dropsondes are assimilated. Overall, assimilation of GH dropsonde data also results in statistically significant improvements of ~10% in track forecasts through 84-h and MSLP forecasts through 108 h (Fig. 1).

Among the more intense TC cases (≥50 kt), two subgroups are considered based on 24-h intensity change: steady-state (SS) and non-steady state (non-SS). GH dropsondes demonstrate a larger impact on the non-SS cases than the SS cases. This impact is evident in terms of a large reduction of position, intensity, and IKE errors during the 4-h DA window, as well as superior relative skill for position, intensity, and structure in the final mean analyses. As a consequence, the resulting forecasts for non-SS cases are generally associated with higher skill for both track and intensity compared to SS cases. It is noteworthy that the non-SS track forecast skill is higher than those of all cases (Fig. 2).
Lastly, the forecast impact of GH dropsondes in the presence of crewed aircraft data is examined. Overall, statistically significant track-forecast improvements are seen with GH dropsondes regardless of whether

crewed aircraft data were available, but intensity improvements from GH dropsondes are only seen (beyond 36 h) when crewed aircraft data were absent. When assimilated with crewed aircraft data, GH dropsondes have a mixed impact on intensity forecasts.

The results above have been accepted for publication in Monthly Weather Review (Christophersen et al. 2008).

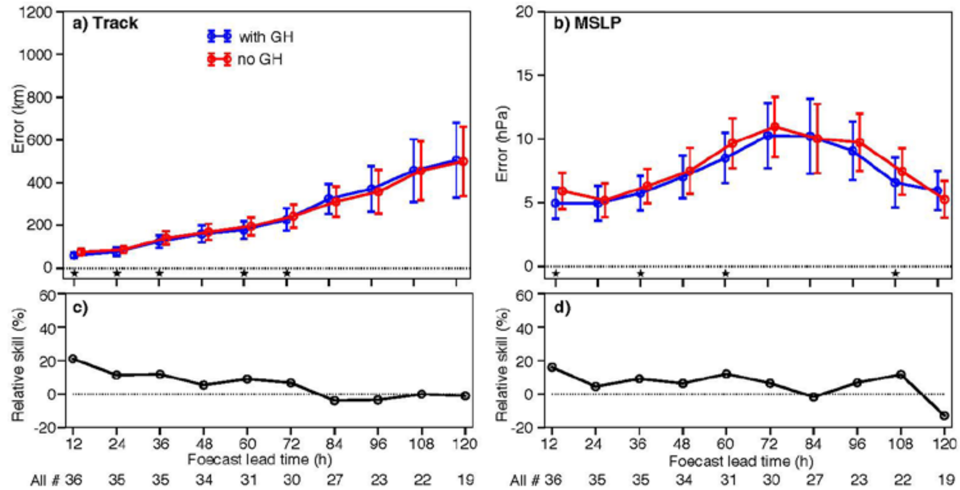

Figure 1: Average (a) track and (b) MSLP forecast errors and (c-d) their corresponding relative skill (% improvement) for cases with and without dropsondes assimilated. The 95% confidence intervals for the errors at each forecast lead time are shown in error bars. The forecast errors at a given forecast lead time that are at least 90% statistically significant are indicated in stars in (a-b). The errors and confidence intervals for cases without dropsondes are slightly displaced in x-axis to avoid overlapping with the ones with dropsondes.

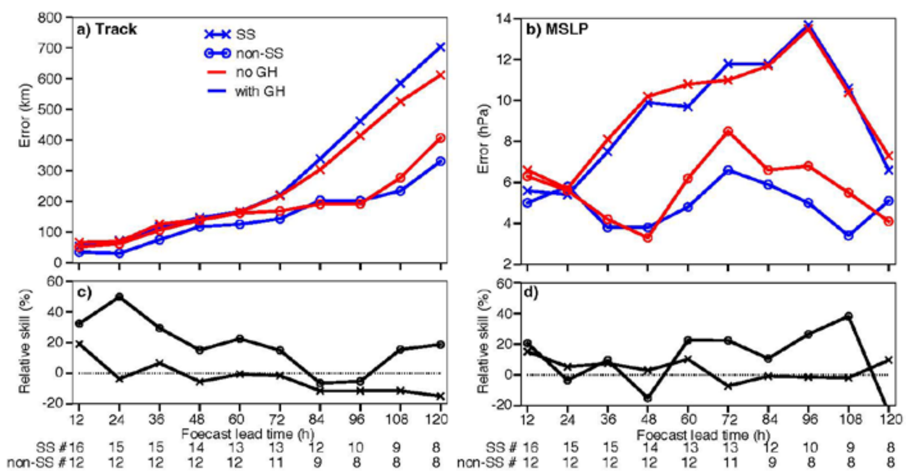

Figure 2: Average (a) track and (b) MSLP absolute forecast errors and (c-d) their corresponding relative skill (% improvement) for strong (with intensities ≥50 kt) non-SS and SS cases with and without GH dropsondes assimilated. The 95% confidence intervals for the errors at each forecast lead time are shown in error bars. The forecast errors at a given forecast lead time that are at least 90% statistically significant are indicated in stars in (a-b), where the open stars are for SS cases and filled stars are for non-SS cases. The displacement in x-axis at each forecast lead time for the errors and confidence intervals of the cases without dropsondes is only applied to avoid overlapping with the ones with dropsondes.

Research Performance Measure: The case studies and the composite study that examine the impact of Global Hawk dropsondes have both been accepted as peer-reviewed journal articles.

Coyote UAS Sampling Strategy OSSE

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

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To evaluate the impact of the Coyote UAS observations on tropical cyclone analyses and forecasts and how that impact may be enhanced through modifications to the sampling strategy.

***Strategy*:** To test various Coyote sampling strategies using observing system simulation experiments (OSSEs) with NOAA/AOML/HRD's Hurricane Ensemble Data Assimilation System (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: OAR/AOML
NOAA Technical Contact: Molly Baringer

Research Summary:

The Coyote is a small uncrewed aircraft system (UAS) that is released through the dropsonde chute of the NOAA P-3 aircraft. To date, the Coyote has been successfully deployed twice in Edouard (2014) and six times in Maria (2017), targeting the eyewall and inflow layer of the storms. Observing system experiments (OSEs) assimilating data collected during the Edouard and Maria missions have shown positive vortex-scale impacts from Coyote observations. In addition to the OSEs, preliminary observing system simulation experiments (OSSEs) have been conducted to evaluate the impact of data collected along hypothetical Coyote flight tracks and provide guidance for planning future Coyote deployments.

In the Coyote OSSEs, synthetic Coyote observations (T, q, u, and v) and a control set of observations from a NOAA P-3 aircraft (tail Doppler radar radial velocity, flight level, and dropsondes) were generated from the Nolan et al. (2013) nature run and assimilated into HWRF using NOAA/AOML/HRD's Hurricane Ensemble Data Assimilation System (HEDAS). The most recent set of experiments compared the impact of a Coyote track similar to what was flown during Mission 1 into Maria (2017) versus a modified version of the track that remained in the eyewall and completed a circumnavigation around the eye during its descent. The modified flight track led to some improvement in the analysis of the azimuthally averaged moisture and wind fields (Figure 1). Additional experiments are currently underway to test sampling strategies that take advantage of the longer flight duration that will be possible with planned upgrades to the Coyote.

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

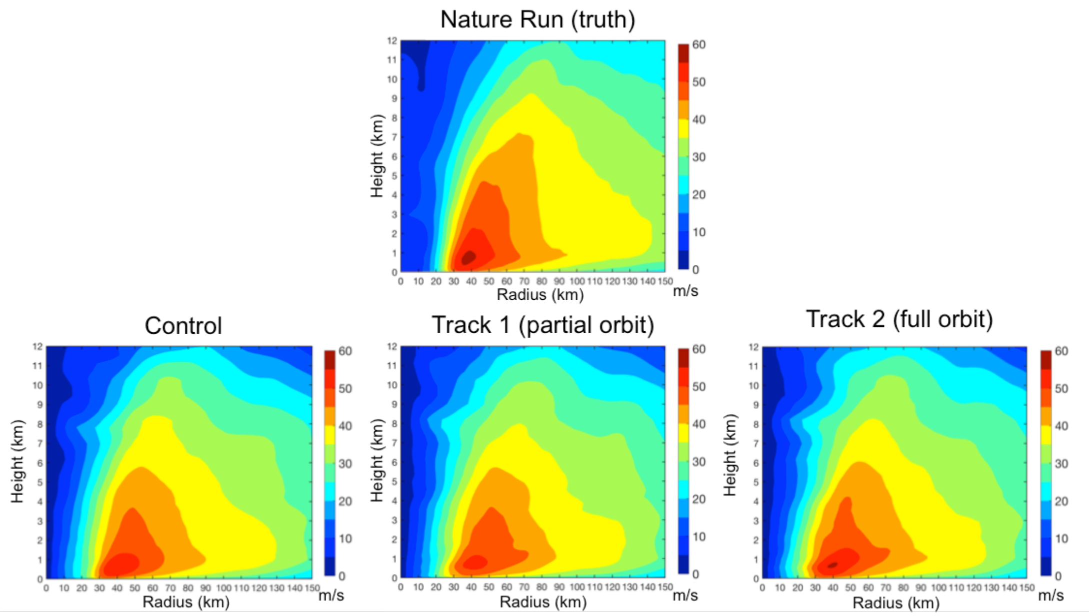

Figure 1: Tangential velocity analysis averaged azimuthally around the storm center for the nature run (truth), control (no Coyote), and two Coyote flight patterns.

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Global Hawk UAS Dropsonde Sampling Strategy OSSE

Project Personnel: B. Dahl, A. Aksoy and J. Dunion (UM/CIMAS)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives**:** To assess the relationship between Global Hawk UAS sampling strategies and data impact on tropical cyclone analyses and forecasts.

Strategy**:** To conduct an observing system simulation experiment to test impact of Global Hawk dropsondes deployed in various spatial distributions.

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: Phillip Hall

Research Summary:

The Global Hawk unmanned aircraft system (UAS) has the unique capability of sampling tropical cyclones from a high altitude for a length of time that exceeds the capabilities of existing manned reconnaissance aircraft. Global Hawk dropsonde observations have been shown to positively impact the analyzed storm structure and both track and intensity forecasts of tropical cyclones in observing system experiments (OSEs). An observing system simulation experiment (OSSE) was conducted to explore how variations in the spatial distribution of the dropsondes affected the data impact.

Four different spatial distributions of dropsondes were tested: a baseline deployment strategy and three additional strategies where dropsondes were added evenly along the flight path, only within the inner core of the storm (~2x the radius of maximum wind), and only outside of the inner core. Synthetic aircraft observations were generated from the Nolan et al. (2013) nature run and assimilated into HWRF using HEDAS. The OSSE included all 13 possible cases from the nature run storm during its intensification from tropical storm to major hurricane strength. When averaged across all cases, adding dropsondes within 2xRMW along the flight track generally resulted in the most improvement versus the control in the tangential velocity (Figure 1) and moisture analysis fields and in the intensity forecast. A similar amount of improvement was also seen when dropsondes were added evenly along the flight track. A manuscript based on these results is currently being prepared.

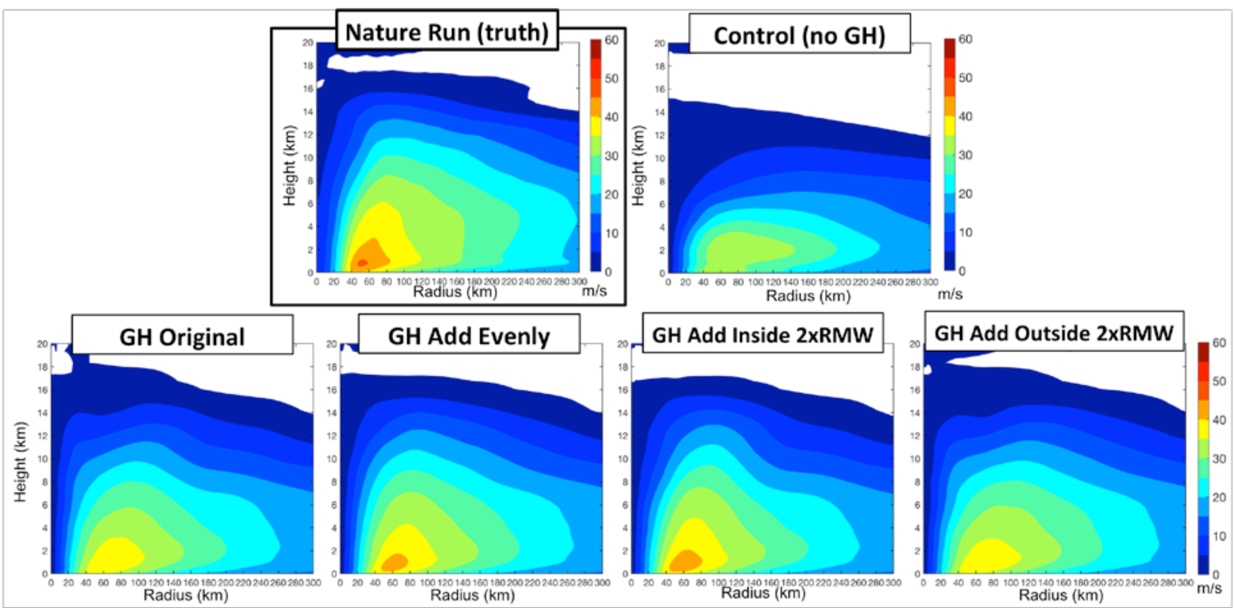

Figure 1: Composite of tangential velocity analysis from all cases averaged azimuthally around the storm center for the nature run (truth), control (no GH dropsondes), and four GH dropsonde sampling variations.

Research Performance Measure: The research objectives have been met.

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 2017-2018 year consisted of the continued development of the Next-Generation Generalized Nesting Framework (NGGNF). NGGNF was designed to transfer meteorological fields from a global (or regional) model onto a hurricane model featuring an independently-oriented, high-resolution grid using the tools of the Earth System Modeling Framework (ESMF) and the National Unified Operational Prediction Capability suite (NUOPC). Prior to the 2017-2018 year, a fledgling system was created that was able to successfully transfer data from the parent domain to a static (i.e., non-moving) high-resolution hurricane model (see 2016-2017 Annual Report). This system relied heavily on existing modules of a particular dynamic model, the Nonhydrostatic Multiscale Model on the B-grid (NMMB).

In Q2 of 2017, with the selection of the Finite Volume model (FV3) to replace the Global Spectral Model (GSM) as the next-generation global dynamical core, the Numerical Modeling Group at AOML/HRD began efforts to remove dependency on NMMB modules in by creating a 'model-independent' version of NGGNF, relying exclusively on the ESMF and NUOPC libraries. The independent system is designed to have to flexibility to be integrated into either FMS (the native framework of the FV3 system developed at GFDL) or as a 'NUOPC capped' component in NOAA Earth Modeling System (NEMS) framework. The new system has demonstrated the ability to transfer tracer data from a parent component to a moving nest component. This method utilizes the tools of the ESMF libraries and is valid for any number of processors for either the parent or nested domains. Nest motion can be in any cardinal direction.

While the coupled-nest motion algorithm within ESMF represents an advancement from the previous (NMMB-dependent) incarnation of NGGNF, transfer of the above code to an evolving NEMS/FV3 framework still requires significant work. The current system is still best described as a 'proof-of-concept' and requires significant development. In Q4 of 2017, the NEMSfv3gfs system was made available and the components of the NGGNF system were transitioned to that system in anticipation of transferring full sets of meteorological data in lieu of a simple test case (the cosine bell shown in Figure 1).

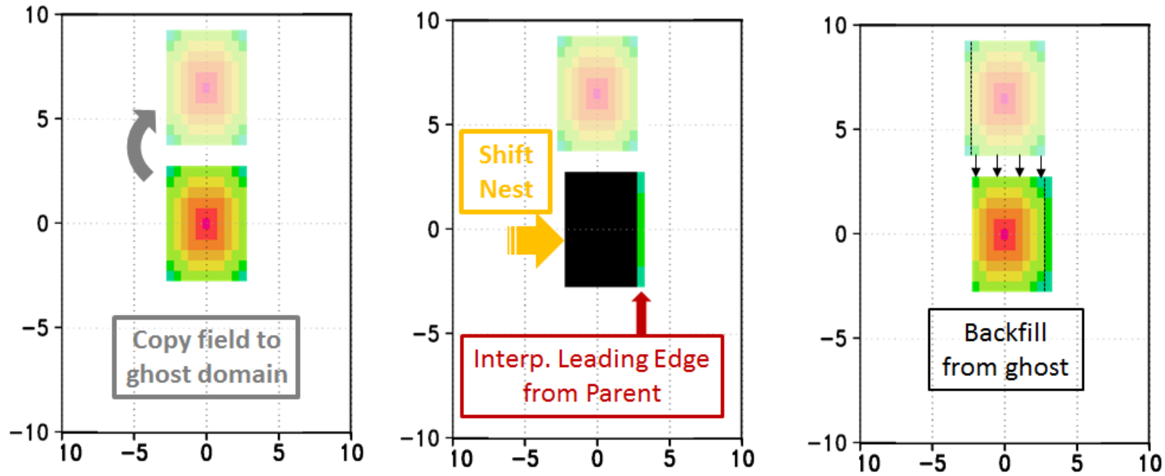

Figure 1: Low-resolution demonstration of NGGNF interpolation of field data (a cosine bell) from a parent domain to a moving nest. First, the existing state of the nested domain is copied (bitwise reproducible) to a ghost domain. The nest is then shifted and data from the parent domain is interpolated onto the grid points of the leading edge. Finally, the remainder of the nest is backfilled from the ghost domain.

Research Performance Measure: Given the evolving nature of the project and the late availability of the NEMSfv3gfs system, the NGGNF system has not yet been fully debugged.

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NOAA/AOML - CARICOOS Hurricane Underwater Gliders

Project Personnel: R. Domingues, G. Rawson and D. Ugaz (UM/CIMAS)
NOAA Collaborators: G. Goni, F. Bringas, G. Halliwell and U. Rivero (NOAA/AOML); R. Bouchard (NOAA/NWS)
Other Collaborators: J. Morell and L. Pomales (UPR, 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 Adaptations 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, **seventeen underwater glider missions** have been successfully completed with the collection of over **18,000** temperature, salinity, dissolved oxygen, and chlorophyll-a profiles were collected by this effort. The current glider fleet is composed of **five underwater gliders**, namely gliders: SG609 (purchased June 2014), SG610 (purchased June 2014), SG630 (purchased June 2016), and SG635 (purchased Feb 2017), and SG649 (purchased May 2018).

During July 1st, 2017 – June 30, 2018, three underwater glider missions (Figure 2) were successfully carried out:

Hurricane Season: Missions Summary – Three gliders (SG610, SG630, and SG635) were successfully deployed in the Caribbean Sea and Tropical North Atlantic Ocean in July 2017 as part of the 2017 NOAA Atlantic Hurricane Season Field Program. During July-November, all three gliders provided continuous observations from the upper-ocean in real-time in support of hurricane intensity forecasts. Over 4,000 temperature, and salinity were collected during this mission. Data collected during the 2017 season included ocean observations sampled in the vicinity, or directly under major Atlantic Hurricanes (Figure 3), namely: Harvey (August, 2017), Irma (September, 2017), Jose (September, 2017), and Maria (September, 2017). The recovery in late-October and early-November 2017 completed the successful missions in support of the 2017 Hurricane Field Program.

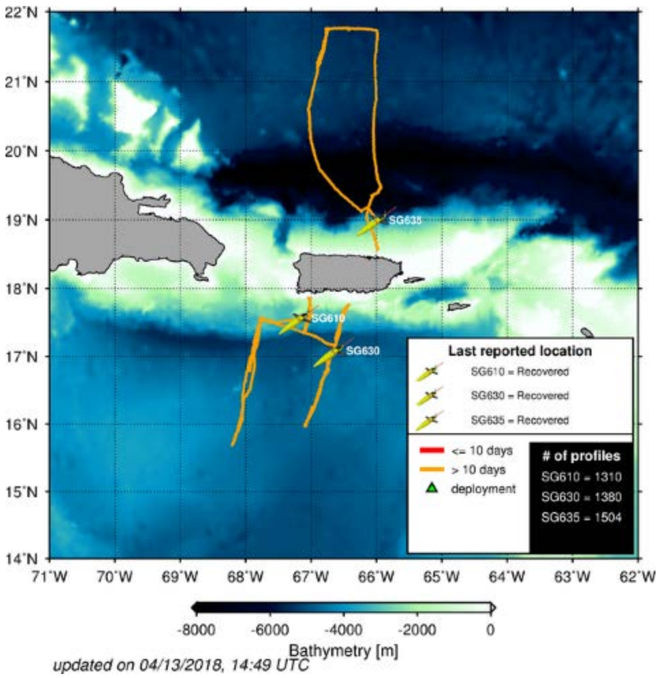

Figure 2: Track travelled by four underwater gliders during the Hurricane Season from July-November 2017.

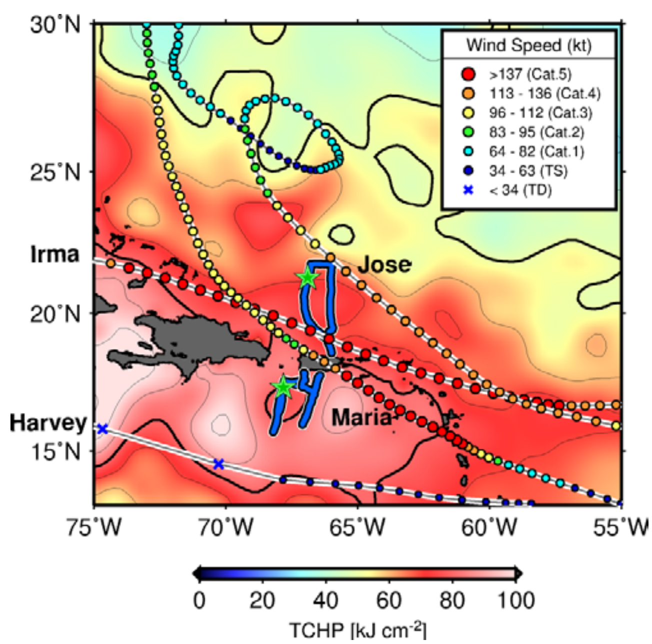

Figure 3: Tracks of major Atlantic hurricanes that travelled over the Caribbean Sea and Tropical North Atlantic Ocean during the 2017 hurricane season. The blue lines indicate the location of some of the underwater gliders, which were parked in fixed locations (green stars) during the passage of the major hurricanes. The background colors show the values of Tropical Cyclone Heat Potential (TCHP) averaged for August 2017, with thin contours every 10 kJ cm^{-2}, and the thick contour indicating 80kJ cm^{-2} and 50kJ cm^{-2}.

All the data collected during Missions 15, 16, and 17 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, new software, sensor calibration, such as the CT sail, so that the best possible data is available for each mission. Consequently, after each refurbishment procedure the science support team then ballasts the gliders to accommodate for their new configurations.

The Hurricane Underwater Glider network will collect ocean observations during the upcoming 2018 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

Ocean conditions of four of the six major hurricanes (Harvey, Irma, Jose, and Maria) of the Atlantic basin are described here. Ocean conditions before, during and after the passage of these hurricanes were continuously monitored by some of these gliders.

Hurricane Harvey travelled in the Caribbean Sea south of Puerto Rico, on August 20, where the upper ocean exhibited TCHP values higher than 80 kJ/cm^2. In this area, underwater glider data showed that a relatively shallow mixed layer favored cooling of the upper ocean, which together with the moderate wind shear contributed to its lack of intensification in that region. Once it reached the Gulf of Mexico, Hurricane Harvey intensified from a tropical depression (30 kts sustained winds) into a Category-4 hurricane (115 kts sustained winds) in less than 48 hours as it travelled over positive TCHP anomalies in the western Gulf of Mexico. Harvey produced the largest amount of rain on record in the continental United States, and caused extensive flooding in the Houston area in Texas.

Hurricane Irma, the strongest TC globally in 2017, reached its maximum intensity (Category-5) on September 6, while traveling over waters north of Puerto Rico and Hispaniola that have TCHP values higher than 70 kJ cm^{-2}. Underwater glider data showed that the upper ocean conditions exhibited low salinity values at the surface, partially suppressing the upper ocean to mix with the colder underlying waters, similar to Hurricane Gonzalo (2014, Domingues et al., 2015, Dong et al., 2017), but opposite to the conditions during Hurricane Harvey. Glider observations also revealed that the upper 50 m of the ocean cooled by approximately 1°C (Figure 4a) as a result of storm-induced mixing.

Hurricane Jose was the third strongest Atlantic hurricane in 2017, and is among the most long-lived cyclones in the Atlantic Ocean. While Jose travelled off Puerto Rico, between 2-3 degrees in latitude to the north of where Irma traveled, its trajectory coincided at time with the cold wake left by Hurricane Irma, therefore experiencing a relatively cooler and well mixed upper-ocean as observed by underwater glider data (Figure 4b). These cooler ocean conditions may have partly contributed to its weakening from Category 4 to 3.

Hurricane Maria travelled in the Caribbean Sea and later through the same approximate area that Irma passed in the tropical North Atlantic On September 20. After entering the Caribbean Sea following a landfall in Dominica, Maria peaked in intensity with maximum sustained winds of 175 mph (280 km/h) and a minimum pressure of 908 mbar, making Maria the tenth-most intense Atlantic hurricane. When Maria path was close to the gliders in the Caribbean Sea, these ocean observations revealed the existence of a very stable barrier layer of approximately 30 m (Figure 4c) depth providing appropriate ocean conditions for intensification. On September 20, Maria made landfall to Puerto Rico as an intense

Category-4 hurricane. Interaction with land further weakened the hurricane, though it regained some strength as it travelled over waters with TCHP values of ~70kJ cm^{-2} north of Hispaniola (Figure 3). Further to the north, Maria became a tropical storm on September 28.

Results presented here describing ocean conditions during TC events, highlights the importance of the ocean observing system for TC monitoring and forecasts. For example, ocean observations during the 2017 show that upper ocean conditions may have favored the intensification of major cyclones.

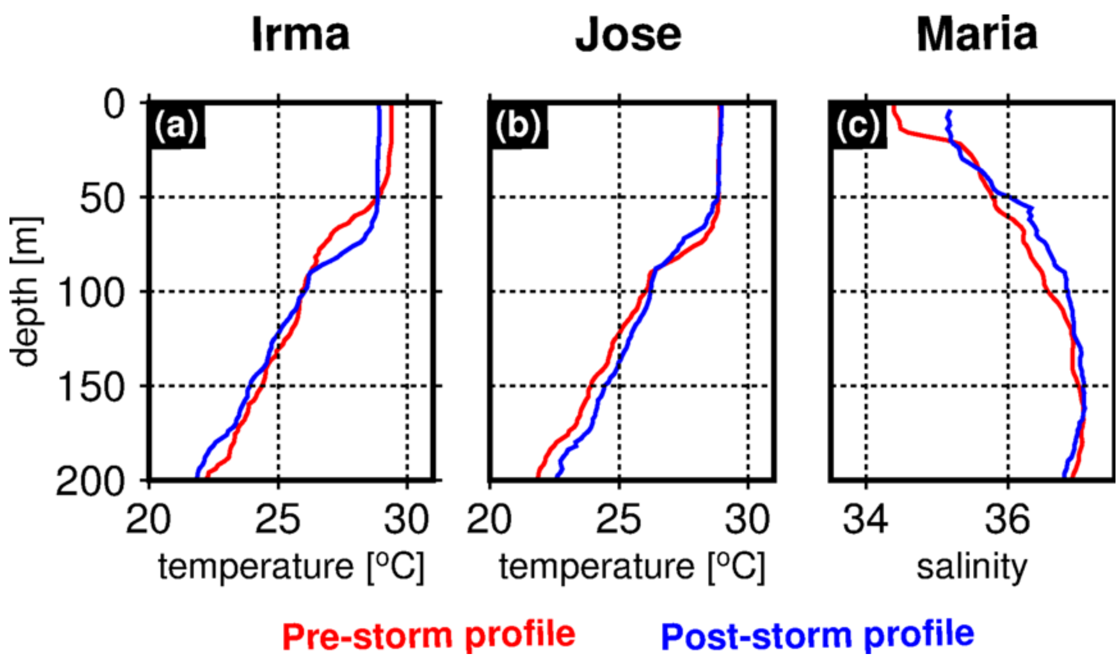

Figure 4: (a, b) Temperature and (c) salinity profiles sampled by underwater gliders before and after the passage of major Atlantic hurricanes in 2017.

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 1, 2017 to June 30, 2018, over 4,200 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.

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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).

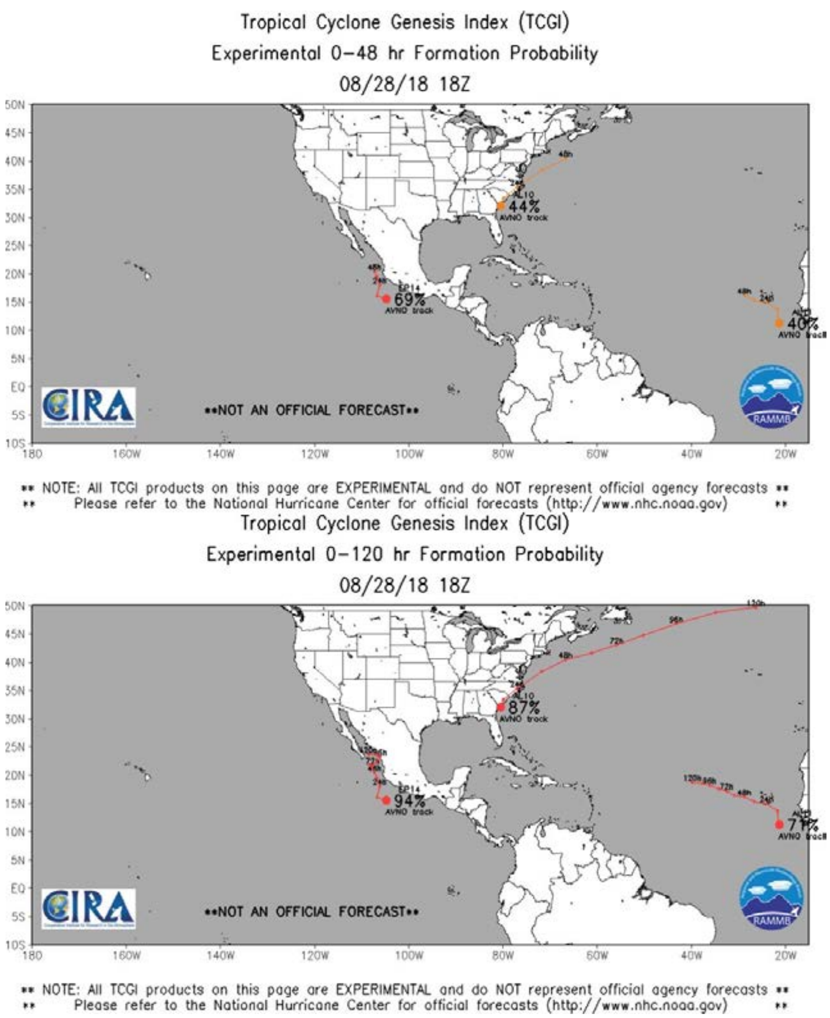

Figure 1: Experimental 48-hr (top) and 120-hr (bottom) graphical versions of TCGI showing 2017 forecasts for AL11 (pre-Hurricane Irma; 30-hr before formation), AL10 (non-developing Potential TC 10), and EP14 (pre-Tropical Storm Lidia; 48-hr before formation). Forecast tracks include positions every 24 hours from 0-120 hours and were derived from the operational GFS model (AVNO). The forecast tracks are colored according to the forecast probability.

Research Performance Measure: This project received a no-cost extension to accommodate IT delays in setting up real-time accessibility to European Centre for Medium-Range Weather Forecasts (ECMWF) model data at NOAA NHC and to allow time for project personnel to run TCGI validation statistics for the new Atlantic and Pacific versions of TCGI. The project team submitted a year-3 no-cost extension report to NOAA in March 2018 and final deliverables are on track for the anticipated August 2018 project completion. The proposal team worked with the Technology & Science Branch (TSB) at NHC to obtain real-time ECMWF tracks and forecast fields needed to run the ECMWF version of TCGI in real-time and real-time tests were successfully carried out. Atlantic and Pacific versions of the updated NOAA Global Forecast System (GFS)-based TCGI and the new ECMWF-based TCGI have been installed and tested on the NCEP supercomputer (WCOSS) and will run in quasi-production for the 2018 season. 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.

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Improving Hurricane Forecasts Using Multimodel Ensembles through Neural Networks Approaches

Project Personnel: T. Ghosh and B. Nag (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: NOAA/AOML
NOAA Technical Contact: Molly Baringer

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).

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.

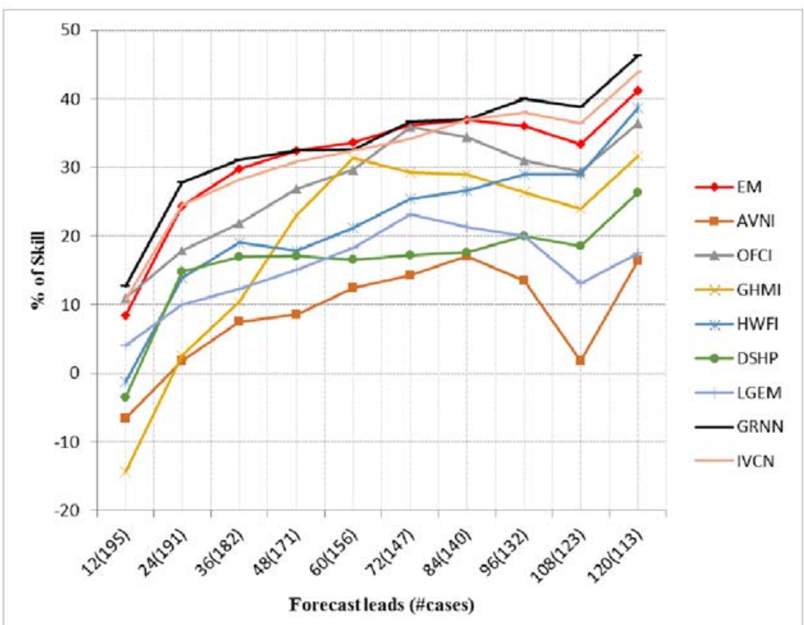

Figure 1: Intensity forecasting skills of GRNN, along with different models, with respect to Climatology and Persistence in case of 2016 season. Ordinate denotes skill based on climatology and persistence, formula provided in text, and the abscissa denotes forecast hours at 12-hour intervals, the number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

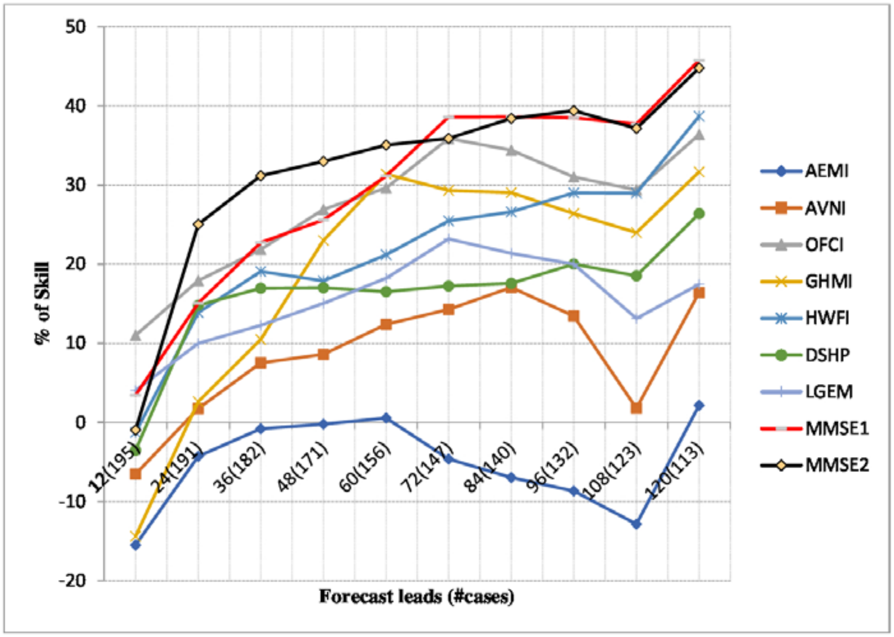

Figure 2: Skills of different models relative to CLIPER5 computed for season 2016. Ordinate denotes skill based on climatology and persistence, formula provided in text, and the abscissa denotes forecast hours at 12-hour intervals, the number of cases are shown in parenthesis.

Research Performance Measure: All proposed milestones were achieved.

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Global Observing System Experiments (OSEs) and Observing System Simulation Experiments (OSSEs)

Project Personnel: A. Kren and S. Casey (UM/CIMAS)
NOAA Collaborators: R. Atlas and L. Cucurull (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To provide quantitative assessments of the impacts of current and 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 Experiments (OSEs) can show us the impacts of current satellites already in orbit and operationally assimilated. Observing System Simulation Experiments (OSSEs), on the other hand, 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 using OSEs and OSSEs, we can demonstrate how large-scale meteorology and changes in observing systems (both current and future) 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.

OSE experiments were performed to evaluate global model forecasts with and without the assimilation of Radio Occultation measurements, infrared and satellite observations, and atmospheric motion vectors. This work was done to evaluate the effectiveness of each satellite platform to increase forecast skill. Experiments were performed using the Hybrid 4DEnVar GFS model that was operational on July 19, 2017 (Q3FY17), with resolution T670 and T254 (EnKF). Two control periods were examined, including northern hemisphere spring (April to May 2016) and summer (August to September 2016), with the verification period covering one month. All instruments denied in the experiments were found to provide value to increasing forecast skill. In particular, removal of the data degrades track and intensity forecasts of tropical cyclones, especially in regards to microwave, radio occultation, and atmospheric motion vector observations.

One area of concern with respect to OSSEs is the representation of known instrument limitations. In the case of the Geostationary Hyperspectral Sounder (GeoHSS) Constellation OSSE, this meant accounting for the impacts that clouds have on IR wavelengths, rendering them unusable in assimilation packages that can only properly account for clear-sky radiances. A number of methods were tested to identify the best way to a) remove observations at a rate that is consistent with removal for real IR observations while b) ensuring that observations that make it past quality control still have a somewhat positive impact on the analysis. This new method applied well to both simulations of currently operational instruments as well as to the test GeoHSS Constellation.

In accordance with HB353 (2017), a summary of initial GeoHSS Constellation results was submitted on August 16th, 2017. Additional work helped refine these results, and showed a near-universal improvement of analysis state with the assimilation of the GeoHSS Constellation instruments. Forecast results were more mixed, with positive impacts on 5-day forecasts noted in the Northern Hemisphere but slightly negative impacts noted in the Southern Hemisphere. Additional work to investigate the reason for this forecast-skill difference is ongoing. Over the next year, additional OSSE work will assess observations simulated from a new nature run, as well as completing a transition to running OSSEs in a Hybrid 4DEnVar framework.

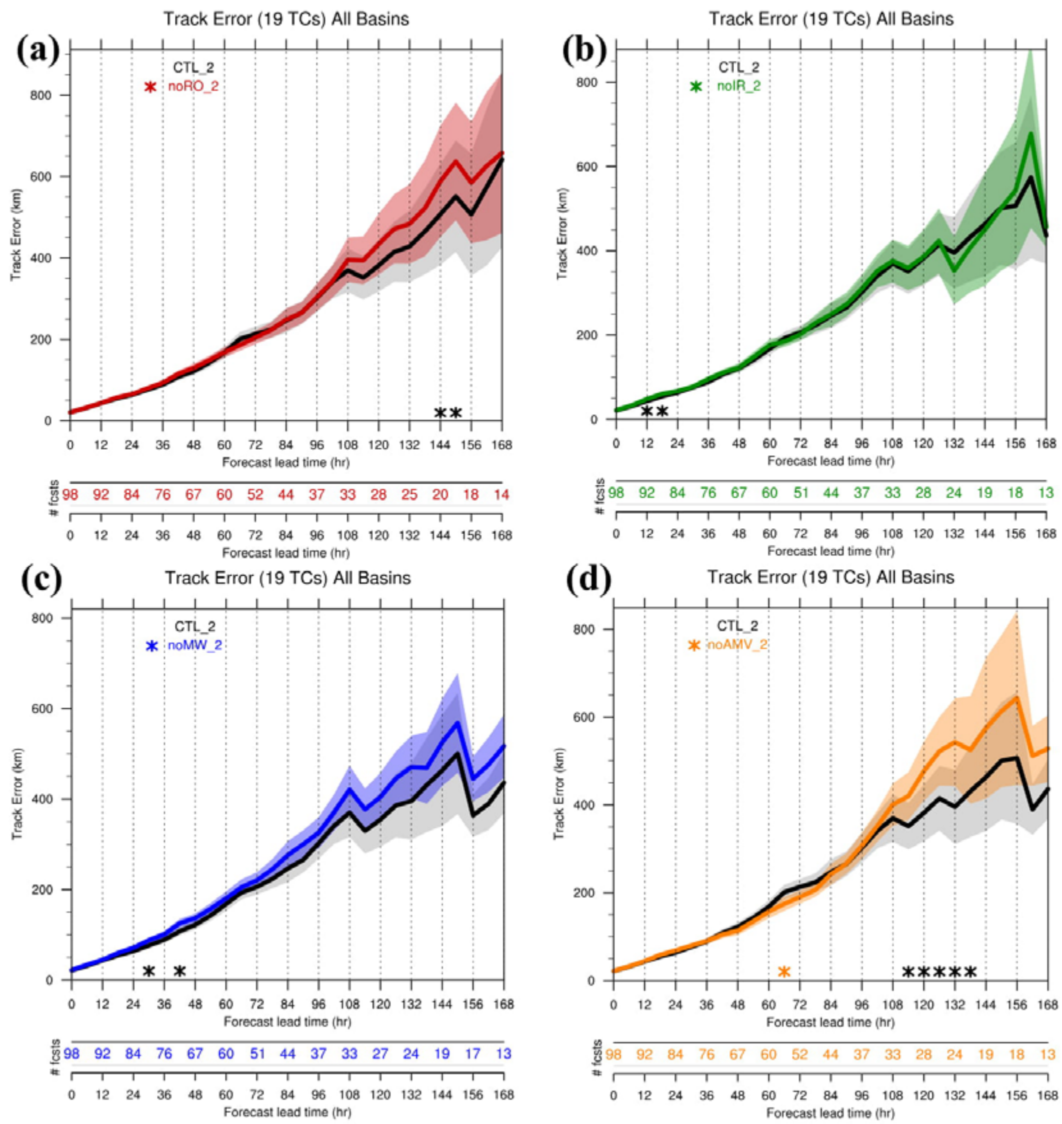

Figure 1: Average absolute track errors (km) during August and September 2016 for 19 tropical cyclones for four OSE experiments: CTL_2 (black; operational configuration), (a) noRO_2 (red; no radio occultation assimilated), (b) noIR_2 (green; no infrared satellite assimilation), (c) noMW_2 (blue; no microwave satellite assimilation), and (d) noAMV_2 (orange; no atmospheric motion vector assimilation), as a function of forecast lead time out to 168 hrs. The number of forecasts (# fcsts) at each lead time for each experiment is shown. Stars denote that differences between the experiments are statistically significant at the 95% confidence interval using a paired t-test. Included in the average track errors is the 1σ sample standard deviation of each experiment (shaded regions). Track error with respect to the default operational configuration is degraded beyond 108 hrs without radio occultation assimilation, neutral overall without infrared observations, degraded at all forecast lead times without microwave satellite data, and significantly degraded without atmospheric motion vectors after 108 hrs.

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

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 todefine 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.

Research Performance Measure: The program started thirteen month ago and is on schedule. The HWRF ensemble forecasts of hurricane Edouard (2014) have finished and detailed analysis has been conducted. A peer reviewed paper has been published on Journal of Atmospheric Sciences.

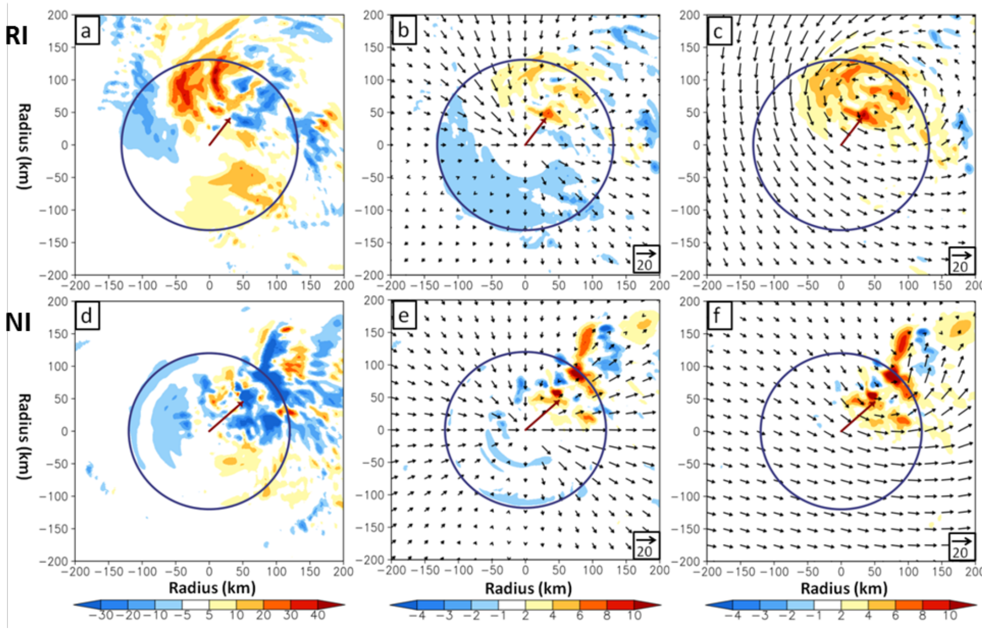

Figure 1: Horizontal cross sections of (a) eddy radial vorticity flux (unit: m s^{-1} hr^{-1}), (b) eddy radial component of storm-relative flow (vector) and eddy vorticity (shading, unit: 10^{-4} m s^{-2}), (c) storm-relative flow (vector) and vorticity (shading, unit: 10^{-4} m s^{-2}) averaged between 6-10 km and -3 h – 0 h. (d)-(f) are the same as (a)-(c) but for the NI member averaged between -7 h – -4 h. Dark blue circles indicate the RMW, and red arrows denote the shear vector.

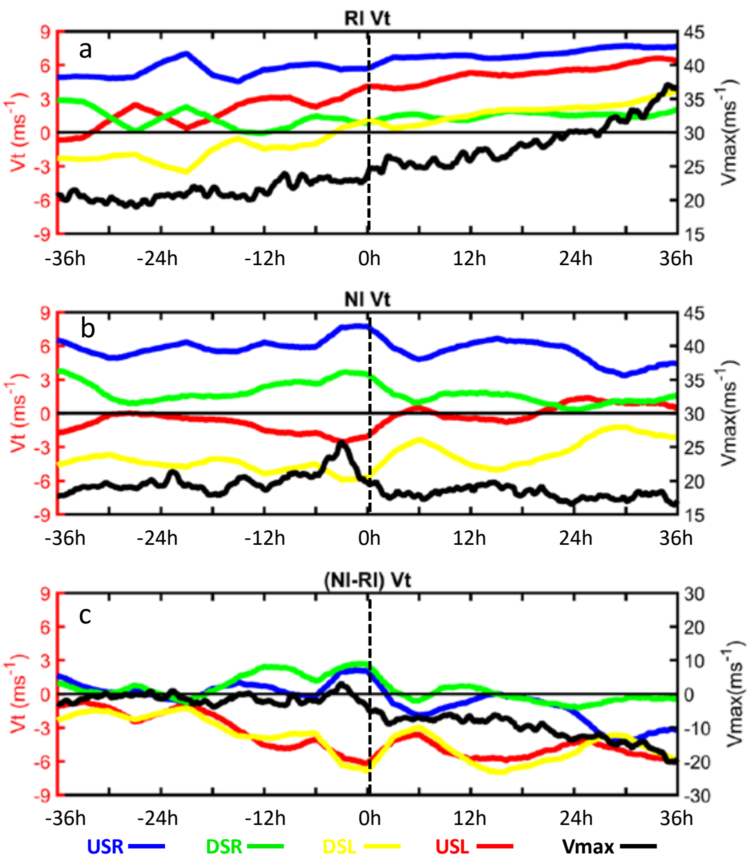

Figure 2: Time series of the composite tangential component of environmental wind in shear-oriented quadrants averaged between 6-10 km altitude within a 500-km radius for (a) RI members, (b) NI members, and (c) the difference between RI and NI members.

Preservation of flight level data from NOAA aircraft

Project Personnel: S. Otero (UM/CIMAS)
NOAA Collaborators: J. Williams (NOAA/AOC); S. Murillo (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To make NOAA aircraft flight level data usable, documented, discoverable and accessible through the data portal of the National Centers for Environmental Information (NCEI).

***Strategy*:** To automate transformation of historical datasets to generate their associated NetCDF and geographic metadata standard.

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:

NOAA's Aircraft Operation Center (AOC) flies into some of Earth's most intense weather systems collecting critical environmental data for operations and research. These data, if made available, will support all of NOAA's goals: Climate Adaption and Mitigation, Weather-Ready Nation, Healthy Oceans, and Resilient Coastal Communities and Economies. AOC has many data sets from missions conducted in hurricanes, strong winter storms, and near severe weather. Prior to 2009, much of the data collected is locally stored in unusable and non-standard formats.

Through funding from the Big Earth Data Initiative (BEDI), supported by the US Group on Earth Observations (USGEO), AOC seeks to improve the discovery, access and use of federally held Earth-system data with a high impact for public- and private-sector decision-making.

The guidance and recommendations of the USGEO Common Framework for Earth Observations on standard protocols and implementations aim to increase interoperability among Federal agencies and harmonize activities with current data-management practices. By following internationally accepted standards such as the NetCDF Climate and Forecast Metadata Conventions (CF), rich metadata can be extracted from NetCDF global and variable attributes to provide documentation about the datasets that correspond to general discovery metadata content conforming to the ISO 19115-2 geographic standard.

Having a definite description of what the data in each variable represents, and the spatial and temporal properties of the data, enables users to decide which quantities are comparable and facilitates finding and assembling data from diverse sources for improved analysis.

At AOC, the initial task involves procuring NetCDF files with raw data for each flight mission. Software was developed to automate the conversion of 1000+ sets of raw flight level data collected from WP-3D and G-IV aircraft missions from 1996 to 2009. These files are far from being CF-compliant, lacking the bare minimum required attributes, such as title, summary, keywords, institution, date created, just to name a few. Through the use of NcML, the NetCDF Markup Language, one has the ability to create virtual datasets that point to the original dataset while manipulating global and variable attributes to achieve CF compliance.

The installation of the UCAR THREDDS (Thematic Realtime Environmental Distributed Data Services) Data Server with its integrated ncISO service provides built-in generation of the ISO 19115-2 metadata based on mappings to the NetCDF attributes. Once the resulting minimally manipulated NetCDFs are loaded into a local THREDDS web server, both the data and its associated ISO XML metadata are catalogued.

The degree of ISO-compliance completeness can be assessed at NCEI Record Services website, by uploading any of the THREDDS-generated XML metadata files. The current score lays at 12/41, a low score but an improvement over the 0 score intrinsic to the original NetCDFs. The ultimate goal is to achieve much higher levels of CF-compliance, so the AOC data can be easily made discoverable in the NOAA Data Catalog (http://data.noaa.gov), managed by NCEI, and hence searchable by other automated search engines and catalogs.

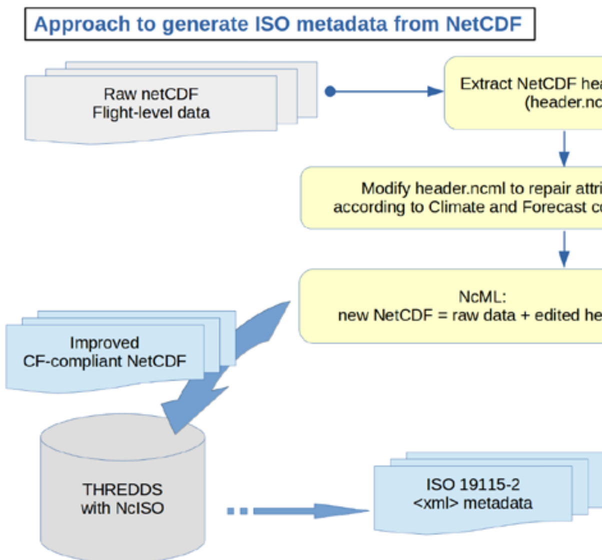

Figure 1: Flow diagram describing steps to produce ISO 19115-2 metadata from NetCDF.

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 and L. Bucci (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 which spans the life cycle of a rapidly intensifying Atlantic hurricane. 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 initial 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. For this reason, all results are provided in terms of the radius of gale-force winds.
Preceding studies examined the radial distribution of G-IV dropsondes, where a positive impact on track forecast is apparent out to almost 2 days when using data obtained closer to the vortex compared to a much shorter-term impact using a flight track at twice that distance. Although a positive impact on intensity forecasts beyond 48 hours is shown for both radii, there is little distinction between the two radial distances. Differences in synoptic-scale environment provide the largest contribution to the improvement in track prediction when assimilating dropsonde measurements near the radius of gale-force winds. This is due to their influence on the strength and location of the vortex within the synoptic scale frontal boundary and subtropical ridge patterns. The sensitivity to azimuthal location of these measurements includes OSSEs for each distribution determined by azimuthal location relative to the storm center position. Results were largely inconclusive but illuminated the need for better coverage near the vortex.

As a continuation of the aforementioned studies, sensitivity experiments addressing flight pattern design were performed. Figure 1 displays three of the flight patterns tested in these experiments where the first pattern is a single circumnavigation flight track as used in the previous experiments. The additional patterns shown are the star and concentric circumnavigation flight tracks. Figure 2 shows the tropical cyclone track errors averaged over all cycles in the experiment. The use of a concentric circumnavigation flight track provides the largest positive impact on track forecasts out to 3 days. Longer-term impacts are dominated by an approaching frontal system. Figure 3 depicts the deep-layer mean wind field for each of the experiments at an analysis time during rapid intensification. The largest differences exist near the vortex, where the concentric circumnavigation configuration best captures the core region. Although the vortex is much better constrained by the alternative patterns at the analysis time, the intensity forecast errors do not differ among different configurations. However, differences in the synoptic-scale environment are marginal at best, thus implying that the improvement of the core contributes to the track forecast improvement for this case.

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 when 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 the upgraded OSSE framework.

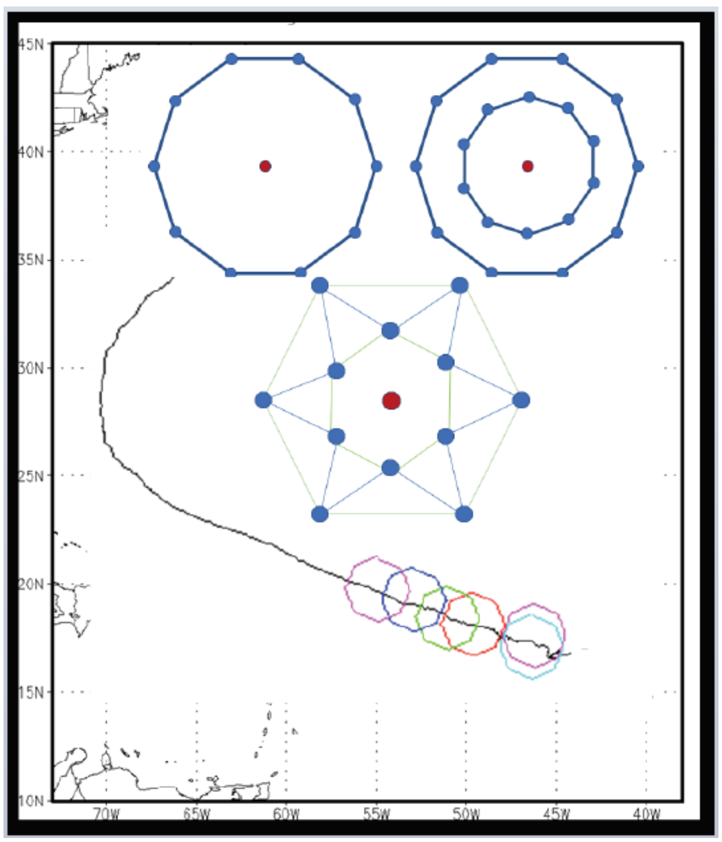

Figure 1: Configuration of three flight tracks tested in the sensitivity experiments: circumnavigation, star, and concentric circumnavigation.

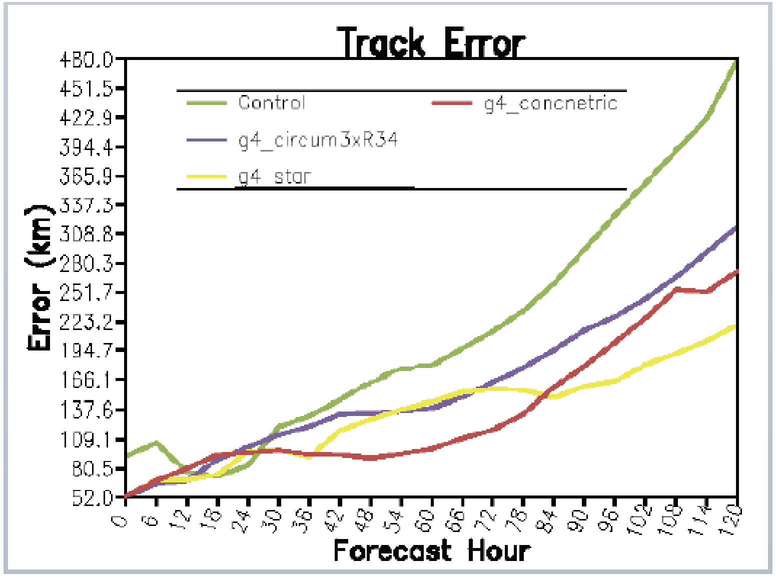

Figure 2: Comparison of absolute track errors among configurations where green is the control, purple is the single circumnavigation design, yellow is the star design, and red is the concentric circumnavigation design.

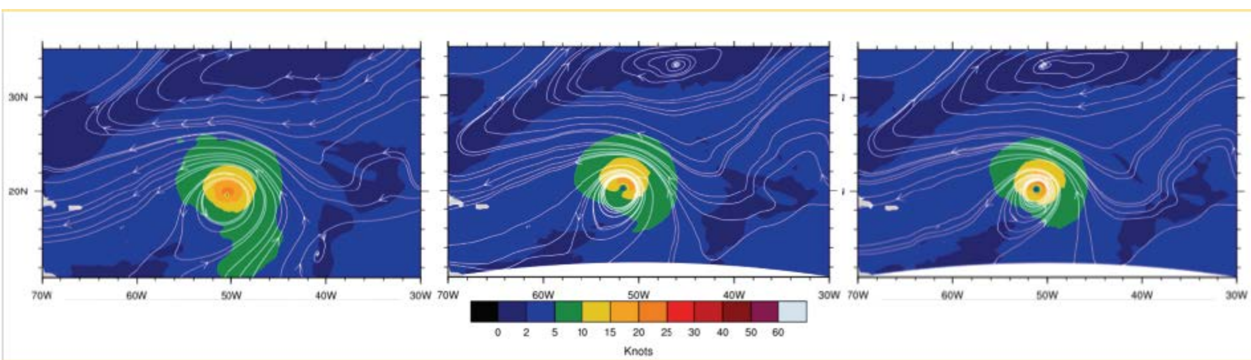

Figure 3: Deep-layer mean winds at analysis time during rapid intensification: (a) nature run field, (b) star configuration analysis field, and (c) concentric circumnavigation configuration analysis field.

Research Performance Measure: This project is on track.

A Twenty One-Year Tropical Cyclone Global Positioning System Dropwindsonde Dataset

Project Personnel: K. Sellwood (UM/CIMAS)
NOAA Collaborators: S. Aberson

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To gather, organize, quality control, and make publicly available all GPS dropwindsonde data collected in and around tropical cyclones and provide support for scientists who wish to use the data in their research.

***Strategy*:** To systematically organize data from past years and incorporate new data as it becomes available.

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:

Since 1996, NOAA, the United States Air Force, and other international agencies have been releasing dropwindsondes in and around tropical cyclones to obtain wind velocity, temperature, humidity, and mass observations from flight level to the ocean surface. These observations are used operationally by meteorological centers to diagnose current conditions and to improve initial conditions of numerical weather prediction models. After the fact, these data are invaluable to researchers in studies of tropical cyclone dynamics and thermodynamics, and in studies of targeted observations and predictability, as well as in climate research. Hundreds of these profiles are obtained annually in the Atlantic and northern Pacific Oceans, and soon may become available in the Indian Ocean. In this program, we gather, organize, and quality control, all GPS dropwindsonde data in and around tropical cyclones. The data is further processed to produce more user-friendly file formats and to provide metadata. We subsequently make these data available to the broader community and provide support for other scientists who wish to use the data for research. These data are organized and made freely available on an ftp site or via the AOML webpage.

This past year, data in the BUFR format used by operational model data assimilation systems was added to the suite of products which are produced. An additional benefit of this format is that it provides unique time and location information with each data point, a feature which is particularly important for hurricane observations. Since NOAA and other aircraft do not yet have the capability to transmit the BUFR data, a method was developed for obtaining time and locations for the format which is currently sent from the planes. This technique is documented in a peer-reviewed journal article and is expected to be implemented during the 2018 Atlantic hurricane season. Support for the modeling community is also provided by research on how best to specify the errors associated with these measurements for data assimilation. Improved location information and error estimates can help increase the overall benefit of assimilating dropwindsonde data into numerical forecast models.

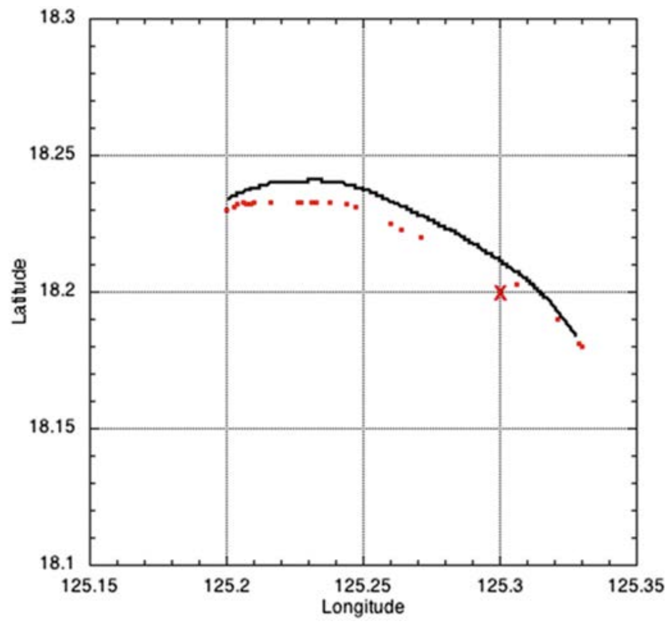

Figure 1: Location estimates for a single dropwindsonde using the values derived from the technique described in Aberson etal, 2017 (red) compared with the actual locations (black) available in the bufr format. The "X" marks the single location which would have been used for data assimilation without this procedure.

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

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An Observing System Experiment for the Hurricane Imaging Radiometer

Project Personnel: K. Sellwood and A. Aksoy (UM/CIMAS)
NOAA Collaborators: S. Aberson (NOAA/AOML)
Other Collaborators: W. Linwood Jones (UCF); D. Cecil (NASA/MSFC)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To assess the potential value of observations obtained using unmanned aircraft and new instrument technology for improving forecasts of Tropical Cyclones.
***Strategy*:** Perform observation system experiments (OSE) to evaluate the impact of assimilating Hurricane Imaging Radiometer (HIRAD) observations into NOAA's operational Hurricane Weather Research and Forecast (HWRF) 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: NOAA/OAR/AOML
NOAA Technical Contact: Molly Baringer

Research Summary:
The hurricane imaging radiometer (HIRAD) was developed for use on high-altitude un-crewed aircraft to obtain ocean surface wind speeds and rain rates in the vicinity of tropical cyclones. The instrument design is based on the same technology as the Stepped Frequency Microwave Radiometer (SFMR) which is now standard on NOAA and U.S. Airforce hurricane hunter aircraft. Unlike the SFMR which is only capable of measuring directly below the plane, the HIRAD antenna allows the instrument to collect data in a horizontal swath across the aircraft track. This extended "view" of the ocean surface provides crucial information for estimating the magnitude and extent of damaging winds and has the potential to improve forecasts when assimilated into numerical models. Because of this advantage, NOAA's Aircraft Operations Center is considering adding HIRAD to its current suite of instruments. To assess the potential benefit of assimilating HIRAD observations into NOAA's operational Hurricane Weather Research and Forecast (HWRF) model and provide insight into how these data impact the forecast relative to SMFR, a set of three observing system experiments (OSEs) were performed using NOAA/AOML's in-house Hurricane Ensemble Data Assimilation System (HEDAS; Aksoy et al. 2012).

The experiments indicated that the benefit derived from HIRAD data could be increased by making changes to the way the observations are assimilated. Relatively fewer, longer data assimilation windows allow more data above the surface to be included and provide time for the model to adjust. Reducing the distance at which the observations are able to influence the model also had a positive impact. These results are expected to be applicable to the assimilation of any surface wind speed observations, including SFMR. When assimilated in the optimal manner, HIRAD observations were found to improve the initial analysis of TC structure as well as the forecasts initialized from those analyses. Analyses and forecasts were slightly better, i.e., closer to observed, when both SFMR and HIRAD were assimilated mainly due to the higher resolution of the SFMR data along the flight track. These results indicate that HIRAD data have potential benefits for improving hurricane forecasts, particularly in addition to conventional SFMR observations. HIRAD and SFMR could provide greater value with adjustments to the data assimilation scheme used to ingest the observations. The results of these experiments have been presented at the AMS 33rd Conference on Tropical Meteorology and are currently being prepared for submission to a peer-reviewed journal.

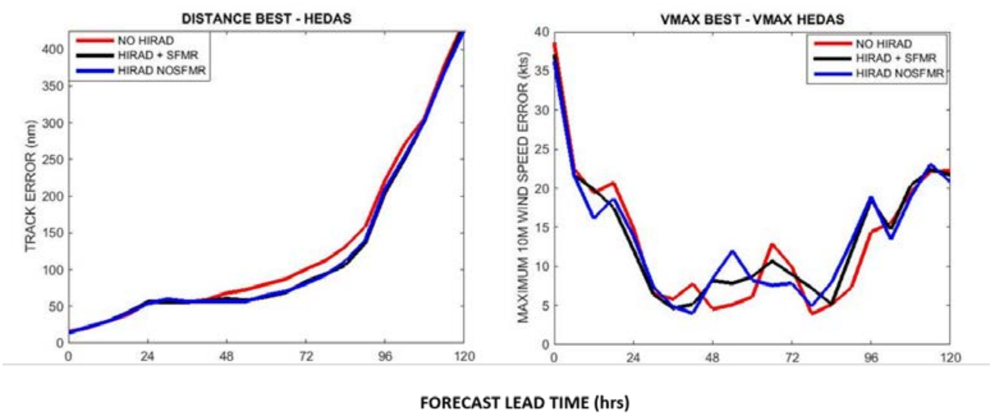

Figure 1: Maximum wind speed and track error averaged over all experiments. HIRAD observations improve the intensity forecast out to about 48hours and the track forecast at nearly all lead times. In general HIRAD combined with SFMR produces the best results.

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

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:

The objective of this work was 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. By comparing distributions of passive microwave (PMW) brightness temperature, which serve as proxies for precipitation organization, we could quantify biases in model forecast precipitation organization. The framework developed under this project can subsequently be used to accumulate statistics over multiple cases, which will facilitate better quantification of those biases. 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.

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).

We first compared 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.

We also compared 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.

Research Performance Measure: Many of the steps towards meeting the overall objective were completed and the work on the subaward is now complete. While our objective was broad and would require significantly more time to complete than what was proposed for the subaward, 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.

Addressing Deficiencies in Forecasting Tropical Cyclone Rapid Intensification in HWRF

Project Personnel: J. Zhang, H. Leighton 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.

We analyzed retrospective HWRF forecasts and compared composited structure at the onset of RI to evaluate the impact of the improvement in the vertical eddy diffusivity on RI forecasts. Dr. Zhang led this effort and documented this result in *Monthly Weather Review*. Dr. Zhang also led the effort of improving HWRF model physics of horizontal diffusion parameterization in collaboration with EMC. Dr. Zhang found that the horizontal mixing length used in the HWRF model was too large compared to the observational result published by Dr. Zhang. Reducing the horizontal mixing length in the operational HWRF model led to 10-15% improvement in the intensity forecast (Fig. 1). Forecasts of biases of both the intensity and storm size were also significantly improved (Fig. 2).

This project also 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. Dr. Leighton led the effort of analyzing the HWRF ensemble forecasts of Hurricane Edouard (Fig. 3). Composite analyses of the TC structure for RI and non-RI members showed that the interaction of the TC inner-core deep convection and environmental flow is very important for RI. The radial eddy vorticity flux is also fund to be important for rapidly spinning up the TC vortex in a sheared environment. This work was published in Journal of the Atmospheric Sciences led by Dr. Leighton. Analysis led by Ms. Sellwood showed that all RI and non-RI forecasts started out with similar, broad and weak vortices. Both sets of forecasts maintained similar intensity up until the period between 48 and 72 hours, when the tangential wind field in the RI members started to become more vertically aligned and the radius of maximum wind speed moved inward by nearly 100 km (Fig. 4). On the other hand, the non-RI members initially contracted and strengthened but were unable to maintain the smaller stronger structure. Composites of the boundary layer structure were also compared between the RI and non-RI members, showing significant difference in the inflow strength and convergence between these two sets of Edouard Forecasts.

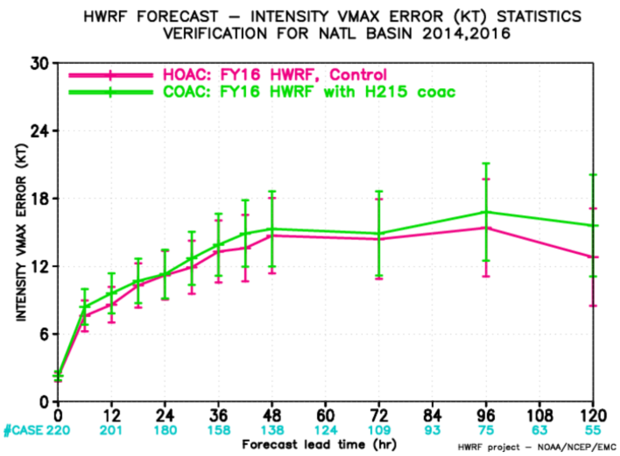

Figure 1: Plots of the absolute error for intensity in HWRF retrospective forecasts of with two different setups of the parameterization of horizontal diffusion in terms of the horizontal mixing length (L_h). In the control experiment (referred to as HOAC), L_h = 800 m as in H216, while the other experiment 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.

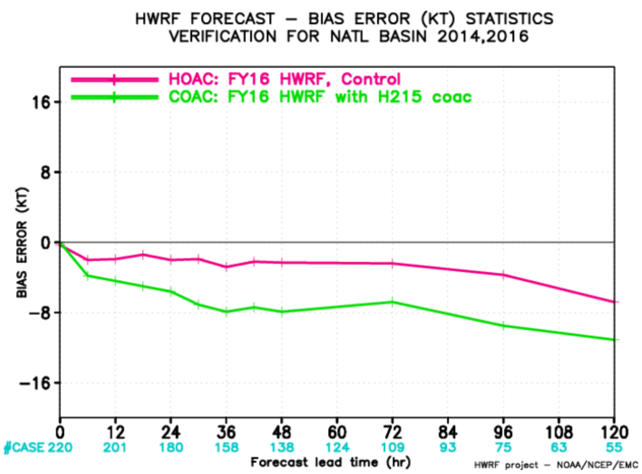

Figure 2: Plots of the biases in intensity in HWRF retrospective forecasts of with two different setups for the parameterization of horizontal diffusion in terms of the horizontal mixing length (L_h). In the control experiment (referred to as HOAC), L_h = 800 m as in H216, while the other experiment used L_h=1900 m and the same 'coac' value as in H215 but with the H216 model.

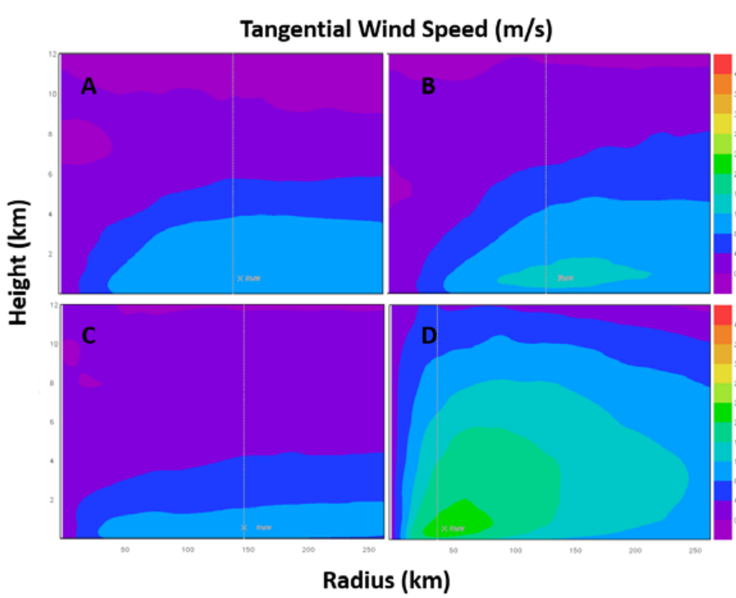

Figure 3: Plots of maximum wind speed from HWRF ensemble forecasts of RI memebers (blue) and non-RI members (black). The best track estimate from the National Hurricane Center is shown in red.

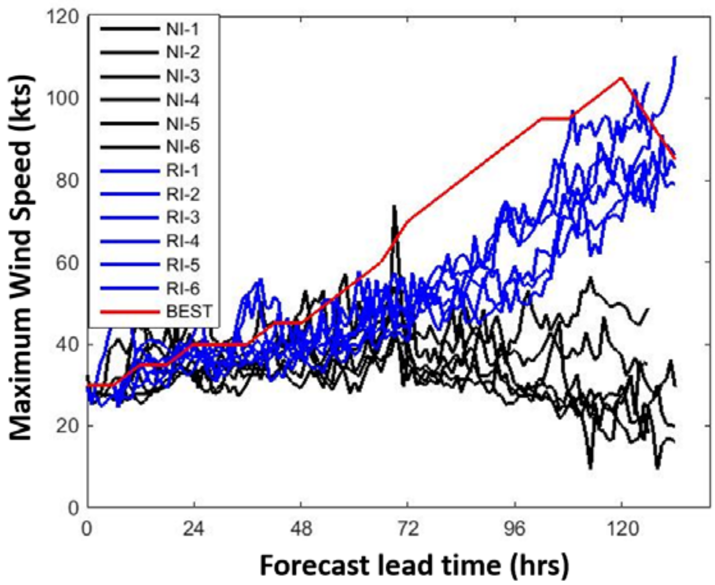

Figure 4: Azimuhtal mean strcucture of tangential wind speed averaged over all 6 ensemble members at 48 h for non-RI (A) and RI (B) and at 72 h for non-RI (C) and RI (D) forecasts.

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 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) and wave model basin for Hispaniola by integrating the boundary condition data from various remote sensing platforms and the related agencies in Haiti and the Dominican Republic in geographic information system (GIS) and updating current basin development tools used by NHC.

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

CIMAS Research Theme:

***Theme 2*:** Tropical Weather

Link to NOAA Strategic Goals:

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

NOAA Funding Unit: 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: We have examined the quality of the TanDEM-X data for Hispaniola by comparing TanDEM-X data with more than 2,000 GPS measurements in The Dominican Republic and the LiDAR data in Haiti. We have selected the best filter for TanDEM-X data by comparing the DTMs from TanDEM-X data generated by four filtering methods with the DTM from LiDAR. We have generated a 12 m DTM for Hispaniola by filtering and interpolating TanDEM-X data and integrated this data with bathymetric data to generate SLOSH inundation maps.

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Hurricane Moving Nest for FV3

Project Personnel: X. Zhang (UM/CIMAS)
NOAA Collaborators: S. Gopalakrishnan and F. Marks (NOAA/AOML); A. Mehra and T. Black (NOAA/NCEP/EMC); L. Harris, Z. Liang and S.-J. Lin (NOAA/GFDL)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** To improve the hurricane forecasts by using the NCEP's unified Earth modeling system.
***Strategy*:** 1-To develop a new capability of movable nest in the Next-Generation Global Prediction System (NGGPS) FV3GFS; 2- To develop the next-generation Hurricane Analysis and Forecast System.

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

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

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

Research Summary:
NHC, NCEP, and FIU propose to develop the Maximum Envelope of Water (MEOW) and Maximum of Under the Strategic Implementation Plan (SIP) for the Next Generation Global Prediction System (NGGPS), the National Centers for Environmental Prediction's modeling system is developing a unified Earth system modeling system that functions on temporal scales from seasonal to sub-seasonal (S2S) on the order of months, down to short-term weather prediction on the order of hours to days. To align the development priorities, OAR's Office of Weather and Air Quality (OWAQ) funded this project to

accelerate the moving nest development in the unified modeling system: FV3GFS. The project officially began 08/1/2017.

Based on the GFDL's static nesting FV3, AOML/HRD successfully ran the nesting FV3 end-to-end system on jet. We also set up the EMC's visualization software on Theia to visualize the FV3 simulations. Under the guidance of SIP, we developed the movable next algorithm within the current FV3GFS framework (Fig. 1) and designed the development roadmap within the next two years (Fig. 2). We also established the close collaboration among the GFDL, EMC, AOML and CIMAS.

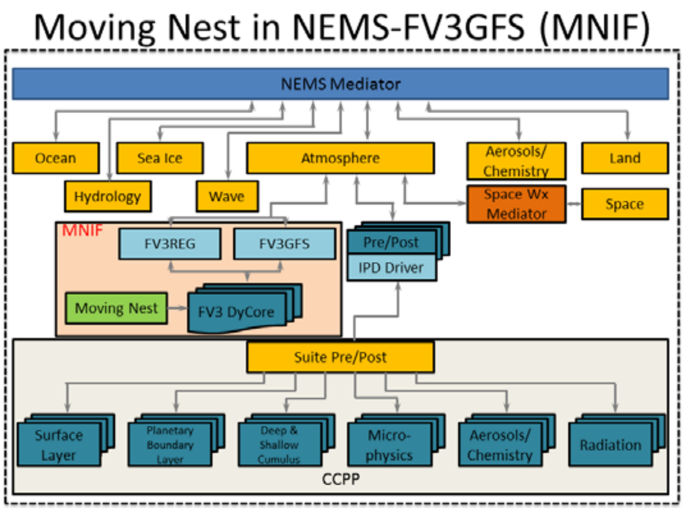


Figure 1: Cartoon from SIP presentation showing how high-resolution nests moving seamlessly within the 6 faces of the FV3 cube sphere grid. For example, nest in position A and B crosses the edge of face 1 and face 6. The nest will stay on one projection. The feedback and downscale at the leading edge of the moving nest will be on the interchangeable equivalent projections between face 1 and face 6 in this instance. The design will guarantee the physical equivalence in the finite volume framework on different cubic faces.

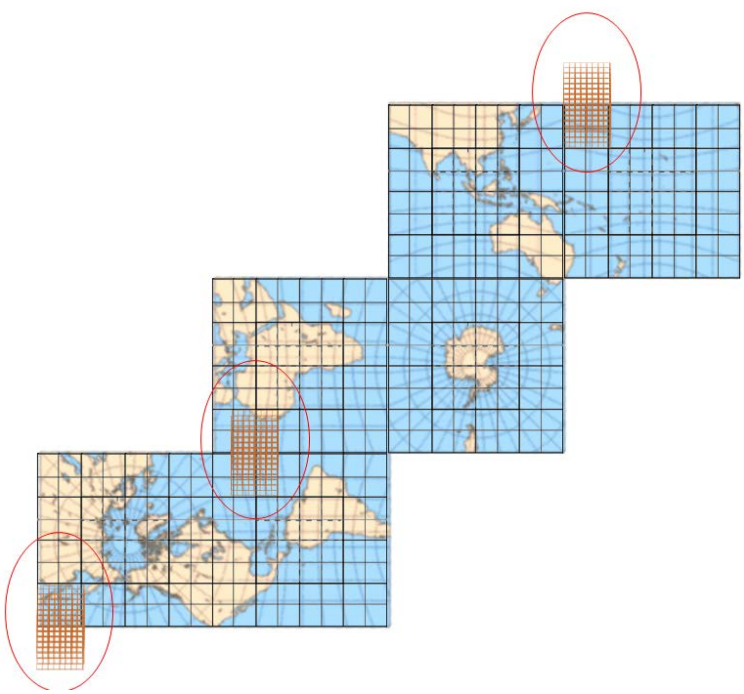
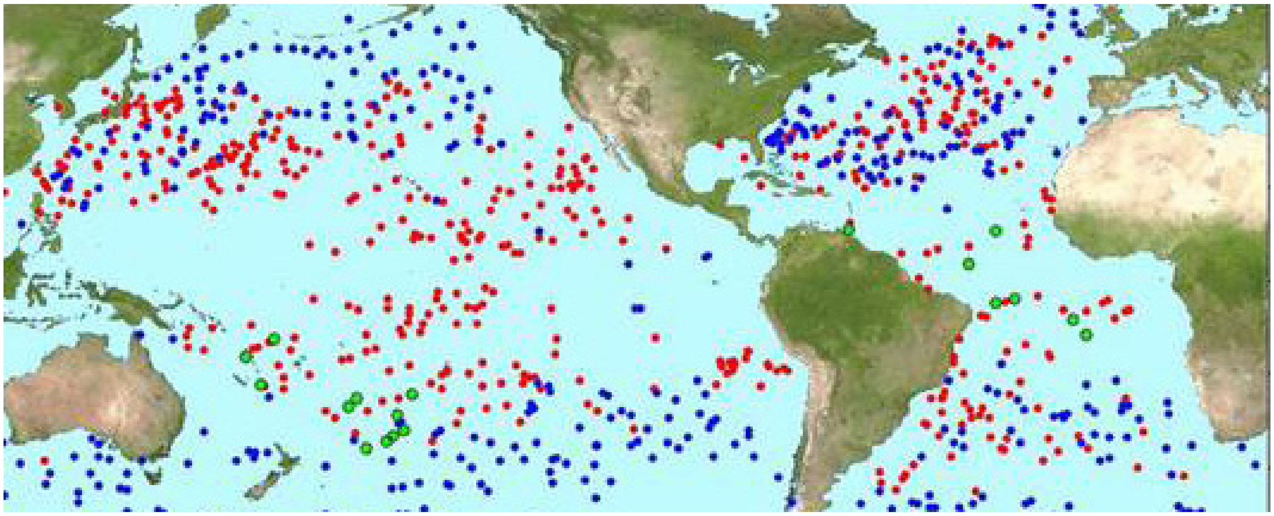


Figure 2: Moving nest development in the NEMS-FV3GFS system framework. The MNIF can be applied in both FV3REG (Regional FV3GFS system, under development) and FV3GFS (Global FV3GFS)

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 and R. Sabina (UM/CIMAS)
NOAA Collaborators: C. Schmid and M. Baringer (NOAA/AOML)

Long Term Research Objectives & Strategy to Achieve Them:
***Objectives*:** To improve our understanding of interannual to multidecadal ocean variability and its role in climate.
***Strategy*:** To monitor ocean parameters over large areas of the ocean through the maintenance of an array 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 (US DAC) at AOML is responsible for deploying floats, and for acquiring and processing the data. The US DAC has developed and maintained an automatic system for decoding, quality control, and distribution of data obtained from the US Argo floats in real-time. The system runs in a 24/7 mode. The data are open to the public, and are used by scientists working on climate models and oceanographic data analysis.

Some of the accomplishments during this time period are:

- 354 floats were deployed by the USA institutions.
- 55 of these floats were deployed jointly by AOML and CIMAS.
- 2,458 US floats actively reported data during this period.
- 87,751 profiles approximately have been distributed on Global Data Centers.
- 76,760 profiles approximately were sent to GTS by the US DAC where 94% of them were distributed during the first 24 hours since the data profiles were obtained.

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 with Bio-chemical data (BioARGO BR files) for the Global Data Center (GDAC), so we are producing Version 3.1 NetCDF files for nearly all types of floats.
- We are also producing ARGO Version 3.1 profile NetCDF Meta-file, Trajectory and Technical files for core-ARGO realtime files.
- Tracked down a number of Fortran Fun-time-erros in internal read and write statements.
- Complete revision of how the PROFILE_<parameter>_QC NetCDF variable is determined.
- Better identify bad lines in the profile data, usually caused by satellite transmission errors, resulting in data line with data values of zero.
- Eight new instrument types were added to the types we process.
- Change to how profiles identified as "frozen profile" are handled.
- A new table, the sensor_parameters table, was added for the Trajectory file.
- Modifications were made in the determination of the VERTICAL SAMPLING SCHEME in profiles.
- Modifications to produce a NetCDF file for the Meta data before any profiles have been received for the float.
- Change to accommodate profiles with no "standard" primary profile. Create a NetCDF files with two profiles, but missing data flag n nprof=1. This was done for both core-ARGO and BioAROG file types.
- Changes to use the PSAL (salinity) flags in CNDC (conductivity) profile data.
- If no "normal" parameters are available to determine the Julian daytime of a profile (ascent end, transmission start, normal position block) a new parameter PROFILE_UPLOAD_TIME_QC will be used, if available.
- General messaging is being revised. Change to "WARNINGS" are nearly finished, and change to "FATAL & NON-FATAL ERRORS are in progress. Writes to trace, log and error output files are also being modified.

Decoders/data ingestion software developments:

- Decoding capability for an Iridium float (NAVISIR_TSOPJ2) is added
- Software that checks the completeness of supplied data files has been adapted to process new float types SOLODIR_TS38 from PMEL and ALTOIR_TS12 from WHOI
- Updated existing programs for generating .bufr format files from NetCDF files, and also included data from Bio-Profile NetCDF files
- Modifications to existing software has been made to handle variance between AOML generated real time Bio-profile and UW supplied generated real time files.
- FTP software has been modified to reduce the overall time taken to find and transfer NetCDF files from AOML to public server.
- Argo Web page on AOML's web server was updated.
- Developed new and revised existing software as needed due to new or changing requirements.

Creates and maintains documents on the architecture and use of the software.

- Revised software to download GDAC index tables for data tracking during transition to another computer. Software to clean up certain directories as well as for backups to our mirror as part of the transition.
- Developed the software and wrote documentation including instructions to consolidate argo.init and argo.rc system files. The purpose of this software is to facilitate switching operations between mirror systems.
- Developed software to find missing cycles and to generate them for Argos floats.
- Created documents of the architecture and use of the software

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

US Argo Atlantic deployments were coordinated and done by AOML. During the past year, several deployments of Atlantic Argo floats were made by CIMAS and NOAA personnel on scientific cruises and from ships of opportunity. Vessels are constantly sought out to assist with the deployment of Argo floats. Planning and logistics for these cruises are done in coordination with WHOI to ensure the number of floats available for the cruise, and ensuring that the ship and the scientific parties have space and are able to deploy the floats.

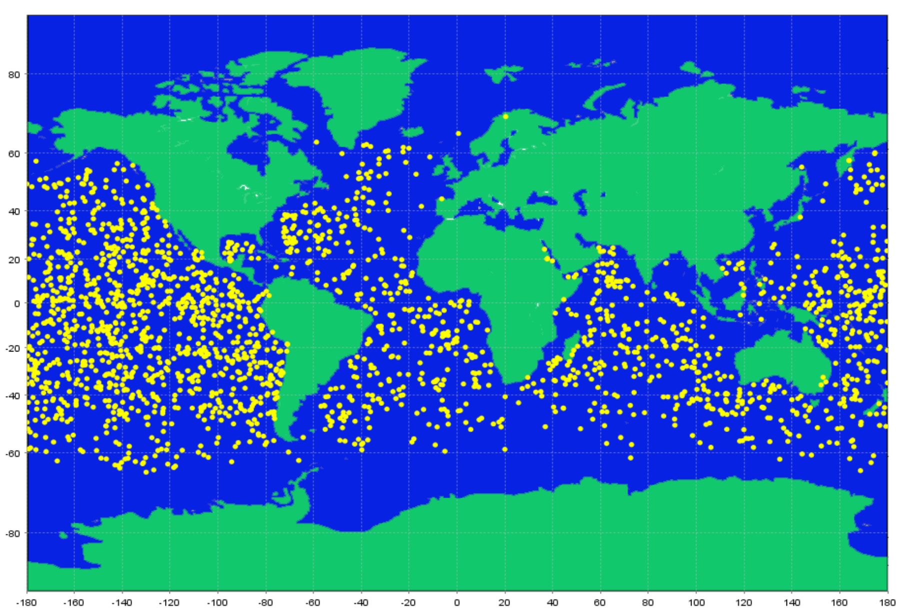


Figure 1: Location of US Argo floats in July 2018.

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

Are Eastern Tropical Pacific Coral Reefs Becoming More Resilient to ENSO?

Project Personnel: A. Baker (UM/RSMAS)
NOAA Collaborators: D. Manzello (NOAA/AOML)
Other Collaborators: P. Fong (UCLA); T. Smith (UVI); P. Glynn (UM/RSMAS)

Long Term Research Objectives and Strategy to Achieve Them:

Objective: To study the long-term response of coral reefs in the tropical eastern Pacific (Panama) to the El Niño event of 2014-16.

Strategy: To undertake a field expedition to the reefs of the Gulf of Chiriqui (Uva Is.) and the Gulf of Panama (Saboga Is.) to collect environmental data and samples.

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: OAR/AOML
NOAA Technical Contact: Molly Baringer

Research Summary:

Our research team received an NSF RAPID grant to investigate the impact of the predicted 2014-2015 El Niño-Southern Oscillation (ENSO) on the resilience of coral reef ecosystems in the eastern tropical Pacific. While we successfully captured bleaching events of various magnitudes in our study sites during 2014-15, another unexpected and even stronger event took place in 2016. This ENSO provided a unique opportunity to not simply document coral loss, but to evaluate changing ecological forces that may stabilize or destabilize coral reef communities through the course of serial bleaching and recovery events during a major ENSO event, yielding vital insights for how targeted management can help maintain reef ecosystem function in a high-CO2 world. Our original RAPID covered the three trips to each site we proposed for "before", "during", and "after" the 2014-15 ENSO; however, our "after" trip coincided with the second, intense 2016 ENSO. This project funded an additional trip to Panama to document recovery from the 2nd bleaching event.

We are testing hypotheses using targeted sampling and experiments before, during, and after these sequential ENSOs on Uva, Saboga (Panamá), and Darwin (Galápagos) reefs. These reefs span a gradient in aragonite saturation state that provides a real-world model system for future high-CO2 conditions. Key mechanisms that may increase resilience, reduce mortality, and limit the loss of ecosystem functioning following this ENSO, include: (1) increases in the relative abundance of thermotolerant symbionts resulting in higher survival of multiple coral species across all depths; (2) the maintenance of strong top-down control by intact herbivore communities; and (3) the strengthening of nutrient-limitation in shallow regions limiting algal competition. However, we also predict there will be a limit to resilience mechanisms beyond which reefs can no longer adapt and ecosystem functions break down. This series of ENSOs provides a unique opportunity to transform our understanding of coral reef resilience and its limits in the face of climate-related disturbance.

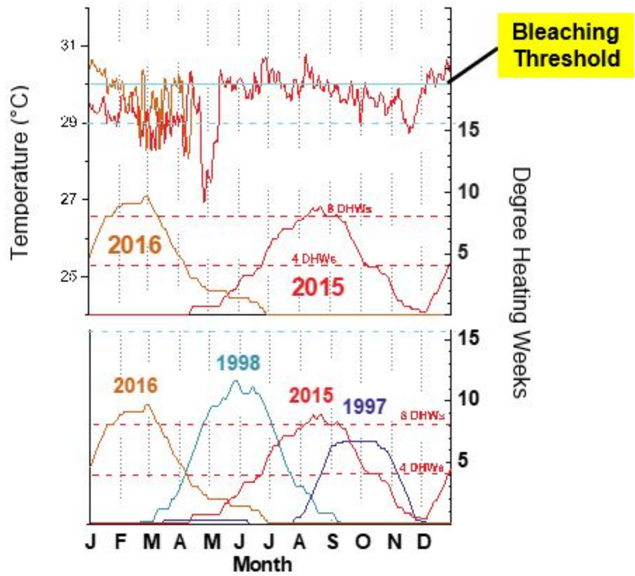


Figure 1: Thermal stress on coral reefs in the eastern tropical Pacific. Upper panel shows the relative strength of the 2015 and 2016 events, and lower panel compares these events to the very strong El Niño of 1997-98. Data from *in situ* temperature probes located at 3 m depth on Uva Island reef, Panama. Temperature plots show the temperature (left-axis) during the study period and the accumulation of Degree Heating Weeks (DHW, right axis) based on a 30°C bleaching threshold (Glynn et al. 2001). Degree Heating Weeks were also calculated for the same thermistor location for the 1997-98 El Niño.

Research Performance Measure: We anticipated that this expedition would be mounted in spring 2018. However, in order to better compare data with previous collections, we decided to delay the trip to August 2018, so that data could be collected at the same time of year. The August trip will involve participants from UM/RSMAS, UVI, UCLA and NOAA (or their proxies), but because the trip has not yet occurred we do not have data or findings for this report period.

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The GO-SHIP Repeat Hydrography Program

Project Personnel: L. Barbero, D. Volkov, G. Berberian, J. Hooper, K. Sullivan, N. Mears and I. Smith (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: Kathy Tedesco

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 2017/2018 the Pacific Ocean PO6, Southern Ocean SO4P and Indian Ocean IO7N transects were completed in full (Figure 1).

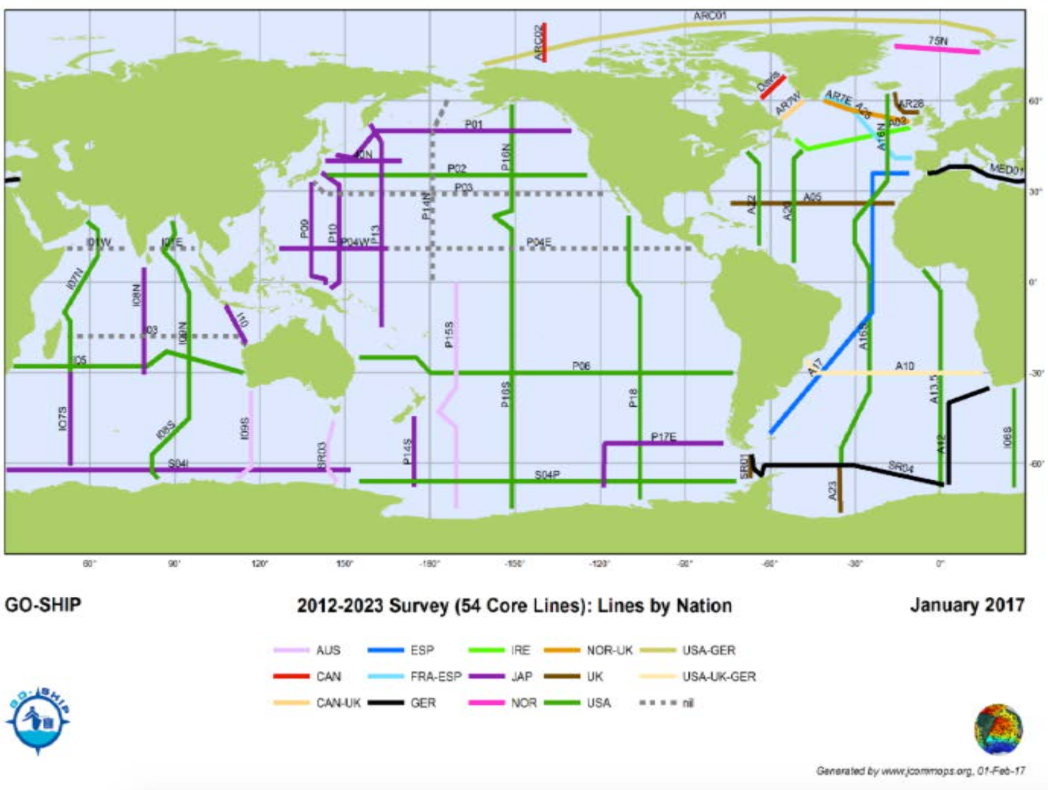

Figure 1: Tracks of the GO-SHIP lines. In FY18 the Pacific cruise P06, the Southern Ocean SO4P and the Indian Ocean IO7N sections were occupied.

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 stored 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 2017/2018 we completed zonal sections along 30 ˚S in the Pacific Ocean (called P06) and along 67 ˚S in the Southern Ocean-Pacific (called S04P), as well as a meridional transect in the Indian Ocean, called I07N with full physical and chemical characterization of over 350 water column profiles. CIMAS project personnel and NOAA collaborators were responsible for inorganic carbon measurements on all cruises, and dissolved oxygen, nutrients and CTD operations on P06 and I07N. additionally, I07N was led by Dr. Denis Volkov (CIMAS). This transect has been re-occupied for the first time in over 20 years

(Figure 2). Security concerns in the area had prevented the transect from being completed on a decadal basis.

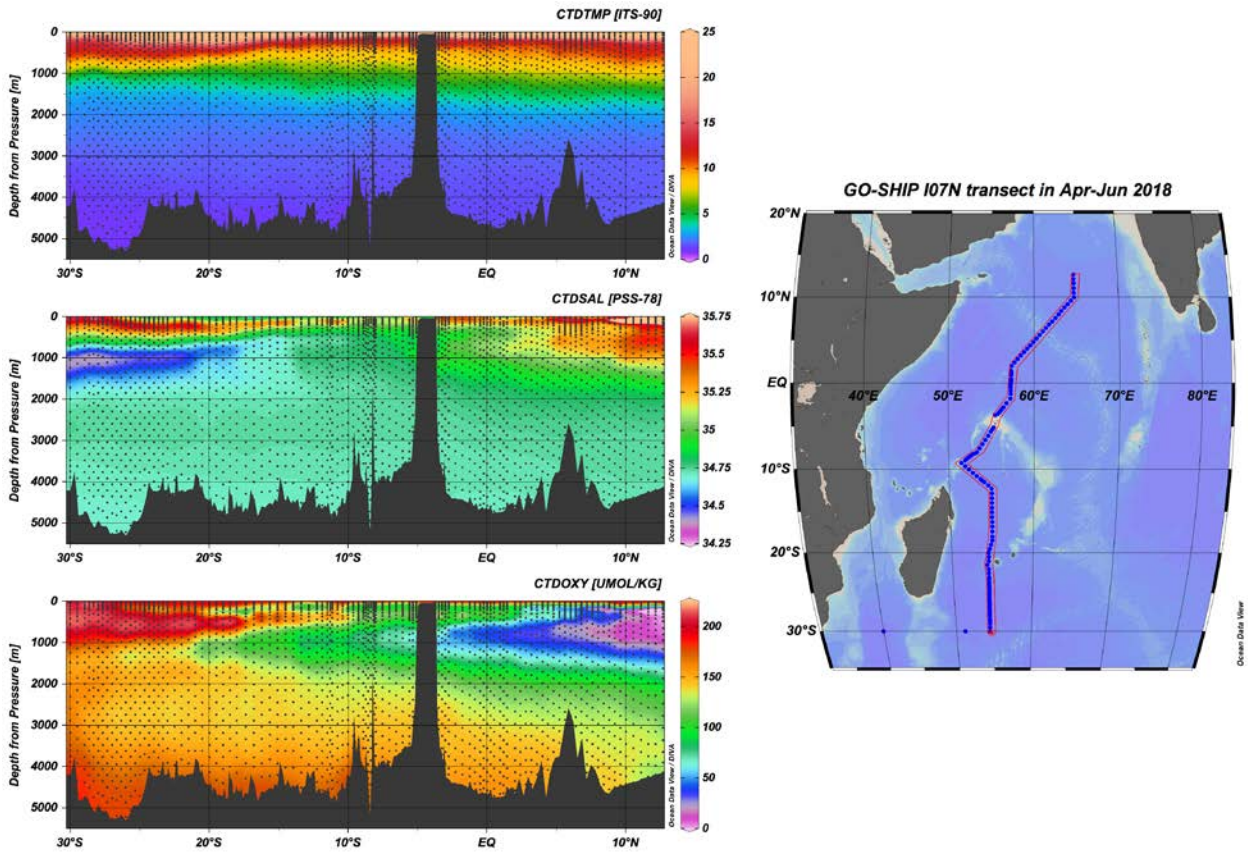

Figure 2: Profiles of temperature, salinity, and dissolved oxygen concentration along the IO7N transect in April-June 2018.

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-18 of completing the re-occupation of the P06, SO4P and IO7N cruises was met.

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

Project Personnel: L. Barbero, D. Pierrot, K. Sullivan, N. Mears, I. Smith and J. Hooper (UM/CIMAS)
NOAA Collaborators: R. Wanninkhof and M. Baringer (NOAA/AOML)
Other Collaborators: C. Langdon (UM/RSMAS)

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 use 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 health and productive ecosystems*

NOAA Funding Unit: Ocean Acidification Program (OAP) Office of OAR
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 third GOMECC (Gulf Of Mexico Ecosystems and Carbon Cruise) along the coastal waters of the Gulf of Mexico took place (Figure 1). The data have been quality checked and will be sent to NOAA's NCEI (National Center for Environmental Information) (formerly NODC) by end of summer. The comprehensive determination of inorganic carbon system parameters provides needed inputs to determine the aragonite saturation state in the Gulf.

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.

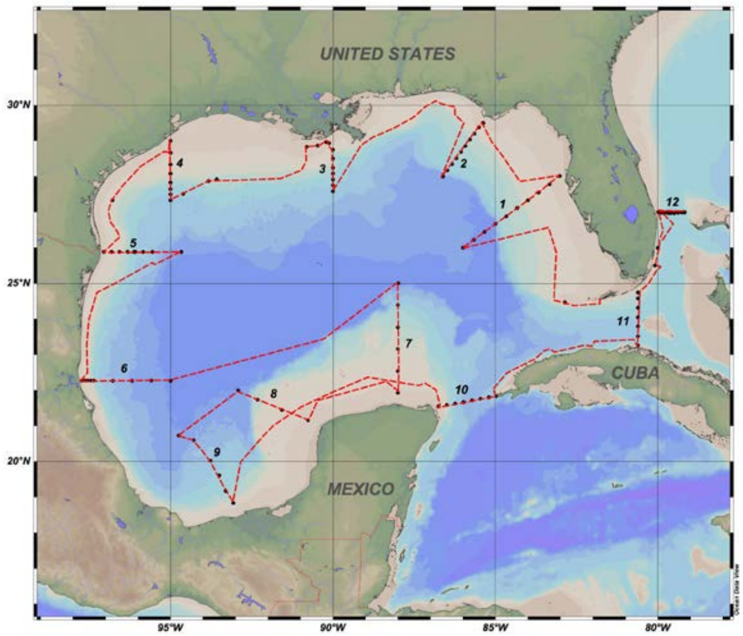

Figure 1: Map of the stations occupied during the GOMECC-3 cruise in 2017.

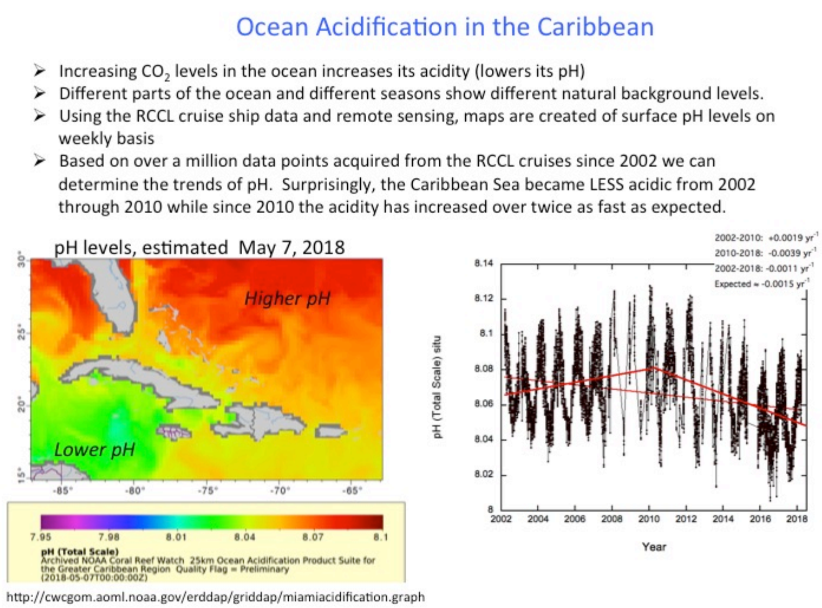

Figure 2: Algorithms mapping ocean acidification in the Caribbean on a monthly basis. The 16-year data record shows strong and unexpected multi-annual trends in surface pH in the region.

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 2018.

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Developing Acoustic Classification Methods for Reef Fish Species in the Gulf of Mexico, Southeastern US Coast, and US Caribbean Sea

Project Personnel: K. Boswell (FIU)
Other Collaborators: G. Pedersen (CMR, Norway)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** 1) Identify spectral features (or discrete multifrequency characteristics) of species or species group target strengths that can be exploited for classification. ii) Determine taxonomic levels for different species/groups that could theoretically be distinguished by target strength spectral features; 2) Assess aspect angle and distribution of target strengths of reef fish in-situ; 3) Conduct collaborative acoustic/optical data collection on planned surveys using wideband and multifrequency narrowband echosounders.

***Strategy*:** Reef fish surveys at SEFSC currently rely on camera based visual methods to provide fishery-independent indices of abundance for assessments. These methods sample limited volume and can only provide indices of abundance due to uncertainty with sampling volume. Acoustic surveys, on the other hand, can cover larger areas and provide estimates of density or abundance, but currently lack certainty in identification to apportion the acoustic biomass to species. With development of acoustic classification techniques, the two methods could be complementary and reduce variance in survey indices.

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*

NOAA Funding Unit: NOAA/NMFS/SEFSC/ASTWG
NOAA Technical Contact: Charles Thompson

Research Summary:

Due to extensive delays in receiving an executed contract, we have not progressed nearly as far as we would have expected. To date a Postdoctoral researcher (Dr. Camilo Roa) has been hired to focus effort on modeling swimbladders from CT scans of dominant reef species from the Gulf of Mexico. Several quantitative classification schemes have been developed and tested with interest on determining the potential of taxonomic classification based on theoretical scattering models from CT-scans. At present, models suggest that classifiers are between 80-90% effective in taxonomically discriminating among species using wideband scattering models.

Research Performance Measure: With respect to the stated objectives, we have made moderate progress on Objective 1. We expect that through the next year, we are likely to fully address the remainder of the stated objectives.

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Hourly Near-Surface Oceanic Velocity and Temperature 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 past, 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). In the past fiscal year, the product was updated to version 1.01 which 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.

This year, PI Elipot continued to work with the GDP Data Assembly Center personnel and NOAA collaborator Rick Lumpkin on the upcoming update version 1.02 of the dataset, which will be released later in 2018.

In addition, a novel and unexpected aspect of the hourly surface drifter was investigated: the potential ability of the GDP array to provide regional and global estimates of mean sea level (MSL). The buoys of the GDP are now tracked by GPS for which altitude information is potentially available along longitude and latitude coordinates. In a simulation study, it was shown that the spatial sampling of the GDP is sufficient to generate estimates of linear decadal trend for global MSL with an uncertainty less than 0.3

mm per year (See Figure 1) which is a requirement for climate studies. The results of this study were submitted for potential publication to *Scientific Reports.*

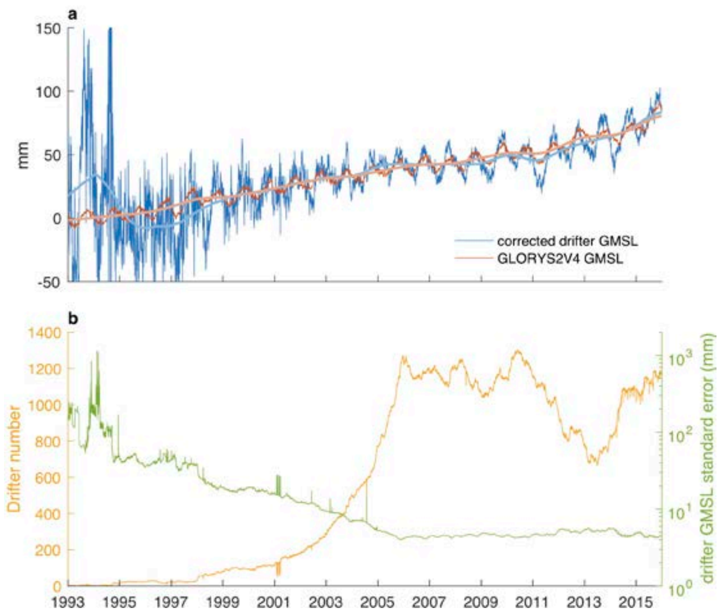

Figure 1: a. Relative Global Mean Sea Level (GMSL) estimates. The blue line is the estimate from simulated sea level measurements along real drifter trajectories and the red line is the reference estimate from the GLORYS2V4 ocean reanalysis. The thicker lines are the 9-month smooth estimates after removal of seasonal cycle estimates. b. Left axis: estimated GMSL error from drifters due to unresolved ocean physics by the ocean reanalysis. Right: number of active drifters in the hourly GDP database per day.

Research Performance Measure:
A manuscript about the potential capacity of the high frequency drifter dataset to measure global mean sea level was submitted within this fiscal year and is currently under review: S. Elipot (2018), *Measuring global mean sea level changes with surface drifting buoys*, Scientific Reports.

Contrary to anticipations, the upcoming version of the dataset will not include sea surface temperature estimates. This specific project's goal was not achieved because the needed resources were underestimated.

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AOML's South Florida Program (SFP): Long-Term Measurement of Physical, Chemical, and Biological Water Column Properties in the South Florida Coastal Ecosystem

Project Personnel: M. Gidley, G. Rawson, I. Smith, L. Visser, C. Quenee and K. Montenero (UM/CIMAS)
NOAA Collaborators: L. Anderson (NOAA/FKNMS); E. Johns, C. Kelble, C. Sinigalliano and B. Vandine (NOAA/AOML)
Other Collaborators: HW. Lee, J. Lopez and M. Wickes (NSU)

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.

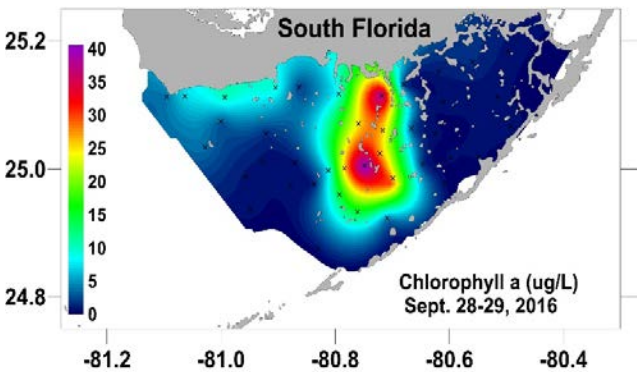

Figure 1: Chlorophyll a contour of Florida Bay showing an algal bloom (cyanobacteria) in the central bay. Chlorophyll levels reached twice that of the previous bloom in 2005-2007 and were the highest measured over the last 20 years of monitoring.

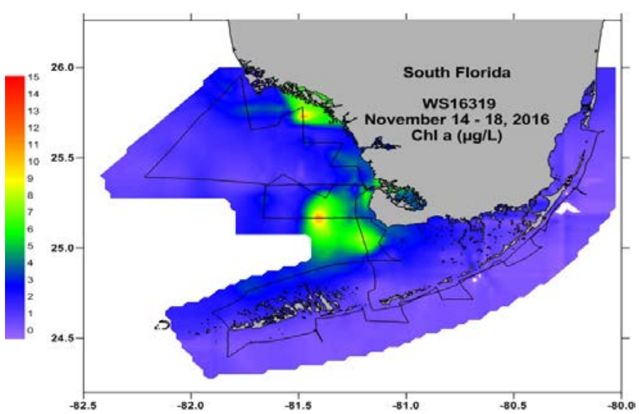

Figure 2: Chlorophyll a contour of South Florida coastal waters showing elevated chlorophyll levels off the coast of Florida Bay and the Shark River, and along the southwest Florida shelf. These maps and numerous other measured parameters are posted on the SFP web site at www.aoml.noaa.gov/sfp.

Research Performance Measure: All major research objectives are being met on schedule. The emphasis during this report period (1 July 2017 – 30 June 2018) 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

Research Remote Sensing and In-Situ Observations for Operational and Climate Applications

Project Personnel: M. Goes (UM/CIMAS)
NOAA Collaborators: G. Goni (NOAA/AOML)
Other Collaborators: J. Trinanes (U. 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 core objective 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 hosts 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 products been distributed through the OceanWatch and CoastWatch nodes has been diversified during this period to include additional datasets:

a) Add in-house VIIRS Global NRT Chlor and VIIRS GLobal SST from L2 data
b) VIIRS global ocean color fields (daily, weekly, monthy) and NOAA/NESDIS Altimetry from the CoastWatch Central Server

c) 1-day, 3-day and weekly USF AFAI indexes are available from our TDS, ERDDAP and OceanViewer servers. Coverage includes the Caribbean and GoM. Maximum Chlorophyl Index (MCI) fields from OLCI at 1.2km and 300m resolution are currently being estimated and compared to the AFAI fields (Figure 1).
d) GOES-16 fields integrated with the GOES-W and MSG daily fields. This was a requirement to expand the region east of 30W.
e) GOES-16 hourly fields at 2-km resolution are being distributed and integrated into OceanViewer.
f) The MW products have been updated to reduce latency and to include additional data (e.g. F18 SSMIS)

One of the most important results of this project during the period covered by this report is the presentation of a new web page with the goal of supporting the hurricane field program during the hurricane season. The objective is to be able to provide easy access to information on data that are available through the GTS, AOML, and other sources, that may help HRD, EMC, and others during planning and then analysis. It is available at: http://cwcgom.aoml.noaa.gov/cgom/OceanViewer/index_hrd.html. These maps could also be used to monitor the TCHP fields, integrate hurricane forecast information and glider operations. It also integrates selected satellite and in_situ datasets with the possibility to compare both and visualize Argo, XBT and Glider profiles in NRT (Figure 2).

The OceanViewer interface has been updated to include new functionalities and services, such as, full-screen button for animations, selectable legend, getFeature vs getCapabilities for external WMS servers, and improving routines to remove currents over land.

The inputs of the algorithm to estimate the parameters of the seawater carbonate system (pH, alkalinity, …) in the Caribbean Sea have been updated to improve robustness and reduce latency. In addition and besides the daily fields, the weekly and monthly fields are being estimated in NRT.

In collaboration with OCED at AOML, ship carbon data was collocated with satellite data for the period 2002-2018 in the Caribbean and Gulf of Mexico. Additionally, gridded products for SST, wind stats, SSS, MLD and NFLH for the same period were provided. The objective is to improve the models to characterize, understand, and predict carbon fluxes at regional levels.

Continue testing the use of VIIRS, OLCI and MODIS data to generate MBON Seascapes fields. Current configuration works with data from all these sensors, at regional and global scale.

Some papers published during this period and listed in section Publications are described below:

a) A new study published in the journal mBio shows that *Vibrio parahaemolyticus* infections have undergone a steady geographical expansion over the last two decades. Although factors underlying this process are complex and multifactorial, the most fundamental change in the epidemiological context of this pathogen has been the transition from infections caused by locally-restricted strains to the surge and transcontinental expansion of epidemic clonal types. This paper identifies the major drivers behind the evolution and successfully expansion of epidemic clones under current scenarios of coastal warming. Satellite datasets have been used to estimate this signal in various regional hotspots.

b) Another paper, published in Environmental Health Perspectives, highlights how different climate change scenarios modify the suitability of marine conditions for *Vibrio* infections. Recently, the European Centre for Disease Prevention and Control (EDDC) developed a platform, the ECDC Vibrio Map Viewer, to monitor coastal marine areas with environmental conditions favorable to *Vibrio* growth. These fields are originally estimated on a daily basis and on global scale by the Atlantic OceanWatch node at AOML, and are provided through interoperable channels to ECDC, which is the point of access in the Baltic region. Monitoring the environmental conditions of coastal waters is critical, given the projected increase in SST and the potential severity of Vibrio infection moving forward. The Vibrio fields computed at AOML can be used to globally forecast the environmental suitability of coastal waters for Vibrio, and these forecasts can then be used to inform public health decision makers for their consideration on public safety warnings. Through this cascade of steps – risk assessment, monitoring of environmental suitability, dissemination and communication, and response – these viewers constitute an important link in an early warning system for Vibrio infections in the Baltic Sea, anticipated to become more abundant in a warming climate.

c) A new paper in Emerging Infectious Diseases focuses on the evolution and types of *V. parahaemolyticus* infections in NW Spain. These infections abruptly emerged in 1998 and, over the next 15 years, were associated with large outbreaks caused by strains belonging to a single clone. We report a recent transition in the epidemiologic pattern in which cases throughout the region have been linked to different and unrelated strains. Global genome-wide phylogenetic analysis revealed that most of the pathogenic strains isolated from infections were associated with globally diverse isolates, indicating frequent episodic introductions from disparate and remote sources. Moreover, we identified that the 2 major switches in the epidemic dynamics of V. parahaemolyticus in the regions, the emergence of cases and an epidemiologic shift in 2015-2016, were associated with the rise of sea surface temperature in coastal areas. This association may represent a fundamental contributing factor in the emergence of illness linked to these introduced pathogenic strains.

d) An abstract was submitted to 2018 Ocean Sciences Meeting, held in Portland, OR. It was accepted and presented within the session "PO003: Detection, Analysis and Modeling of the Distribution and Transport of Oceanic Debris". The work “A Framework for Analyzing the Trajectories of Ocean Surface Debris: Its Application to Parts Confirmed to Be from MH370”, authored by J. Trinanes, J. Olascoaga, G. Goni, N. Maximenko, D. Griffin and J. Hafner, describes how the integration of remote sensing and in-situ data within ocean physical models can greatly improve the knowledge on the trajectories of ocean debris. Their trajectories are mainly affected by complex ocean circulation features and wind forcing, which can change due to buoyancy. We describe here a trajectory analysis methodology, which was published in the Journal of Operational Oceanography, to study the potential origin of the debris from flight MH370, which disappeared in March 2014, found in Reunion Island. Using data from undrogued drifters, we generated probability and travel time maps from both direct and indirect one-step trajectories. Additionally, synthetic drifters were advected forward and backward in time using numerical model surface ocean current fields. The results of this work provide an assessment of the possible areas in the Indian Ocean where the fragments of the aircraft could have originated, and provide a framework for the study of ocean debris backward and forward in time both for scientific and operational applications. These results are also consistent with several confirmed findings of MH370 fragments in the Western Indian Ocean. This study highlights the importance of sustained in-situ and satellite observations to better determine the ocean conditions and improve the forecast and analysis of the trajectories of surface debris.

We participated in the following meetings and courses:

a) Training Course: "Best Practices for Oceanography and Phytoplankton analysis", organized by the Technological Institute for the Control of the Marine Environment of Galicia (INTECMAR). A presentation on operational satellite oceanography was made on Nov 14th, 2017.

b) On June 19th, Joaquin Trinanes participated in the Corbi Data summit 2017. The aim of this initiative was to discuss and bring together interdisciplinary perspectives on Big Data. Joaquin’s presentation linked genomic epidemiology of waterborne pathogens and environmental information within an scalable computation framework.

c) Joaquin Trinanes and Gustavo Goni attended the 2017 CoastWatch, OceanWatch, PolarWatch (CWOWPW) Annual Meeting that took place between July 31-Aug 4 in Santa Cruz, CA. The current status and most relevant advances related to the processing and distribution of near real time satellite-derived datasets at regional and global scales were presented. The meeting was organized by the NOAA CoastWatch West Coast Regional node and focused on 4 main themes: CWOWPW vision and planning, new satellite products, node and central operational updates, and technical development activities.

d) Workshop "Implementing and Monitoring the Sustainable Development Goals in the Caribbean: The Role of the Ocean" in St Vincent, Jan 17th-19th: Session: Observational requirements for ocean-related variables and indicators.

e) SG-GTSPP-IV meeting in Oostend, Apr 11th-13th. The Global Temperature-Salinity Profile Program is an international project to develop and maintain a global ocean Temperature-Salinity resource with data that are both up-to-date and of the highest quality possible. Countries contributing to the project are Australia, Canada, France, Germany, Japan, Russia, and the United States. During this meeting we presented the US report as well as a report of the progress on actions from previous meetings (netCDF4&metadata&databases).

f) Workshop *Sargassum* and Oil Spills Monitoring Pilot Project for the Caribbean and Adjacent Regions in Mexico City, May 2nd– 4th. Discussion about the requirements for *Sargassum* monitoring and forecasting. During the first half of 2018, a large bloom of *Sargassum* has been detected in the western Caribbean (Figure 1).

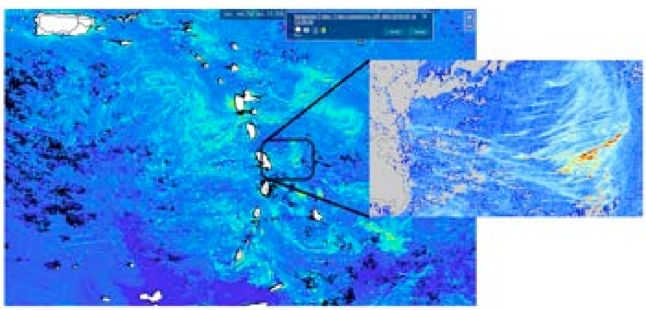

Figure 1: Comparison between 1-km weekly AFAI (source data: Chuanmin Hu, USF) and 300-m MCI fields from OLCI/S-3A (right).

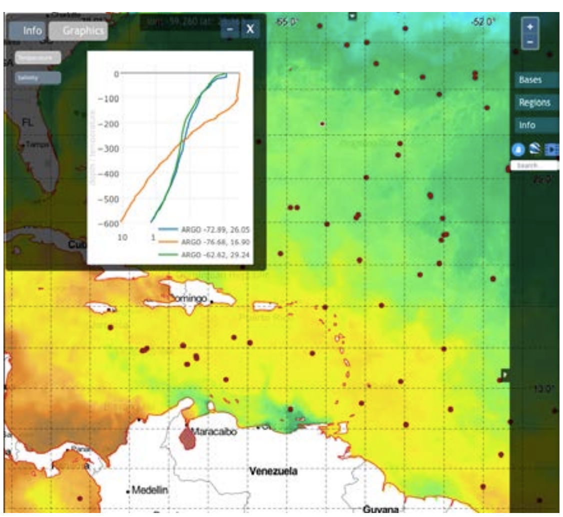

Figure 2: The OceanViewer interface has been customized to support the hurricane field program, integrating in-situ, satellite and modeled data.

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. The visualization and data distribution tools are being used for multiple purposes, such as studying the distribution of *Sargassum* and the impact of ocean variability on *Vibrio*-related illnesses. These solutions have been integrated within a SOA framework.

Ship of Opportunity Program

Project Personnel: C. Gonzalez, Z. Barton, R. Domingues, M. Goes, H. Lopez, J. Christophersen, G. Rawson, P. Halsall and D. Ugaz (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); 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) measuringthe 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 that are used in real-time operational forecasts and for understanding long-term changes in climate. The XBT Network is one of the main components 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. Deployments are carried out from 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. The XBT network currently in place has been recommended by the international scientific community (Figure 1) during the OceanObs99 and OceanObs09 meetings, and during the five XBT science meetings that have already taken place since 2011.

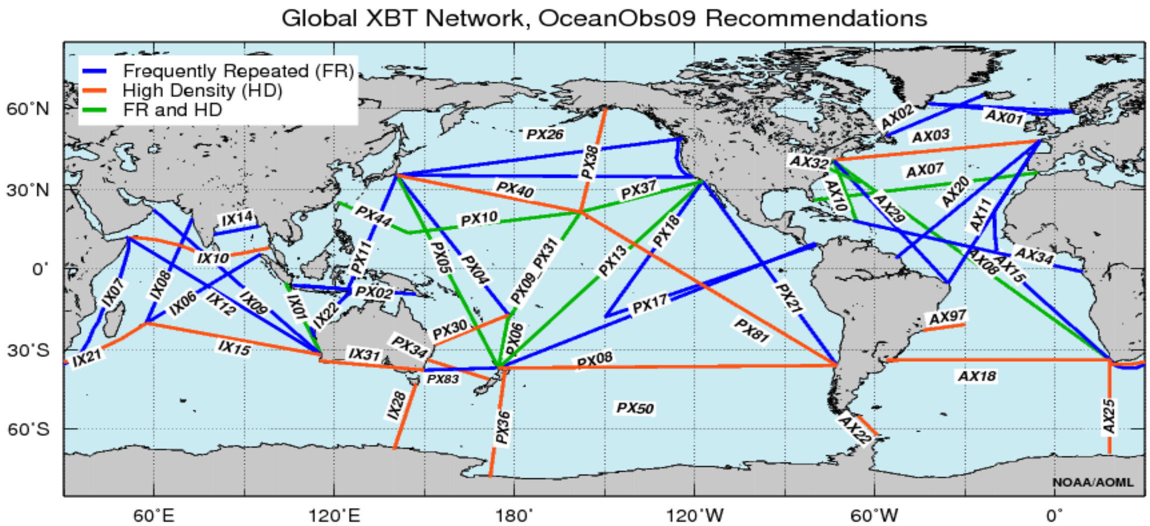

Figure 1: OceanObs09 XBT transects recommended by the scientific community to be occupied in frequently repeated mode (FR, in blue), high density mode (HD, in orange) or both (in green).

The global XBT network is a truly international effort. The countries that provided the largest contributions to the AOML XBT operations (including deployments, data processing, data quality control, and data analysis) during the last year were Australia, France, South Africa, Brazil, Italy, and Argentina. In average, approximately 20,000 XBTs are deployed per year globally, of which NOAA/AOML is involved in some aspect of the logistics, operations, data processing, etc., of about 80% of them. NOAA/AOML leads or co-leads with its international partners the implementation and operations of 12 Atlantic Ocean transects. In addition, the XBT network is supported by scientists from several countries, in the analysis and assessments of XBT biases to reduce errors in the temperature profiles.

XBT-derived temperature profiles represent between 10% and 15% of all global, non-mooring, temperature profiles. The main contribution of the XBT network is to provide temperature measurements to:

- Monitor changes of key surface and subsurface currents,
- Assess meridional heat transport in all ocean basins,
- Help initialize and validate climate and weather numerical forecast models, and
- Supplement other observational platforms to assess the variability of the global upper ocean heat content.

All XBT transects have been justified by their impact on our understanding of how the upper ocean dynamics and thermal structure may be linked to long-term climate signals, extreme weather events, ecosystem assessments, etc. Scientists using XBT data produce approximately 100 manuscripts annually in peer reviewed scientific publications, in addition to presentations at scientific meetings, and a large number of other applications in which several products for ocean condition monitoring are created. XBT publications in refereed journals since 2000 total approximately 1,200. There were approximately 50 peer-reviewed XBT publications that used NOAA XBT data during **FY2017**. For a complete list of XBT-related publications please visit our XBT bibliography page at: http://www.aoml.noaa.gov/phod/goos/xbtscience/bibliography.php

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. Some of the XBT transects have been maintained for many years, such as AX32, which runs from Newark to Bermuda. This transect is geared towards investigating the variability of the Gulf Stream, and has been carried out for 34 consecutive years since 1981. These measurements represent the longest time series available of the Gulf Stream.

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.

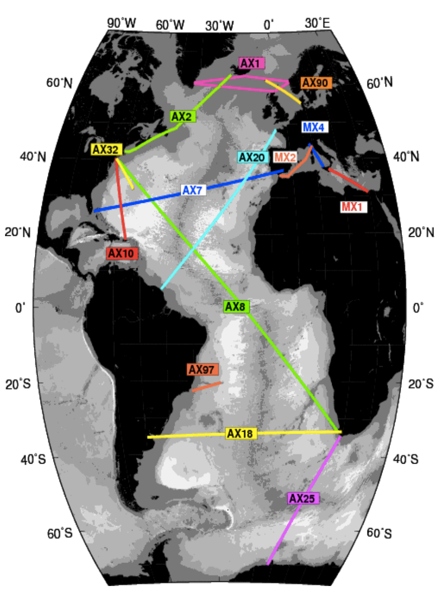

Figure 2 – Location of the 4 High Density XBT transects (AX07, AX08, AX10, and AX18) maintained solely by NOAA/AOML, and the 7 transects (AX01, AX02, AX20, AX25, AX32, AX90, AX97, IX01, IX12, IX28, MX01, MX02, and MX04) maintained by NOAA/AOML in collaboration with the University of Paris, IRD/France,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

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 **2017 (total of 15,933 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).

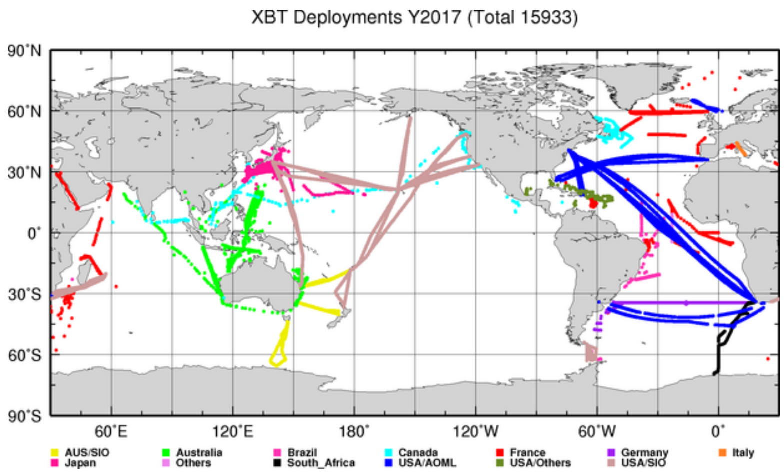

Figure 3: Locations of XBT deployments by AOML and the international community during calendar year 2017.

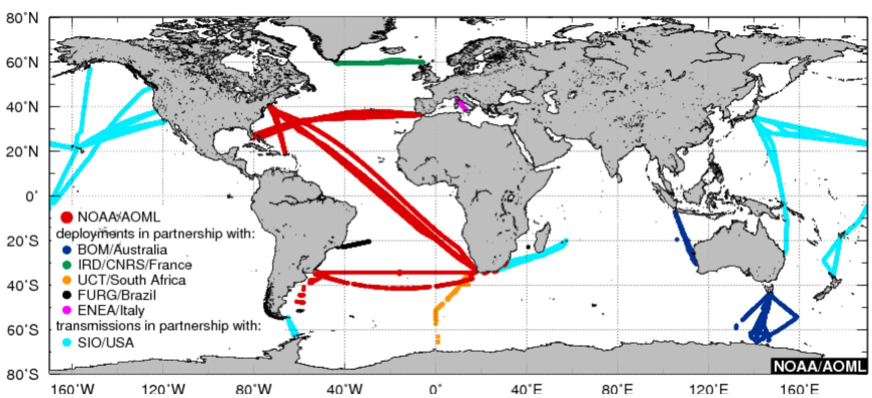

Figure 4: Location of the NOAA/AOML XBT deployments and NOAA/AOML-supported XBT deployments/transmissions during FY2017 carried out by NOAA/AOML or in partnership with national and international collaborators.

The data obtained through 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. Additional scientific (delayed-time) quality control is carried out at NOAA/AOML to provide data with high quality for climate studies. These data are distributed to NOAA/NCEI and to other data distribution centers.

In order to continue with the effort to improve data quality, NOAA/AOML scientists carry out experiments and analysis on XBT biases and are collaborating with Lockheed Martin Sippican to develop a new, upgraded XBT probe with tighter weight tolerance and temperature calibration that will be able to provide climate quality observations. This project is also involved in activities aimed toward the continuous development of new technologies in support of the operations carried out as part of the XBT network. During recent years the engineering group at NOAA/AOML has developed, tested, and implemented, new equipment for the automatic deployment of several models of XBTs during cruises with high rate of deployments, and for the transmission of data in real-time using the Iridium Satellite Network. Further work is currently underway for the development of and XBT data recorder.

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 marine 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 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 5), 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.

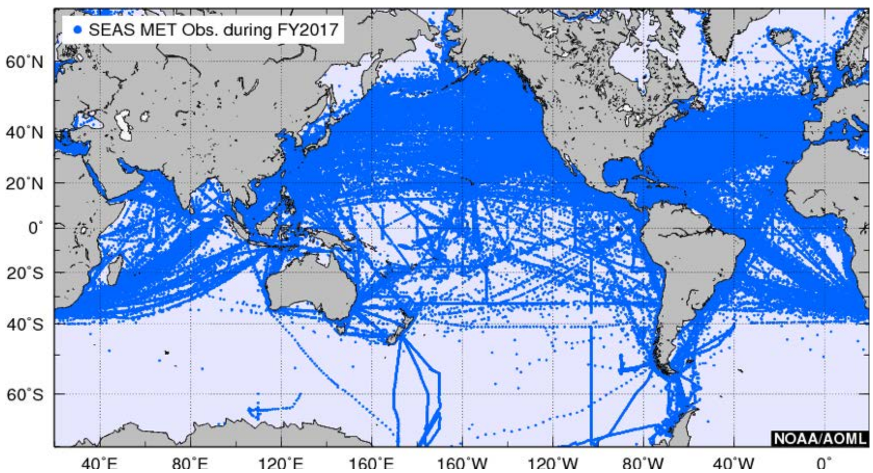

Figure 5: Locations of the approximately 500,000 marine weather observations obtained from 2,000 ships of the US/VOS distributed through the GTS using SEAS software during FY2017.

In addition, because of the expertise of the personnel involved in the XBT network, this project is also partly responsible for the installation, operation, and data management of ThermoSalinoGraphs (TSGs), which are instruments that continuously measure the values of sea surface temperature and salinity along the ship path. During **FY2017** NOAA/AOML continued the TSG operation in support of the pCO2 operations. During this period NOAA/AOML received, processed and distributed TSG data from 3 ships of the SOOP (*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 10 ships of the NOAA fleet (*RV Pisces, RV Oregon II, RV Fairweather, RV Ronald Brown, RV Bell M Shimada, RV Oscar Elton Sette, RV Gordon Gunter, RV Oscar Dyson, RV Nancy Foster, and RV Thomas Jefferson*). Approximately 6 million TSG records were processed at NOAA/AOML during FY2017 (Figure 6), and distributed through several data centers including NOAA/NCEI and GOSUD. The operation of TSG equipment is performed with the SEAS software.

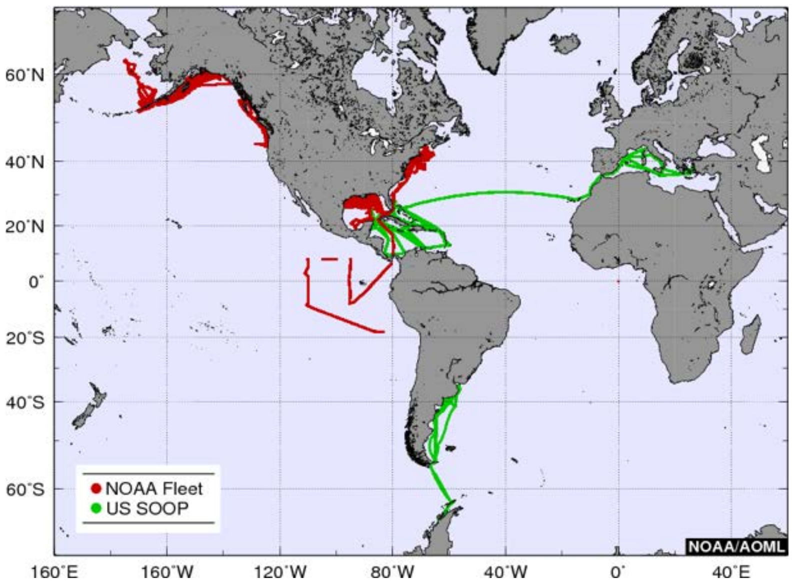

Figure 6: Location of approximately 6 million TSG observations received and processed by NOAA/AOML during FY2017 from ships of the SOOP and the NOAA fleet.

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 Drifter Program (Figure 7), and to the global Argo array (Figure 8) to maintain its array by having the XBT ship riders deploy their instruments along XBT transects.

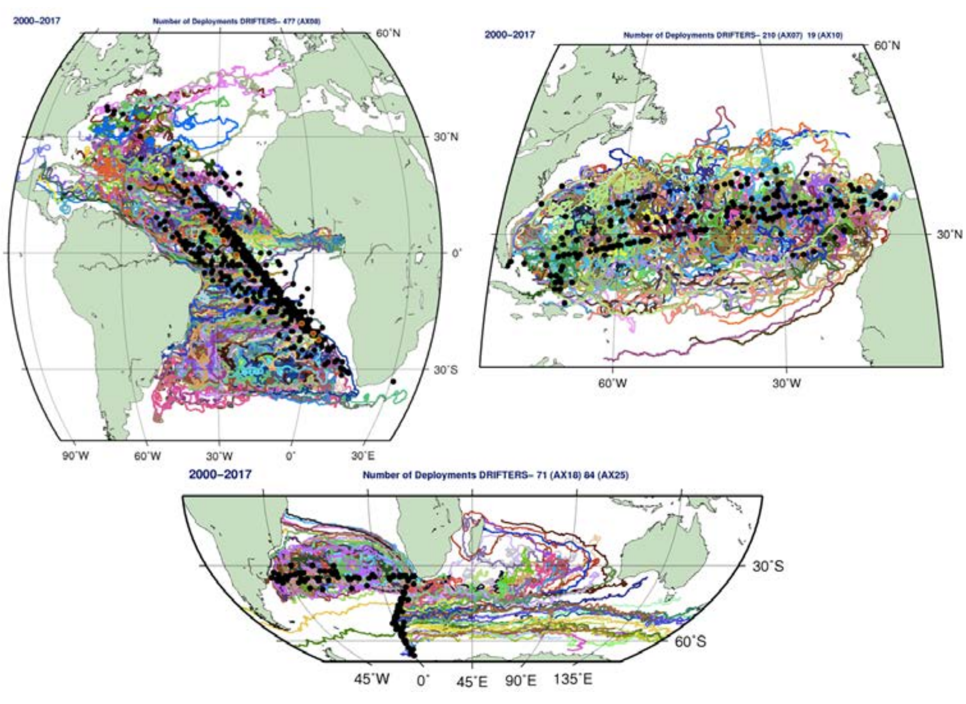

Figure 7: Location of deployments (black circles) of surface drifters carried out from XBT ship riders since 2000. Trajectories of these drifters are color lines.

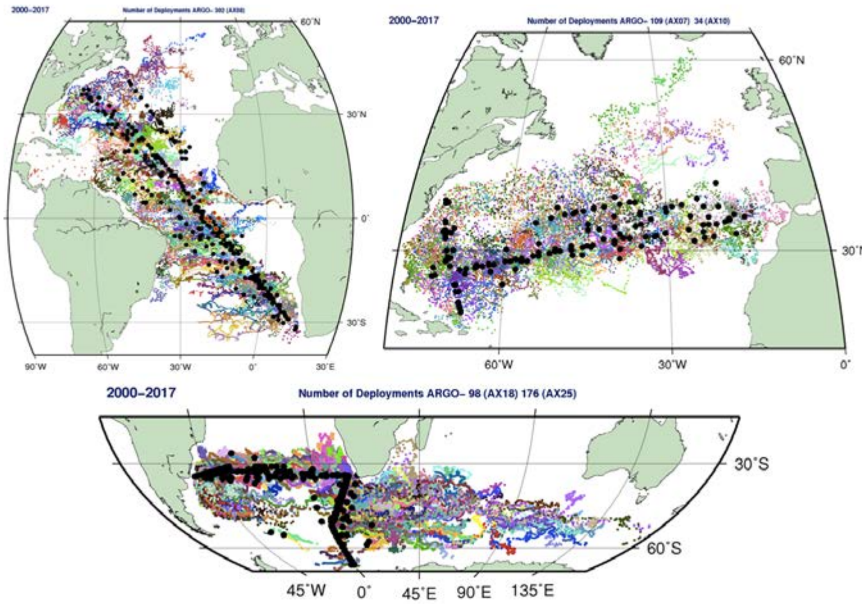

Figure 8: Location of deployments (black circles) of profiling floats carried out by XBT ship riders since 2000. Locations of observations from these floats are indicated by color dots.

Science Update

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: AX07 in the North Atlantic (Figure 9), and AX18 in the South Atlantic (Figure 10). **During 2017**, the MHT XBT across AX7 in the North Atlantic showed a higher than average annual mean of **1.21 PW**, versus the total average of 1.1 PW. In the South Atlantic, average heat transport calculated across AX18 for 2017 was **0.65 PW**, which is slightly above the overall average of 0.59 PW.

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., (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.

(c) Goes et al. (2018): In this study, a new methodology is proposed to infer salinity in the Atlantic Ocean from the water surface to 2000 m depth, which addresses the seasonality in the upper ocean and makes inference about longer term changes in salinity. It builds upon previous studies by (i) including additional data, (ii) expanding the coverage of synthetic salinity estimates from regional to the whole Atlantic basin, and (iii) allowing the temporal variability of salinity by resolving seasonality and making inference about interannual to decadal variability of salinity in the Atlantic Ocean. Our results show that when seasonality is accounted for, the variance of the residuals is reduced in the upper 150 m of the ocean, and the dynamic height errors are smaller than 4 cm in the whole study domain. The sensitivity of the integrated meridional heat and freshwater transports to different empirical methods of salinity estimation is studied using the high-density XBT transect across 34.5°S in the South Atlantic Ocean. Results show that accurate salinity estimates are more important on the boundaries, suggesting that temperature-salinity compensation may be also important in those regions.

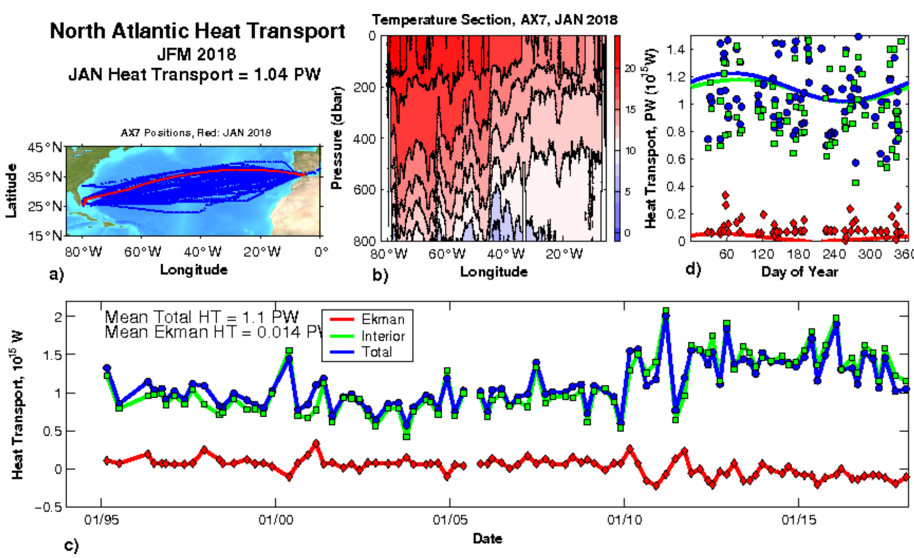

Figure 9: North Atlantic MHT calculated using data from the AX07 high density XBT transect, which runs from Florida, USA, to Gibraltar.

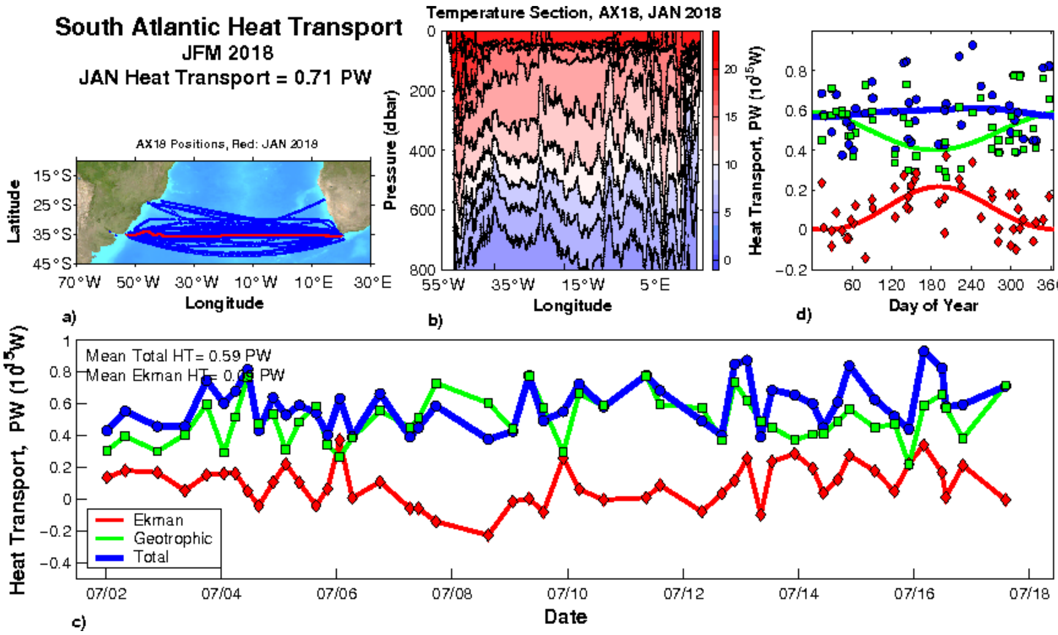

Figure 10: South Atlantic MHT calculated using data from the AX18 high density XBT transect, which runs from the Rio de la Plata region to South Africa.

Science Update

The main accomplishments of work carried out by the NOAA/AOML XBT network during FY2017 were:

- Maintenance of all NOAA/AOML XBT transects, including the deployment of approximately 7,700 XBTs;
- Real-time transmission into the GTS of more than 90% of all XBT data acquired in the deployments;
- Automatic quality control of all NOAA/AOML and Scripps XBT profiles;
- Insertion of all NOAA/AOML and Scripps XBT data in near-real time into the GTS;
- Scientific quality control of all Atlantic XBTs and submission of these data to NCEI;
- Strong scientific use of XBT data for studies of surface, subsurface, and boundary currents, meridional heat transport, attributions of coastal sea-level changes and XBT fall rate;
- Collaboration with Sippican to design an improved XBT probe; and
- Design and development of web pages in order to provide easy access to the XBT data.

Additional experiments were conducted during 2017 to determine the year-to-year variability in the specifications of the probes during the manufacturing process. During the experiment the weight of the main components of Deep Blue XBT probes manufactured between 1996 and 2016 were measured. The experiment revealed that the total weight of XBT probes exhibits differences of as much as 15g or 2% of the nominal 730 g weight for these probes. It was also revealed that the weight of the wire is responsible for at least 80% of these differences. These weight differences represent a possible maximum difference in fall speed of the probes in the water of 0.136 m/s (Figure 11) which can cause a linear maximum depth offset of 17 m at a depth of 850 m . This maximum depth offset represent 2% of the probe depth and accounts for the maximum depth accuracy as indicated by the manufacturer.

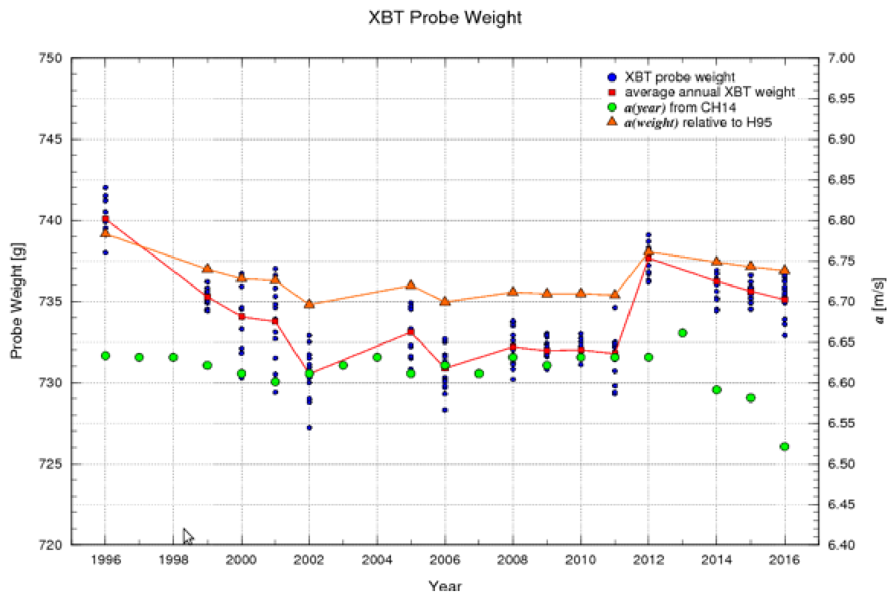

Figure 11: XBT probe weight variability (blue circles) for probes manufactured between 1996 and 2016. The average fall speed (orange triangles) relative to the Hanawa et al 1995 (H95) fall rate equation is directly correlated to the average annual weight of the probes (red squares) and shows consistency with the annual variability of the corresponding fall rate equation a coefficient according to Cheng et al 2014 (CH14, green circles).

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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Investigation of the Movement of Adult Billfish in Potential Spawning Areas

Project Personnel: J. Hoolihan and E. Prince (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:

Age and growth studies to determine maximum size and longevity of Atlantic blue marlin *Makaira nigricans* has generated new estimates for growth parameters. 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 bands present in hard parts.

We have examined cross sections of anal fin spines sampled from 1600+ Atlantic blue marlin gathered from Venezuelan fisheries. We are currently in the process of analyzing age, size at age, and maximum longevity. Fin spines from billfish present numerous challenges when attempting to discern and enumerate growth annuli. One particular problem is that the vascular core of the spine enlarges over time, which can effectively destroy early growth bands (Fig 1). To compensate for this loss, we estimate the size of the spine radius at which the first annual growth band appears. Using that estimate we back-calculate for lost growth bands to determine a corrected age. Based on our analyses to-date, we estimate that Atlantic blue marlin are capable of living to greater than 40 years. However, that is true for relatively few fish from those sampled. In addition, there are indicators that the larger, older fish are being eliminated due to overfishing.

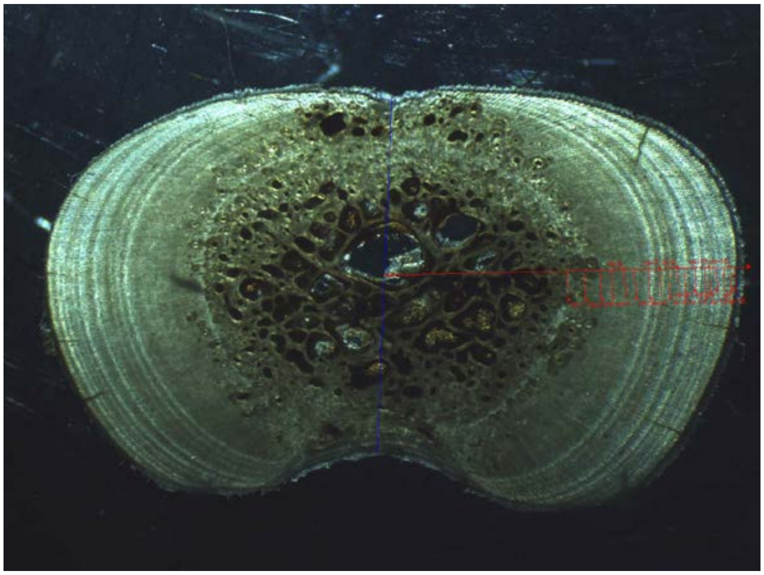

Figure 1: Cross section of the second anal fin spin from an Atlantic blue marlin showing the presumed annual growth bands used to determine age. Erosion of the vascular core is evident.

We are in the process of investigating the effects of habitat on vulnerability of pelagic fisheries in the eastern tropical Atlantic Ocean. The Atlantic Oxygen Minimum Zone has exhibited increased vertical compression of the surface mixed layer habitat over recent decades (Fig 2), concentrating predators and preferred prey into progressively shallower surface zones, thereby increasing their catchability over time. We examined 60 years of ongoing deoxygenation in the central Atlantic Ocean and its effects on vertical habitat of large pelagic predators and compared it to longline catch and effort data both inside and outside the Oxygen Minimum Zone for nine Atlantic species. Longline fishing catch and effort increased steadily during this period with effort focused predominantly in the central Atlantic area during the last two decades. The purse seine fishery has recently incorporated deploying Fish Aggregating devices on top of the ETA OMZ which compresses surface species horizontally. At least 6 out of 9 major Atlantic stock assessment species examined were impacted by the vertical and horizontal compressed habitat.

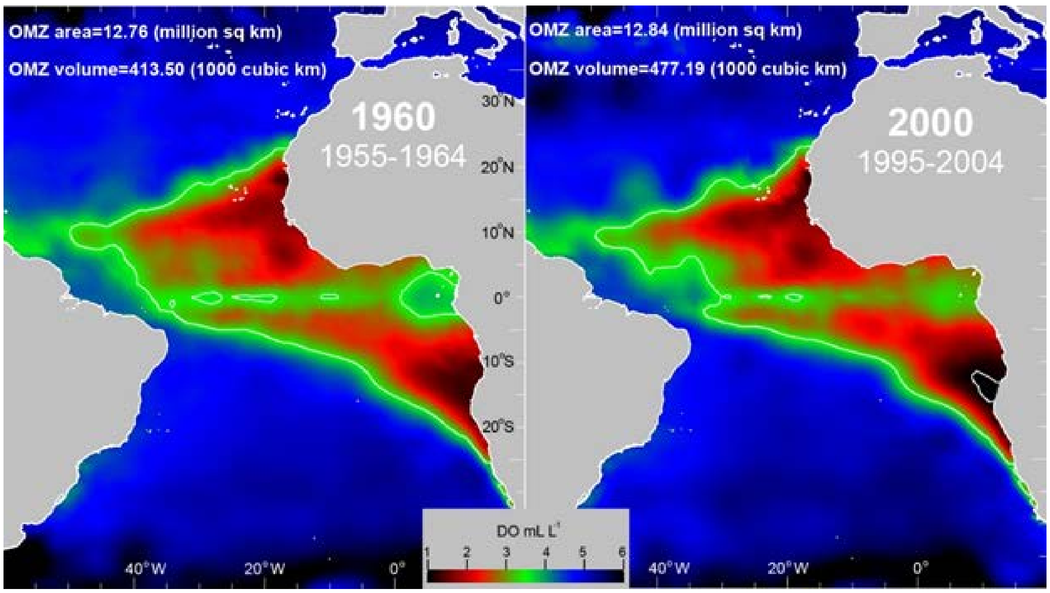

Figure 2: Surface area (km^2) of the eastern tropical Atlantic oxygen minimum zone for the initial 1960 decade (1955-1964, **a**) and the most recent decade 2010 (1995-2014, **b**) included in our analyses. Representation of the zone was based on a DO threshold of <3.5 mL L^{-1}. DO levels below this value are increasingly more hypoxic.

Research Performance Measure

- Peer-reviewed manuscripts for both blue marlin aging and pelagic fisheries proximate to the Atlantic oxygen minimum zone studies are in the writing process.
- 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: Menghua Wang

Research Summary:

To date, during the reporting period of 7/1/2017 – 6/30/2018, the following activities have been conducted to achieve the project objectives:

Participated in the cruise survey onboard the R/V Ronald H. Brown to collect bio-optical data in the Gulf of Mexico between 18 July and 21 August 2017 (the GOMECC-3 cruise). Most data have been processed and quality controlled to support VIIRS cal/val. Some optical profiling data are still being diagnosed to assure calibration accuracy. Most importantly, an ALFA system has been used onboard to collect surface flow-through data to measure fluorescence of different pigments, from which different phytoplankton functional types (PFTs) can be identified. Such synoptic data will serve as ground truth to develop and validate VIIRS PFT algorithms in the near future.

Participated in the cruise survey onboard the R/V Point Sur (University of Southern Mississippi to collect bio-optical data in coastal and offshore waters on both the east and west coast of Florida between 9 and 18 May 2018. The same measurements as above were conducted, with most data to be processed and water samples to be analyzed. ALFA system was also used on this cruise.

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 summer 2017 and reported progress.

Compared VIIRS and MODIS in their capacity in detecting and quantifying *Sargassum* macroalgae.

Published a paper (Wang and Hu, 2018) to document the findings – basically the two sensors are comparable.

Applied VIIRS and MODIS in studying a *Sargassum* bloom in the East China Sea, with results published in GRL (Qi et al., 2017).

Worked on VIIRS validation using field measured reflectance data. A manuscript is being prepared (Barnes et al., in preparation).

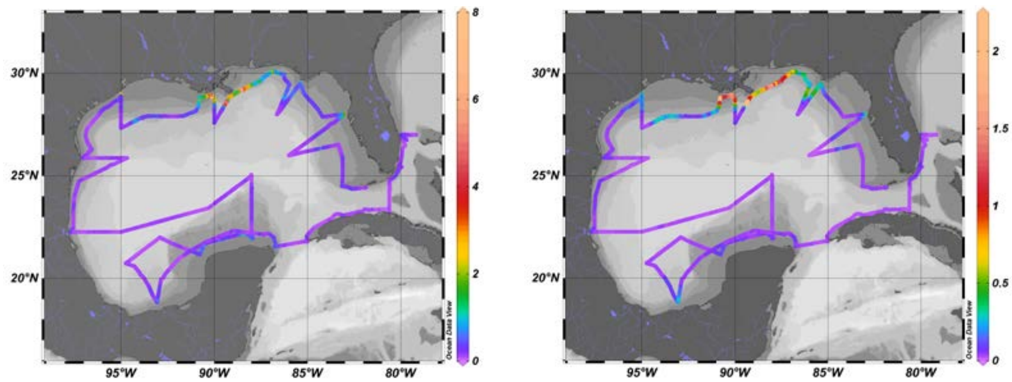

Figure 1: Fig. 1 shows fluorescence of chlorophyll and colored dissolved organic matter along the GOMEC-3 cruise track. High values occurred near the Mississippi delta due to river and other non-point source discharge.

Cruise track of GOMECC-3 between 18 July 2017 and 21 August 2017, where chlorophyll fluorescence (left) and CDOM fluorescence (right) from surface waters measured by the ALFA instrument are color coded.

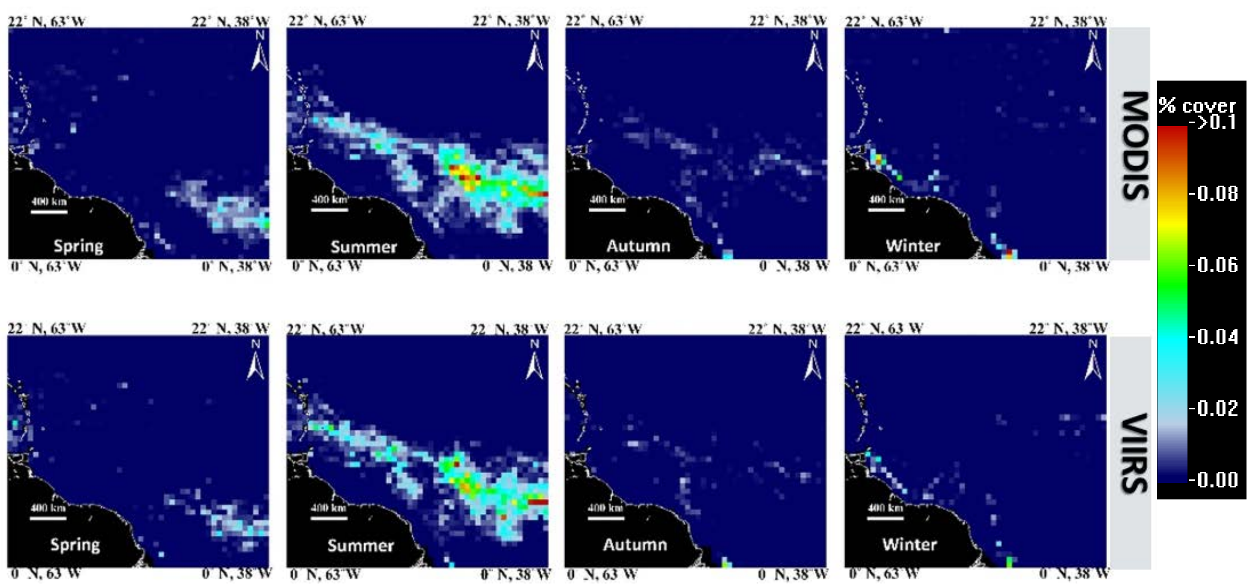

Figure 2: shows a comparison between VIIRS and MODIS in their quantified *Sargassum* macroalgae distribution in the central West Atlantic. Overall, the two sensors are comparable in their performance *Sargassum* distribution in the central West Atlantic derived from MODIS (top) and VIIRS (bottom) for the four seasons (Wang and Hu, 2018).

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)

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/AOML
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.

Biomonitoring is a fundamental tool that provides data for the management of the marine environment, and regular monitoring of biota allows for assessing the impacts of anthropogenic stressors, such as climate change and fishing activities. Recent advances in genomic technologies have paved the way for new methodologies for monitoring the oceans. Specifically, environmental DNA (eDNA), genetic material sloughed off or left behind by organisms in the marine environment, is a new way to measure the abundance and diversity of organisms. Collecting eDNA samples is still reliant on traditional manual and ship-based sampling methods. This research aims to establish equivalency of eDNA sampling methods on-board MBARI's Environmental Sample Processor (ESP) and Long-Range AUV to reduce reliance on ship time.

In December 2017, we conducted a field trial of the 3rd Generation ESP coupled to the long range AUV (hereafter name "eAUV") to test the eAUV vehicle and sampling behaviors. During this experiment, we tested the ability of the eAUV to both collect water samples while corkscrewing up or down the water column (i.e., "smear") and to trigger sampling based on on-board vehicle sensors (conductivity, salinity, temperature and fluorescence) (Fig. 1). Further, we tested tracking the submerged AUV using acoustic communications with a surface wave glider (Fig. 1). A major accomplishment of this deployment was repeated sampling while drifting within a specific volume of water. This continuous sampling provided samples that will document the evolution of the water mass in both space and time. DNA from these samples has been extracted and is currently being processed using qPCR.

An additional set of experiments were completed in June 2018 with the MBARI Controlled, Agile, and Novel Observing Network (CANON) expedition and the NOAA Pelagic Juvenile Rockfish Recruitment and Ecosystem Assessment Survey (Rockfish) to complement the samples collected during the same research expeditions completed in 2017. The complement samples were collected to compare eAUV and traditional ship based water and net-tow sampling on-board MBARI's *R/V Western Flyer* and NOAA's *R/V Ruben Lasker*. eAUV sample capacity was increased this year to provide more eAUV rendezvous stations with the ships. Sample filters collected during these two research cruises are currently frozen and will be analyzed later in 2018.

Results for the methods equivalency experiments performed in 2017 are currently being written into a manuscript for submission to a peer reviewed journal. This manuscript will highlight the equivalency of sample collection and preservation methods using the ESP, eAUV and traditional laboratory based methods. The manuscript will highlight how ESP sampling and preservation is equivalent to traditional laboratory methods when sampling the same water mass. An important finding of this manuscript reveals that while eAUV samples are collected in close proximity to ship based samples, they may report differences in the target populations. These findings emphasize the phenomenon of "patchiness" in the ocean and the importance of defining sampling objectives.

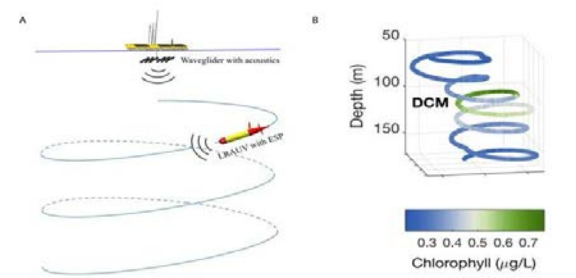

Figure 1: A) Illustration of eAUV spiral sampling behavior and acoustic communications with a surface wave-glider. B) An example of spiral sampling behavior through the deep chlorophyll maximum (DCM) on the eAUV.

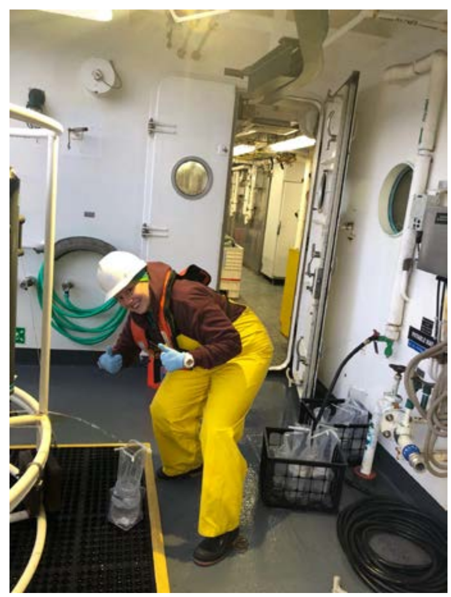

Figure 2: Dr. Kirsten Harper excitedly collecting water samples from the CTD for analysis by 'omics techniques.

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.

All major objectives have been or are being met. The research is on schedule. Coordination with the California Cooperative Oceanic Fisheries Investigations (CalCOFI) survey cruise has been changed to focus on the MBARI Controlled, Agile, and Novel Observing Network (CANON) expedition and the NOAA Pelagic Juvenile Rockfish Recruitment and Ecosystem Assessment Survey (Rockfish) which allow for more flexibility in obtaining paired samples between ships and the eAUV.

Juvenile Sportfish Monitoring in Florida Bay, Everglades National Park

Project Personnel: M. La Martina, D. Sinnickson, I. Smith, L. Visser, I. Zink, C. Quenee and K. Montenero (UM/CIMAS)

NOAA Collaborators: J. Browder and J. Contillo (NOAA/SEFSC); 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).

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.

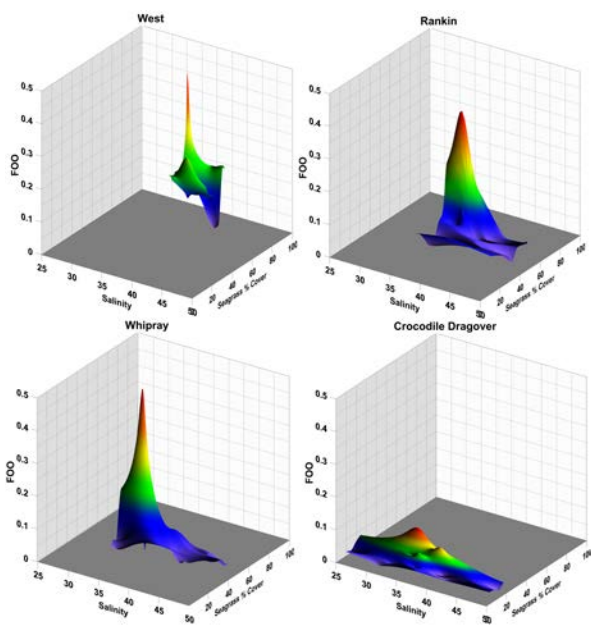

Figure 1: Contour plots depict the relationship between the juvenile spotted seatrout population, salinity, and seagrass within each sub-region of Florida Bay. Spotted seatrout occur more frequently with lower salinities and higher seagrass percent cover.

Figure 2: Photograph of a juvenile spotted seatrout caught in our trawls (*Cynoscion nebulosus*).

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. We are currently reviewing data and analyzing for a study of the effects from Hurricane Irma in September 2017.

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Biogeochemical Measurements

Project Personnel: C. Langdon, S. Ladewig and E. Pontes (UM/RSMAS); L. Chomiak (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/COD
NOAA Technical Contact: Kathy Tedesco

Research Summary:
The Biogeochemical Measurements project funds my involvement (discrete 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-2018 we completed IO7N, a section in the western Indian Ocean from 30°S to 18°N, completing 126 water column profiles. My group performed a total of 2,824 high precision oxygen measurements. Figure 1 shows the oxygen concentrations measured in 2018. This line was last occupied 23 years ago in 1995. Concerns about piracy have prevented a reoccupation until 2018.

The I07N cruise started in Durban, South Africa on April 23rd 2018 and ended in Goa, India, on June 6th 2018. The cruise consisted of two legs with a mid-point port stop in Victoria (The Republic of Seychelles) from May 15th 2018 to May 19th 2018. During the cruise 126 CTD casts (including 2 test casts) were carried out, and 15 Argo floats, 10 SVP drifters, and 3 wave buoys were deployed. The CTD/Rosette operations were carried out using 24, 12-L bottles. The final segment of the I07N line in the Arabian Sea is of particular interest because it crosses the Arabian Sea oxygen minimum zone (OMZ). The Arabian Sea OMZ is the thickest of the three oceanic OMZ and it is of global biogeochemical significance.

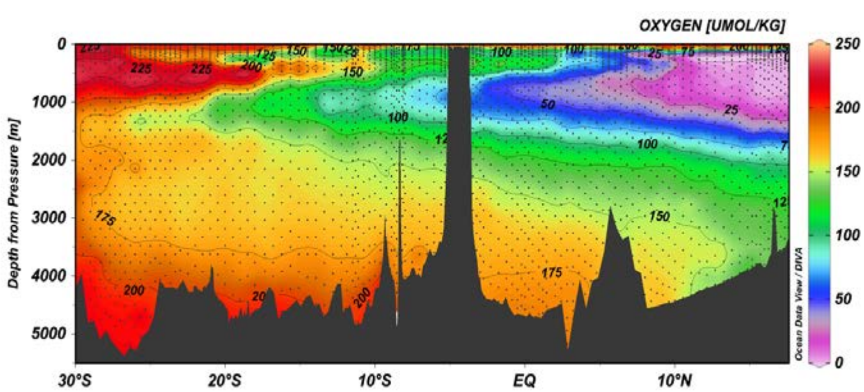

Figure 1: Oxygen section through the western Indian Ocean along the IO7N line in 2018.

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 are being quality controlled and archived with CCHDO (http://cchdo.ucsd.edu/) within the six-months of completion of each cruise. The performance measure for FY-18 of completing the re-occupation of the IO7N cruise and archiving the data within six-months is on track for being met.

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ECOA 2018

Project Personnel: C. Langdon and E. Pontes (UM/RSMAS)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To determine where and how much the near shore waters of the US East coast are becoming acidified both due to update of excess CO_2 from the atmosphere and as the result of hypoxia caused by eutrophication.

Strategy: Carry out hydrographic surveys along the east coast of the US at regular intervals (2007, 2012, 2015 and 2018).

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

NOAA Funding Unit: OAP

NOAA Technical Contact: Libby Jewett and Dwight Gledhill

Research Summary:

The first East Coast Ocean Acidification Cruise (ECOA-1) was completed in May-June 2015. The second East Coast Ocean Acidification Cruise (ECOA-2) began on June 25, 2018 and is scheduled to end on July 29, 2018. The effort is in support of the coastal monitoring and research objectives of the NOAA Ocean Acidification Program (OAP). The cruise is designed to obtain a snapshot of key carbon, physical, biogeochemical parameters and production rates as they relate to ocean acidification (OA) in the coastal realm. This was the fourth comprehensive occupation of the coastal waters, with the previous cruises occurring in 2007, 2012 and 2015. The previous efforts were named the Gulf of Mexico and East Coast Carbon (GOMECC) cruises I and II and ECOA-1. During each of these cruises key knowledge and data gaps were realized including: 1) a need to sample contributing Scotian Shelf and Labrador Slope waters, 2) a need to sample closer to the coast in order to better understand the effects of land fluxes on OA and 3) the need to characterize biological rate processes that affect distributions of carbonate parameters.

Our efforts are intended to complement mooring time series and other regional OA activities. The cruise included a series of transects complemented by lines laid out approximately parallel to the coast. A comprehensive set of underway measurements were taken between stations along the entire cruise track (Figure 1). Full water column CTD/rosette stations were occupied at 215 specified locations. A total of 15 scientists from UNH, UDEL, Princeton, ODU, UM and AOML/NOAA participated in the 34-day cruise, which departed from Newport, RI, on 25 June, and arrived on schedule in Miami, FL on 29 July 2018.

A total of 2000 discrete oxygen analyses were performed. These data were used to calibrate the oxygen sensor on the CTD. An additional 125 analyses were performed on sea water drawn from the ship's uncontaminated sea water line. These data were used to calibrate a second oxygen sensor the Uni of Delaware group was using to obtain a continuous record of the surface water along the ship track. These data will be used by the UDel group to obtain an estimate of primary productivity based on the oxygen supersaturation corrected for physical effects based on Argon supersaturation.

Figure 1 shows the 2018 ECOA-2 cruise track. This track repeats lines that were obtained in 2007, 2012 and 2015 during the GOMECC 1 and 2 and ECOA-1 cruises. These data will be analyzed to map out regions where the oxygen levels are hypoxic and therefore also low in pH, i.e. regions of coastal acidification. With four cruises of data, we will be able to determine with some confidence of the regions of low oxygen, low pH waters are growing in geographic extent or in intensity.

The data from this cruise will be made available at http://www.aoml.noaa.gov/ocd/gcc once quality checking has been performed.

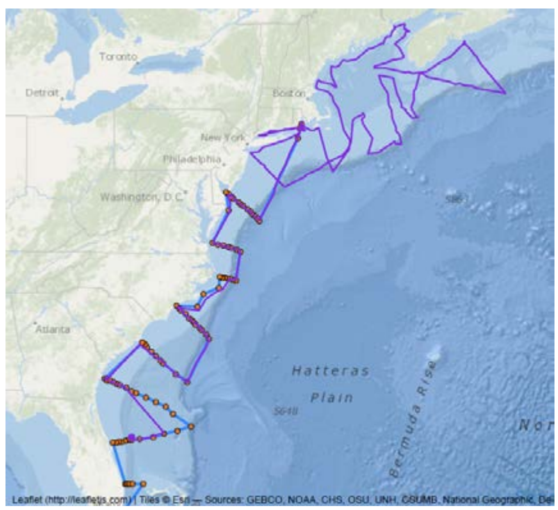

Figure 2: ECOA-2 2018 Cruise track.

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 are being quality controlled and archived with CCHDO (http://cchdo.ucsd.edu/) within the six-months of completion of each cruise. The performance measure for FY-18 of completing the re-occupation of the IO7N cruise and archiving the data within six-months is on track for being met.

Dimensions: Analysis of Microbiomes from Three Coral Species

Project Personnel: J. Lopez and M. Wickes (NSU); M. Gidley and S. Rosales (UM/CIMAS); H. Won Lee (UM/RSMAS)
NOAA Collaborators: C. Sinigalliano and 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 Marine Biodiversity Observing Network (MBON) project, NOAA AOML, UM CIMAS, 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 Microbiome Observing Network (CMON) 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. CMON 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, conducting MST analyses, and conducting NGS analysis for bacterial 16S rRNA genes from the microbiome communities. Additional MST analysis and NGS analysis of samples will continue into FY 2019.

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.

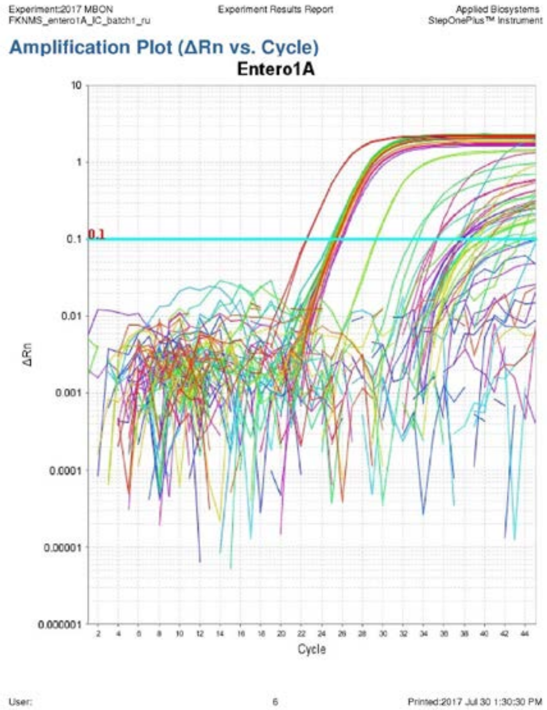

Figure 2: Quantitative real-time PCR amplification plot measuring the abundance of 16S ribosomal genes from enterococci bacteria in selected reef waters and coral tissues of the Florida Keys National Marine Sanctuary.

Research Performance Measure: All major research objectives are being met on schedule. The emphasis during this report period (1 July 2017 – 30 June 2018) has been on reef water, sediment, and coral tissue sample collection, metagenomic DNA extraction, MST (microbial source tracking) analysis, and next-generation-sequencing of bacterial ribosomal 16S RNA gene sequences from the microbiome communities of these samples.

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Ocean OSSE System Development and Applications for QOSAP

Project Personnel: M. Mehari and M. Le Hénaff (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: Molly Baringer

Research Summary:

This project is performed by the joint AOML/CIMAS/RSMAS Ocean Modeling and OSSE Center (OMOC). An ocean OSSE system has been developed following strict design criteria and rigorous evaluation procedures that enable a-priori 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 OSSE system Nature Run in the new North Atlantic domain (98ºW to 20ºW, 5ºS to 45ºN) 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.

During the previous year, work was performed to quantify the impact of deploying arrays of underwater gliders to reduce initialization errors in ocean prediction models, with particular emphasis on improving coupled hurricane prediction. One particular focus was to document the additional positive impact that is realized by using moving platforms, such as gliders, compared to using stationary platforms, such as moorings. Maps of RMSE with respect to the truth represented by the Nature Run calculated over the time interval July to October 2014 are presented for dynamic height at the surface relative to 1000 m (D_{1000}, Figure 1). For profiles collected from stationary platforms, large RMSE reduction is concentrated around each measurement location. Observations collected at fixed locations therefore have a limited radius of influence. By contrast, the ability of each moving glider to map a subregion of the analysis domain extends the radius of influence and roughly equalizes error reduction across the domain.

Work has also been performed to extend the OSSE system Nature Run and to perform data denial experiments to quantitatively assess the impact of ocean observing systems during the active 2017 hurricane season. Both OSE and OSSE experiments are underway. 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.

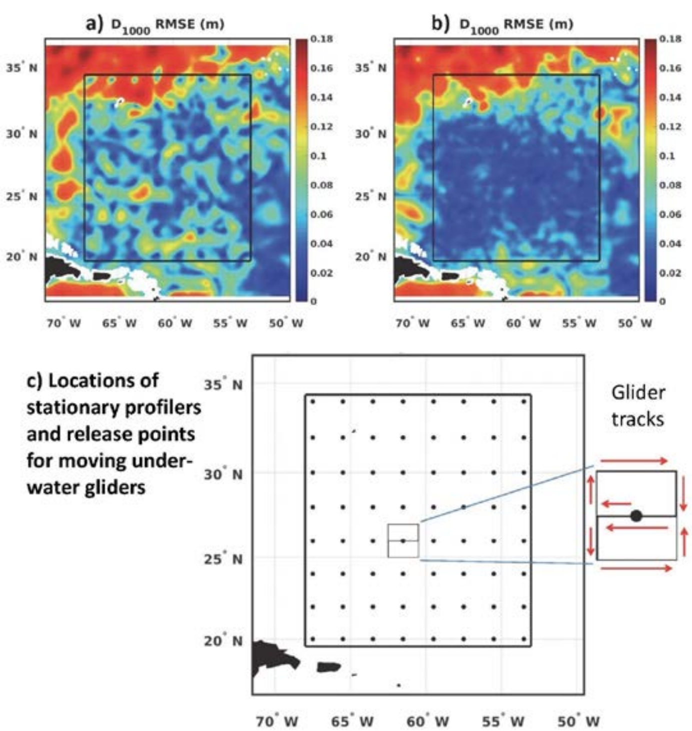

Figure 1: Maps of root-mean-square error in dynamic height at the surface relative to 1000 m for (a) the stationary profiler experiment, and (b) the moving glider experiment, calculated over the time interval from July to October 2014. Stationary profilers and gliders were released at longitude-latitude grid points shown in panel (c) with separation distances of 2.0º. All gliders released at these same points executed a reverse figure eight pattern over a track spanning 2º longitude and latitude while travelling at a speed of 0.25 m s^{-2}. Both stationary and moving platforms sample T, S profiles to 1000 m depth.

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 deploying underwater glider arrays during the 2014 hurricane season to evaluate their impacts when added to the existing ocean observing system. OSEs and OSSEs are now being performed to evaluate ocean observing systems during the 2017 hurricane season. 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, M. Bourassa and D. Dukhovskoy (FSU)
NOAA Collaborators: R. Lumpkin (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To develop and test a new drifter technology for observing currents at the very surface of the ocean, and mature the technology so that it will be available for wide application at the conclusion of the project.

Strategy: To implement improvements into a prototype concept for an ultra-thin surface drifter; to test the drifter in two large-scale field experiments; to use results of the experiments to gain further understanding of the vertical structure of near-surface currents.

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: NOAA/PMEL
NOAA Technical Contact: Chris Sabine (NOAA/PMEL); Alan Leonardi (NOAA/OER)

Research Summary:

The goal of this project was to develop and test a new drifter technology for observing currents at the very surface of the ocean, and mature the technology so that it will be available for wide application at the conclusion of the project. The main objectives and tasks of this project included: Implement improvements in the electrical components and logic including circuit board design and programming, field testing the new drifter design together with other more commonly used methods for measuring near-surface currents, and analysis of results from the field trials to gain further understanding of the vertical structure of near-surface currents. Major accomplishments during this project included: 1) Initial large-scale field experiment of prototype drifters, along with more traditional CODE- (Davis-) style shallow drogued drifters within the footprint of coastal HF radar; 2) Production of a set of surface drifters using the newly engineered drifter design for field testing; 3) A second large-scale field experiment using the new drifters together with drifters from the NOAA Global Drifter Program (SVP – Surface Velocity Program – Drifters).

The Stokes Drifter (so named because it measures the total surface velocity including the Stokes drift component) is a thin cylindrical hull containing electronic components, batteries and ballast to achieve buoyancy with < 1cm exposed above the sea surface. The hull is approximately 15cm in diameter and 5 cm high (just recently, a new hull has been designed with height reduced to approximately 4 cm). A circuit board (PCB) contains a GPS module, a satellite transmitter module, antennae, a microcontroller, two analog-digital converters (ADCs) for connecting external sensors, and other necessary components (Figure 2). Given the small aspect ratio of the drifter, it is not self-righting and can flip under wave action. Thus, antennae are connected to each side of the circuit board, and input from an accelerometer is used by the microcontroller programming to determine which antennae to use for transmission. This novel approach to drifter design allows a very thin hull profile to be used, requiring only one satellite transmitter, thus saving substantially on component cost and satellite data costs.

Two large-scale field trials were conducted during this project. The first was a deployment offshore of Orange Beach, AL on 24 January, 2017 that included thirty 5-cm thick (4 cm submerged) PVC proxies to the Stokes Drifters released together with fourteen of CODE-style drifters and 28 drifters that were similar to the Stokes Drifter, but constructed with 10-cm hulls (9 cm submerged). In addition, 300 drift cards were released with beaching locations determined by volunteer citizen observers. This location is also covered by coastal HF radar (Long-Range CODAR) that measures currents at approximately 2-3m depth. This experiment was designed to measure currents at several depths for analysis of the vertical structure of the near-surface shear, as well as measurement characteristics of the different methodologies. The second field experiment was conducted in collaboration with the NOAA/AOML Global Drifter Program (GDP) in collaboration with R. Lumpkin (AOML). For this deployment, fifteen 10-cm drifters, seventeen 5-cm drifters, and twelve drogued SVP drifters were released from the F.G. Walton Smith during NOAA's bi-monthly 27°N survey on July 19-20, 2017. This experiment was used for performance testing of the final drifter hull and electronics design, and comparison to the SVP drifters.

During the first field experiment, co-located drifter velocity measurements from the first field experiment, 5-cm, 10-cm, and CODE drifters were deployed in clusters along with drift cards. The 5-cm and 10-cm drifters generally tracked together for the initial days of the experiment, while the CODE-style drogued drifters behaved substantially differently (Figure 1). Observation of the clusters of drifters shortly after deployment also support that the thin drifters remained clustered with the drift cards while the CODE drifters separated from the cluster (Figure 2), were analyzed to yield new understanding of the vertical shear near the ocean surface and differences between the Stokes Drifter total surface velocity measurements and other traditional surface velocity measurement techniques. Results of the analysis show that the mean vector difference between the 10-cm (9 cm submerged) drifters and the 5-cm (4 cm submerged) drifters was 0.982 (Figure 3). However, there is a significant relationship between the magnitude of this shear and the wind speed. The CODE drifter velocities were on average only 77% of the Stokes Drifter velocity, and there was also evidence of clockwise Ekman turning in the measurements at different depths. Scaled magnitudes of velocity vector differences computed between the HF radar data and bin-averaged velocities from the different drifter types show that the HF radar-estimated velocity magnitudes are only approximately 55% (65%) of the 5-cm (10-cm) drifter velocities, but not significantly different from the CODE drifter velocity.

Results from this study were presented at the 2017 ASLO Aquatic Sciences Meeting and a scientific journal manuscript is in preparation (anticipated submission July 2018). A patent for this technology has been applied for. We are working with the FSU Commercialization office to transfer this technology to a commercial entity for mass production for wide application. Mass production capability has been set up with manufacturers for the custom electronics, a newer hull design, and a custom gel battery. The electronics have undergone FCC certification. We are in collaboration with Irridium to expand satellite communications capability to that network. Several of these drifters have been manufactured for use in an upcoming field experiment in collaboration with NASA/JPL and the University of Washington in the eastern Pacific in August, 2018.

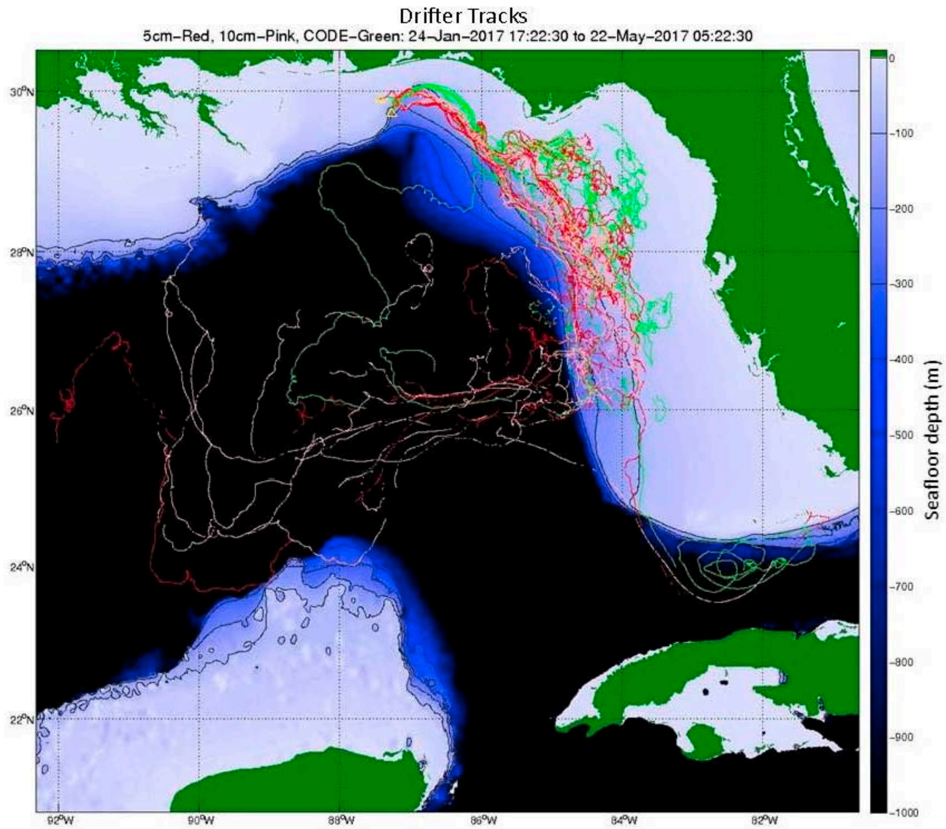

Figure 1: Drifter tracks from the 24 January 2017 Orange Beach, AL deployment. Red tracks indicate 5-cm drifters (4 cm below the water line), pink tracks indicate 10-cm drifters (9 cm below the water line), and the green tracks represent the drogued (CODE- or Davis-style drifters, drogue depths 0.5-1.5m). Yellow triangles indicate deployment locations.

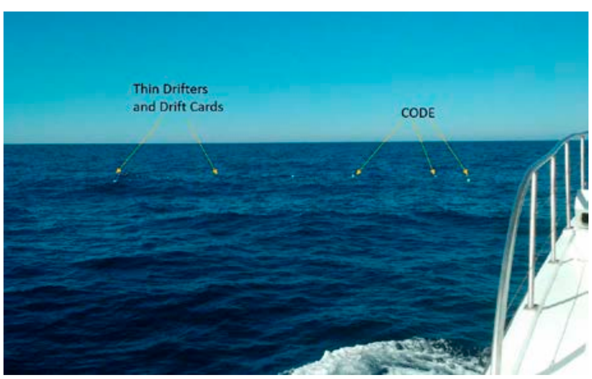

Figure 2: Photograph of a cluster deployment of 5-cm, 10-cm, and CODE drifters along with orange buoyant drift cards, approximately 5 minutes after being deployed within a region of roughly 5 m in diameter. Note the clustering of the thin hull drifters with the drift cards, and the separation of the drogued CODE drifters.

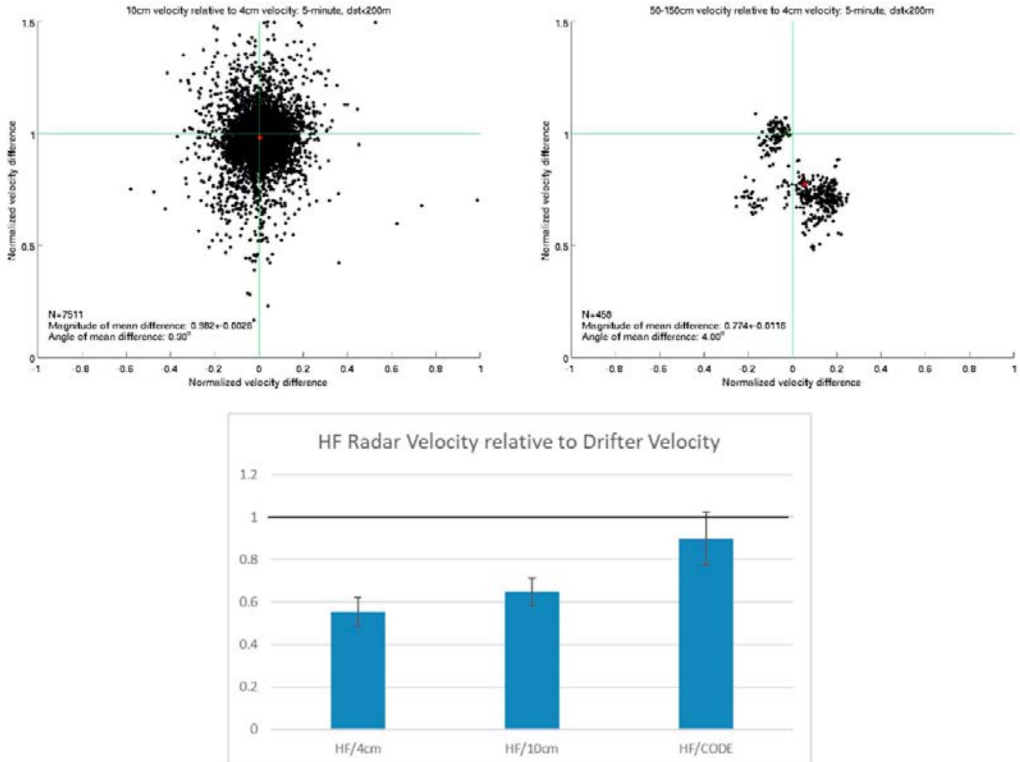

Figure 3: Top: Scatterplots of vector velocity differences between the 10-cm drifters and the 5-cm drifters (left) and the CODE drifters and 5-cm drifters (right), normalized by the 5-cm drifter velocity. The mean vector velocity difference is shown by the red dot in each plot. Bottom: Magnitude of the mean velocity difference between the HF Radar estimated velocity and the binned (6 km, 1 hour) velocity from each drifter type, scaled by the drifter velocity. Error bars represent the 95% confidence intervals.

Research Performance Measure: All major objectives have been met, with the exception of the journal article detailing the results of the field experiments and drifter technical description is in preparation and has not yet been submitted. We anticipate submission by the end of July 2018.

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Surface water partial pressure of CO_2 (pCO_2) measurements from ships

Project Personnel: D. Pierrot, K. Sullivan, L. Barbero, N. Mears and Z. Barton (UM/CIMAS); R. Woosley and Carmen Rodriguez (UM/RSMAS)
NOAA Collaborators: R. Wanninkhof and G. Goni (NOAA/AOML)
Other Collaborators: F. Millero (UM/RSMAS); 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 sea-air fluxes on different time scales (Figure 1).

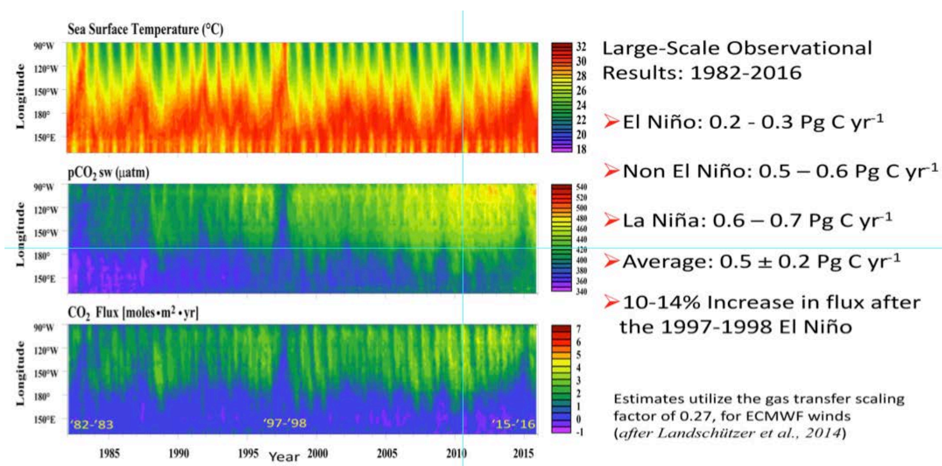

Figure 1: Longitude - time plot of SST, pCO_2 and CO_2 flux in the tropical Pacific from 1982 to 2016 computed using SOOP pCO_2 and SST measurements. The warm anomalies are correlated with the strong and weak El Niño events. A significant decadal increase in overall outgassing flux occurred after the 1997–98 El Niño event.

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 over 80 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 Ocean Carbon Coordination Project (IOCCP) of UNESCO/IOC. A major product, the Surface Ocean Carbon Atlas (SOCAT) version 5 containing over 21.5 million pCO_2 data points, was released in June 2017. Efforts to produce SOCAT version 6 are underway with the annual release in the summer of 2018.

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*, and cruise ships *Equinox* and *Allure of the Seas* of the Royal Caribbean Cruise Lines (RCCL) have been transmitting TSG data in near-real time. All the ships that are part of the project send complete daily files of pCO_2 to shore via Internet or Iridium. A 15 year time series of data including the trends is shown in Figure 2.

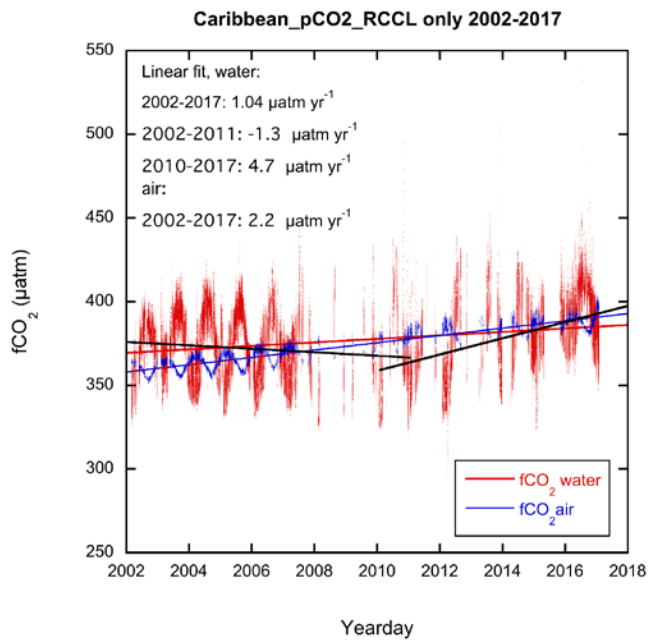

Figure 2: A 15 year time series of data in the Caribbean Sea including the trends from the Royal Caribbean Cruise Lines (RCCL) ships *Explorer of the Seas, Equinox* and *Allure of the Seas.*

Frank J. Millero, 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 a 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. Over 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., 2018). 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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Environmental Microbiology: Characterization of marine microbiomes and molecular source tracking of microbial contaminants

Project Personnel: S. Rosales, M. Gidley, P. Jones and X. Serrano (UM/CIMAS); H. Lee (UM/RSMAS)
NOAA Collaborators: C. Sinigalliano, B. VanDine and J. Hendee (NOAA/AOML)
Other Collaborators: L. Johnston and D. Palacois (CNMI/BECQ); J. Lopez and M. Wickes (NSU); T. Troxler (FIU)

Long Term Research Objectives and Strategy to Achieve Them:
Objectives: To metagenomically characterize the microbiomes of specific marine habitats, measure selected microbial contaminants and pathogens in these habitats, and conduct technology transfer training in this microbial source tracking.
Strategy: To conduct molecular microbial source tracking studies of land-based sources of pollution (LBSP) for critical marine habitats in South Florida and in the Commonwealth of the Northern Mariana Islands and to characterize the biodiversity and community structure of microbiomes in these critical habitats. To provide training and technology transfer of the molecular methods used for this to other agencies, resource managers, and the private sector.

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: CRCP, FKNMS and OAR/AOML

NOAA Technical Contact: John Tomczuk (CRCP); Gabrielle Canonico (FKNMS); Molly Baringer (OAR/AOML)

Research Summary:

This program is a collection of several leveraged projects with a shared theme and approach, using next generation sequencing of marine microbiomes combined with molecular microbial source tracking of Land-Based Sources of Pollution (LBSP) microbial contaminants and pathogens to assess the environmental quality and potential influences of LBSP and other environmental stressors on critical habitats such as coral reef communities and coastal waters in the Florida Keys National Marine Sanctuary (FKNMS), Southeast Florida coastal waters, beaches, and reef tract, and coastal waters and reef tract of Saipan Lagoon in the Commonwealth of the Northern Mariana Islands. Another critical component of this work is to conduct methods training workshops and technology transfer activities to teach the molecular methods used for this and to enable transfer of this technology (particularly the molecular microbial source tracking methods) to other agencies responsible for environmental resource management and to the private sector to help enable the more widespread utilization of these tools for resource management. This work involves CIMAS personnel efforts on the CRCP-funded technology transfer workshop project with the Bureau of Environmental Coastal Quality (BECQ) of the Commonwealth of the Northern Marinana Islands (CNMI), a United States unincorporated territory. This CRCP project for the CNMI BECQ also includes an LBSP source-tracking study for Saipan lagoon that was integrated with a companion study on stable nitrogen isotope source tracking of these same samples by American University and the CNMI BECQ. The primary goals of this project are to establish MST analytical capacity at the BECQ while also providing BECQ management with a primary base-line study of LBSP patterns in Saipan Lagoon based on microbial and stable isotope tracking patterns. Leveraged CIMAS work within this theme also involves another independent project in the Florida Keys, the Marine Biodiversity Observing Network of the FKNMS, where samples of marine sediment, near-coral water, and coral tissue from 3 species of coral at 6 different sentinel reefs were collected and analyzed by next generation sequencing and MST analysis to characterize the biodiversity and potential LBSP exposure of these coral habitat microbiomes. The results of this are integrated with the larger FKNMS MBON project to examine biodiversity characteristics across tropic levels in the Florida Keys. A third leveraged independent project utilizes these same molecular tools to examine the microbiome structure and microbial contaminants of urban tidal floodwaters from supertidal events in Southeast Florida such as "King Tides". These results are being utilized by local agencies, governments, and other groups in preparation and resiliency planning for sea level rise impacts. For example, this work has helped inform planning documents by the Miami-Dade County RER on anticipated impacts of sea level rise on the regional septic and sanitary infrastructure. In addition, CIMAS personnel have established at AOML an environmental bioinformatics computational analysis facility and have organized a regional users group for environmental bioinformatics that is helping to inform a wide variety of environmental 'Omics-related projects and initiatives including fisheries population genetic studies, coral biodiversity and restoration studies, habitat connectivity studies, LBSP source tracking studies, environmental pathogen studies, and a wide range of microbiome characterization studies.

Figure 1: Dean Palacois of the CNMI's Bureau of Environmental and Coastal Quality (left) and CIMAS visiting scientist Maribeth Gidley (right) extract metagenomic DNA from samples gathered in Saipan's coastal waters and coral reefs to track microbial contaminants using molecular methods. This effort was both to train CNMI BECQ personnel in these MST techniques, and to document and track patterns of LBSP-associated host-specific fecal indicating bacteria impacting the Saipan Lagoon.

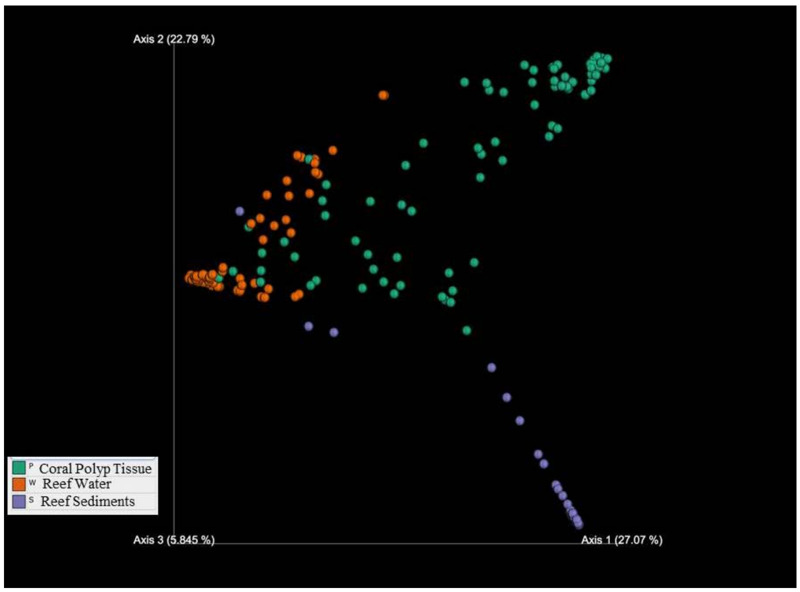

Figure 2: PCoA plot for Bray Curtis Dissimilarity Principal Coordinate Analysis of bacterial community 16S ribosomal DNA sequences collected from reef waters, reef sediments, and coral polyp tissues from sentinel reefs in the Florida Keys National Marine Sanctuary. The clustering pattern reflect a multi-axis visualization of the relative extent of similarity between the population composition and biodiversity of the microbiomes from these samples. Green dots represent bacterial populations from coral polyp tissues, orange dots from water collected near coral heads, and purple dots from coral sediments.

Research Performance Measure: All major research objectives are being met on schedule. The emphasis during this report period (1 July 2017 – 30 June 2018) has been on collection and analysis of FL Keys MBON coral samples, collection and analysis of Saipan Lagoon water samples, MST technology transfer and training for the CNMI BECQ, analysis and bioinformatics of previously collected urban tidal flooding samples, MST technology transfer and testing for PALL Corporation GeneDisc qPCR platform, and on-going bioinformatics computer analysis support for the NOAA AOML 'Omics initiative (multiple 'Omics projects.

Ingesting Sea Surface Height Anomalies from the Jason-3 and Sentinel 3A Missions to Enhance the NESDIS Operational Ocean Heat Content Product Suite

Project Personnel: L. Shay (UM/RSMAS)
Other Collaborators: E. Maturi and D. Donahue (NESDIS)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** The Jason-3 altimetry mission primarily focuses on its use in mesoscale oceanography is based on a 10-day repeat track. The sea surface height anomaly (SSHA) data are a key component in calculating the daily ocean heat content (OHC) product operationalized for three basins, North Atlantic, and North and South Pacific, at NOAA/NESDIS. In addition to Jason-3, the effort also includes entraining the Sentineal-3A data which have a 27-day repeat track. Here, the inclusion of these missions is assessed when combined with other altimeters such as Jason-2, Cryosat-2 and SARAL missions.

***Strategy*:** Jason-3 and Sentinel 3A SSHA data are evaluated for filling in gaps to assess possible improvements to the OHC product suite that used Jason-2, SARAL and Cryosat-2 mission data. The OHC product was calculated with and without these missions to assess its impact on the product suite. Central to this objective is that isotherm depths (20 and 26oC), ocean mixed layer depth, and OHC were carefully evaluated from in-situ data from Argo floats, drifters, expendable bathythermographs (XBT) transects, long-term Pirata and TAO moorings and airborne AXBTs, and AXCTDs as discussed in the report to NESDIS listed below.

CIMAS Research Theme:

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

Link to NOAA Strategic Goals:

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

NOAA Funding Unit: NOAA/NESDIS
NOAA Technical Contact: Eileen Maria Maturi

Research Summary:

Using the three daily systematically merged regional temperature and salinity climatologies for the North Atlantic (Meyers et al., 2014: SMARTS); North Pacific (McCaskill et al., 2016: SPORTS) and the South Pacific (SPOC), the addition of Jason-3 to the operational OHC product for NOAA/NESDIS was investigated (Sentinel 3a comparisons will be completed by the end of the summer). Using recent data from August 2016, the Jason-3 ingest reduced the mapping errors following the Mariano and Brown (1992) approach. The SSHA differences at positions of near-cross track were determined using 1 and 3 day intervals and found to be approximately 8 cm for all three basins. OHC root-mean square differences calculated with and without these missions lowered the normalized mapping errors. Thus, adding the additional altimeter data improved the product. Understanding the limitations involved with a multi-mode mission is important to explain how this new wave of radar altimeters can be used in the future of sensing the open ocean from space.

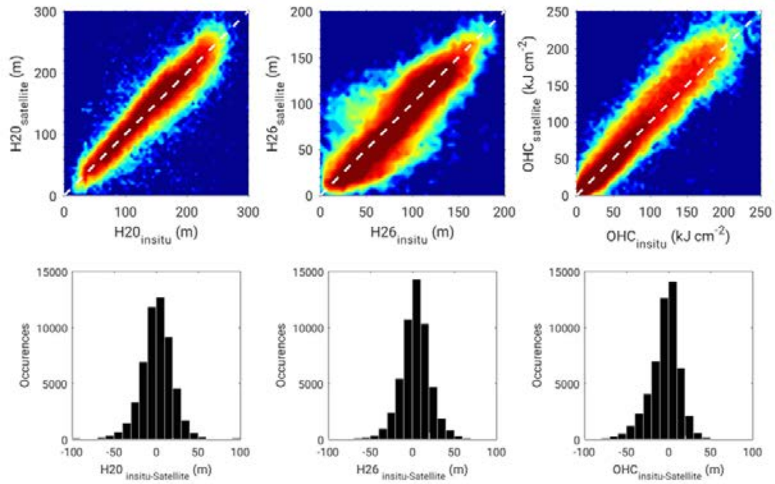

Figure 1: Regression (top) between in-situ and satellite measurements and a probability distribution function graph (bottom) of the in-situ minus the satellite measurements for depth of the 20ºC isotherm (H20: left panels), depth of the 26ºC isotherm (H26: center panels), and the oceanic heat content (OHC: right panels) from all three basins from July 2016-December 2017 calculated with Jason-2, SARAL, Cryosat-2 and Jason-3 using more than 50,000 coincident in-situ thermal profile measurements.

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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*:** Investigate the interaction between the large-scale circulation on the shelf, bottom flow and environment, and how events driven by 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 targeted two deployments sites, both in the Gulf of Mexico. The first was a 24 hour deployment in the Apalachicola Bay where we investigated 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 targeted the benthic boundary layer as well as the pycnocline on the outer shelf. We determined flow and turbulent flux parameters as well as bulk mixing over a period of a few 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 Apalachicola Bay. 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 velocity and CTD data clearly showed the velocity structure and shear during the tidal cycle. In addition, bottom tracked data during surface drifts has shown that the trajectories calculated from acoustic tracking agree well with trajectories obtained from GPS. The drifter's ability to track changing bottom topography was tested and shown to be operational. A science deployment was conducted on the northern shelf of the Gulf of Mexico and resulted in several new CTD sections, as well as velocity, CTD and oxygen data measured by two drifters over the period of 4 days. The data is currently being processed and analyzed to investigate the interaction between large-scale circulation and the bottom layer on the shelf, bottom flow and turbulence and how events such as eddies and wind influence circulation and upwelling on the shelf. In addition, we will calculate Reynolds, and Richardson or Froude numbers to evaluate mixing and relate the observations to external forcing of tides and winds.

(See Figure 1 for a picture of the drifter during the science deployment off the coast of Louisiana, Figure 2 for an example of the bottom tracking abilities of the platform, Figure 3 for an example of a trajectory calculated from bottom tracked data, Figure 4 for the dive in deep water, and Figure 5 for velocities obtained by the drifter.).

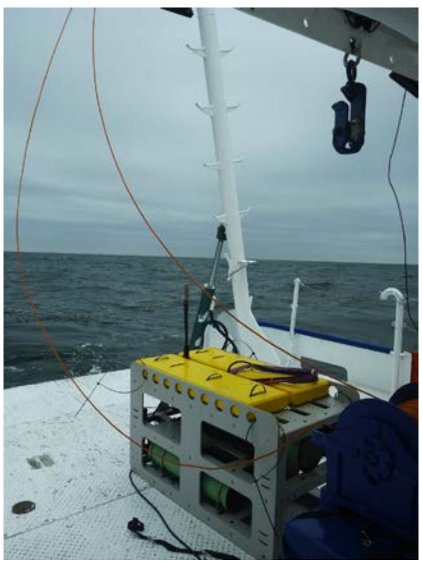

Figure 1: The platform before being deployed on the shelf of the Gulf of Mexico, offshore of Louisiana in April 2018.

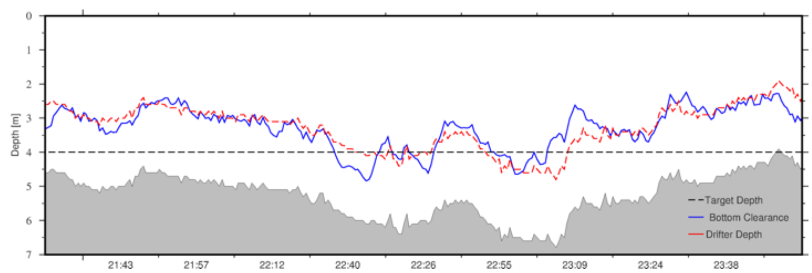

Figure 2: An example of the platforms ability to track changing topography. The red solid line shows the target depth of this dive, and the red broken line shows the 2 m bottom clearance in case of topography. The blue line indicates the actual dive depth if the platform.

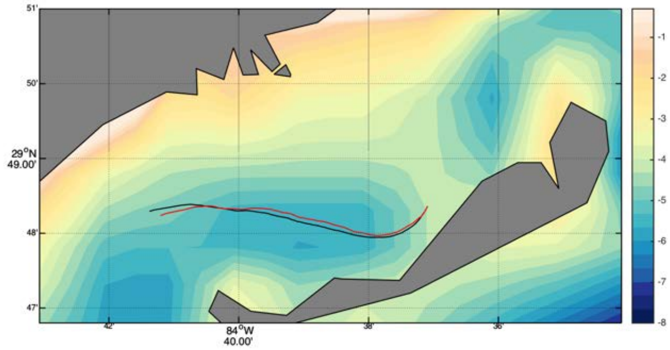

Figure 3: Example of tracking the Drifter using the ADCP bottom track velocities. The blue track shows the trajectory from the Iridium GPS locations. The red trajectory was calculated using the ADCP's velocity over bottom and the first GPS point as a start point. The bottom topography was obtained from etopo.

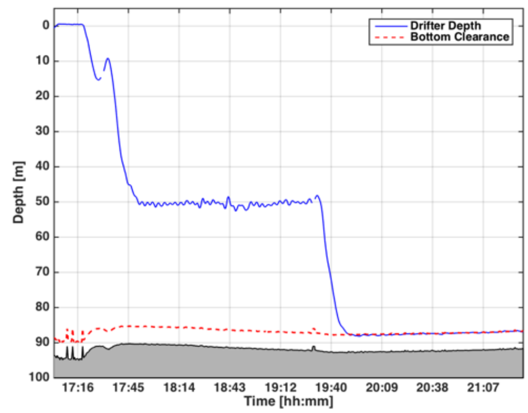

Figure 4: Offshore dive. The blue line shows the actual depth of the CBD. The red broken line shows the 5 m bottom clearance that the CBD had follow. Topography was obtained from the ADCB data.

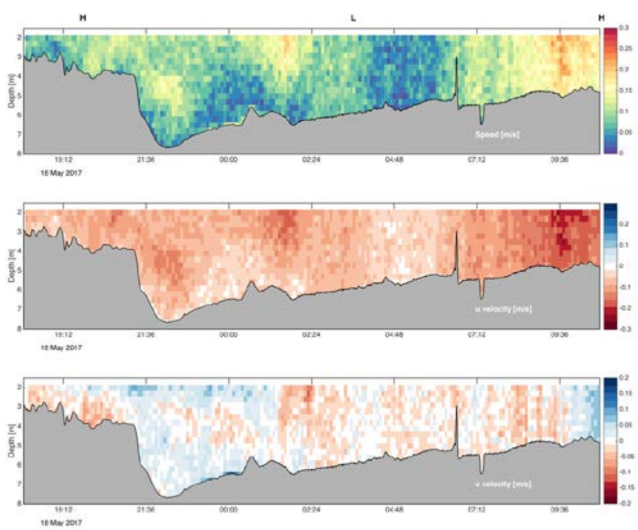

Figure 5: Velocity obtained by the Drifter. Top panel: Speed [m/s] obtained from the ADCP Data. Middle panel: The u velocity [m/s] obtained by the ADCP. All positive velocities (shown in blue shading) are east, while negative velocities (shown in reds) are westward. Bottom panel: Same as the middle panel but for the v velocities. All positive v velocities (blues) are oriented to the north, while negative velocities (reds) are oriented to the south. For all three panels, the shown bottom topography was calculated by the ADCP.

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 a 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 conducted in April/May and is the last in the testing phase of the platforms. The deep dive went well and the drifter was able to follow a pre-set depth for several hours, before diving and following the bottom for the last part of the test. Data from a test in Apalachicola Bay showed that the drifter can resolve not only tidal cycles, but also dynamics such as a plume of dense water, and wind driven overturning, and flow forced by local topography. The results of these data have been submitted to the Journal of Atmospheric and Oceanic Technology and are currently under review.

Marine Optical Buoy (MOBY) Operations and Technology Refresh

Project Personnel: K. Voss and A. Gleason (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 on both the Suomi-NPP and the JPSS-1 (or NOAA-20) platform.

Strategy: We are maintaining the operation of the Marine Optical Buoy (MOBY), moored off 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 and now JPSS-1 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 STAR/NESDIS/NOAA CoastWatch site.

We have also been working on a "Refresh" of the optical and electronic systems in the MOBY system. For several years we have known that the current MOBY system was nearing its end of life and it was critical that a technology refresh occur. Thus, we are 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: MOBY pre-launch, being brought out to the ship in the Univ. of Hawaii Marine Facility. The new dual spectrometer (the bright silver housing, along with the white spectrometer tubes) is attached on top of the MOBY instrument housing. It is about to be loaded onto the side of the R/V Ka`imikai-O-Kanaloa to be brought out to the mooring site near the island of Lanai, Hawaii.

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. For over a year, we have been fielding the updated control system and the portion of the optical system, which covers from 350-700 nm (blue-red). Just this month we fielded a dual system, which measures the light field from 350 to 900 nm (blue to near infra-red).

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PIRATA Northeast Extension

Project Personnel: D. Ugaz, G. Rawson, R. Roddy and J. Christophersen (UM/CIMAS)
NOAA Collaborators: R. Perez, G. Foltz, R. Lumpkin and C. Schmid (NOAA/AOML)

Long Term Research Objectives and Strategy to Achieve Them:

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

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

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 to collect a suite of oceanographic and meteorological observations in the region. PNE is a joint AOML/PMEL project that expands the PIRATA array of next generation T-Flex 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 R/V Ronald H. Brown from March 7th to April 14th 2018. During the 39-day, nearly 8000 nautical mile journey from Fort Lauderdale, Florida to Durban, South Africa, the science team measured the upper ocean and near-surface atmosphere of the tropical Atlantic. G. Foltz served as Chief Scientist for the cruise, with scientific support provided by C. Featherstone, L. Pomales, and D. Ugaz. G. Rawson prepared and calibrated instruments prior to the PNE cruise. CIMAS personnel were joined by mooring technicians S. Kunze and D. White from NOAA/PMEL, scientist B. Kisjeloff from Germany, who oversaw the deployment/recovery and calibration of dissolved oxygen sensors, and volunteer L. Pomales from the University of Puerto Rico.

PIRATA buoys were recovered and redeployed at 20°N, 38°W; 11.5°N, 23°W; and 4°N, 23°W. The mooring at 20.5N, 23W was not recovered and a new mooring was not deployed because of rough seas and high winds. We also serviced a rain gauge and longwave and shortwave radiation sensors at the 0°, 23°W French PIRATA mooring. Conductivity-temperature-depth (CTD) casts were conducted at 50 out of the 68 planned stations, including calibration casts for dissolved oxygen loggers. 12 Argo profiling floats and 10 surface drifters were deployed, as well as 55 surface drifters that were developed and deployed as part of a project to investigate the trajectories of sargassum and marine debris in the North Atlantic, led by G. Goni, R. Lumpkin, and U. Rivero.

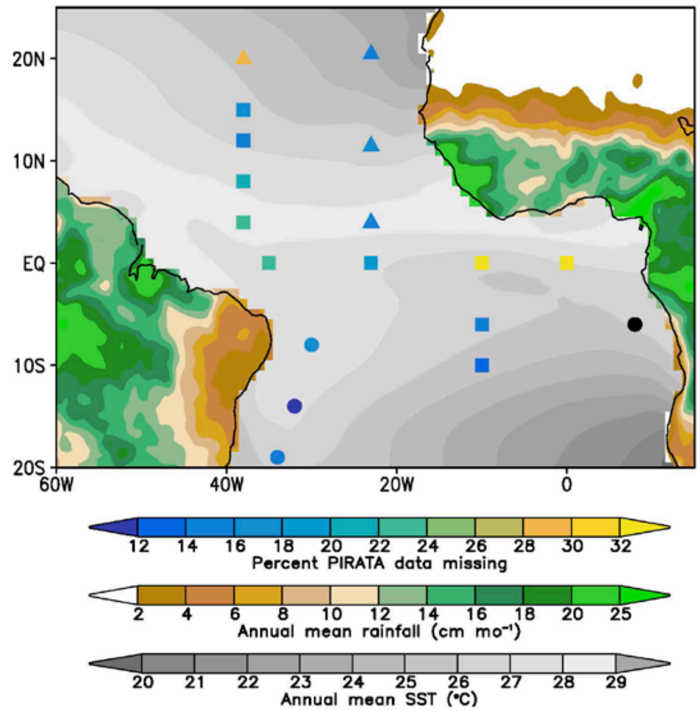


Figure 1: Annual mean satellite microwave sea surface temperature (SST; gray shading) and rainfall (colored shading). Locations of the "backbone" PIRATA array, first deployed in 1997 (squares). Positions of the northeast extension (triangles) and southwest extension moorings (circles), first deployed in 2005–06. Position of the southeast extension mooring (black circle), part of PIRATA since 2013 and not part of ePIRATA because of its short duration. For moorings, colors indicate the percentage of original PIRATA data that are missing at each location. ePIRATA fills these gaps and corrects existing data for instrumental biases.

Research Performance Measure: All major objectives are being met.
G. Foltz, C. Schmid, and R. Lumpkin developed an enhanced PIRATA data set for tropical Atlantic ocean-atmosphere research that was published in J. Climate in February 2018. The data will be updated regularly and made publically available.

R. Perez, G. Foltz, R. Lumpkin, and C. Schmid analyzed the first year of data from eleven current meters deployed at the 4°N, 23°W PNE mooring as part of the Tropical Current Atlantic Observations Study (TACOS). A paper on the first year of data has been submitted to Geophysical Research Letters. TACOS data has yielded several surprising new results: Mean zonal velocity and vertical shear were strongest between 32 and 37 m, with mean near-surface eastward currents that were weaker than expected. Despite the Atlantic cold tongue being anomalously warm, energetic tropical instability waves (TIWs) were observed. Meridional velocity fluctuations were generally larger than those of zonal velocity. TIW velocity fluctuations extended down to 87 m and perturbed the thermocline and the depth of maximum vertical shear squared, although they generated only modest vertical shear when compared to the shear in boreal winter and spring. These fluctuations propagate upward to the surface with vertical phase speeds between 12-15 m day^{-1}. Coherent velocity, vertical shear, and temperature variations are examined in a composite TIW. The impact of these currents on temperature, salinity, and air-sea fluxes will be the subject of future study.

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 and D. Gloeckner (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 the PI 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, the PI did some data cleaning: Replaced the incorrect vessel number and areas, excluded abnormal values, and corrected some error records. Second, the PI 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, the PI used simulation methods, randomly selected 50%-100% of trips, and for each trip the PI randomly measure the length (weight) of 2-10 fish individuals. This resampling was repeated for 100 times, and the distribution of the effective sample size, Kolmogorov-Smirnov test, variation between trips, variation within trips, and their ratio were estimated.

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. The detailed results can be find in the folder "result eff 100 sample 08312017", and the 3d and 2d figures can be found in the folders "3d eff length 100 resample", "2d eff length 100 resample", "3d eff weight 100 resample", and "2d eff weight 100 resample". Figures 1 and 2 are examples.

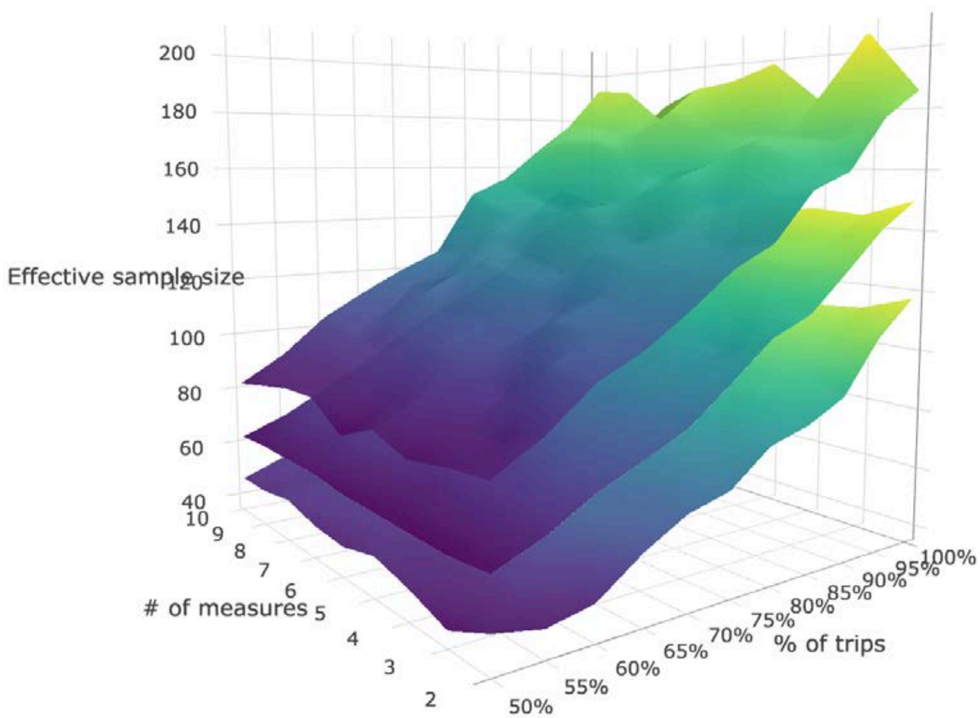


Figure 1: Median, lower 2.5% and upper 97.5% confidence interval of estimated effective sample sizes for the length of Gulf of Mexico red snapper in 2003 when sub-setting the records from the original survey. Similar figures are plotted for Kolmogorov-Smirnov test, variation among trips, the variation within trips and their ratio.

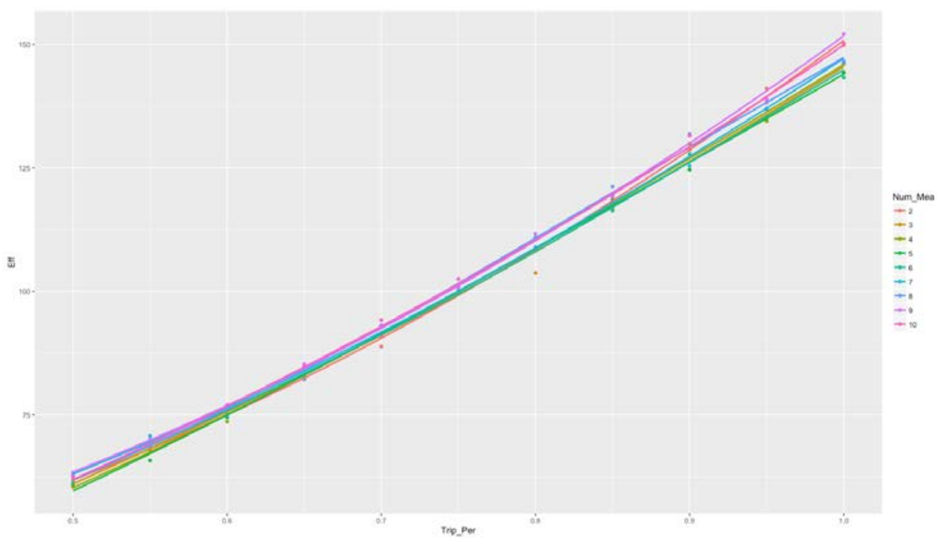


Figure 2: The median estimated effective sample sizes for the length of Gulf of Mexico red snapper in 2003 when sub-setting the records from the original survey. Similar figures are plotted for Kolmogorov-Smirnov test, variation among trips, the variation within trips and their ratio.

To validate the results, the PI used the simulation method and examined the effects of changing the number of trips on the estimated effective sample size, total variation, variation between trips, variation within trips, and their ratio. 2%-100% of the trips were bootstrapped, and for each trip, the length (weight) of 5 fish individuals were measured (for each species). Every resampling was repeated for 50 times. The results indicate that the variation among trips is consistently much larger than the variation within each trip, and the estimated effective sample size changes with the number of trips in the same direction. The detailed results can be found in the folders "2d eff percentage of trip length (weight) by year (month or area) resample 5". Figure 3 is an example.

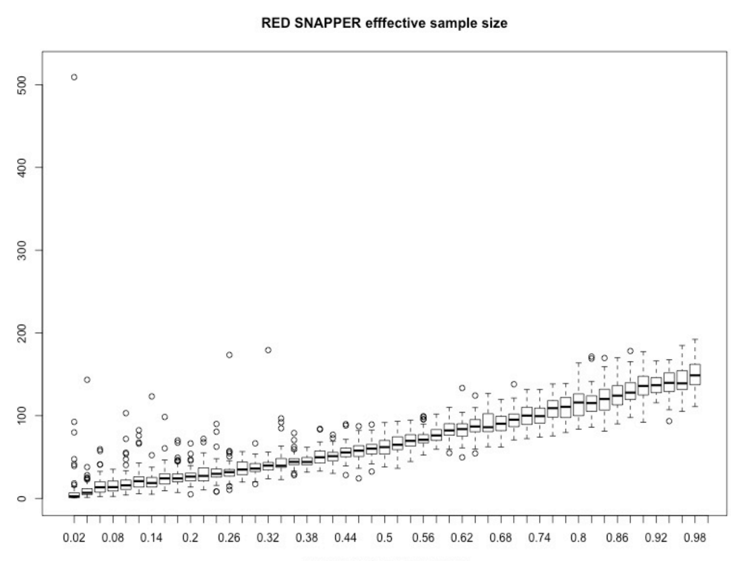


Figure 3: Trace the change of the estimated effective sample size under various the number of trips. Similar figures are plotted for total variation, variation among trips, the variation within trips and their ratio.

The unreported landing and reporting errors are the two main obstacles to accurate and precise landing estimations. In this project, the PI examined the general and species-specific unreported rates, as well as the general and species-specific underreported rates. These results can help us not only validate captains' reports about trips and landings, but also estimate the bias and the uncertainty of the total annual head-boat landings from captains' reports. In addition, the number and the percentage of the un(der)reported case for each vessel are also investigated, and ploted by year and species, which can further help fisheries managers to identify dishonest captains and track their behaviors. The detailed figures can be found in Tableau files "UnhonestGu(At).twb", "UnderRepGu(At).twb" and "at(gu)_landingbias", but also be re-ploted by using R and saved in the folder "figure unreported and underreported". The unreported rate was higher in mid-1980s, but the number of case started to decrease. For the decades from mid 1980s to 2000s, the unreported rate was maintained around 60% (Figure 4). In the most recent 10 years, both the unreported case and rate decreased, which can be considered as a good sign that the reported landings are getting more accurate. The underreported rate is relatively stable during the past decades, which was around 5% (Figure 5).

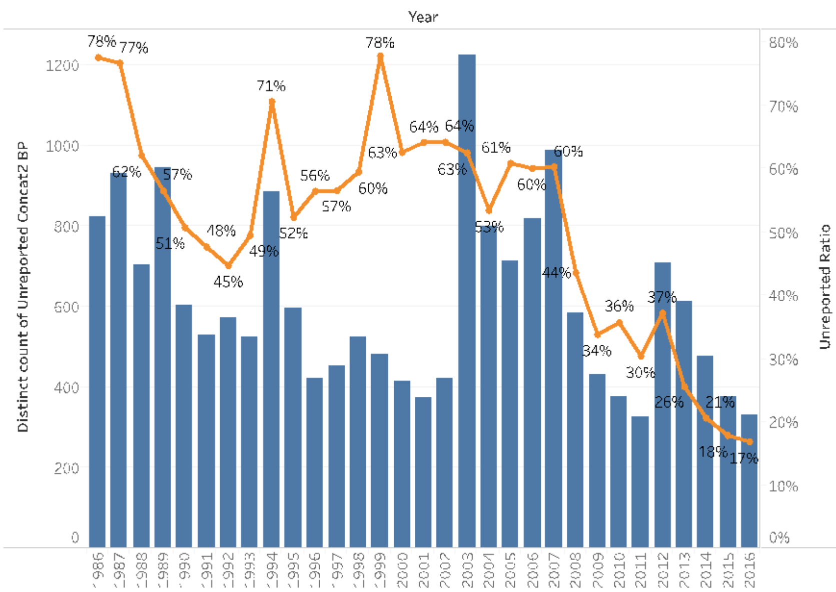


Figure 4: Unreported case number (blue bar) and rate (orange line) from 1986-2016.

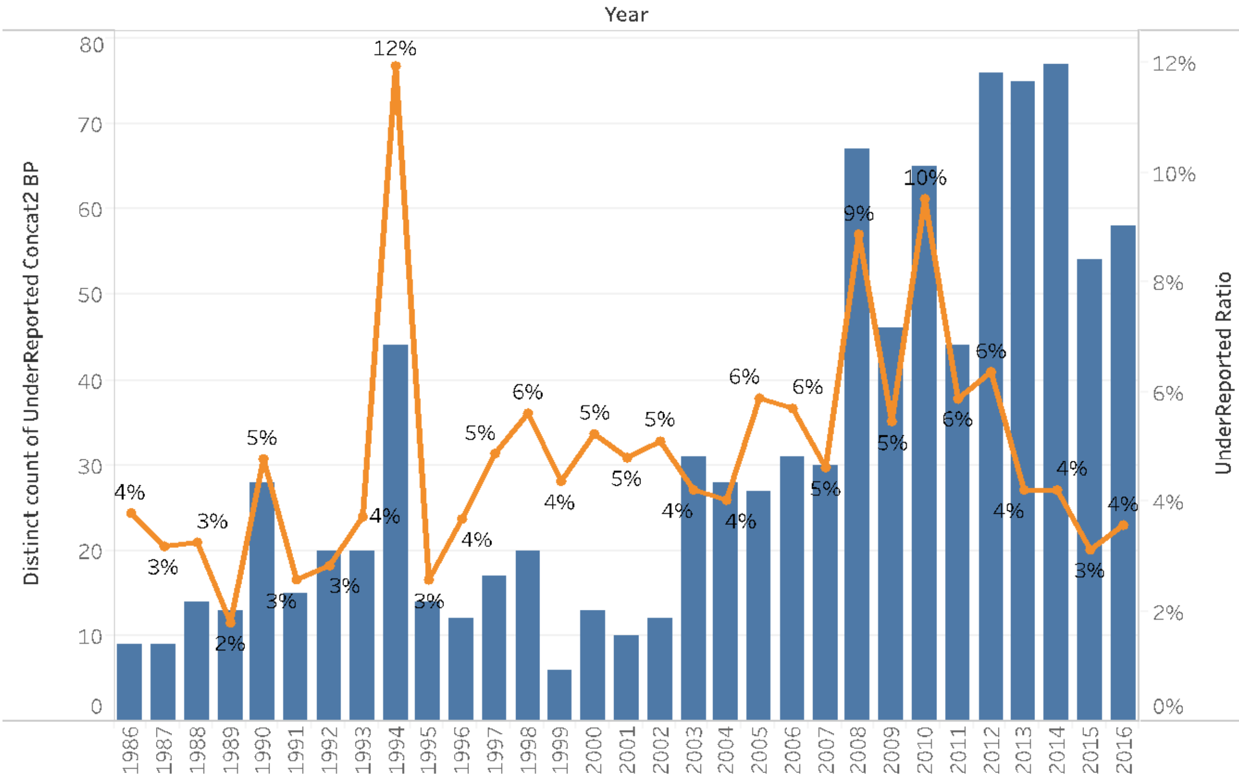


Figure 5: Underreported case number (blue bar) and rate (orange line) from 1986-2016.

In addition, the PI also analyzed the temporal pattern of data collection according to the NOAA collaborator's requirements. For each species, the number of measurement for each trip and the number of trips are visualized by year, month and area. The results indicated that number of measurement for each trip varies a lot among species, but the number of trips are concentrated in certain years, months and areas (Figures 6-8). The PI also found that for some species, the data volume of weight is more abundant than that of the length.

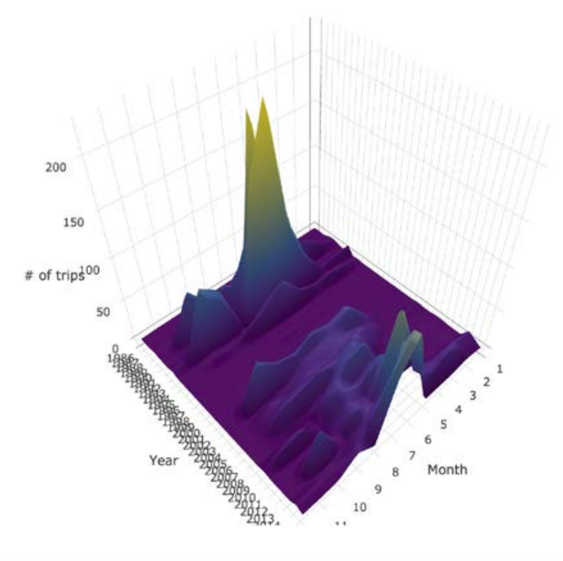


Figure 6: Number of trips distributions for Gulf of Mexico red snapper over years and months.

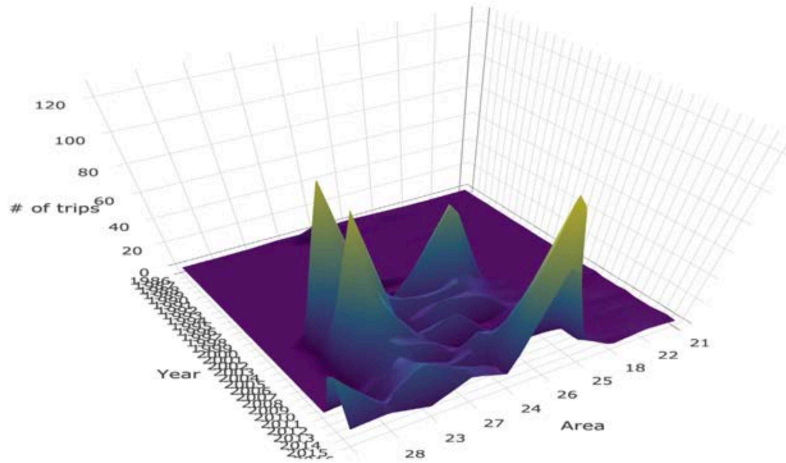


Figure 7: Number of trips distributions for Gulf of Mexico red snapper over years and areas.

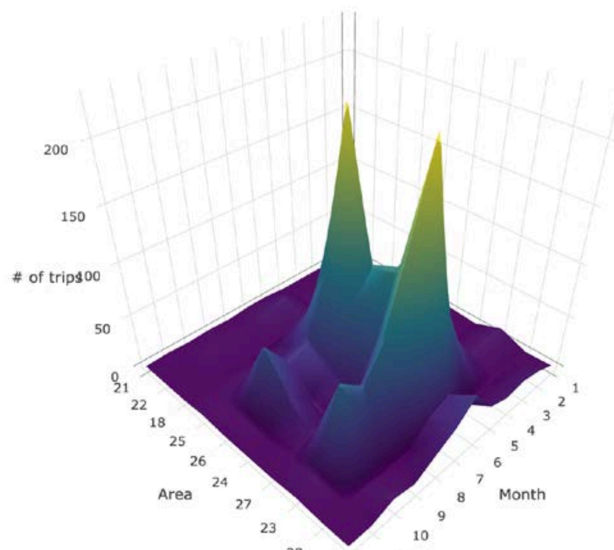


Figure 8: Number of trips distributions for Gulf of Mexico red snapper over areas and months.

Research Performance Measure: This project has been finished on schedule. All objects have been completed.

Using Time Series and Empirical Dynamic Models to Forecast the Fishing Prohibition Date

Project Personnel: Y. Zhang (FIU)
NOAA Collaborators: S. Turner and D. Gloeckner (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:

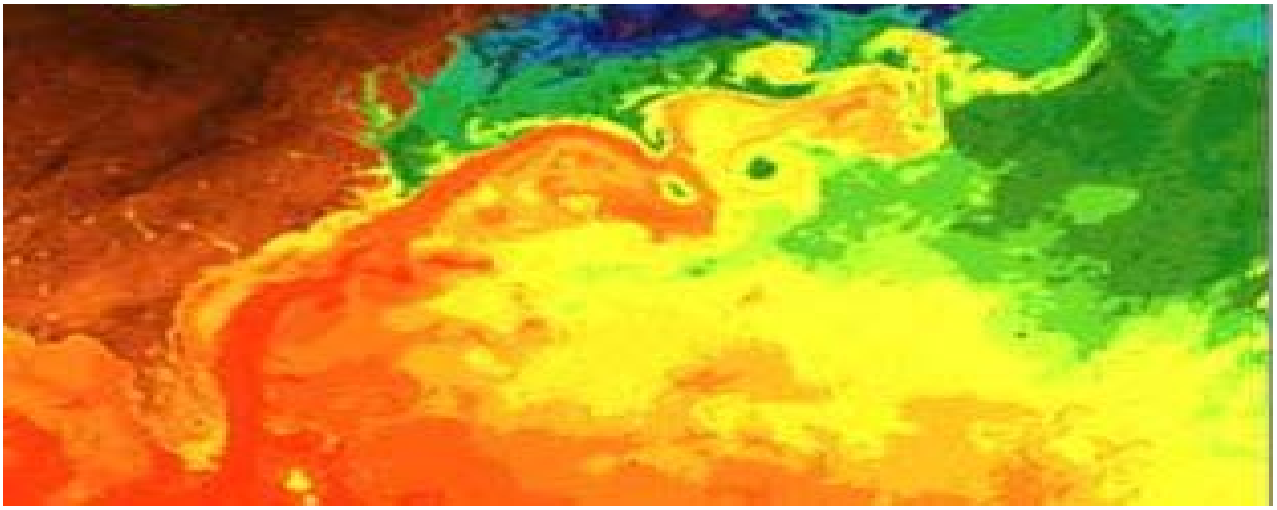
***Goal 1*:** Healthy Oceans – *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems.*

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

Research Summary:

The PI received a dataset from NOAA/SEFSC in late 2017. Since some scientist in NOAA/SEFSC have already started some analyses by using the time series model, the PI and the NOAA collaborator determined to modify the project objectives. The first step is to explore the environmental factors (such as fishing effort, longitude, latitude, sea surface temperature, sea surface height, salinity, water speed, wind speed, depth, and distance to shore) that may relate to the landings. For each species, the PI will conduct multivariate statistical analyses to the trips landings under various gears.

There have been several unexpected delays (late arriving of data, retirement of the NOAA collaborator, maternity leave of the PI, and changing of the objectives), which have affected the project timeline. The PI expects a period of adjustment associated with the sponsor action and is requesting additional time to accomplish the project. The PI and NOAA collaborator have determined to extend this project for another 10 months with no additional cost. The application has been submitted to CIMAS at the beginning of 2018, but has not been processed yet.



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).

1) We performed a long-term integration of the eddying global simulation with the DRAKKAR forcing set (DFS5.2) that covers 1958-2015 and a detailed evaluation of the circulation in the Southern Atlantic Ocean using available observations. The model results represent the basic circulation features reasonably well, including the vertical and horizontal structure of the AMOC across 34.5°S, the ACC through the Drake Passage near 65°W, and the zonal flows across a combined section to the southeast of Africa. The time mean transports of the AMOC, ACC, and the Weddle gyre diff from observational estimates by 10-30%. The model results are used to explore the circulation pattern associated with the AMOC: The upper limb of the AMOC is from the Agulhas Leakage and the super gyre (which connects the subtropics of the Indian/Atlantic oceans) prevents a direct feed of cold Pacific Water into the AMOC; the cold water does modify the temperature/salinity properties of the southern Atlantic Ocean and impact the heat/freshwater transports). Also, the lower limb of the AMOC (i.e., the North Atlantic Deep Water) flows southward along western boundary to near 45°S and turns eastward to flow across the Mid-Atlantic Ridge (Figure 1). The coherence of the AMOC throughout the whole Atlantic is also examined and a manuscript summarizing these results will be submitted to *JGR-Ocean*.

2) We examined the AMOC variability in the phased 5 of the climate model inter-comparison project (CMIP5). The AMOC variability in these coupled simulations exhibits a magnitude and meridional coherence that is similar to that in the forced simulations (COREII) of similar resolution on the interannual to decadal timescales. On multi-decadal time scale, however, the AMOC variability in CMIP5 is weaker (by a factor of 2) and meridionally less coherent in the coupled CMIP5 simulations than in forced COREII (Figure 2). The CMIP5 also show a weaker long-term variability in NAO, but because there lacks a robust NAO-AMOC relationship in the CMIP5 simulations, one cannot fully attribute the weaker NAO as the cause of weaker AMOC in the CMIP5. A revised manuscript summarizing these results is submitted to *Climate Dynamics.*

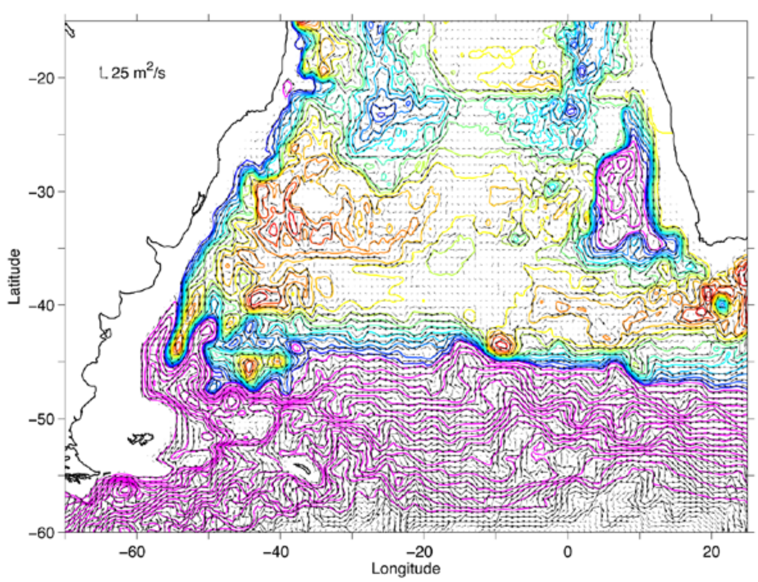


Figure 1: Modeled long-term mean circulation pattern in the North Atlantic Deep Water layer, based on an eddying global ocean-sea ice simulation. The vectors are the transport per unit width in m^2/s and contours are streamfunction with contour interval of 2 Sv.

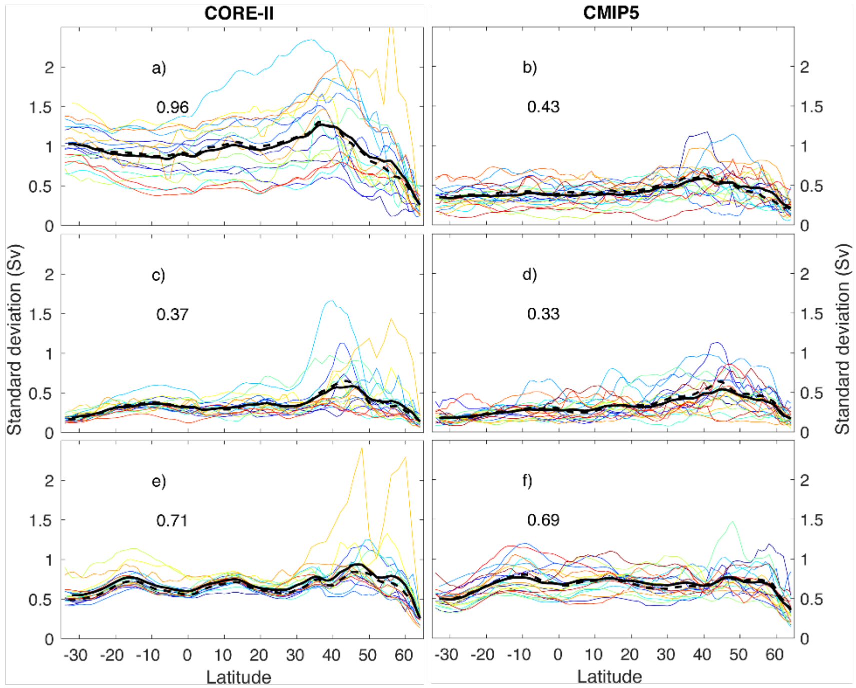


Figure 2: Standard deviation of the AMOC transports as a function of latitude in the forced CORE-II and coupled CMIP5 simulations: a-b) multidecadal, c-d) decadal, and e-f) interannual. Colored lines from blue to red represent 18 and 20 individual simulations in CORE-II and CMIP5. The thick black lines are multi-model averages for all the simulations (solid line) and for the first nine simulations (dashed lines) that share the same ocean-sea ice models between CORE-II and CMIP5. The numbers are the averaged standard deviation value over the whole Atlantic (30S-60N) for all the CORE-II/CMIP5 simulations.

Research Performance Measure: We met our original near-term objective of establishing an overall evaluation of the existing 1/12° eddy-resolving global HYCOM simulation in representing the southern Atlantic Ocean circulation and address the cause for the unrealistic model results. We then performed a new multi-decadal global simulation (1/12°, from 1958 to 2015) and re-evaluated the model results in the southern Atlantic Ocean.

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) is used as a test case study area for the development of a biophysical component within an Earth System modeling framework. The hydrodynamic modeling component is based on the HYbrid Coordinate Ocean Model (HYCOM), which has been applied in high resolution ($1/50^0$), with data assimilation and an accurate representation of basin-wide connectivity processes, which are crucial for coastal to offshore biophysical interactions. The HYCOM hydrodynamic model has been coupled with the Carbon, Silicate, Nitrogen Ecosystem (CoSiNE) model.

During this reporting period, work focused on identifying less known processes that influence basin-wide connectivity. A major known process controlling connectivity patterns is the variability in Loop Current (LC) extension, from an extended phase (approaching the Mississippi Delta) to a retracted phase (approaching Cuba and the Florida Straits). Previous studies have focused on northern to central basin processes, especially the formation and detachment of the anticyclonic LC Eddies (LCEs or rings), with contribution from cyclonic eddies (C) surrounding the LC. Our new findings focus on the southern GoM, where we have identified an additional group of eddies that influence LC variability (and actually also the Florida Current, FC, variability). These eddies are anticyclones near Cuba (which we named “CubAN” eddies) that form at the LC base and, under certain conditions, may detach from the LC and move eastward.

The influence of southern GoM eddies on the LC evolution and, hence, the basin-wide connectivity is exhibited on Figure 1. The example is for changes over a 10-day period (10 to 20 April), when a CubAN eddy was detached from the main LC body under the influence of a cyclonic eddy at the western entrance of the Florida Straits. These two eddies (anticyclone and cyclone) are revealed as two large areas with negative (-0.30 m) and positive (0.30 m) Sea Surface Height (SSH) differences at 83.5ºW and 82.5ºW, respectively, between the two dates (Figure 1a). These two regions are the only ones with significant SSH differences in the Florida Straits during this 10-day period, which was marked by the formation and eastward evolution of a CubAN eddy (CA), under the influence of a cyclonic eddy (C) at the LC base. The ocean color images confirm the presence of this eddy dipole along the Cuban coast on 21 April (Figure 1c); the spatial distribution of the Color Index (CI) clearly shows the cyclonic circulation between the LC (west) and the CubAN eddy (east). The eddy dipole was absent on 7 April, when the LC/FC system was dominant along the Cuban coast (Figure 1b); the dark blue areas (low CI), representing the LC/FC system are reduced inside the Straits on 21 April. Two additional areas with anticyclonic intensification were detected over the northern (25ºN) and western (87ºW) fronts of the LC, where the SSH increased by 50 cm in only 10 days. A clear northward extension of the LC took place during this short period, associated with the evolution of mesoscale processes over the western Straits of Florida. The darker blue areas in the ocean color images confirm the change in the northern location of the LC between the two dates, showing its extension towards the central northern Gulf on 21 April.

The above results confirm that southern GoM processes may influence the LC evolution and the overall basin-wide connectivity in the Gulf of Mexico. Finally, we found that this connectivity is also influenced by another group of anticyclonic eddies that we studied in detail for the first time. These are shed form the main LC body and travel northward, along the West Florida Shelf slope. Their significance on fragile ecosystems (as those of the South Florida coral reefs) has been discussed in Kourafalou et al. (2018). These processes have been incorporated in metrics toward improving the model predictability.

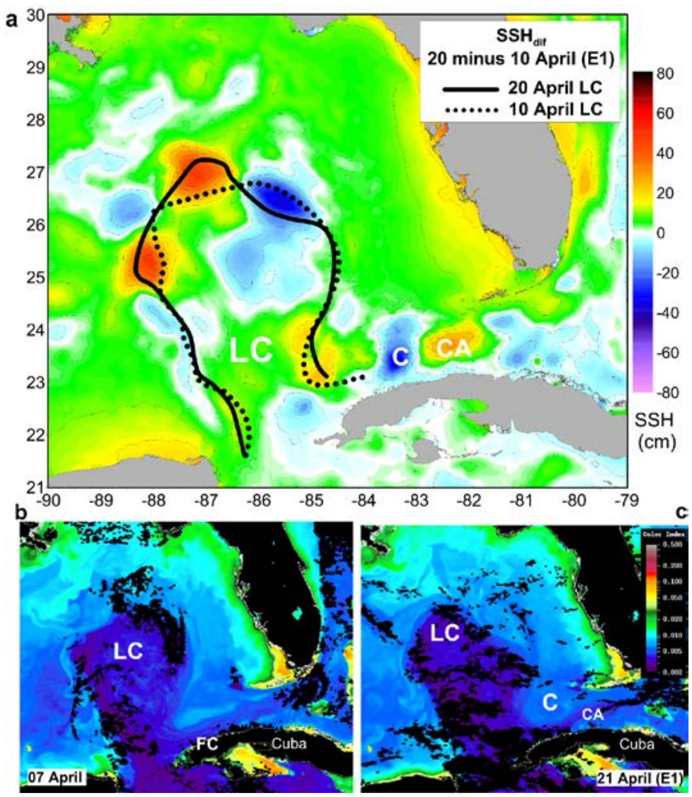


Figure 1: Horizontal distribution of model fields: (a) simulated Sea Surface Height difference (SSH_{dif}) between 20 April and 10 April; respective Color Index (CI) maps, derived from MODIS, (b) 7 April and (c) 21 April. The Loop Current (LC) and associated eddies are also marked: Florida Straits cyclonic eddy (C), Cuba anticyclonic eddy (CA). The SSH 17 cm contours on 10 and 20 April, derived from the model simulations, are marked in (a) with black dashed and solid lines, respectively.

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, while promoting the understanding of the governing dynamical processes. The overarching goal is to contribute to the Quantitative Observing System Assessment Program (QOSAP), by integrating process understanding, 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 (see: coastalmodeling.rsmas.miami.edu). Improvements in model predictability include the study of novel processes that impact dynamics in marginal seas. This is a step toward extending our basin OSSE system to the coastal and shelf areas. An example is shown in Figure 1, where the presence of the West Florida Shelf (WFS), starting from a narrow strait area (Florida Straits) has a profound effect on basin-wide mesoscale dynamics. During the well-known process of the detachment of an anticyclonic LC Eddy (LCE), another type of anticyclonic eddy is also detached form the LC. Upon detachment, LCEs travel westward, toward Mexico. These newly studied anticyclones, however, travel northward, along the WFS slope; we name these “secondary” LC anticyclonic eddies “Western Florida Anticyclones: WFAs” for distinction.

Figure 1 shows the spatial distribution of the Mixed Layer Depth (MLD) over the eastern GoM on a demonstration day (1 July). Deep mixed layer (>50 m) was computed along the Florida Straits, inside the LCE and along the WFS, where the LC evolution is characterized by the formation of a WFA eddy. This type of LC evolution, related to the WFA eddy formation, can be observed during periods of close LC proximity to the shelf slope. We found that WFAs may influence the circulation over the shelf, but they also contribute toward an important regional process, the release of eddies form the LC, with a resulting loss in anticyclonic vorticity of the oceanic current. This is a significant finding, connecting shelf to open sea dynamics. We also found that these anticyclones are detached from the main LC body, further reducing the LC length following an episode of short LC extension (after LCE detachment). Although often smaller than (and thus "secondary" to) the LCEs, WFAs are significant. We note that the MLD inside the WFA in Figure 1 is even deeper (>50 m) than inside the LCE. The formation of this particular WFA is also confirmed by the AVISO satellite data (dark solid line in Figure 1).

The activities described above are under our ocean modeling and OSSE framework, which enables the advancement of a) process understanding and b) strategies for observing system design and quantitative evaluation of observing systems, by quantifying the improvement of model forecasts through the assimilation of specific observations and the accurate representation of the related dynamical processes.

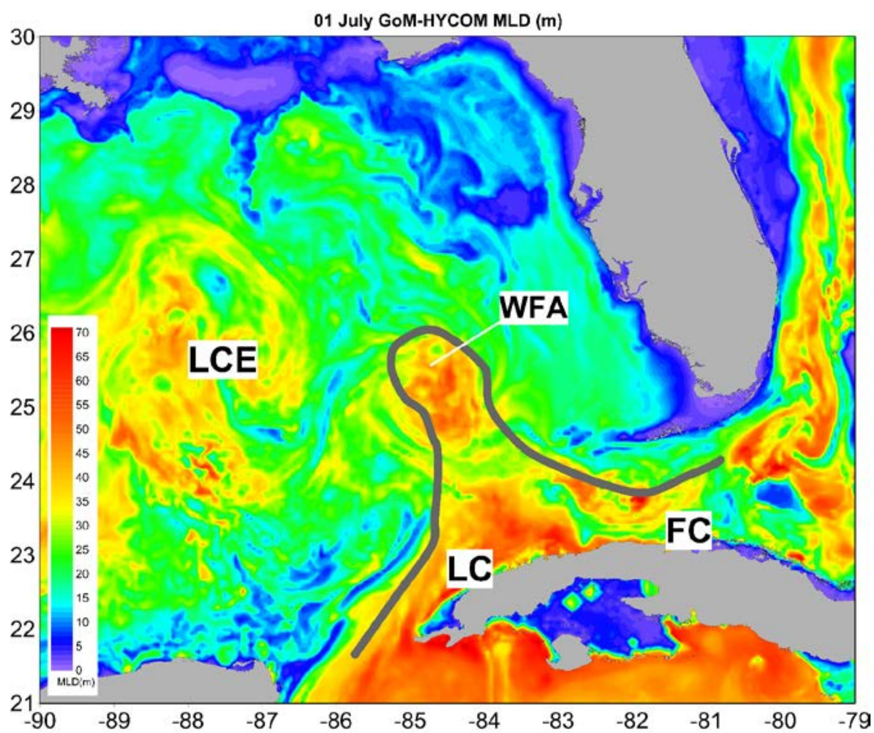
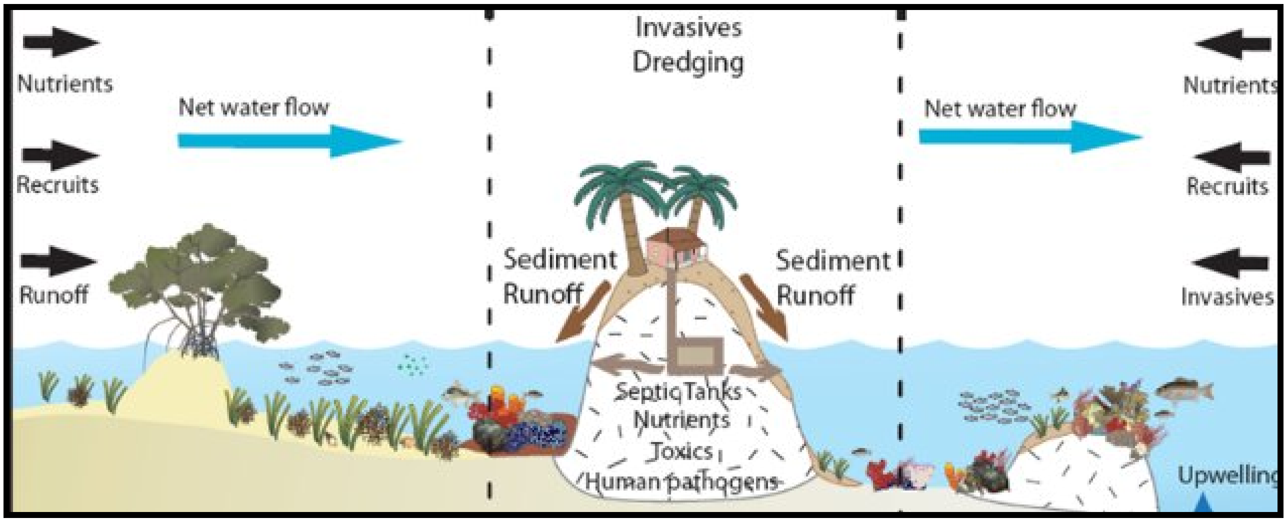


Figure 1: Horizontal distribution of Mixed Layer Depth (MLD) as derived from GoM-HYCOM model on 1 July. The Loop Current (LC), the Florida Current (FC), the detached LC Eddy (LCE) and the Western Florida Anticyclone (WFA) are indicated. The SSH 17 cm contour, derived from AVISO MADT fields (which represents the LC front), is marked with a grey solid line.

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 and S. Smith (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, 2018). 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.

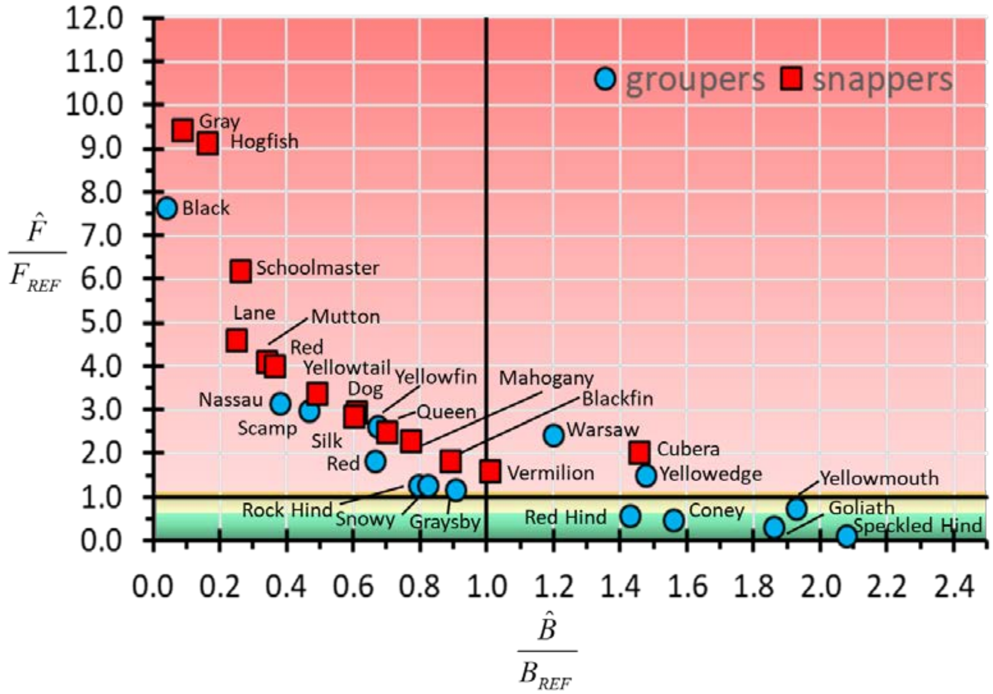


Figure 1: Limit control rule "Kobe plot" showing estimated spawning stock biomass (x-axis) and fishing mortality rate (y-axis) with respect to resource sustainability reference levels for 35 species of exploited grouper and snapper reef-fishes in southern Florida (Ault et al., 2005b, 2014, 2018; blue circles, groupers; red squares, snappers and wrasses).

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.

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, D. Gloeckner and L. Beerkircher (NOAA/NMFS)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives: To work with SEFSC staff under the direction of Stephen Turner and D. Gloeckner 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 2017 to May 2018, research focused on continued improvement of the information systems for the pelagic longline fleet and Gulf of Mexico vertical line and reef longline fleets. The statistical sampling design developed in the previous year for camera auditing of the pelagic longline fleet was further refined. 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. The statistical sampling strategy entailed selecting a subset of the camera data for auditing the BFT catch reported by fishers. Using logbook and observer BFT data for recent years (2015-2016), principles of statistical survey design 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. Efficient data processing and statistical procedures were developed in collaboration with NOAA SEFSC staff to generate randomized camera auditing sampling plans on a quarterly basis.

A second research focus was the further refinement of 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. The GRA in the Mid-Atlantic Bight straddles the boundary of two spatial fishing zones, the Mid-Atlantic Bight (MAB) and South Atlantic Bight (SAB). Pelagic longline fleet trips were analyzed for the period 2010-2016 to delineate a new spatial area, the Atlantic Bight Gear (ABG) analysis zone, which encompassed concentrated areas of fishing in the vicinity of the GRA (Fig. 1). Using this new spatial zone, the sampling plan was refined for allocating observer sampling effort to detect changes in bluefin tuna catch, effort, and CPUE inside and outside the GRA in the Mid-Atlantic Bight.

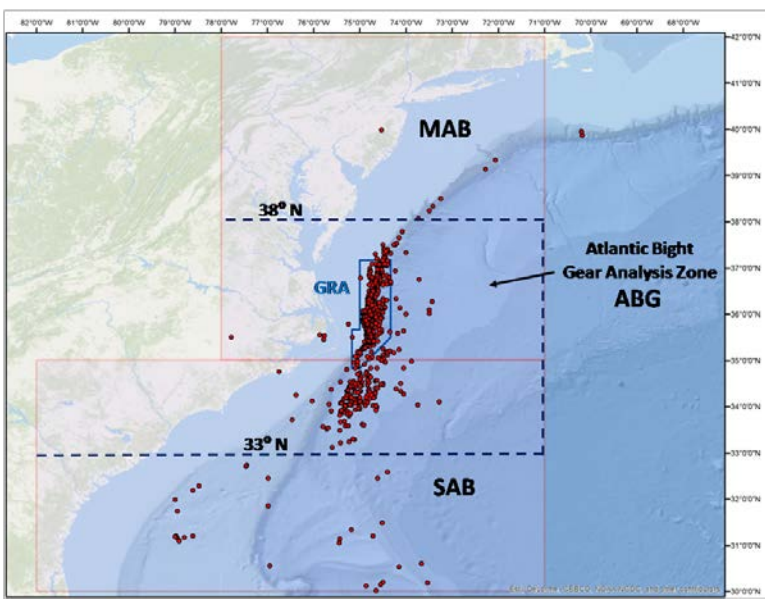

Figure 1: Spatial distribution of longline sets for complete trips that fished at least one set within the Mid-Atlantic Gear Restricted Area (GRA), Dec-Apr 2010-2016. The Atlantic Bight Gear (ABG) analysis zone includes portions of the Middle Atlantic Bight (MAB) and South Atlantic Bight (SAB) fishing zones.

A third research focus was the development of survey design-based statistical procedures for estimating catch, effort, and CPUE by species for the Gulf of Mexico vertical line and reef longline fleets. Efficient estimation of these metrics was carried out using logbook data for both fleets, designating a fishing trip as the statistical sample unit, and employing survey design estimators for population totals for catch and effort and a ratio-of-means estimator for CPUE.

Research Performance Measure: All major objectives have been met.

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Creel Survey of private boat recreational fishing in the US Virgin Islands: phase II

Project Personnel: D. Die (UM/RSMAS)
NOAA Collaborators: M. McPherson (NOAA/SEFSC)
Other Collaborators: T. Gedamke (MER Consultants)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** Characterize and compare recreational fishing activity on St. Croix and St. Thomas, USVI and the social and economic dimensions of recreational fishing on both islands.
***Strategy*:** To 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 angler.

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 (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 project team administered a voluntary survey from January 17 to August 30, 2017 (Phase II) to boat-based recreational fishers on St. Croix, St. Thomas, and St. John, USVI to gather data on effort, catch, socioeconomic, and demographic information. The effort information collected included the number of fishers, gear used, species targeted, and whether the trip was charter or not. It also included boat dimensions, which were collected one time only. Catch information included number of fish caught, species, weight, length, and the fisher's (planned) disposition of the catch. Socioeconomic information included trip expenditures, such as fuel and oil, ice, and total trip cost for vacationers and demographic information. The sampling design implemented in 2017 was modified from the one adopted in 2016 (Phase I) to increase efficiency with a reduction in staffing levels by, for example, incorporating an individual-based approach to sampling charter operations.

Research Performance Measure:
In total 418 sampler days were completed, yielding 190 recreational trips intercepts, 2,878.03 pounds of fish sampled, 244 fish measured for length, and 453 socioeconomic surveys completed.

The fishing activity observed reflects a very low level of activity which implies that if one where to desire to precisely estimate recreational boat based landings utilizing a stratified design, sampling efforts will have to be considerable large. Given such design, and at the staffing levels used during this study, it is likely that such a survey would be cost – prohibitive. We have three primary recommendations to address this consideration:

1) Develop a formal agreement with DRNA to integrate sampling efforts, and allow for an individual based sampling design on the charter sector.
2) Develop an integrated port sampling program to sample both commercial and recreational landings at any site being sampled.
3) Develop a long-term sampling plan which considers project objectives and strategies to meet management needs in the most cost-effective way possible. For example, given the low overall recreational activity, sampling only at key sites (e.g. high usage) could be used to develop a relative index of landings.

Finally, multiple landing sites in the USVI were severely damaged due to hurricanes Maria and Irma in 2017, affecting not only the launch areas but also fishing equipment located in the immediate area. Future studies should confirm current usage of previous landing sites prior to developing a final sampling design because fishing effort has shifted between sites as fishers recover, replace fishing equipment and repair launch facilities and boats.

Figure 1: Surveying recreational landing in the US V.I. Wahoo tournament landing in St. Thomas. Photo credit: Kayla Tennant

Figure 2: Total recreational trips sampled by month.

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 has been carried out 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). This framework was used to address selection of proxy fishing mortality reference points and to test whether simple harvest control rules could successfully lead to stock rebuilding. On-going work includes examining length-based management procedures that incrementally adjust ACLs to nudge stocks towards optimality-based reference points. Emphasis is placed on the life history of spiny lobster, as this species is the subject of an on on-going stock assessment that W. Harford is directly involved with. An MPS intern is working on simulation-testing of the reliability of non-equilibrium mean-length mortality estimators.

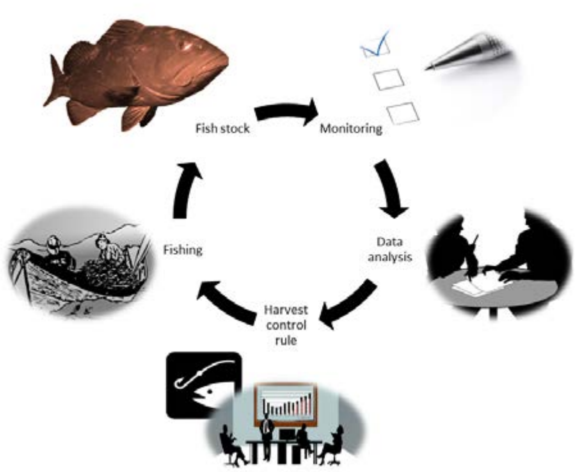

Figure 1: Management strategy evaluation as conducted through closed-loop simulations.

Research Performance Measure: 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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Effects of Nitrogen sources and plankton food-web dynamics on habitat quality for the larvae of Atlantic Bluefin tuna in the Gulf of Mexico

Project Personnel: A. Jugovich, E. Malca, A. Mnich, A. Shiroza, K. Shulzitski and S. Privoznik (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 and R. Swalethorpe (Scripps Inst. of Oceanography, UCLA); K. Selph (University of Hawaii at Manoa); R. Laiz-Carrion and J. Quintanilla (Malaga IEO, Spain); L. Vasquez-Yeomans and E. Sosa-Cordero (ECOSUR, Mexico)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To define and investigate the effects of Nitrogen sources and plankton food-web dynamics on the habitat quality of larval stages of Atlantic bluefin tuna in the Gulf of Mexico ecosystem

***Strategy*:** To complete targeted fisheries oceanography surveys and subsequent isotopic analyses in the Gulf of Mexico for larval bluefin tuna during their spawning season while collectin concurrent plankton and measuring oceanographic indicators.

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 NOS, NCCOS

NOAA Technical Contact: Frank Parker

Research Summary:

The western stock of Atlantic bluefin tuna (*Thunnus thynnus*) is only known to mainly spawn in the Gulf of Mexico and adjacent areas, during spring (April to June). Previous and ongoing collaborations have confirmed that spawning activity exists throughout the Gulf of Mexico, with some limited spawning found in the Mexican Caribbean, Cuba and north of the Bahamas by our previous oceanographic surveys. In 2018, we carried out year 2 of our sampling efforts in the Gulf of Mexico as part of the NOAA RESTORE Science Program project.

The 2018 research survey conducted intensive sampling of circulation features, collecting and preserving larvae for studies of growth, isotopic trophodynamics, condition and feeding patterns. Scientists from UM/CIMAS, NOAA-SEFSC, Florida State University; Scripps Inst. of Oceanography, Univ. California at San Diego, University of Hawaii at Manoa; The Instituto Español Oceanográfico, Malaga, Spain, participated during the 2018 research cruise. The NOAA research vessel Nancy Foster was used for duration of sampling completing 141 stations from 28 April to 20 May, 2018 in the Gulf of Mexico.

Similarly to cruises completed in previous years, physical data from CTD casts, and biological data from plankton net tows were collected *in situ*. Satellite imagery, flow-through measurements, and modeled habitat outputs from the "BFT_index" provided by NOAA AOML for the Gulf of Mexico were used to guide sample collections. This year at select stations, the ship remained tracking a water mass (using satellite tracked buoys) for up to 96 hrs and conducted repeated plankton tows in order to better understand how patterns change over the course of day-cycles. We collected vertically stratified water and plankton in order to let us better understand where in the water column larvae are located. Samples were sorted at sea and subsets of larvae were either frozen separately in liquid nitrogen for tissue stable isotope analyses or preserved in ethanol to preserve high quality DNA for subsequent genetic analyses. We will continue our collaborations with the Instituto Español Oceanográfico in Spain to compare results between the Gulf of Mexico, the Western Caribbean and the Mediterranean Sea through the ECOLATUN project collaboration.

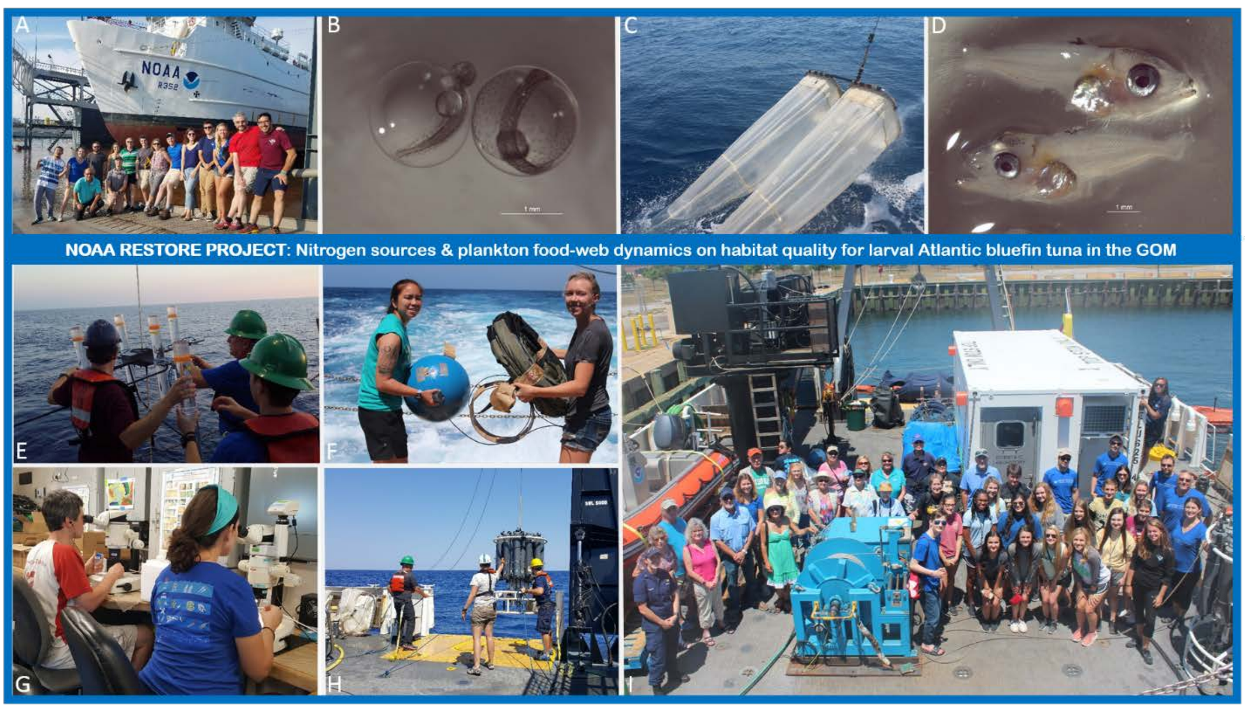

Figure 1: A) NF1802 science team at the end of leg 2 with NOAA Ship Nancy Foster B) Larval fish eggs collected during the 2018 survey, C) Plankton nets used to collect plankton and bluefin tuna larvae (Bongo-90 net) D) larval Atlantic bluefin tuna collected during 2018 survey E) Sediment trap deployment to 150 m F) lagrangian drifter deployments by graduate student Thomas and CIMAS Affiliate Mnich, G) Live examination of plankton samples by FSU and UM scientists, H) Deployment of CTD rosette by NOAA scientist and personnel, I) Open House partial group photo in Pensacola, FL in May 2018.

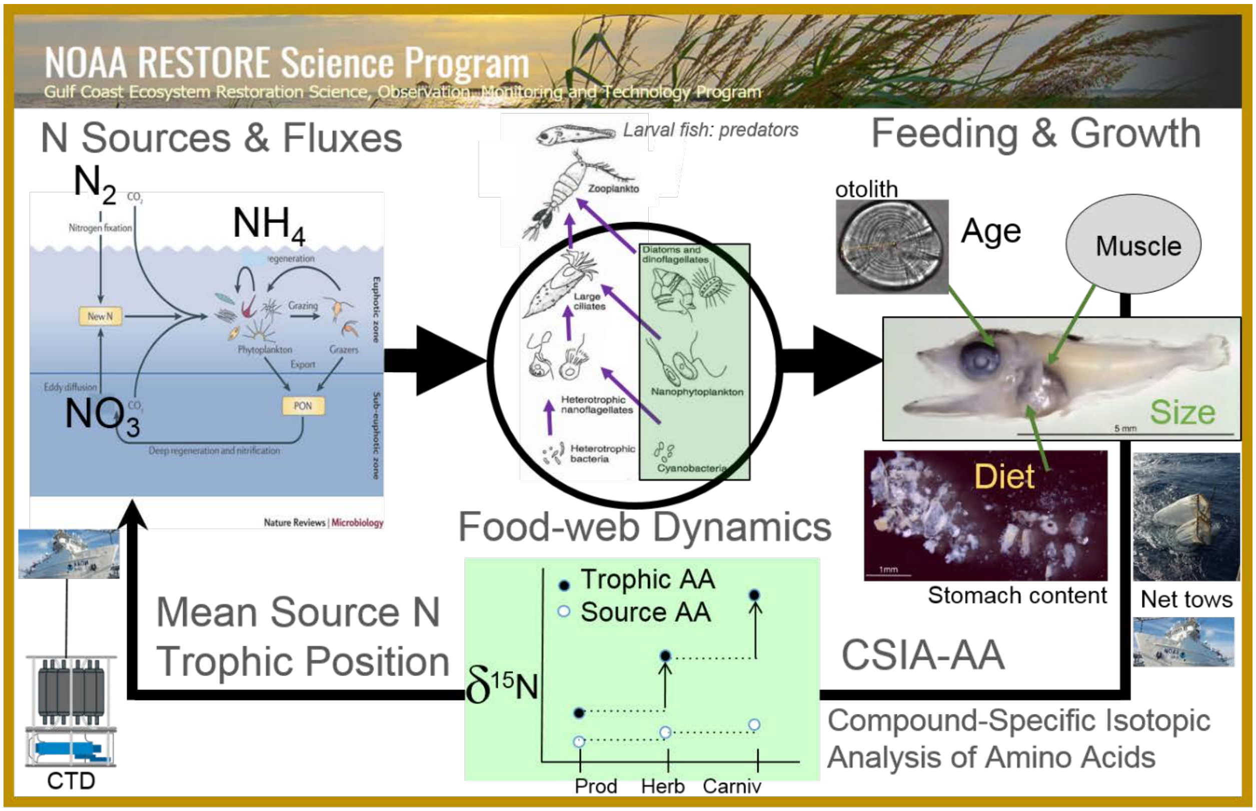

Figure 2: Schematic of the project supported by the NOAA RESTORE Science Program encompassing the pathways of the nitrogen sources and fluxes in the food web from bacteria to larval Atlantic bluefin tuna as one of the top predators in this ecosystem.

Research Performance Measure: The research program is on schedule. The science team held a 2-session during the Ocean Sciences Meeting in February in Portland, OR to present preliminary results of year-1 of the project and plan year-2 of sampling.

This year's (NF1802) cruise was successfully completed on May 20, 2018. Due to ship repairs, the survey lost a handful of science days, however, we were able to accomplish our science goals. Sample processing started at sea and sorting will begin later this summer.

Year-1 of the NOAA RESTORE project collections (NF1704) has been completely sorted and identification of larval bluefin tuna has been completed. For the trophodynamics aspect of the project, stomach contents analysis has been completed, with larval tissues sent in January and a subset were sent to obtain the compound specific stable isotope signatures. Finally, frozen samples of ichthyoplankton, mesozooplankton, and microzooplankton were shipped to the IEO laboratory in Malaga, Spain for nitrogen and carbon processing. Otolith removal has been completed on the larval bluefin tuna from this dataset and will be aged this year.

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

Project Personnel: M. Le Hénaff (UM/CIMAS); V. Kourafalou, H.-S. Kang and Y. Androulidakis (UM/RSMAS)
NOAA Collaborators: K. Johnson (NOAA/SEFSC)
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 analyze observations relevant to ecosystems, to perform numerical simulations relevant to biology and ecosystems, and to perform observing system experiments using biophysical and 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:

In order to investigate the impact of observations on biology and ecosystem estimates, we use a suite of models. The first one is the circulation model HYCOM. We have set-up a model configuration at 2-km resolution over the Gulf of Mexico, with assimilation of observations. It also includes realistic river forcing, with daily discharge values for all rivers in the U.S. side of the basin, which includes the larger rivers. We also used a high-resolution (~900m) model configuration of the Florida Straits to analyze mesoscale anticyclonic eddies along the northern Cuban coast (Kourafalou et al., 2017). These eddies, which were described for the first time, affect the Florida Current meandering and the eddy activity in the Straits of Florida, which are crucial for larval replenishment and the health of the reefs in the Florida Keys National Marine Sanctuary (FKNMS) and the Dry Tortugas Ecological Reserve. These processes also affect the Loop Current system evolution in the Gulf of Mexico.

In addition to the circulation model, we have developed a full ecosystem model for the FKNMS that incorporates monthly Chlorophyll-a (Chl-a) and Sea Surface Temperature (SST) satellite imagery products. The spatially explicit distribution of biomass in the Ecospace model is driven by the predator/prey dynamics from the Ecosim (1-D) model, a movement parameter, fishing effort, and functional responses to underlying environmental drivers. We performed simulations to test the impacrt of MPA sizes, fishing effort intensity, and movement parameter values. Fishing effort appears to have the largest effect on biomass and catch, while changing MPA size alone has a minimal effect on catch and biomass relative to movement and fishing effort.

In parallel of the modeling effort, we use observations to describe ocean events that can potentially affect biology and ecosystems within the Gulf of Mexico. We performed an analysis of satellite ocean color images over the period 1997-2017, to identify episodes of transfer of rich, coastal waters from the continental shelf to the Gulf interior and the Straits of Florida. Example images showing these three types of events are shown in Figure 1: Figure 1A presents an episode of coastal waters exported from the Campeche Bank to the Gulf interior. Figure 1B shows an episode of coastal waters advected from the Campeche Bank to the Florida Straits, in 2016. Figure 1C illustrates an episode of export of Mississippi River waters from the Mississippi Delta region to the Florida Straits. A census of such events shows that the export of Campeche Bank water into the deep Gulf of Mexico occurs very regularly (50% of observations), while the transport of Campeche Bank water to the Florida Straits is much less common. Finally, the transport of Mississippi River water to the Florida Straits is highly episodic, characterized by events which persist for 1-2 months. A paper is in preparation to present these results (Otis et al., 2018). These ocean color images have also been essential in understanding the coral mortality event that affected the Flower Garden Banks National Marine Sanctuaries in July 2016.

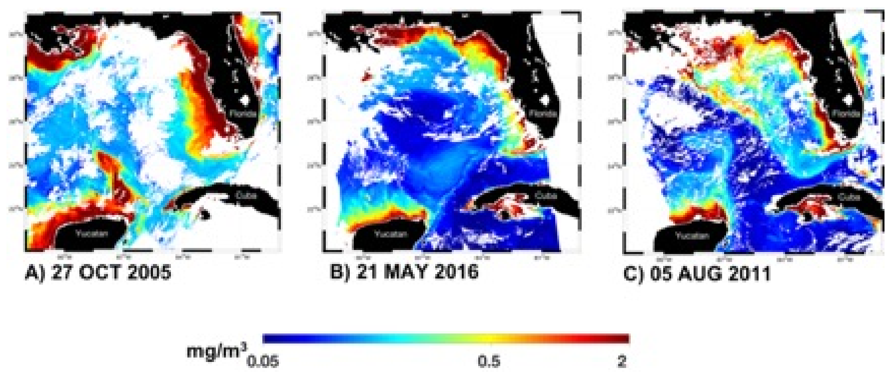

Figure 1: MODIS-Aqua satellite images of chlorophyll-a concentration (mg/m3) showing examples of the three event types of export of coastal waters in the Gulf. Image A (October 27th, 2005): Transport of water from Campeche Bank into the central Gulf of Mexico. Image B (May 21st, 2016): Transport of water from the Campeche Bank to the Florida Straits. Image C (August 5th, 2011): Transport of Mississippi River water to the Florida Straits.

Research Performance Measure: During the reporting period, the project led to 1 publication and to 3 presentations at international conferences (1 at the Gulf of Mexico Oil Spill and Ecosystem Science Conference in New Orleans, LA, on February 5-8, 2 at Ocean Sciences Meeting in Portland, OR, on February 11-16). In addition, we have been collaborating with ecosystem managers in the Gulf of Mexico to support their mission. First, we helped the Flower Garden Banks National Marine Sanctuaries managers understand the coral mortality event that affected one of their sites in July 2016. We participated in the Mini-Symposium they organized in Galveston, TX, on February 27-28, during which we presented our results, and we submitted a manuscript to *Remote Sensing of Environment* (Le Hénaff et al., 2018). In addition, we developed a web tool to monitor the conditions in and around the Sanctuary, in order to identify potential extreme events (*https://usf-imars.github.io/img-dash/index.html*). Then, we interacted with managers working in the Florida Keys National Marine Sanctuaries to provide them with useful information. At the large scale, they value our contribution to the understanding of the processes connecting the Florida Keys to the Gulf of Mexico interior and upstream the Loop Current system. At the local scale, the results from the ecosystem model we have developed will help them answer questions formulated in the Sanctuary condition report.

Courtesy of Daniel Benetti

RESEARCH REPORTS

THEME 6: Ecosystem Management

Reef Visual Census (RVC): Reef Fish Monitoring in the Florida reef tract and US Caribbean

Project Personnel: J. Blondeau and C. Langwiser (UM/CIMAS)
NOAA Collaborators: J. Bohnsack, M. Johnson and L. Grove (NOAA/SEFSC); K. Edwards (NOAA/NCCOS); M. Nemeth (NOAA/Restoration)
Other Collaborators: M. Feeley (NPS); Z. Hills-Starr (NPS); M. Brandt (UVI); M. Scharer (UPR); L. Henderson (USIV/DPNR); D. Santavy (EPA)

Long Term Research Objectives and Strategy to Achieve Them:
Objectives To provide continued reef fish and benthic habitat monitoring in Florida's coral reef tract and US Caribbean Islands 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.
***Strategy*:** Employ a multi-agency, 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 and US Caribbean.

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:

The Reef Visual Census (RVC), now part of the National Coral Reef Monitoring Program (NCRMP), is a continuous, long-term monitoring effort aimed at large-scale tracking of reef fish and coral reef habitat metrics along the Florida reef tract, from Martin County to Key West, including the Dry Tortugas, US Virgin Islands and Puerto Rico. NCRMP is a federal program for conducting sustained and standardized observations of biological, climatic and socioeconomic indicators in all U.S. states and territories. 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 coral ecosystem.

A multi-agency approach, consisting of local, state and federal partners is paramount in accomplishing a large-scale monitoring program. NOAA's Southeast Fisheries Science Center and National Centers for Coastal Ocean Science are now the co-leads for NCRMP's biological component in the Atlantic, Gulf and Caribbean basins. With the aid of various partner agencies, we are able to characterize reef fish populations and their habitat associations across a large spatial scale, as well as, the benthic composition and coral demographic structure. In addition, the stratified random sampling design allows us to accomplish our objectives efficiently and in the most cost effective manner. The benefit of a healthy coral reef ecosystem goes beyond an 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 provide the baseline data needed to track changes in fish populations and habitat health due to anthropogenic impacts and natural events, we need a continuous monitoring effort to inform management decisions.

Research Performance Measure: Divers conducted stationary point counts for fish, line point intercept and coral demographic surveys for habitat assessments along the insular shelf of Puerto Rico, St Thomas/St. John and St. Croix. Trained divers (57) from local, academic, state and federal agencies conducted 2,460 individual dives (Figure 1) to complete the 2017 mission of tracking biological trends in Puerto Rico and the US Virgin Islands (Table 1).

Domain	Fish	Benthic
Puerto Rico	240	162
St. Croix	181	175
St. Thomas/St. John	237	235

Table 1: Number of Primary Sample Units (PSU) sampled in each domain.

All data went through an extensive QAQC procedure after completion of the field component to ensure quality analytical datasets. Data is now publicly accessible, archived and metadata published to comply with federal access to research regulations. Data are used to assess three main components 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. Biological trends and key metrics will be incorporated into jurisdictional (domain level) report cards. All milestones and objectives were met.

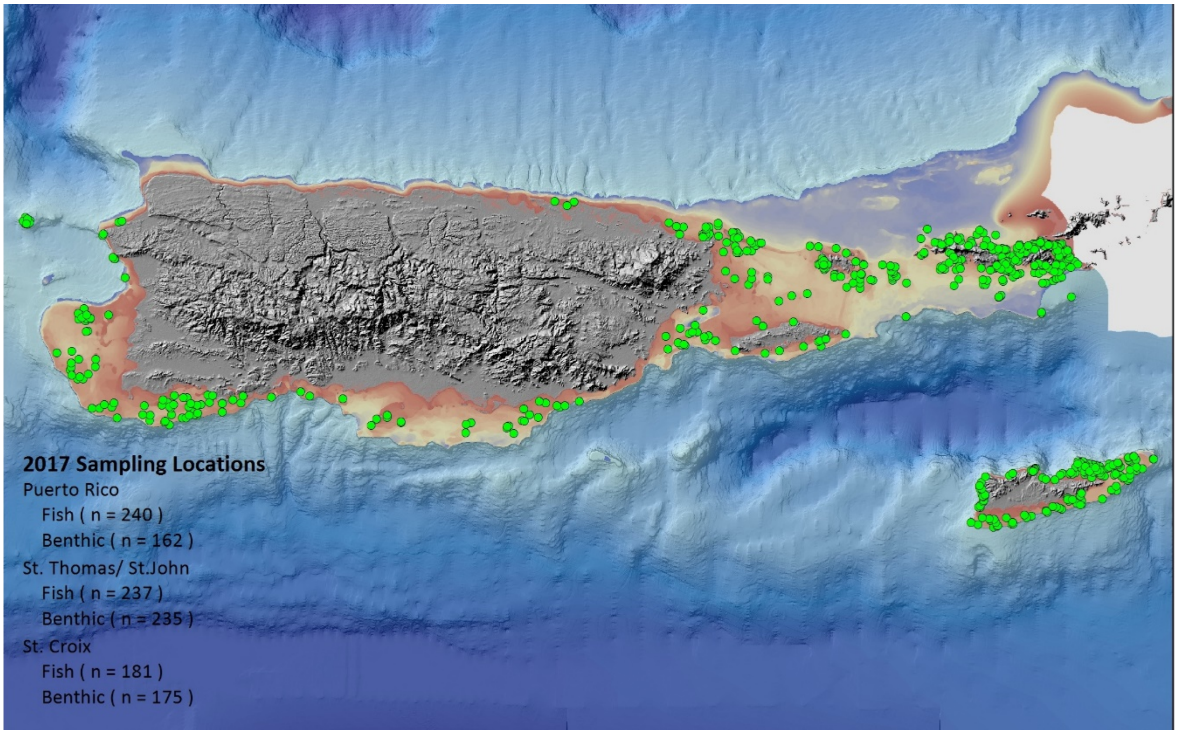

Figure 1: Sampling site locations for 2017 in the US Virgin Islands and Puerto Rico

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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:

Climate change and increasing anthropogenic activities are causing rapid changes to environmental and ecological processes in the Arctic Ocean. To better understand these changes, scientists have increased research efforts in these regions, but to date the number of studies on Arctic nearshore habitats are lacking. We respond to this paucity of information and investigates patterns in Arctic nearshore fish communities and food webs to gain insight to how these ecosystems may shift as these changes continue. We used multivariate statistical analysis to examine patterns in community structure and composition to determine that Arctic nearshore fish communities are largely driven by prey availability, salinity and temperature; and that lower-latitude species are probably being advected North through the Bering Straight and will continue to increase in numbers as conditions continue to warm. We improved the ability to apply stable isotope methods to Arctic food web studies by determining more appropriate model parameters using a laboratory-based isotope study on a common Arctic nearshore fish, and discuss its potential as a biological monitor species. These new parameters are used to confirm that a shift in prey resource dependence occurs across the seasonal shift from ice-covered winter to open-water summer conditions. Changes in basal resource dependence also occur later in the season across a latitudinal gradient where a shift to dependence on allochtonous inputs from nearby rivers increased trophic diversity. Using isotopic niche space theory, it was determined that the Arctic nearshore has a diverse prey base but that niche spaces of lower-latitude species and true Arctic species do overlap, and if numbers of lower-latitude fish continue to increase it will likely increase competition for resources for potentially less adaptable Arctic fish. On the other hand, if pelagic productivity is expected to increase and support larger fish biomasses, then there will be more than enough resources for true Arctic species and lower-latitude species to coexist, thus creating a more diverse prey base for piscivores in the Arctic.

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 used to determine the tissue turnover rates of Arctic sculpin (*Myoxocephalus scorpioides*) to be used in further analyses.
(4) To establish the ability of stable isotope analysis to be used to identify and monitor changes in trophic structure or basal resource dependence. We used tissue-dependent stable isotope analysis to

identify the temporal shift in basal resource dependence from ice-algae to marine primary producers that occurs during the shift from ice-covered winter to open-water summer conditions. We also used stable isotopes in Pacific Capelin across the majority of its latitudinal range to investigate prey resource usage across an array of environmental conditions.

(5) 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 used to determine the trophic discrimination factors of Arctic sculpin (*Myoxocephalus scorpioides*) to be used in further analyses.

(6) To understand food web structure and basal resource dependence in Arctic nearshore fish communities. Stable isotope analysis of carbon and nitrogen in tissues of nearshore fish were used to determine the basal resources on which they depend, and to describe their trophic position and niche space.

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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 (UCSB)
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. To date, user reports and historical data have been compiled into a geospatial database and provided to SEFCRI management, and an integrated field sampling approach was conducted throughout the region.

In the 2017/2018 period, we focused our efforts on synthesizing data collected from previous funding years into three manuscripts. The first describes the response of Goliath Grouper spawning aggregations and associated fish communities to anthropogenic and environmental disturbances, and is prepared for submission in a peer-reviewed journal. The second manuscript characterizes the increase in fish biomass and change in community structure associated with the formation of fish spawning aggregations, and is currently in internal review before submission. Currently the third manuscript is being prepared, and will cover the state of aggregation research in the SEFCRI region. This manuscript will consolidate all of the data collected in the field and publically available data to produce a comprehensive overview of FSA research and the status of FSAs in the SEFCRI region.

A fourth product is also being prepared, describing the Target Strength to Length relationship for large reef fish using multiple frequencies and wideband echosounding approaches. We anticipate completing this aspect of the project in the fall of 2018, following the collection of supplementary data to aid improving the current models (Figure 1). These data will aid in developing a rapid non-invasive survey approach to assess the status of fish spawning aggregations, especially in regions that are logistically difficult to sample with alternative approaches.

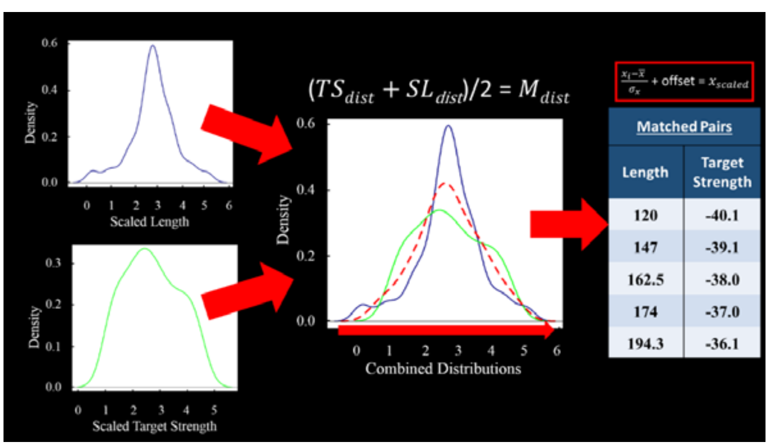

Figure 1: Graphical representation of the scaling and transformation process used to develop a mean sampling distribution for target strength and standard length samples. Individual samples from length and target strength data were scaled about their respective mean and standard deviations (left). Scaled values were overlaid and a smoothed mean distribution (red dotted line) was created to derive matched length and target strength pairs (center). Scaled matched values were then back-transformed, or “de-scaled” and used in a least squares model to solve for the slope and intercept coefficients within the standard target strength to length model (right).

Research Performance Measure: The historical reports and data gathered in previous funding years were relayed to the SEFCRI working groups for the development of their regional management plan and Marine Spatial Planner (http://ourfloridareefs.org/tool/) (Figure 2 & 3) in 2016.

Data related to the community response to disturbances has been presented at numerous conferences and meetings both locally and internationally; including the 2016 GCFI conference, the 147th American Fisheries Society Annual Meeting, the 2017 Florida International University Biosymposium, and the 2nd Annual CRCP Learning Exchange. These data have been compiled into manuscript format, which is in the process of being submitted to Marine Ecology Progress Series for publication. Data pertaining to both the TS-L models and the overall review of FSA research were presented at the 70th GCFI conference, and are being prepared for publication in the peer-reviewed literature.

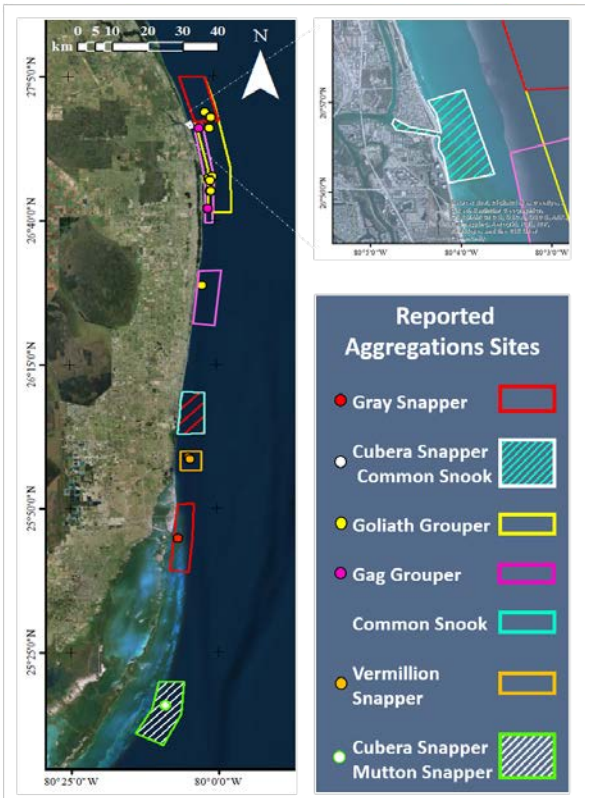

Figure 2: Reported aggregation sites were presented to the SEFCRI-TAC for the development of their regional resource management plan and Marine Spatial Planner (http://ourfloridareefs.org/tool/). Polygons are representative of a generalized aggregation area, while points relate to specifically identified aggregation locations.

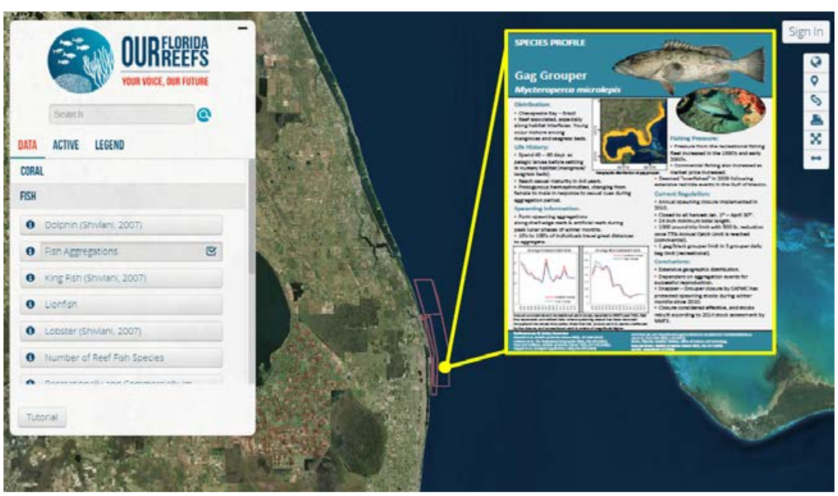

Figure 3: An example of the web based Geographic Information System being provided to SEFCRI and NOAA that will include; distribution, life history, known spawning information, historical susceptibility to fishing, known status of the fishery regulations, and a list of references related to the commercially and recreationally fish species that aggregate to spawn in South Florida.

Deep-Sea Coral Research off South Florida: Data Dissemination from Past Projects

Project Personnel: S. Brooke (FSU)
NOAA Collaborators: P. Etnoyer (NOAA/NCCOS)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To ensure that data collected through NOAA funding reaches the public domain in a scientifically defensible format to enable scientists, conservationists and management entities to use the information.

***Strategy*:** To extract historical data generated by NOAA and ensure it is available in the form of databases and/or manuscripts and reports.

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: NOAA Deep Sea Coral Research and Technology Program
NOAA Technical Contact: Peter Etnoyer

Research Summary:

In 2005, Brooke received funding from NOAAs Office of Ocean Exploration for a research cruise (https://oceanexplorer.noaa.gov/explorations/05deepcorals/welcome.html) to study deep sea coral ecosystems off the east coast of Florida. During the cruise, 14 dives were completed, resulting in 14 habitat surveys and 150 samples from these deep coral sites. During the cruise, a 'shallow' (430m) coral bioherm was discovered off Cape Canaveral, and a possible Wreckfish (*Polyprion americanus*) spawning site was observed off the Miami Terrace. Deliverables included a final report to NOAA as well as copies of all tapes and data, and a significant outreach effort. In addition, a graduate student (K. Shirur) at Nova Southeastern (Supervisor: Dr. C. Messing) used these data to produce his M.Sc. thesis in 2008, titled "Quantitative Habitat Characterization and Benthic Assemblage Structure of Deep-water *Lophelia pertusa* and *Enallopsammia profunda* Reefs of Eastern Florida." This thesis contains a great deal of valuable information that enhances our understanding of deep sea coral ecosystems off the southeastern US; however, the data have not been published, nor have the coral data been extracted for use by management agencies

Funds were requested for Brooke to prepare a peer-reviewed manuscript from data presented in the aforementioned M.Sc. thesis. As part of this project's deliverables, data on locations of the coral species observed during the cruise will be submitted to NOAAs DSCRTP for inclusion in their deep-sea coral database.

Research Performance Measure: Performance measures include a manuscript and data sheets with coral locations from the 2005 submersible dives. The manuscript is entitled 'Quantitative Habitat Characterization and Benthic Assemblage Structure of Deep-water *Lophelia pertusa* and *Enallopsammia profunda* Reefs off Eastern Florida' (Brooke S., C. Messing, K. Shirur). The data sheets are ready and will be submitted together with the manuscript draft by the project due date of June 30, 2005. The contract had a completed manuscript submission date of 3 months after funding was available (Funding was available August 15, 2017). The thesis data interpretation proved more challenging than previously thought and required extensive manipulation and additional video review.

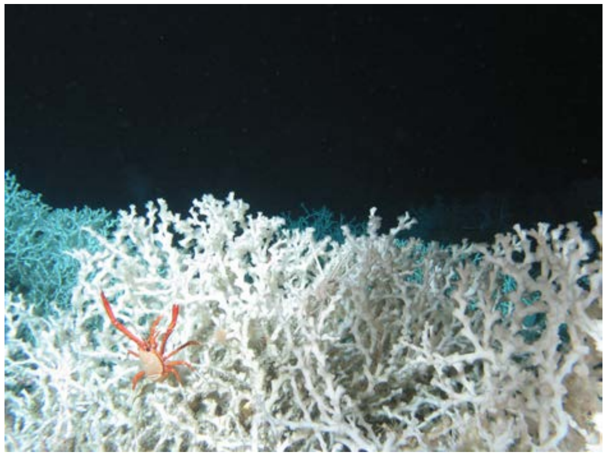

Figure 1: A galatheid crab (*Euminida picta*) among the branches of the deep sea coral *Lophelia pertusa*, which builds extensive reefs along the southeastern US slope.

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Pelagic Observer Program

Project Personnel: S. Davies (UM/CIMAS)
NOAA Collaborators: L. Beerkircher, S. Cushner and A. Davis (NOAA/SEFSC)
Other Collaborators: T. Morrell and J. Heidt (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*)

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.

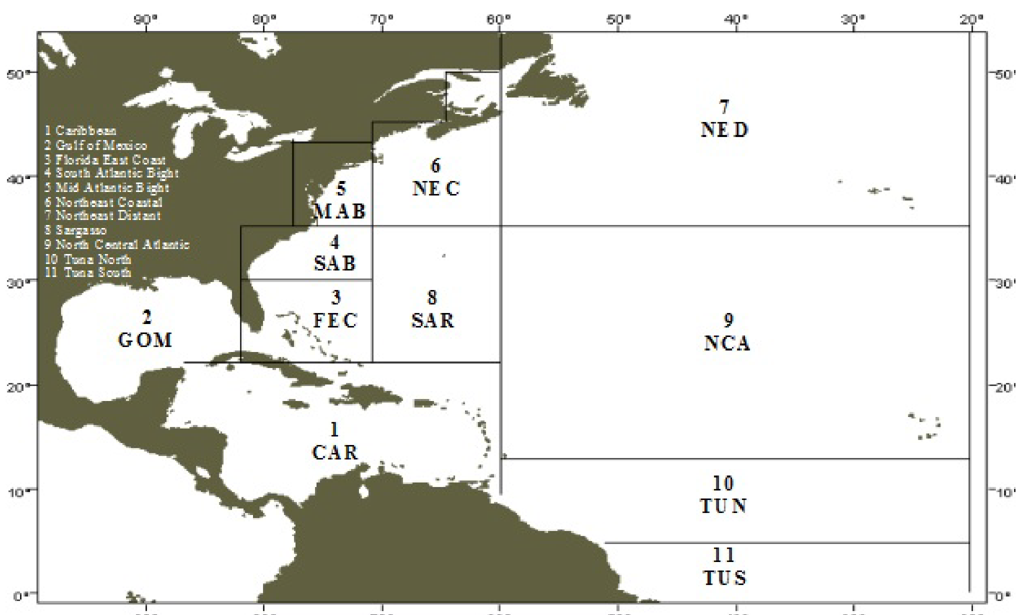

Figure 1: Geographic range of pelagic longline fleet and observer coverage

Research Performance Measure: At the end of Quarter 2, 2018, the targeted goals of the program are being met.

Trophic Interactions and Habitat Requirements of Gulf of Mexico Bryde's Whales

Project Personnel: K. Boswell, M. Hiethaus and J. Kiszka (FIU)
NOAA Collaborators: L. Garrison, M. Soldevilla and K. Mullin (NOAA/SEFSC)
Other Collaborators: J. Hildebrand (Scripps Inst. Of Oceanography)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To develop a comprehensive ecological understanding of Gulf of Mexico Bryde's whales (*Balaenoptera edeni*), including the physical, oceanographic, and biological features defining critical habitats and their ecological role in Gulf of Mexico marine food webs.

***Strategy*:** To conduct ship-based surveys to assess the habitat, spatial distribution, and foraging ecology of Gulf of Mexico Bryde's whales using a multi-faceted approach that integrates visual and acoustic monitoring, environmental sampling, trawling, biopsy sampling for genetic, stable isotope and pollutant (trace elements and persistent organic pollutants) analyses, and deployment of animal-borne tags at fine and coarse scales.

CIMAS Research Theme:

Theme 5: Ecosystem Modeling and Forecasting (*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*)

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

Research Summary:

The Gulf of Mexico Bryde's whale population suffered injury due to the Deepwater Horizon (DWH) oil spill. This is an extremely small, isolated population with an estimated abundance of 33 individuals, a restricted habitat range, and very low levels of genetic diversity. The scale of the DWH injury and the small population size makes Bryde's whales a priority species for recovery management and restoration activities to promote recovery.

The primary objective of this research project is to develop a comprehensive ecological understanding of protected Gulf of Mexico Bryde's whales, including the physical, oceanographic, and biological features defining critical habitats and their ecological role in Gulf of Mexico marine food webs (Research Area D). To address this objective, we propose to conduct three seasonal ship-based surveys to assess the habitat, spatial distribution, and foraging ecology of Gulf of Mexico Bryde's whales using a multi-faceted approach that integrates visual and acoustic monitoring, environmental sampling, trawling, biopsy sampling for genetic, stable isotope and pollutant analyses, and deployment of animal-borne tags sampling at fine and coarse scales. Models will be developed from the resulting data that will identify key trophic interactions, improve characterization of Bryde's whale habitat, and provide information to managers that will inform restoration and population recovery activities

The project results will contribute directly to the development of restoration plans, recovery plans, and environmental impact studies that are key to the effective conservation of Bryde's whales in the Gulf of Mexico.

Research Performance Measure: During the cooperative agreement period, the first research cruise has been prepared and all necessary equipment have been purchased, including two camera tags (CATS-CAM), satellite tags and VHF transmitters/receivers (necessary to recover the camera tags). The first research cruise planned during year 1 of the project was planned in May 2018, but took place from June 21 to July 8, 2018 because the NOAA ship *Gordon Gunter* needed repairs. This first cruise gave us the occasion to test all the equipment, and start collecting data. The ship followed predetermined transects with a CTD launch at 06:30 and 19:00. The EK60 was active day and night throughout the cruise to sample across multiple habitats, except in the vicinity of the Bryde's whales to avoid possible impact on the animals. Every time a Bryde's whale was encountered and weather permitting, a tagging boat was launched to collect photo identification data, collect biopsy samples, deploy kinematic and camera tags, and collect environmental DNA samples (component not included in the original proposal). We managed to have clear pictures of Bryde's whale's dorsal fins as well as one biopsy sample. A single Acousonde tag that deployed on a whale for a duration of 27 hours. Environmental eDNA samples were collected in the vicinity of four whales. Weather conditions have been relatively poor during the cruise, which limited our ability to undertake more deployments.

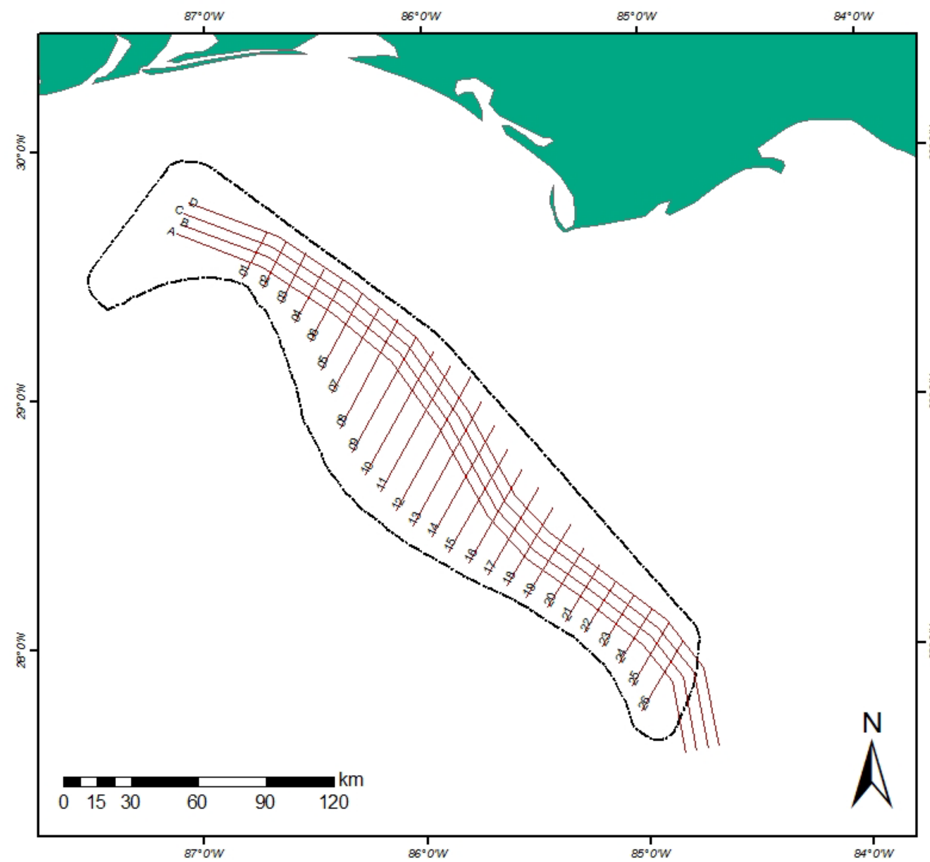

Figure 1: Cruise plan

Gulf of Mexico Integrated Ecosystem Assessment

Project Personnel: A. Gruss, K. Kearney, W. Harford, C. Quenée, N. Trifonova, S. Martin, S. Blake and K. Montenero (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 nation's coastal wetlands. However, the footprint of the GoM extends well beyond the coastal waters of Texas, Louisiana, Mississippi, Alabama, and Florida. Through its upstream linkages it impacts and is impacted by 31 of the 50 states comprising the greater Gulf of Mexico watershed. Clearly, sustaining the resilience of this marine ecosystem and the services it provides is vital to our nation and its economy.

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

At the broader Gulf of Mexico scale we recently analyzed over 100 indicators representing physical, biological, and economic aspects of the GoM and using a Drivers-Pressures-State-Impact-Response (DPSIR) framework, identified an ecosystem-wide reorganization in the mid-1990s (Figure 1, Karnauskas et al. 2015). Additional analyses showed a shift in composition of fishery landings in the GoM in the late 1970s that aligned with the advent of the Magnuson-Stevens Fishery Conservation and Management Act, and shifts in the mid-1960s and 1990s aligned temporally with changes in the Atlantic Multidecadal Oscillation (AMO; Figure 2). Based on this comprehensive analysis we provide recommendations on how resource managers can adjust to various climate regimes in the broader Gulf of Mexico.

Figure 1: Socioecological conceptual model of the Gulf of Mexico region. Integrates biophysical components with human dimensions for the region.

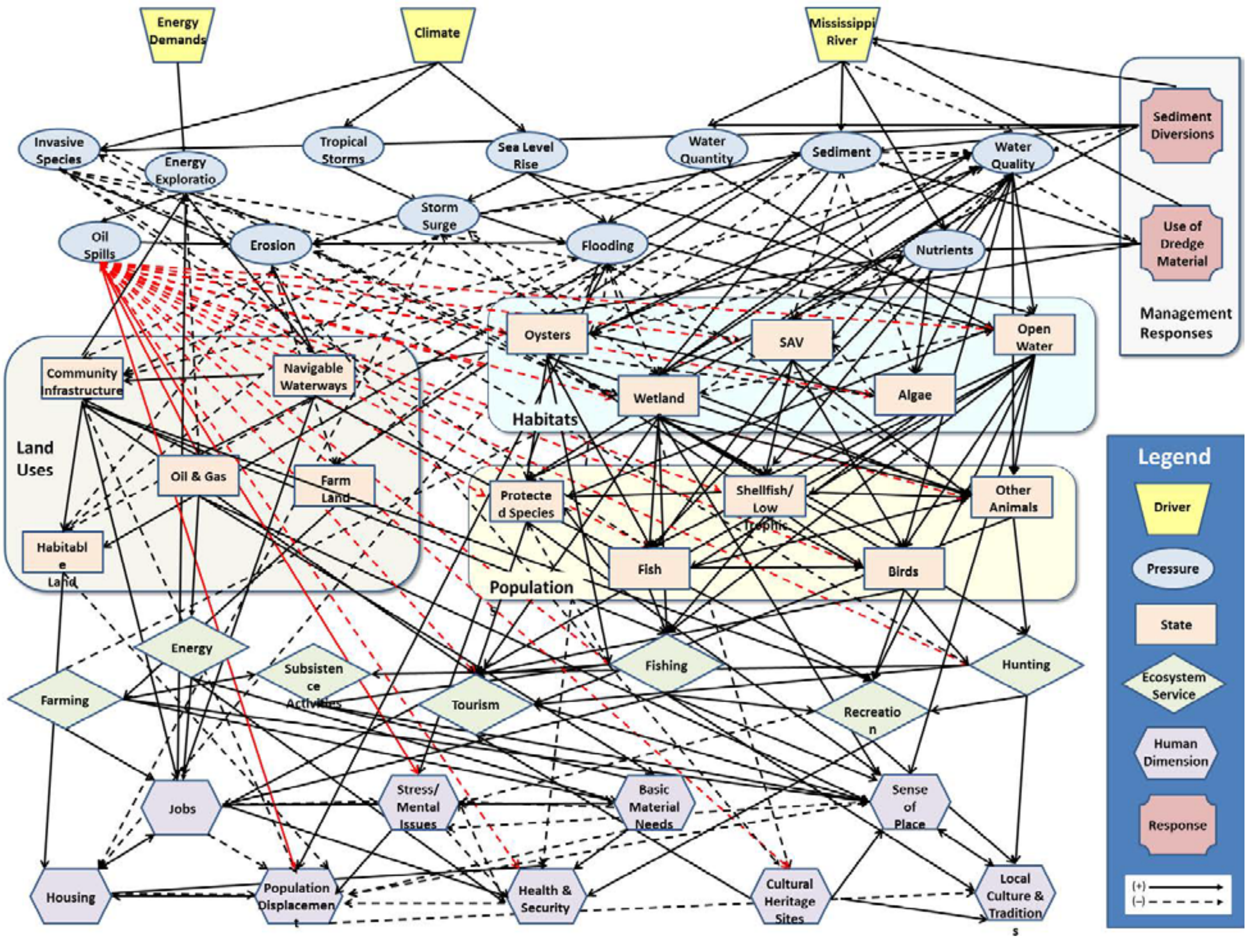

Figure 2: Conceptual model for the Mid-Barataria Sediment Diversions project in southeastern Louisiana.

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 published an update to the Gulf of Mexico Ecosystem Status Report, which was well received in the region and are planning a second update. We are also conducting a case study in the Barataria Bay are of southeastern Louisiana to study the impacts of proposed sediment diversions and developing a plan to collaborate with the Florida Keys National Marine Sanctuary to develop and integrated ecosystem assessment framework to inform their management needs. We are also working on identifying and analyzing tipping points in the Gulf of Mexico as part of the national Ocean Tipping Points Program. Finally, we held a Gulf of Mexico IEA Regional Team meeting in Key West this year to further our efforts and develop our next three-year work plan.

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Caribbean Reef Ecosystem Research, USVI Larval Distribution and Supply

Project Personnel: A. Jugovich, E. Malca, J. Mostowy, S. Privoznik, A. Shiroza and K. Shulzitski (UM/CIMAS)
NOAA Collaborators: J. Lamkin and T. Gerard (NOAA/SEFSC); N. Norton (NOAA Corps)

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. Surveys 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 2015-2017. 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, and preliminary identifications complete for 2017. The most recent cruise is currently underway, scheduled from 6 – 25 June 2018, replicating collections at some historical stations and adding additional sampling techniques. We completed a total of 150 stations planned, yielding approximately 100 plankton samples (oblique bongo tows).

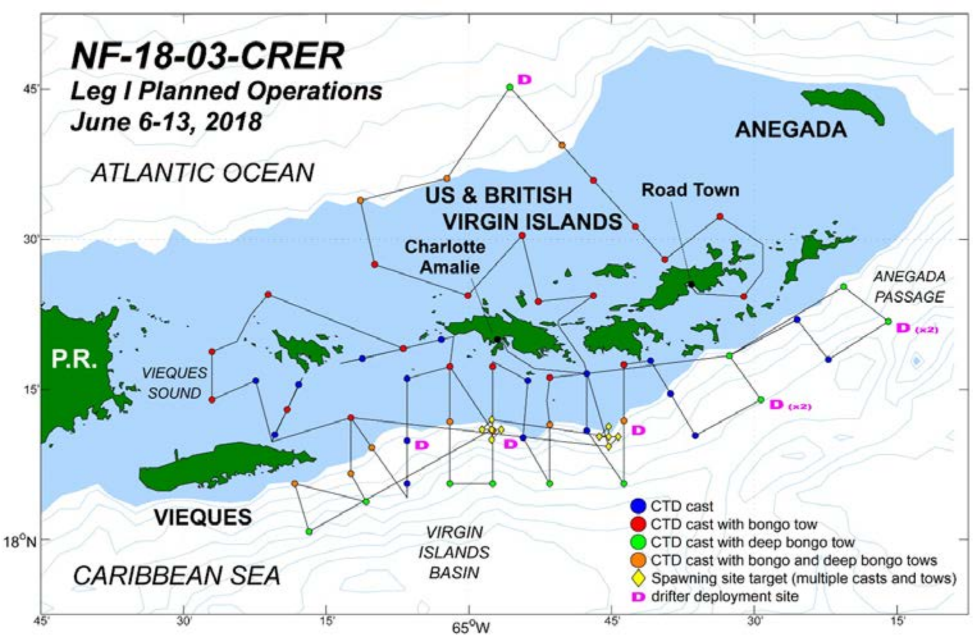

Figure 1: Survey track indicates study area and station locations for the cruise NF1803 aboard the NOAA Ship Nancy Foster.

2016 National Coral Reef Monitoring Program – SEFCRI Benthic Sampling

Project Personnel: K. Kilfoye and R. Spieler (NSU)
NOAA Collaborators: M. Johnson (NOAA/SEFSC); S. Viehman (NOAA/NOS)
Other Collaborators: S. Smith (UM/RSMAS); J. Blondeau (UM/CIMAS); J. Kimball (The Baldwin Group Inc.)

Long Term Research Objectives & Strategy to Achieve Them:

***Objectives*:** To provide information to assess and report the status and trends of environmental conditions and living reef resources along the northern Florida Reef Tract, specifically targeting corals and benthic communities within the SEFCRI (Southeast Florida Coral Reef Initiative) region that spans through four counties in southeast Florida (Martin, Palm Beach, Broward, and Dade) during the summer/early fall of 2016.

***Strategy*:** To complete NCRMP benthic surveys (Line Point Intercept and Coral Demographic Surveys) in the SEFCRI region, complete data entry and initial quality control (data proofing) for all surveys, and assist with report completion pertaining to the SEFCRI region data.

CIMAS Research Theme:

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

The main focus of this this project was to collect data that would reflect the current status of corals and the benthic community along the northern Florida Reef Tract. To accomplish this, a habitat-based random stratified survey design that was utilized for 2016 coral reef fish sampling (Southeast Florida Coral Reef Fishery-Independent Assessment; SEFCRI region RVC) was used to establish a subset of 100 benthic survey locations throughout the entire southeast Florida region.

At each survey site, one Line Point Intercept (LPI) survey and one Coral Demographic survey was performed along a 20 meter transect line. During LPI surveys, the diver identified biotic or abiotic cover (and the underlying substrate) under the transect tape at set intervals. During a Coral Demographic survey, the diver recorded information on all corals >4cm in maximum diameter that lay within a 10 meter segment of the survey area established by the transect tape. Site photographs and additional data on benthic fauna (queen conch, spiny lobster, *Diadema antillarum*) and topographic complexity were taken at each site as well.

Following survey completion, data were entered into an online data entry system (managed by NOAA), which was later subjected to a rigorous proofing and quality assurance/quality control procedure before an analysis ready dataset was created. Data analysis and reporting was performed by NOAA staff operating independently from this project. At this time, no results are available for inclusion.

Research Performance Measure: All of the research performance measures were met on schedule and without delay. NCRMP benthic surveys were completed by November 2016, data entry was completed by December 2016, quality assurance/quality control procedures were completed during February 2017, and the PI rendered assistance to NOAA-SEFSC and RSMAS staff as needed for the remainder of the award period as the final report was being prepared.

Figure 1: A diver conducting a line point-intercept survey along a transect line in Palm Beach County, Florida.

Figure 2: A diver conducting a coral demographic survey along a transect line in Dade County, Florida.

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, L. Carrillo-Bibriezca, (ECOSUR); C. Gonzalez and M. González (MARfund)

Long Term Research Objectives and 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*:** To carry out larval and oceanographic collections to assess larval transport & recruitment pathways in the Mesoamerican reef system. In addition, to enhance international capacity for the topic of connectivity as it relates to research and management with local and regional practitioners in the Mesoamerican Reef.

CIMAS Research Theme:

***Theme 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 project carried out the activity titled Connectivity Exercises or "ECOME 6" that was executed during the new moon of October 2017. 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.

One of the goals this year was to create and share amongst MPA practitioners and scientists a report encapsulating the five ECOME exercises representing the 2010-2017 activities in the Mesoamerican Reef.

Research Performance Measure: Through our collaborative work, several manuscripts, reports and theses 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. One manuscript was published that modeled larval swordfish habitat in the western tropical Atlantic and a second manuscript is currently under peer review that modeled lionfish larval distribution in the Mesoamerican Reef-Caribbean region using larval and oceanographic datasets from the oceanographic surveys from 2011, 2012 and 2015 Reef. Similarly, a scientific poster was presented at the Ocean Science Meeting in Portland, OR that aged larval blue marlin from Cuban waters collected during a 2015 and 2016 survey of the 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 informal training events within the region to augment additional monitoring sites for the ECOME exercises including increasing capacity of the MPA "Sanctuario de Manatí" in the Zaragoza Channel between Mexico and Belize. On-site training was provided by L. Vasquez Yeomans. 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.

Figure 1: Schematic of ECOME exercises from 2010-2016 as summarized in a technical report created and shared with MPA practitioners and scientists in the Mesoamerican Reef System. Participants, MPAs, and reef fish collected during the ECOME exercises are shown.

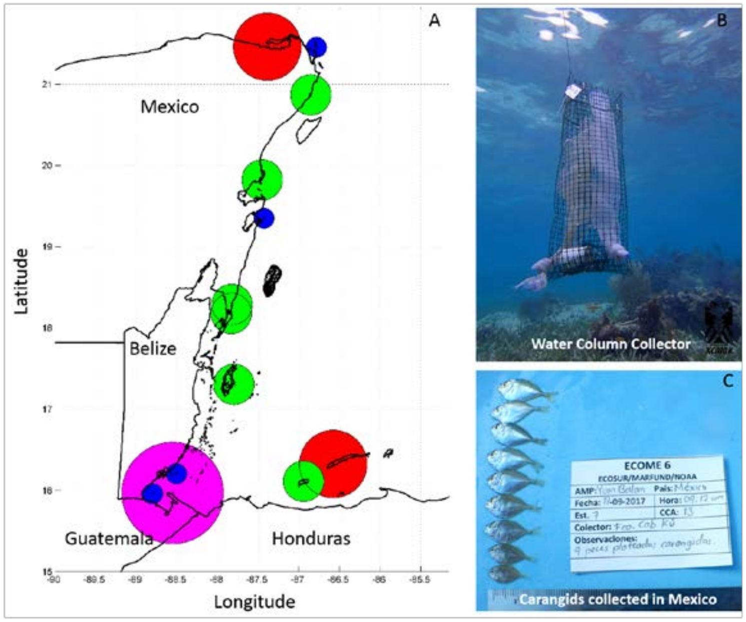

Figure 2: A) Abundance and distribution of reef fish collections throughout the study area for the five ECOME exercises. The size of the symbol indicates combined abundance at each MPA B) The standard gear utilized by all marine protected areas participating in the ECOME exercises, the water column collector. C) Juvenile jacks collected using the water column collector during the September 2017 ECOME exercise in Yum Balam, Mexico.

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Net Revenues of the Federal Fin-Fish Commercial Fisheries in the Southeast

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 annually report net revenues of commercial fishing operations in the Southeast's reef fish, snappers and grouper, and coastal migratory pelagics (mackerel) fisheries. A central gap in the Southeast's commercial fishery economic assessments are estimates of net revenues for federally-managed fin-fish fisheries, include two catch share fisheries that are part of the national performance indicator project.

***Strategy*:** To ensure both statistical representativeness and meaningfulness/usefulness of the economic results, the annually collected economic data is 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 have been built and implemented. The inaugural technical memorandum for the 2014 Gulf of Mexico reef fish fishery was published in November 2018. Follow-up technical memorandums for the years 2015 and 2016 have been finalized and are in review. Furthermore, the inaugural technical memorandums for 2014-2016 for the South Atlantic Snapper-Grouper and Coastal Migratory Pelagics fisheries are in development. 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 presented at the WRFC8 on a novel crowdsourcing-based data collection method.

Research Performance Measure: The economic analysis of economically and statistically meaningful sub-populations of the Gulf of Mexico federal fin-fisheries (including at the trip- and annual/vessel-levels) is complete and the reporting design is in progress. For South Atlantic federal fin-fisheries, the economic analysis of economically and statistically meaningful sub-populations in ongoing and the reporting design is in progress. The overall response rate and quality of the data collection continues to be high. The design for enhancements to the economic panel data set in the data warehouse have begun. 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)

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. 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 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. The MRA faculty are not formally defined or limited, as any faculty member at USF-CMS can have students in the MRA program, and all faculty members can opt to contribute to MRA-related teaching and research.

There are currently 27 fulltime USF-CMS students participating in the MRA program, with 10 being Master's students and 17 being doctoral students. 33% are male and 77% are female. 96% are U.S. citizens. 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). In recent years, MRA students have generally represented about 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. For example, Dr. Ainsworth's course *Ecosystem Modeling* has been attended by 28 fisheries professionals from ten different NMFS labs on the east and west coasts of the US (listed below). Agency professionals 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 25 graduates to date. Of these, 48% work for government agencies, 32% work in academia (as continuing students or as faculty), and 20% work in private-sector environmental jobs (details are provided under *MRA Graduates* below).

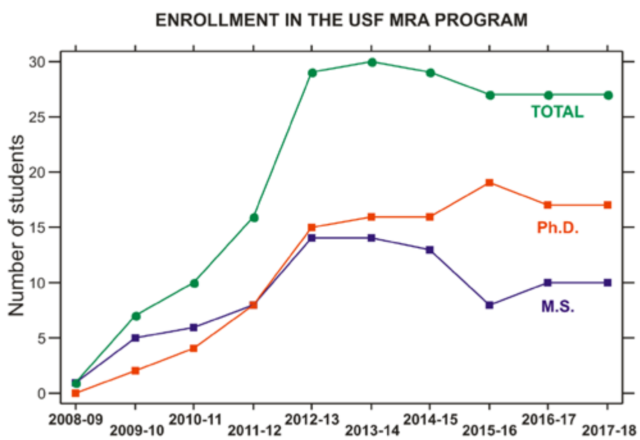

Figure 1: Enrollment in the USF-CMS Marine Resource Assessment (MRA) program by type of student and academic year.

Figure 2: Cam Ainsworth co-teaching a *Management Strategy Evaluation* short course with other QUEST faculty at ICES 2017 (September 2017).

Figure 3: The *Management Strategy Evaluation* course was attended by approximately 30 state, federal and international fisheries managers (ICES 2017, September 2017).

Figure 4: Students in the Marine Resource Assessment program conducting Red Snapper fecundity analysis in the Stallings Lab at USF-CMS.

Figure 5: A Cuban chimaera sampled off the northwest coast of Cuba during an R/V *Weatherbird II* longline survey. The survey was desiged to characterize fish communities at the large marine ecosystem (LME) scale and to obtain samples for contaminant and life history studies.

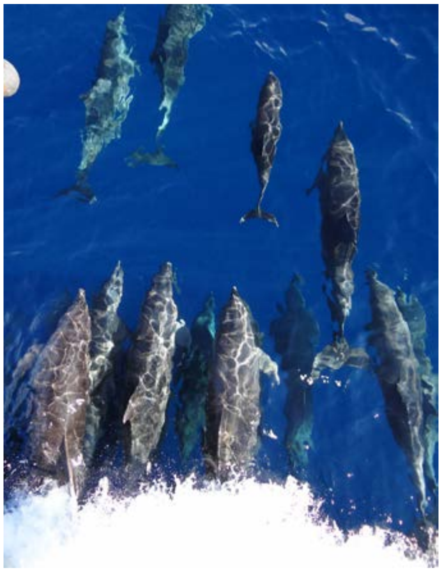

Figure 6: A dolphin pod riding the bow wave of the R/V *Weatherbird II* during a resource assessment survey cruise.

Figure 7: Deploying standardized longline sampling gear aboard the R/V *Weatherbird II* during summer 2017.

Figure 8: MRA students Susan Snyder, Elizabeth Herdter, and Kristina Deak with fish that were collected as part of a fish-community and contaminant analysis of the Gulf of Mexico.

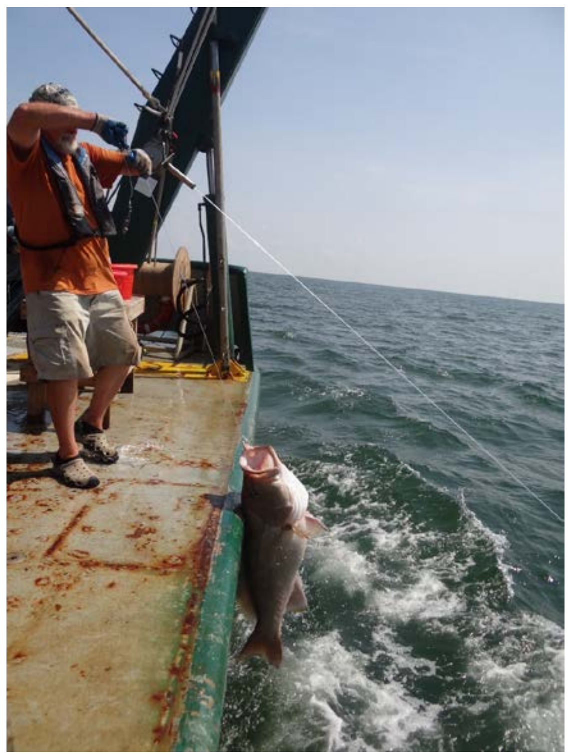

Figure 9: Steve Murawski (USF-CMS) collecting a Yellowedge Grouper from the Gulf of Mexico aboard the R/V *Weatherbird II*.

Automation of stock assessment inputs and data products

Project Personnel: A. Shideler (UM/CIMAS)
NOAA Collaborators: D. Gloeckner (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To automate the production of the inputs required for fisheries data reviews and assessments to accommodate increased numbers of stocks requiring assessments; to produce standardized data outputs.

***Strategy*:** To evaluate current data extraction programs in use by various analysts at the Southeast Fisheries Science Center and identify needed improvements. To automate these programs and store the resulting data in a centralized location that can be readily accessed by data users. To create procedures that will produce standardized data outputs, including for when data is extracted for confidential and non-confidential data users.

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:

Analysts with the Southeast Fisheries Science Center (SEFSC) conduct stock assessments for federally managed fish species through the SouthEast Data, Assessment, and Review (SEDAR) collaborative process at the request of the South Atlantic Fishery Management Council, the Caribbean Fishery Management Council, and the Gulf of Mexico Fishery Management Council. Since beginning in 2002, analysts have participated in 62 SEDARs, with some SEDARs encompassing the assessment of multiple species. As SEDARs have increased in number (Figure 1) and complexity over time without an increase in staffing, so has the need to increase efficiency in supplying data inputs used in the assessments.

Additionally, each year the SEFSC produces reports for the South Atlantic Fishery Management Council and the Gulf of Mexico Fishery Management Council. These Stock Assessment and Fishery Evaluation (SAFE) Reports provide the respective councils with information on commercial vessel-reported landings from the coastal logbook program, biological samples of species taken by the Trip Interview Program (TIP), and dealer-reported landings in the Accumulated Landings System (ALS). Previously, several SEFSC staff members periodically produced these reports. Now, these reports are in the process of being automated. The TIP SAFE report programming complete and the coastal logbook SAFE report programming in review. During the automation process, assignments of records to the South Atlantic and Gulf of Mexico regions were standardized. Additionally, for the coastal logbook SAFE report, we accounted for stock boundaries that differ geographically from South Atlantic/Gulf of Mexico regional boundaries in the programming; the format is flexible and can be easily edited should stock boundary definitions change in the future.

Research Performance Measure: We have completed reviewing and rewriting computer programs that generate Stock Assessment and Fishery Evaluation (SAFE) reports for the Trip Interview Program

(TIP). The program for each region (South Atlantic, Gulf of Mexico) takes less than one minute to run and can be reran at regularly scheduled intervals. The coastal logbook SAFE report program has been completed and is under review. The Accumulated Landings System (ALS) program is under development as source data issues are being resolved.

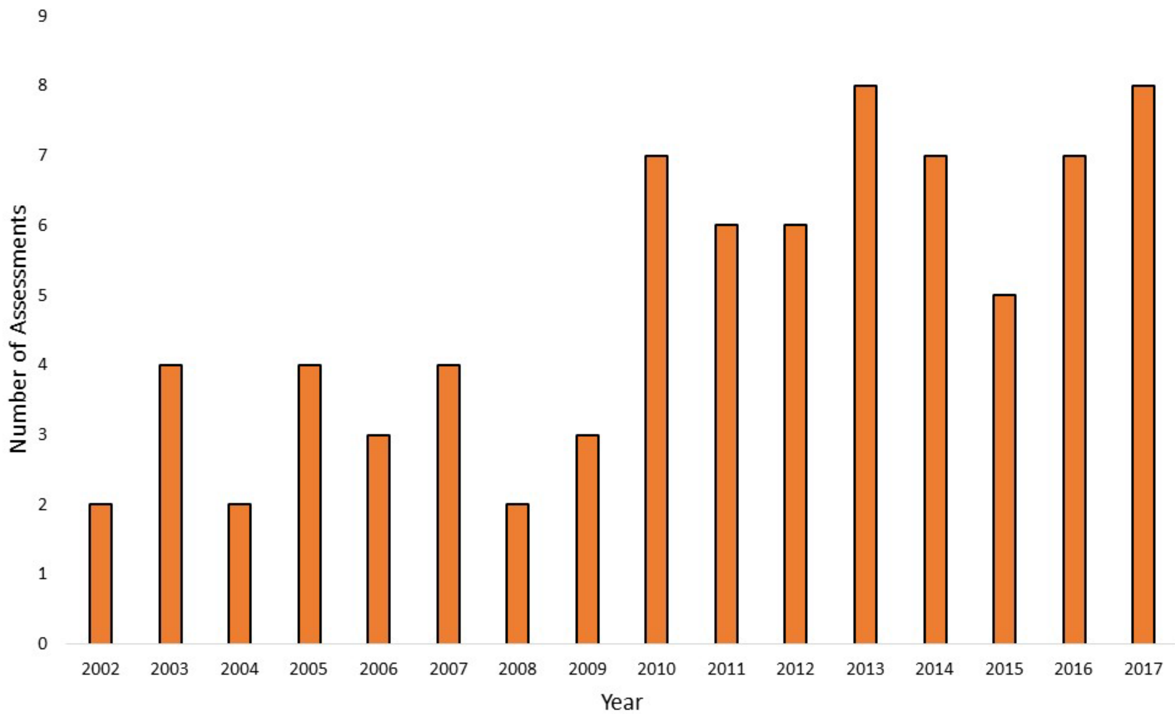

Figure 1: Number of SEDAR assessments (including benchmark, standard, and update assessments) conducted per year from 2002 through 2017.

National Marine Sanctuaries as Sentinel Sites for a Demonstration Marine Biodiversity Observation Network (MBON)

Project Personnel: K. Shulzitski and M. Le Henaff (UM/CIMAS)
NOAA Collaborators: T. Gerard and J. Lamkin (NOAA/SEFSC)
Other Collaborators: F. Mueller-Karger, M. Hepner and D. Otis (USF); M. Rider (UM/RSMAS)

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 have already been 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 the observed 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 within the FKNMS) and time (i.e., time series of RVC dataset). 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 were used to determine the operational metrics produced for end users of this MBON dataset (e.g., infographic, map). This work was presented in February 2018 at the Ocean Sciences Meeting in Portland, OR.

In collaboration with Mitchell Rider, Matthieu Le Henaff, and Dan Otis, ocean color images are currently being analyzed in order to quantify the passage of mesoscale and submesoscale eddies through the Straits of Florida. Images from 2017 were used to develop and quality control eddy quantification metrics (Figures 1 and 2). The analysis for 2017 images is now complete and analysis for 2016 images has begun. Image analysis through 2013 is expected to be complete by September 2018.

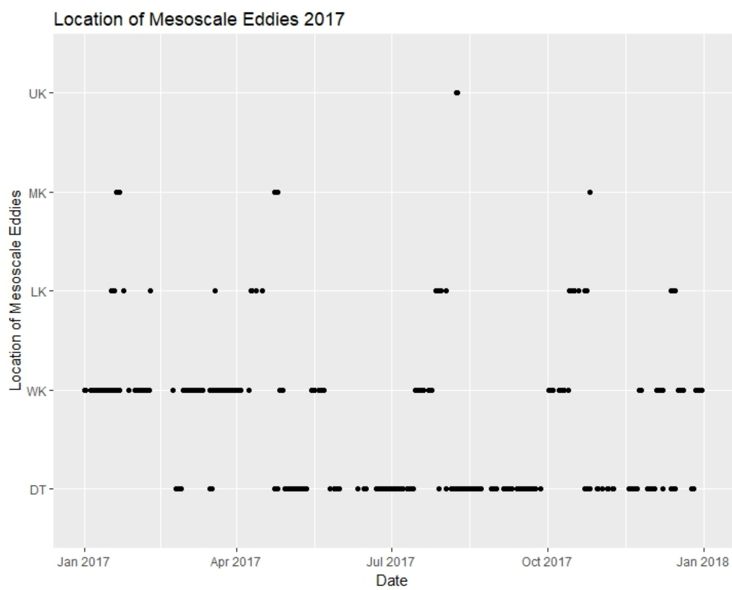

Figure 1: Mesoscale eddy propagation through the Straits of Florida in 2017; DT = Dry Tortugas, WK = western Keys, LK = lower Keys, MK = middle Keys, and UK = upper Keys.

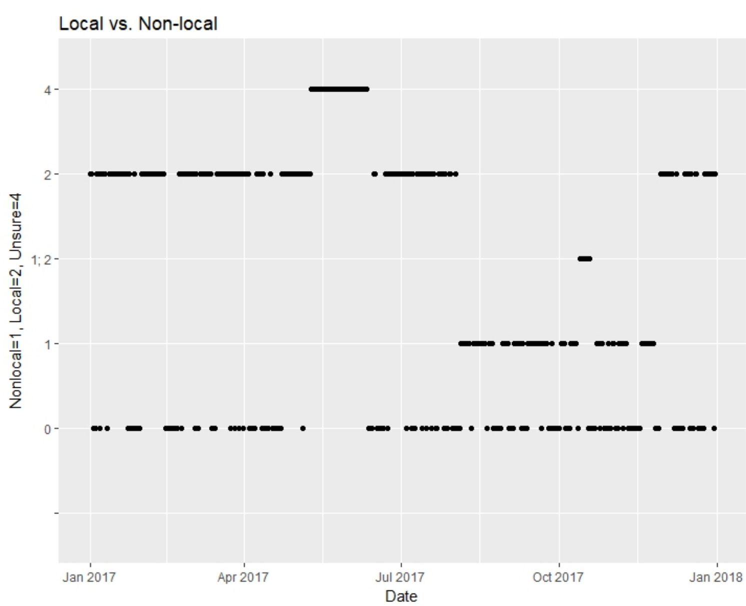

Figure 2: Local and non-local eddy formation in the Straits of Florida in 2017. Local formation occurs on the SW Florida shelf while non-local formation occurs along the front of the Loop Current in the Gulf of Mexico.

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

Project Personnel: D. Williams, A. Bright, R. Pausch and A. Peterson (UM/CIMAS)
NOAA Collaborator: L. Grove (NOAA/SEFSC)
Other Collaborators: Coral Restoration Foundation (Tavernier, FL)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** To 1) identify and document demographic variables such as recruitment, mortality, etc., in the *Acropora* spp. population in the upper Florida Keys, 2) document threats including disease, predation, and bleaching, impacting the remaining eklhorn coral, *Acropora palmata*, and determine the relative importance of each threat, and 3) continue undertaking hypothesis-driven field experiments evaluating *Acropora* spp. restoration strategies.

Strategy: To assess on a quarterly basis the status of individually-tagged colonies of *A. palmata* at several sites in the upper Florida Keys. Second, to monitor nursery-raised *A. palmata* fragments outplanted in a variety of configurations to determine the effect of genotypic diversity on the long-term 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:

As part of a long-term monitoring program, surveys collecting demographic data of wild *Acropora palmata* are conducted 3-4 times per year to track individual colonies and related ecological stressors affecting this keystone species. The study plots (150m²) are located at nine different sites along the reef tract offshore of Key Largo (two of the nine sites are surveyed once per year). Certain parameters have been selected to document colony abundance, condition, and recruitment, among others. Since 2004, fourteen years of monitoring have documented major losses associated with episodic events including bleaching events and tropical storms along with more chronic threats including disease and predation. The three surveys conducted within the past year were completed August through October of 2017 and June 2018.

Along with the rest of the Florida Keys reef tract, our survey sites experienced a range of substantial damage from Hurricane Irma in early September 2017. Sustained winds over Key Largo reefs averaged 50-64 knots with maximum gusts reaching 80 knots (based on NOAA CMAN tower data). Extra effort was made to survey the population immediately following this natural disturbance and to mitigate damage by securing loose fragments. Seven of the nine monitored reef sites lost a total of 53% live cover of *A. palmata* (estimated using a live area index) and lost 124 colonies of the 320 colonies present at those sites the year prior (a loss of 39% of *Acropora palmata* colonies). Irma was the most destructive storm observed in the 14-year timespan of this study, and caused the loss of approximately half of *A. palmata* live tissue area at upper Florida Keys reef sites. Frequent disturbance events such as this are outpacing coral growth and recruitment, making intervention strategies increasingly necessary.

Propagating coral in offshore nurseries and transplanting fragments to the reef, or outplanting, is one intervention strategy currently in use for reef restoration. The recovery plan drafted by NOAA Fisheries as part of the US Endangered Species Act, specifically includes restoring dense thicket-type stands of acroporids as a criteria for recovery. Additionally, the monitoring component of this project has found higher density stands have increased resistance to some stressors. In support of a strategy for restoring thicket type stands, we began an experiment designed to examine the effectiveness of outplanted *A. palmata* in developing thicket structures based varying interspersion of genets within outplanted plots. In other words, the goal of this study is to test if diversity and spatial arrangement of genets affects the success of outplants growing into healthy, resilient stands of *A. palmata*. This experiment, initiated in summer 2016, is supplemental to already completed studies testing the effect of outplant size, reef habitat, and individual genotype on outplant success. Semi-annual surveys were conducted May and December of 2017, and are expected to continue through 2020.

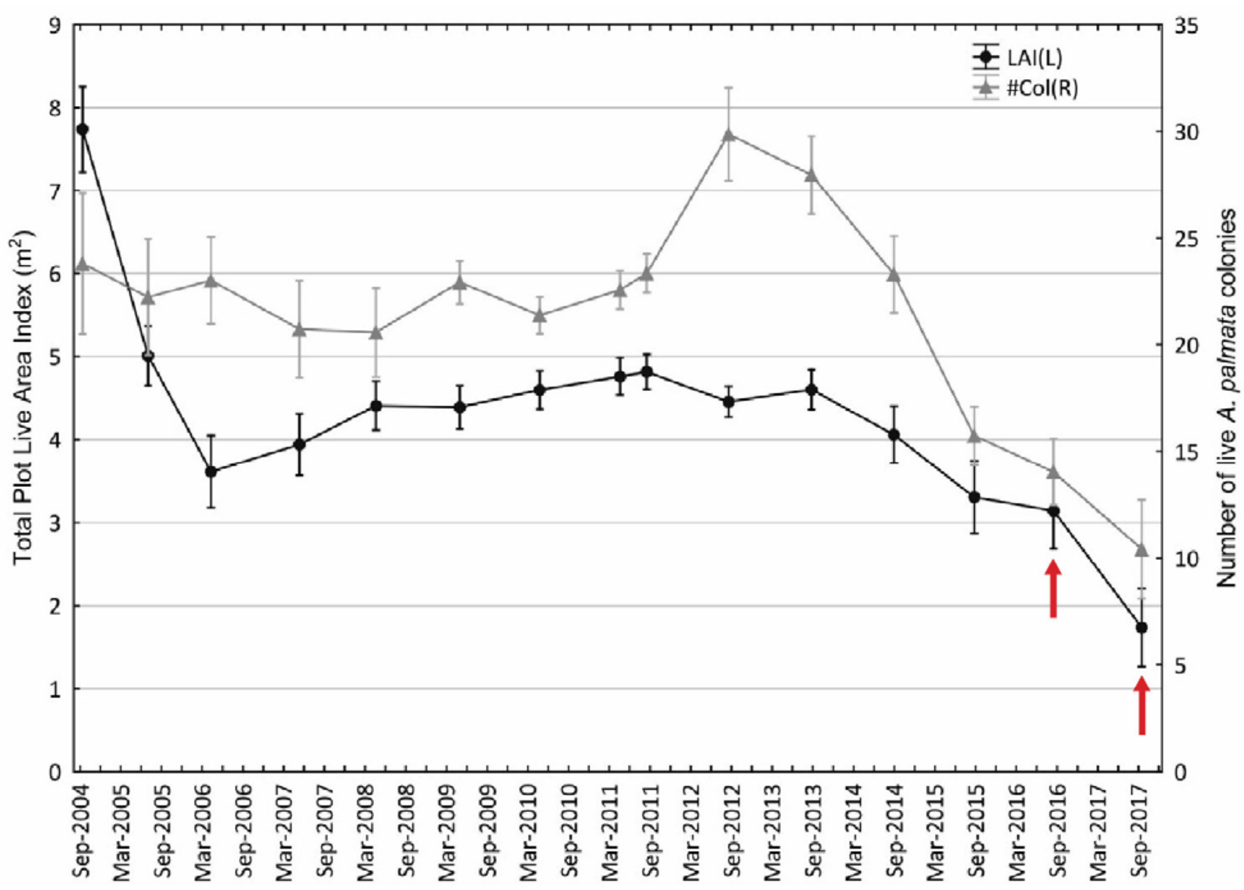

Figure 1: Abundance of Acropora palmata in the upper Florida Keys expressed as Live Area Index, a measure of tissue cover, and the number of colonies in a 150m² plot. Error bars are standard error. The red arrows indicates the change in LAI and number of colonies from September 2016 to September 2017, pre- and post-Hurricane Irma. The change in total plot live tissue area decreased by 53% (36m² loss of LAI) and the number of colonies decreased by 39%.

Figure 2: The extent of the damage caused by Hurricane Irma at one of our fixed Acropora palmata monitoring sites at Molasses Reef. The image on the left was taken in September 2016 and the image on the right was taken from the same perspective in late September 2017. This particular study plot lost 90% of the live elkhorn coral during the hurricane. Photo credit: Dana Williams (RSMAS/CIMAS).

Research Performance Measure: Two of three planned monitoring surveys off the Florida Keys were completed. Weather and resources prevented the completion of one planned survey. However the passage of Hurricane Irma in September 2017 made additional surveys necessary and these were completed in October 2017. During these surveys we were able to document loss of coral and to rescue loose *Acropora palmata* fragments and secure them to the reef with epoxy. Despite significant loss, monitoring will continue into the next year as planned.

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Support of the National Coral Reef Management Fellowship Program

Project Personnel: W. Wood-Derrer (NSU)
NOAA Collaborators: J. Tomczuk, D. Wusinich-Mendez and P. Maurin (NOAA/CRCP)
Other Collaborators: T. Joshua (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 Fellows in each jurisdiction, benefits to both the Coral Fellow, 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 Fellows 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 Fellowship 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 fellowship strives to assist both the NOAA CRCP and jurisdictions in meeting this need.

CIMAS Research Theme:

***Theme 6*:** Ecosystem Management

Link to NOAA Strategic Goals:

***Goal 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, the first cohort (2016-2018) of coral fellows finished the fellowship and the new cohort (2018-2020) were selected and hired for all seven jurisdictions – American Samoa, CNMI, Florida, Guam, Hawaii, Puerto Rico and USVI. By placing this second coral fellowship cohort, this project has furthered capacity building in coral reef management in all seven jurisdictions.

The 2016-2018 cohort successfully finished their workplans and left the agency in January 2018. Of note, the Guam and American Samoa fellows have moved on to full-time positions coral reef management positions in the local agency, building local capacity. The USVI coral fellow is a currently a Fulbright Scholar in Barbados and hopes to return to the USVI after her time there to work on coral reef conservation. The Puerto Rico fellow is starting her Ph.D. and will return to Puerto Rico upon completion to continue working in marine ecosystem management. With the majority of the first cohort remaining or planning to return to their respective jurisdictions, capacity building will continue.

The 2018-2020 cohort started in their respective jurisdictions in January 2018. Orientation Training was held at NSU in Ft. Lauderdale, FL in late January 2018. The orientation was conducted by meeting facilitator Kevin Doyle, where the fellows and their respective jurisdictional supervisors, along with the NOAA CRCP project team, developed their work plans for the next two years. The fellows also received professional development training and orientation to NOAA's CRCP and NSU.

All workplans for the 2018-2020 coral fellowship were approved by NSU and NOAA CRCP in May 2018.

NSU and NOAA CRCP project staff have bi-monthly check-in calls with the seven coral fellows, which at times also include the local agency POC/supervisor. There is also interaction on a regular basis with NOAA CRCP jurisdictional liaisons.

As of May 2018, four of the coral fellows have also planned their professional development training for summer 2018. The remaining three will plan theirs for fall 2018.

Research Performance Measure: The 2016-2018 fellows met all goals for the program and completed their workplans in their respective jurisdiction prior to departure. The 2018-2020 coral fellows have also met all goals to date - they were successfully placed in their respective local jurisdictional agency and are starting on their workplan implementation and continue to have regular contact via scheduled calls with NSU and NOAA.

2016–2018 NATIONAL CORAL REEF MANAGEMENT FELLOWS

NSU NOVA SOUTHEASTERN UNIVERSITY
Halmos College of Natural Sciences and Oceanography

The National Coral Reef Management Fellowship Program is a partnership between Nova Southeastern University's National Coral Reef Institute, NOAA's Coral Reef Conservation Program, the U.S. Department of Interior Office of Insular Affairs, and the U.S. Coral Reef All Islands Committee.

The program recruits Coral Reef Management Fellows for the seven U.S. coral reef jurisdictions (American Samoa, the Commonwealth of the Northern Mariana Islands, Florida, Guam, Hawaii, Puerto Rico, and the U.S. Virgin Islands) to address current capacity gaps and to build longer-term capacity in these locations. This is done by placing highly qualified individuals whose education and work experience meet each jurisdiction's specific coral reef management needs. The program's goal is to develop a thriving collaborative fellowship program that builds excellent next-generation leaders and capacity for effective local coral reef ecosystem management.

American Samoa • Sabrina Woofter

Sabrina Woofter is from Jacksonville, Florida. She received her B.A. in Anthropology from the University of North Florida and her M.A. in Environmental Studies from the University of North Carolina—Wilmington.

As the fellow for American Samoa, Woofter is working with local communities and governmental agencies to improve the health of the area's coral reef ecosystems through the Coral Reef Advisory Group. Her project is focused on improving stormwater understanding and implementing best management practices in local communities to combat land-based sources of pollution. She also aims to improve climate change resilience by increasing local community awareness through the development of community resilience plans and the translation of outreach and education materials about climate change into the Samoan language.

Guam • Whitney Hoot

Originally from Annapolis, Maryland, Whitney Hoot holds a B.A. in Sociology and Environmental Science from Barnard College, Columbia University, and an M.S. in Sustainable Development and Conservation Biology from the University of Maryland—College Park.

During the fellowship, she is working on crafting an island-wide reef resilience strategy for Guam that incorporates extensive stakeholder feedback to create a new framework for coral reef management among the island's natural resource agencies. Additionally, she is coordinating the island's coral reef response team and developing standard operating procedures to address acute reef impacts—such as vessel groundings, oil spills, coral disease outbreaks, and bleaching events.

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

2018–2020 NATIONAL CORAL REEF MANAGEMENT FELLOWS

NSU
NOVA SOUTHEASTERN UNIVERSITY
Halmos College of Natural Sciences and Oceanography

The National Coral Reef Management Fellowship Program is a partnership between Nova Southeastern University's National Coral Reef Institute, National Oceanic and Atmospheric Administration's Coral Reef Conservation Program, the U.S. Department of Interior Office of Insular Affairs, and the U.S. Coral Reef All Islands Committee.

NOAA CORAL REEF CONSERVATION PROGRAM

The program recruits Coral Reef Management Fellows for the seven U.S. coral reef jurisdictions (American Samoa, the Commonwealth of the Northern Mariana Islands, Florida, Guam, Hawaii, Puerto Rico, and the U.S. Virgin Islands) to address current capacity gaps and to build longer-term capacity in these locations. This is done by placing highly qualified individuals, whose education and work experience meet specific coral reef management needs, in each jurisdiction. The goal is to develop a thriving collaborative fellowship program that builds excellent, next-generation leaders and capacity for effective, local coral reef ecosystem management.

American Samoa • Motusaga Vaeoso

Originally from American Samoa, Motusaga (Motu) Vaeoso holds a B.S. in Biology from Chaminade University of Honolulu.

During her fellowship, Vaeoso will collaborate with partners of the Coral Reef Advisory Group (a collaboration of five agencies working to manage American Samoa's coral reefs) to develop, coordinate, and implement a sustainable fishing outreach campaign targeted at local fishers, village communities, and school students. She will also assist with the planning and development of the inaugural Tutuila Ridge-to-Reef Report Card, which rates the health of coral reefs and associated watersheds using existing coral reef monitoring and socioeconomic data. The report card will serve as a decision-making tool for appropriate village community members and leaders.

Guam • Mallory Morgan

Born and raised in Cocoa Beach, Florida, Mallory Morgan holds a B.S. in both Environmental Studies and International Relations from Florida State University and an M.A.S. in Marine Biodiversity and Conservation from Scripps Institution of Oceanography at the University of California—San Diego.

As the Coral Fellow on Guam, Morgan will work to engage Guam's growing tourism industry to reduce harmful impacts and foster sustainable recreational use. She will develop various training programs and outreach, based on extensive stakeholder feedback, to build an industry-wide understanding of the threats to Guam's coral reefs and best management practices. The goal is to generate buy-in from the tourism industry as an active partner in coral reef conservation, critical to Guam's economy and that of natural resource management. Placed at the Bureau of Statistics and Plans, Morgan also will support the Guam Coral Reef Initiative, including Guam Year of the Reef 2018 community engagement activities.

02-024-18MCP

Puerto Rico • Melissa Gonzalez

Melissa Gonzalez is from Davidsonville, Maryland. She received a B.S. in Environmental Science from Bridgewater College and an M.S. in Sustainable Development and Conservation Biology from the University of Maryland—College Park.

As the fellow in Puerto Rico, Gonzalez will work in the Department of Natural and Environmental Resources to develop conservation and management strategies for key reef herbivore species. She will work with stakeholders to compile data and develop action plans for species that contribute to macroalgal herbivory on local coral reefs. In addition, she will be generating a geospatial database of the areas of need and opportunity for these species, as well as public education and outreach materials.

U.S. Virgin Islands (USVI) • Austen Stovall

Originally from Kill Devil Hills, North Carolina, Austen Stovall earned her B.S. in Biology from Wake Forest University.

As the fellow for the USVI, Stovall will work with the Department of Planning at Natural Resources at the St. Croix East End Marine Park (STXEEMP). Her efforts will focus on developing a Responsible Boating Initiative program to prevent negative impacts of boaters on STXEEMP's natural resources and to establish infrastructure for interagency response to groundings and derelict vessels. Concurrently, she will work on a Restoration Action Plan that outlines priority areas of restoration and steps necessary for implementation.

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 will work 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 will include planting grasses and trees in the watershed, as well as assisting with monitoring the stream and coastal water quality on Rota.

Florida • Maurizio Martinelli

A New York City native, Maurizio Martinelli holds a B.A. in International Development Studies from McGill University and an M.A.S. in Marine Biodiversity and Conservation from Scripps Institution of Oceanography at the University of California—San Diego.

Martinelli will join the Coral Reef Conservation Program of Florida's Department of Environmental Protection. He will focus primarily on the coordination of the management response to a persistent and unprecedented coral disease outbreak on the Florida Reef Tract. He will lead development on the Coral Disease Response and Management Plan for the Florida Reef Tract in order to better prepare Florida's coral reef managers for future disease events.

Hawaii • Alessandra Shea

Born and raised in Newport Beach, California, Alessandra Shea received her B.S. in Society and Environment from University of California—Berkeley, and her M.A. in Geography from University of Hawaii—Manoa.

During the fellowship, Shea will work in the Department of Natural Resources in the Division of Aquatic Resources for the state of Hawaii. Her projects will focus on coral bleaching and fisheries management, developing curriculum for coral bleaching outreach programs through the Eyes of the Reef Network, and standard operating procedures for bleaching events in both her agency and in the Coral Bleaching Collaborative. She also will take a lead role in developing the Strategic Communication Plan and Encouraging Responsible Behavior Objective aspects of the Marine 30x30 Initiative, part of the Sustainable Hawai'i Initiative, a state-led program to effectively manage 30 percent of the state's nearshore waters by 2030.

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 and K. McCarthy (NOAA/SEFSC)
Other Collaborators: O. Rodriguez (Jamison Professional Services)

Long Term Research Objectives and Strategy to Achieve Them:
***Objectives*:** Maintenance to DRT (Data Request Tracking System) and FTM (Fisheries Trip Matching System).
***Strategy*:** DRT: Give maintenance to DRT system and do the updates requested by the users; FTM: We are constantly updating the data and running jobs to find new matching trips.

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

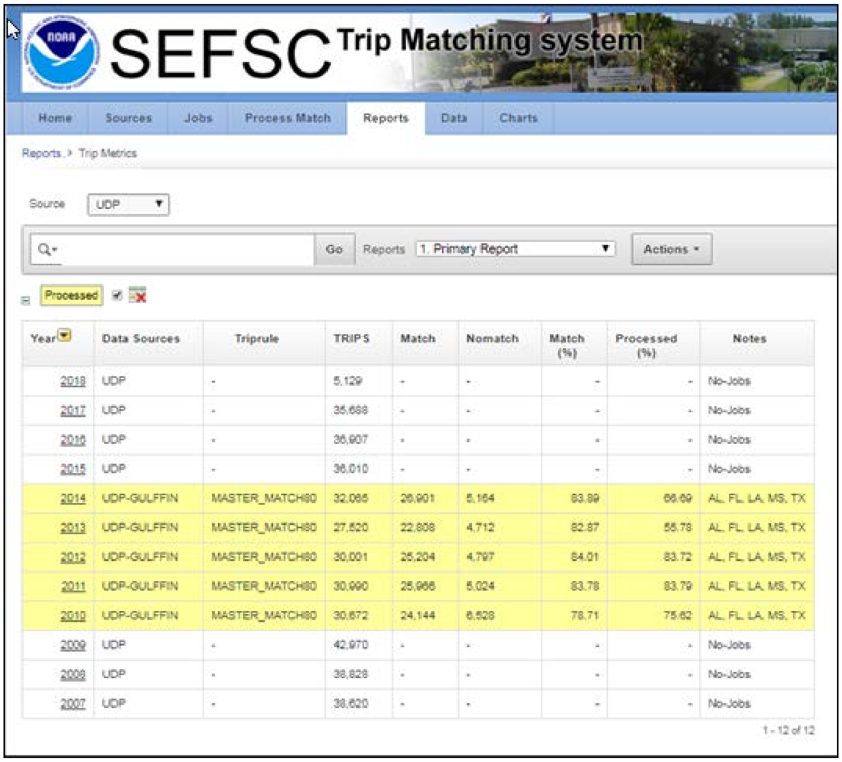
Link to NOAA Strategic Goals:
***Goal 1*:** Healthy Oceans: *Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems*

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 assign a data request and also allows to keep track of how the request is progressing.

FTM: Continuously run a new job to create new matches and keep monitoring of the data updates.

Research Performance Measure: DRT: Operational with users suggestions; FTM: Operational.



Year	Data Sources	Triprule	TRIPS	Match	Nomatch	Match (%)	Processed (%)	Notes
2018	UDP	-	5,129	-	-	-	-	No-Jobs
2017	UDP	-	35,688	-	-	-	-	No-Jobs
2016	UDP	-	36,907	-	-	-	-	No-Jobs
2015	UDP	-	36,010	-	-	-	-	No-Jobs
2014	UDP-GULFFIN	MASTER_MATCH80	32,066	26,901	5,164	83.89	66.69	AL, FL, LA, MS, TX
2013	UDP-GULFFIN	MASTER_MATCH80	27,520	22,808	4,712	82.87	55.78	AL, FL, LA, MS, TX
2012	UDP-GULFFIN	MASTER_MATCH80	30,001	25,204	4,797	84.01	83.72	AL, FL, LA, MS, TX
2011	UDP-GULFFIN	MASTER_MATCH80	30,990	25,966	5,024	83.78	83.79	AL, FL, LA, MS, TX
2010	UDP-GULFFIN	MASTER_MATCH80	30,672	24,144	6,528	78.71	75.62	AL, FL, LA, MS, TX
2009	UDP	-	42,970	-	-	-	-	No-Jobs
2008	UDP	-	38,828	-	-	-	-	No-Jobs
2007	UDP	-	38,620	-	-	-	-	No-Jobs

Figure 1: Trip Matching System

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Protected Species Research and Data Management

Project Personnel: L. Aichinger Dias (UM/CIMAS)
NOAA Collaborators: L. Garrison, J. Litz and M. Soldevilla (NOAA/SEFSC); D. Palka (NOAA/NEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives: To collect and manage data on protected species in the U.S. waters of the Atlantic Ocean and Gulf of Mexico; To support the National Oceanic and Atmospheric Administration (NOAA) and the Southeast Fisheries Science Center (SEFSC) missions in management of protected species.

Strategy: To collect broad-scale data during aerial and vessel surveys on the distribution and abundance of cetaceans and sea turtles in the U.S. waters of the Atlantic Ocean and Gulf of Mexico; To develop and implement QA/QC and data management standards for data collected during aerial and vessel surveys; To train staff on the protocols and data management standards developed; To prepare data products from the aerial and vessel surveys and distribute them to NOAA's collaborators; To explore options for the development of a comprehensive geodatabase for historical aerial and vessel survey data; To assist in writing technical reports and scientific publications; To assist the SEFSC in ad hoc research activities as needed.

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 Atlantic Marine Assessment Program for Protected Species (AMAPPS, https://www.nefsc.noaa.gov/psb/AMAPPS/) and the Gulf of Mexico Marine Assessment Program for Protected Species (GoMMAPPS, https://www.boem.gov/gommapps/) both aim to collect broad scale data on the distribution and abundance of protected species, including marine mammals and sea turtles. To achieve this goal, large vessel and aerial surveys were conducted in the offshore waters of the Atlantic Ocean and Gulf of Mexico. In 2017 and 2018, I participated in several of these surveys, acting as a marine mammal observer and as the primary data manager. Once back on land, I further managed and audited the data by implementing standardized QA/QC procedures I have developed since 2016. In addition, in the past year I have trained other staff in the data management standards developed.

I have also employed ArcGIS database systems and developed skills in R-language programming as part of the standardization of procedures for data processing and storage. I have audited historical data with the goal to develop a comprehensive geospatial database for all marine mammal data collected over the years. I also used R programing to generate data products for sharing with NOAA collaborators.

Research Performance Measure: all objectives were completed on time.

- Assisted in project planning and acted as a marine mammal observer and data manager during the summer 2017 and winter 2018 GoMMAPPS research cruises. In 2017, a total of 49 days were spent at sea, 7,302 km of trackline were surveyed and 338 marine mammal sightings were recorded. In 2018, 47 days were spent at sea, 5,830 km of trackline were surveyed and 143 sightings were recorded.
- Audited data collected during one vessel and six aerial surveys conducted between 2014 and 2017 under the AMAPPS program.
- Produced deliverables from the 2014-2017 AMAPPS data to the Northeast Fisheries Science Center (NEFSC) and OBIS-Seamap (http://seamap.env.duke.edu/).
- Assisted in field work during the fall 2017 and spring 2018 seasons of the Biscayne Bay Bottlenose dolphins (*Tursiops truncatus*) Photo-ID project.
- Wrote the summaries reports for the spring and fall 2017 AMAPPS aerial surveys.
- Trainings accomplished: 8-hour Hazardous Waste Operations and Emergency Response (HAZWOPER).
- Assisted in project planning and will act as a marine mammal observer and data manager during the Resources and Ecosystems Sustainability, Tourist Opportunities, and Revived Economies (RESTORE) Act cruise in the Gulf of Mexico, planned for June 2018.

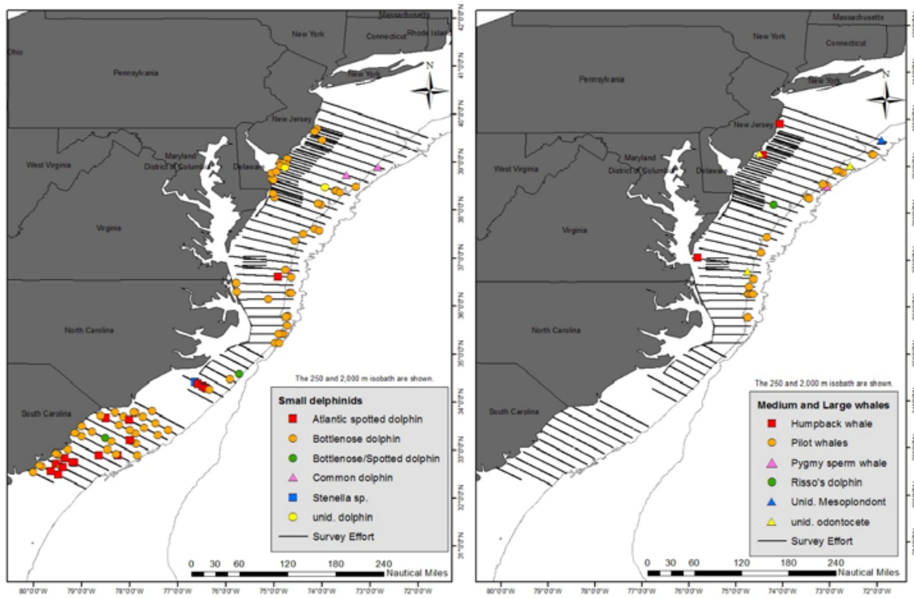

Figure 1: Cetacean sightings recorded during the AMAPPS fall 2017 aerial survey

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Marine Mammal Research

Project Personnel: A. Brossard, J. Wicker and S. Stevens (UM/CIMAS)
NOAA Collaborators: J. Litz and J. Contillo (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives: To conduct a thorough data audit of historical Biscayne Bay dolphin photo-id data, develop strategies to improve the accuracy and efficiency of cataloging future data, and assist in the collection of data to support the National Oceanic and Atmospheric Administration (NOAA) and Southeast Fisheries Science Center (SEFSC) missions in the management of marine mammals.

Strategy: Conduct an audit of the entire Biscayne Bay photo-id database by reviewing the photos and associated data of each individual. Streamline the process of photo-analysis in order to improve the efficiency and accuracy of the initial data review. Assist in writing technical reports and scientific publications. Respond to stranded marine mammals as needed and assist with the organization and documentation of incoming stranding data collected by the Southeast Region Marine Mammal Stranding Network. Participate in field activities including marine mammal research investigations conducted in Biscayne Bay, the Gulf of Mexico and the Atlantic as needed to support the missions of NOAA's SEFSC. Contribute to the development of and participate in outreach activities associated with NOAA's marine mammal research program.

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 SEFSC has been conducting bottlenose dolphin photo-identification studies in Biscayne Bay since 1990. My primary tasks include reviewing and auditing the historical photo-identification database and catalog (1990 – 2015) and establishing a data management plan for entering new data (2016 forward). During the review of the historical data, I analyzed over 80 previously unidentified marked dolphins from data collected between 2008 and 2015 and either matched them to the current catalog or added them as new animals. I have also been identifying dolphin calves within the dataset and making sure they are linked to the database entries of the mothers, resulting in over 100 different documented mom/calf pairs. These data may be used to determine birth rates, sex ratios, maternal lineages and lifespan of the Biscayne Bay (BB) dolphin population.

By utilizing photo editing software (Photoshop) to analyze scar patterns I have been able to identify over 20 previously undocumented fin changes in the BB dolphin population. This information has improved the accuracy of the sighting histories of those animals by ensuring they are still considered the same animal and not counted as a new animal following the fin change.

I have written a photo-id analysis procedure document to include the use of new software tools (Adobe Bridge and Photoshop) to more accurately identify each photographed animal and track each individual's sighting history. This new procedure will allow the team to find relevant historical photo data more efficiently for future research projects.

In addition to my photo-ID team responsibilities, I also assist NOAA's marine mammal stranding response team. In this role, I am responsible for organizing and tracking Near Real Time stranding reports, Levels A, B and C stranding data and images associated with all animal stranding events in the National Marine Fisheries Service (NMFS) Southeast Region. In 2017, I downloaded the appropriate files from the NMFS Stranding Database (over 720 files) and created a spreadsheet to document cases with missing data which was utilized as a guide by Southeast Region supervisors to follow-up with stranding partners to fill in the data gaps. Since January 2018 I have downloaded and organized stranding case files for over 400 animals. Earlier this year, I also participated in a stranding response to a large (Sei) whale in the Florida Keys.

Lastly, I participated as a marine mammal observer aboard the NOAA ship Gordon Gunter in the Gulf of Mexico for NOAA's GoMAPPS research project.

Research Performance Measure: All objectives were completed on time or are ongoing.

- Conduct bottlenose dolphin photo-id surveys in Biscayne Bay operating as the primary photographer or data recorder during each event.
- Analyze photographs collected during surveys to identify individual animals.
- Conduct a detailed audit of NOAA's photo-ID database ranging from 1990 to the present time.
- Responsible for managing documentation submitted to NOAA's National Stranding Database
- Assist in NOAA's stranding response efforts

- Participated in two legs of NOAA's GoMAPPS cruise working as a marine mammal observer aboard the Gordon Gunter in Jan/Feb 2018.
- Assist in other research efforts as needed to support the NMFS SEFSC marine mammal program

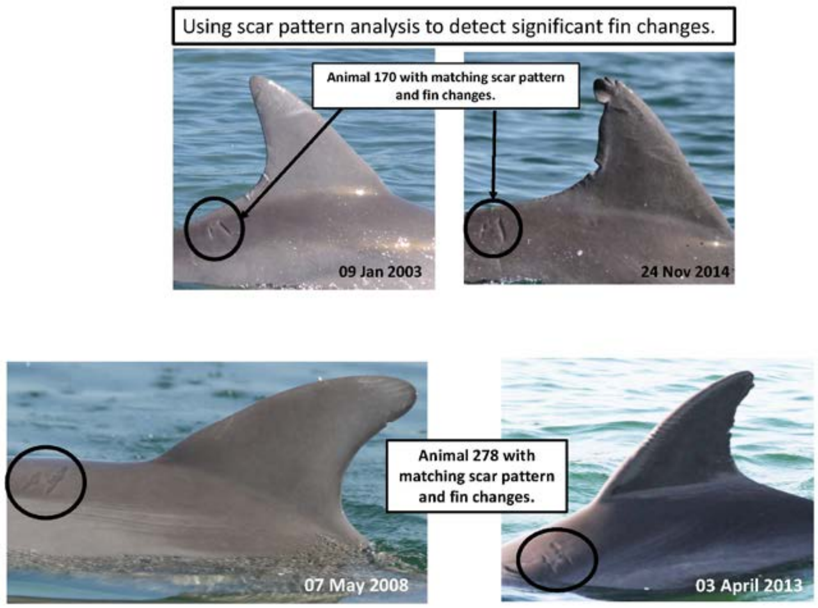

Figure 1: Using scar pattern analysis to detect significant fin changes.

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Characterizing the spatio-temporal occurrence of Gulf of Mexico Bryde's whale calls, ship, and airgun noise presence in the northern Gulf of Mexico.

Project Personnel: A. Debich (UM/CIMAS)
NOAA Collaborators: M. Soldevilla and L. Garrison (NOAA/SEFSC)
Other Collaborators: J. Hildebrand and S. Wiggins (Scripps Institute of Oceanography)

Long Term Research Objectives and Strategy to Achieve Theme:

***Objectives*:** To collect acoustic data to characterize occurrence of Gulf of Mexico Bryde's whales and describe the acoustic soundscape in which they live. To support the National Oceanic and Atmospheric Administration (NOAA) and the Southeast Fisheries Science Center (SEFSC) missions in management of protected species.

***Strategy*:** To analyze acoustic data from four Low-frequency Acoustic Recording Packages (LARPs) and document spatio-temporal occurrence of Gulf of Mexico Bryde's whale calls. To document occurrence and measure received levels of ship and airgun noise in the five LARPs.

CIMAS Research Theme:

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

Link to NOAA Strategic Goals:

Goal 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 Gulf of Mexico, home to 21 cetacean species, is highly industrialized; the levels of oil and gas exploration and commercial shipping traffic are among the highest in US waters. Noise levels in the Gulf of Mexico are also among the highest in US waters, but the contributions of these two industries to the low frequency anthropogenic soundscapes in this area is not well known. To characterize the natural and anthropogenic noise sources that contribute to the Gulf of Mexico soundscape, calibrated Low-frequency Acoustic Recording Packages (LARPs) were deployed at five sites along the northern Gulf of Mexico continental shelf break from Texas to Florida (*Figure 1*). The LARPs recorded continuously from July 2016 through May 2017 at a sampling rate of 2 kHz. Site depths ranged from 180 to 264 m. To evaluate the frequency of occurrence of anthropogenic noise sources, I manually logged ship noise presence in three frequency bands (0-400 Hz, 400-700 Hz, and >700 Hz) and airgun noise presence in three frequency bands (0-100 Hz, >100 Hz, and >200 Hz). Individual Gulf of Mexico Bryde's whale calls were logged based on call granularity and variations in call types were documented from all four LARPs.

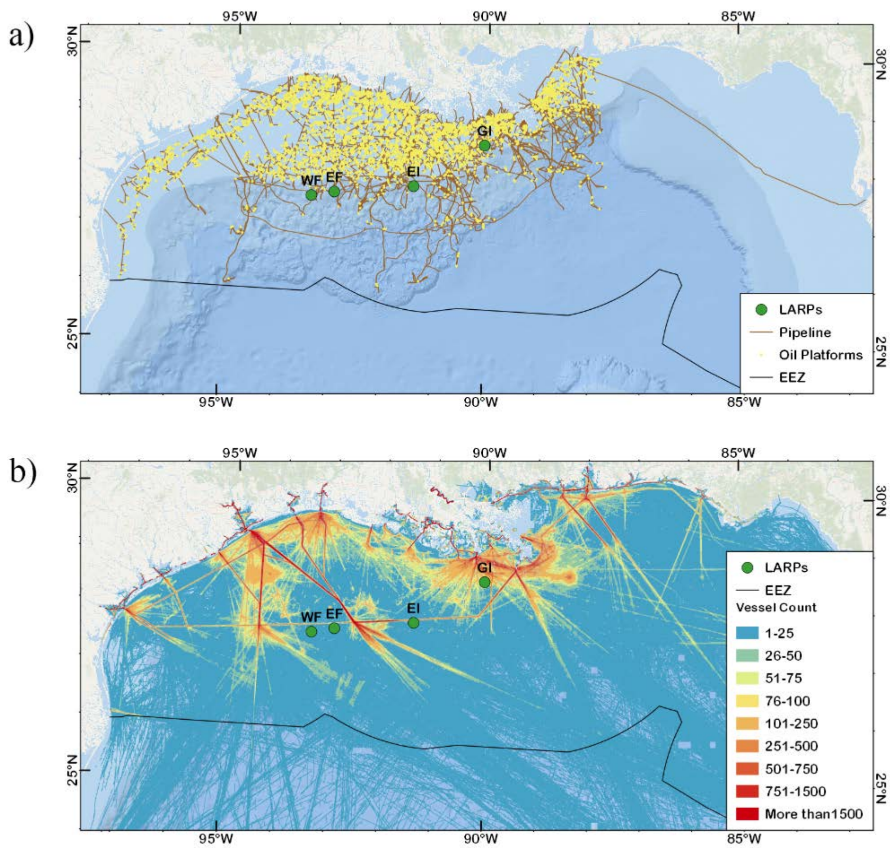


Figure 1: Low-frequency Acoustic Recording Package deployment locations (green dots) in relation to (a) gas and oil pipelines (brown lines) and platforms (yellow dots); and (b) vessel traffic with vessel count colors ranging from blue (1-25 vessels) to red (more than 1500 vessels).

Research Performance Measure: Manual analyses have been completed. Results were presented at the 8th International Workshop on *Detection*, *Classification*, *Localization*, and *Density Estimation* of Marine Mammals using Passive Acoustics.

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.

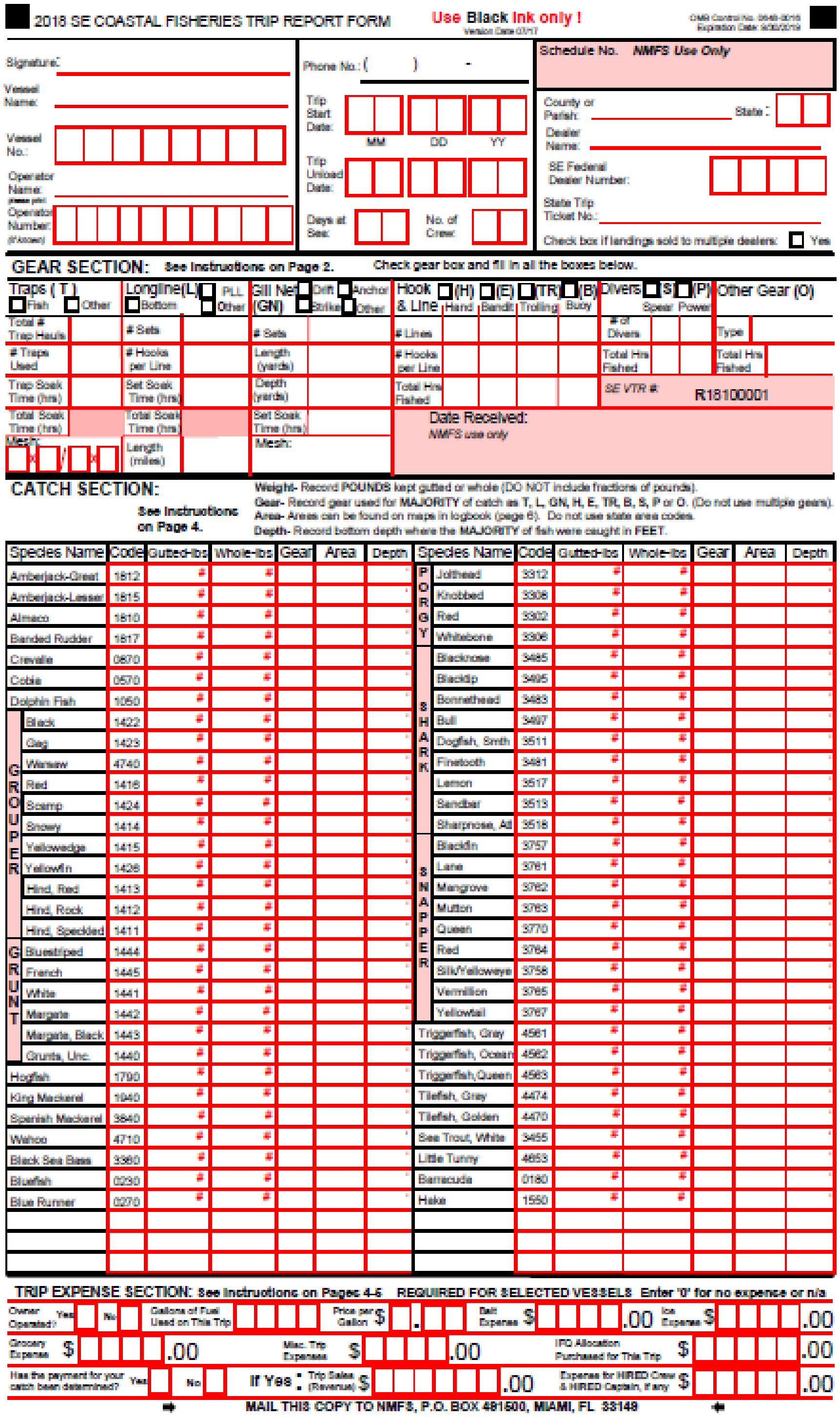
CIMAS Research Theme:
***Theme 7*:** Protection and Restoration of Resources

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 Reef fish, 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 South Atlantic vermilion snapper 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.


2018 SE COASTAL FISHERIES TRIP REPORT FORM

Use Black Ink only !

Signature: | Vessel Name: | Vessel No.: | Operator Name: | Operator Number:

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 / Anchor / Strike / Other	Hook & Line (H) Hand / (E) Bandit / (TR) Trolling / (B) Buoy	Divers (S) Spear / (P) Power	Other Gear (O)
Total # Trap Hauls	# Sets	# Sets	# Lines	# of Divers	Type
# Traps Used	# Hooks per Line	Length (yards)	# Hooks per Line	Total Hrs Fished	Total Hrs Fished
Trap Soak Time (hrs)	Set Soak Time (hrs)	Depth (yards)	Total Hrs Fished	SE VTR # R18100001	
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.

Species Name	Code	Gutted-lbs	Whole-lbs	Gear	Area	Depth	Species Name	Code	Gutted-lbs	Whole-lbs	Gear	Area	Depth
Amberjack-Great	1812						PORGY Jolthead	3312					
Amberjack-Lesser	1815						Knobbed	3308					
Almaco	1810						Red	3302					
Banded Rudder	1817						Whitebone	3306					
Crevalle	0870						SHARK Blacknose	3485					
Cobia	0570						Blacktip	3495					
Dolphin Fish	1050						Bonnethead	3483					
GROUPER Black	1422						Bull	3497					
Gag	1423						Dogfish, Smth	3511					
Warsaw	4740						Finetooth	3481					
Red	1416						Lemon	3517					
Scamp	1424						Sandbar	3513					
Snowy	1414						Sharpnose, Atl	3518					
Yellowedge	1415						SNAPPER Blackfin	3757					
Yellowfin	1426						Lane	3761					
Hind, Red	1413						Mangrove	3762					
Hind, Rock	1412						Mutton	3763					
Hind, Speckled	1411						Queen	3770					
GRUNT Bluestriped	1444						Red	3764					
French	1445						Silk/Yelloweye	3758					
White	1441						Vermillion	3765					
Margate	1442						Yellowtail	3767					
Margate, Black	1443						Triggerfish, Gray	4561					
Grunts, Unc.	1440						Triggerfish, Ocean	4562					
Hogfish	1790						Triggerfish,Queen	4563					
King Mackerel	1940						Tilefish, Grey	4474					
Spanish Mackerel	3840						Tilefish, Golden	4470					
Wahoo	4710						Sea Trout, White	3455					
Black Sea Bass	3380						Little Tunny	4653					
Bluefish	0230						Barracuda	0180					
Blue Runner	0270						Hake	1550					

TRIP EXPENSE SECTION: See Instructions on Pages 4-6 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.

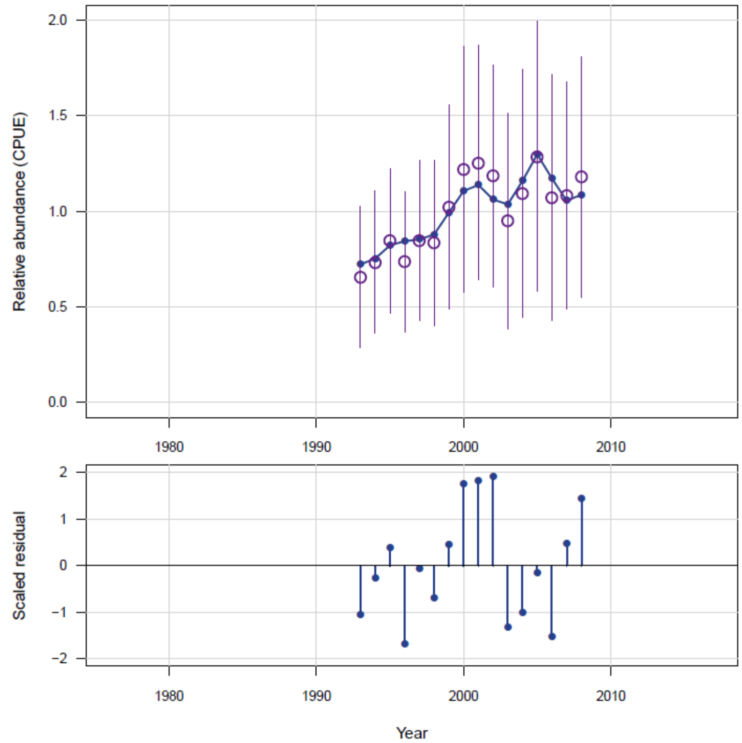


Figure 2: Plots of nominal and relative indices of abundance constructed using South Atlantic commercial coastal logbook vermilion snapper landings and effort data, as presented in the recent SEDAR 55 assessment report, are shown in Figure 2, upper plot. Index residuals are shown in the lower plot. Results of those analyses were used as model inputs for the SEDAR 55 South Atlantic vermilion snapper assessment.

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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 1, 2014. Since then, the system hosted at AOML has received and processed over **15,000** MSR reports from approximately **3,000** 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, 2017 and June 30, 2018, 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.

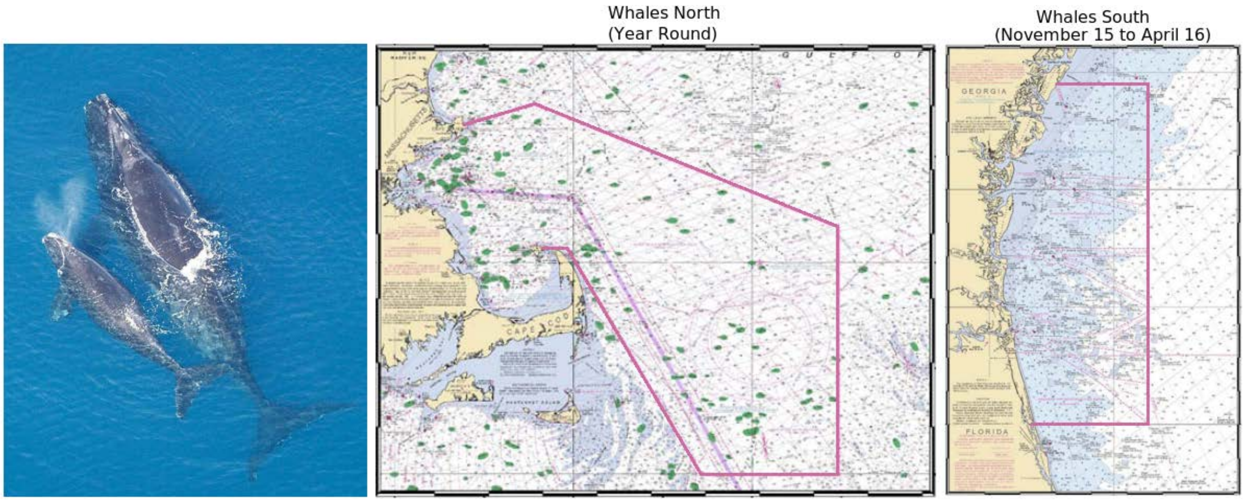

Figure 1: (left) North Atlantic right whale with calf. The (center) Whales North and (right) Whales South reporting areas along the east coast of United States within the Mandatory Ship Reporting system. The reporting requirements for each area are emphasized above the maps.

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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 standardize CPUE indices in 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 use of generalized linear models as well as spatial models for standardization purposes. 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 oceanographic data used in this project.

Research Performance Measure: The research program is on schedule.

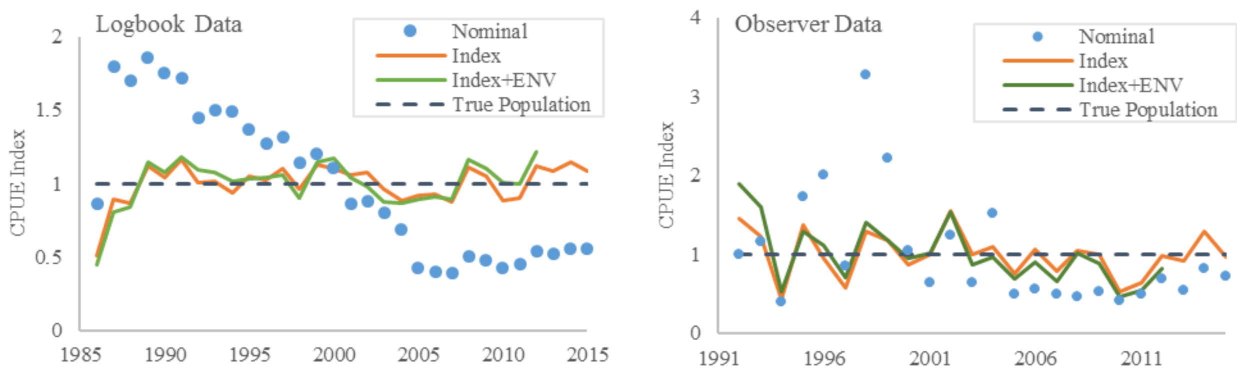

Figure 1: True population trends with standardized indices and nominal CPUE for logbook data and observer data. Grey dashed lines represent true population trend. Green and orange lines are standardized indices while blue dots are the normalized nominal CPUE.

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Impingement and Entrainment of Fish larvae and Coral Planulae

Project Personnel: A. Jugovich, K. Shulzitski, S. Privoznik and J. Mostowy (UM/CIMAS)
NOAA Collaborators: T. Gerard (NOAA/SEFSC)
Other Collaborators: S. Habtes (UVI); A. Barnes (Vitol Virgin Island Corp)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives: To determine baseline numbers of larvae which may be impinged and entrained within the turbines of the Very Large Gas Container (VLGC) ship to be operated by the Vitol Group in the US Virgin Islands.

Strategy: To complete a yearlong survey on larval fish and coral larvae using standard plankton collection gear and methodologies.

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:

A 12-month survey on larval fish and coral planula larvae was led by researchers at the University of the Virgin Islands (UVI) in order to determine baseline numbers of larvae, which may be impinged and entrained within the turbines of the Very Large Gas Container (VLGC) ship to be operated by the Vitol

Group. UVI has requested the expertise and resources of several team members of the larval fish laboratory led by Dr. Trika Gerard and Dr. John Lamkin at the NOAA Southeast Fisheries Science Center laboratory. The lab at SEFSC partners with personnel through the University of Miami Cooperative Institute for Marine and Atmospheric Studies (CIMAS). One taxonomist will travel to St. Thomas at the beginning of the project in order to provide a larval fish identification course, and participate in sample collection surveys to train local technicians to handle all sampling and collection during the next 12 months of sampling. CIMAS personnel will then identify and analyze these larvae. Sample analysis includes microscopy techniques for ichthyoplankton identification to lowest taxonomic level and length measurements. Lab procedures are based on the historical SEAMAP processing protocols, and undergo internal QA/QC to ensure accuracy.

Research Performance Measure: The project has been completed. Plankton sampling took place starting in October 2016 through June 2017. A larval fish training course was conducted in 2017 to provide hands-on training for University of Virgin Islands faculty and staff. Plankton collection results were provided in a technical report that summarized sample collection and processing. A total of 40 samples were sorted to completion, 5591 fish larvae were found in the samples, 3205 from “fine” sort aliquots and 2386 from “coarse” sort aliquots. In addition, 531 lobster larvae, 123 cephalopod paralarvae, and 2909 fish eggs were also removed. Plankton samples were significantly larger and denser than originally planned, and sorting was time consuming when compared to previous sample processing. Over 50% of larvae from “fine-sorted” aliquots were unable to be identified due to extremely small size and early development stage, or damage, and were therefore categorized as “Damaged,” “Unidentified,” or “yolk-sac larvae.” This was true of 27% of “coarse-sorted” aliquot larvae. In the “fine-sorted” aliquots, the most abundant taxa identified was Gobiidae (gobies), followed by *Sparisoma spp* (genus of parrotfish), Carangidae (jacks), and Pomacentridae (damselfishes). In “coarse-sorted” aliquots, the most abundant species identified was *Clepticus parrae* (creole wrasse), followed by the families Scaridae (parrotfish), and Gobiidae (gobies). Initial observations indicate that it is unlikely that any larvae were part of the subfamily of interest, Epinephelinae (groupers), though other larvae in the Serranidae family were identified.

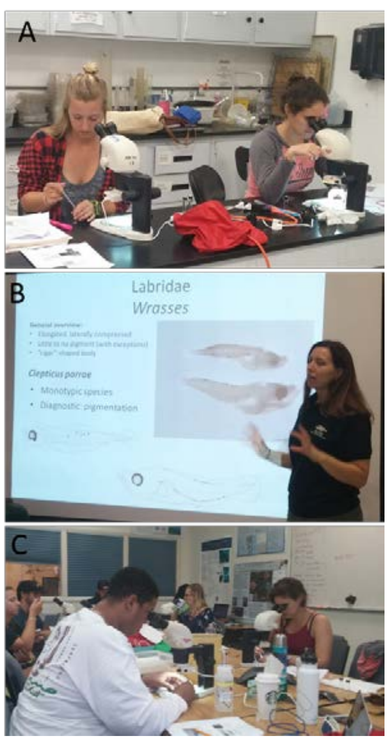

Figure 1: A) University of Virgin Islands students and staff participate in larval fish identification course in St. Thomas, USVI. B) Amelia Jugovich conducts larval fish course C) Dr. Habtes along with UVI students and staff examining larval fish under the microscope to identify species of interest.

Marine Mammal Stock Assessment Reports

Project Personnel: K. Maze-Foley (UM/CIMAS)
NOAA Collaborators: L. Garrison, K. Mullin and P. Rosel (NOAA/SEFSC); S. Horstman (NMFS/SERO); E. Josephson (NMFS/NEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

***Objectives*:** 1) To act as the lead SEFSC editor for annual U.S. Atlantic and Gulf of Mexico marine mammal stock assessments (i.e., Stock Assessment Reports - SARs). 2) To serve as a member of the NMFS Serious Injury Policy Implementation Working Group. 3) To act as administrator of the SEFSC Marine Mammal Protection Act Scientific Research Permit. 4) To serve as the SEFSC contact person for the U.S. Annual Progress Report for the International Whaling Commission (IWC). 5) To assist with the NMFS Marine Mammal Climate Vulnerability Analysis (MMCVA) for marine mammal stocks in the Western North Atlantic (WNA), Gulf of Mexico (GMx), and Caribbean Sea. 6) To perform other duties as requested, such as editing or authoring/co-authoring manuscripts or technical reports, and editing reports of field activities and data sheets for fieldwork.

***Strategy*:** 1) To work with SEFSC marine mammal program leaders to identify SARs that need updated or new SARs that need written, to update or write SARs to incorporate the latest literature and best available information, to work with SEFSC and SERO staff to maintain records of human-caused mortality and serious injury for each marine mammal stock to incorporate into the SARs, to facilitate the multi-step review process (internal, SERO, Atlantic Scientific Review Group, and public comments including those of the Marine Mammal Commission [MMC]) for the SARs and ensure SARs are revised after each step in a timely manner, and to draft formal responses to reviewer comments. 2) To review reports of injured small cetaceans from stranding data, fishery observer programs, law enforcement, and public reports to determine if animals meet the NMFS serious injury criteria, and to write an annual report summarizing serious injury determinations that gets reviewed internally, by SERO, by another NMFS science center, and by the Atlantic Scientific Review Group. 3) To assist with writing permit applications and compiling application materials, to write an annual report for all work conducted under the SEFSC permit by SEFSC and non-SEFSC co-investigators (CIs), to request modifications to the permit as needed, and to respond to questions or requests by CIs or the Permits Office. 4) To compile information on fishery bycatch, strandings, and sytematic surveys and submit annually to the IWC. 5) As part of the MMCVA, to evaluate, for 10 marine mammal stocks, the potential exposure level of predicted environmental changes (e.g., sea level rise, SST) due to climate change and the sensitivity of the stock to these changes based on its ecology (e.g., home range, habitat specificity).

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 (Primary)*

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

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

Research Summary:

During the fall of 2017, I led SEFSC efforts to revise and write draft 2018 SARs. I updated three existing SARs (WNA short-finned pilot whale, WNA rough-toothed dolphin, and GMx bottlenose dolphin bay, sound and estuary stocks [covering 25 individual stocks]) and wrote two new SARs for the GMx bottlenose dolphin stocks in Terrebonne-Timbalier Bay, Louisiana, and West Bay, Texas. These SARs were reviewed internally, by SERO, and by the Atlantic Scientific Group, and I revised each SAR after each step in the review process. These SARs will be sent to NMFS HQ next for further review prior to being posted for a 90-day public comment period. The 2017 SARs (10 stocks) were reviewed by the public and we received those comments in late March of 2018. I helped draft responses to public comments and held conference calls to discuss what revisions we wanted to make based on the public comments, including comments from the MMC. I also worked with the NEFSC SAR editor to edit tables and appendices to accompany the annual SARs and to edit the annual SAR combined document.

Year-round I work with SEFSC and SERO staff to maintain records of human-caused mortality and serious injury for each bottlenose dolphin stock. I also work with SERO to review cases involving dead, stranded bottlenose dolphins that have ingested or were entangled in hook and line fishing gear to assess whether evidence suggested the gear contributed to the stranding/death. Annually, I review all cases of injured small cetaceans, primarily bottlenose dolphins, from various sources such as the stranding database, fishery observer programs, law enforcement, and public reports, to determine if animals meet the NMFS serious injury criteria, and prepare an annual report documenting all the cases and serious injury determinations. The reports are grouped by 5-year blocks to coincide with the years covered by the SARs. The serious injury report covering cetaceans during 2011–2015 completed the NMFS RPTS review process and was finalized, and the next report covering 2012–2016 was drafted and is awaiting further review. All of this information re. human-caused mortality and serious injury is incorporated into the SARs. In order to better document our processes, I have written a first draft of a report entitled "Analysis of Stranding Data to Support Estimates of Human-Caused Mortality and Serious Injury in Common Bottlenose Dolphin (*Tursiops truncatus*) Stock Assessments for the Atlantic Ocean and Gulf of Mexico." This will be a joint report with another NMFS co-author and two SERO co-authors. We will continue to revise and work on this report during 2018.

During early 2018, I compiled information and wrote an annual report for all work conducted under the SEFSC permit by ~35 SEFSC and non-SEFSC CIs. I assisted the permit PI in writing an application for our next 5-year permit covering work from 2019 to 2024. We submitted the application in early March 2018, approximately one year prior to the expiration of our current research permit. We are currently working on revisions to this application based on comments from the NMFS Permits and Conservation Division office. Throughout the year I responded to requests to add or remove CIs as needed or to authorize special work, such as a filming crew to accompany researchers.

Other smaller projects from the past year include working as a co-author on a paper that has been accepted on cookie cutter shark bite wounds on cetaceans of the Gulf of Mexico, compiling an annual report for the IWC, and working as part of a large team on NMFS Marine Mammal Climate Vulnerability Analysis.

Research Performance Measure: all objectives were completed on time.

- Completed 2017 SARs revisions following public comments; these SARs will be published in June 2018.
- Drafted 2018 SARs and revised each following several phases of the review process.
- Wrote a first draft of a report entitled "Analysis of Stranding Data to Support Estimates of Human-Caused Mortality and Serious Injury in Common Bottlenose Dolphin (*Tursiops truncatus*) Stock Assessments for the Atlantic Ocean and Gulf of Mexico."

- Drafted a report "Serious Injury Determinations for Small Cetaceans off the Southeast U.S. Coast, 2012–2016."
- Wrote an annual report summarizing all worked conducted under the SEFSC MMPA Scientific Research Permit.
- Co-authored an application for the SEFSC MMPA scientific research permit to cover research conducted during 2019–2024.
- Compiled and submitted information on behalf of the SEFSC for the U.S. Annual Progress Report for the IWC.
- Completed a Marine Mammal Climate Vulnerability Analysis for 10 marine mammal stocks.
- Co-authored a paper, "Cookiecutter Shark Bite Wounds on Cetaceans of the Gulf of Mexico."
- Presented a poster (senior author) at the 22nd Biennial Conference on the Biology of Marine Mammals, "Interactions Between Common Bottlenose Dolphins (*Tursiops truncatus*) and Hook and Line Gear in U.S. Gulf of Mexico Waters."

Figure 1: An example interaction between a common bottlenose dolphin and hook and line fishing gear in the U.S. Gulf of Mexico. Gear was ingested internally as well as hooked externally. The evidence suggested the gear contributed to the stranding/mortality for this case.

Gulf of Mexico Marine Mammal Stranding Database "GulfMAP" – data diplomat position

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; Louisiana, Mississippi, Alabama and Florida Gulf Coast Marine Mammal Stranding Network; 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.

***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 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 (GoM) were impacted by the Deepwater Horizon (DWH) spill. Pooling the stranding data results from the northern GoM was critical in assessing the injury to marine mammals. Typically, following a stranding event, only the basic stranding data (Level A) are 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 GoM; 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. Last year the first module (Basic animal data) was released. This year that module was updated and the second module of GulfMAP (sample collection and sample tracking) has been released. Plans to continue expanding the database have been drafted. Future modules will include results from necropsies and tissue analyses. 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.

The database manual was created to instruct users on how to use the database, this past year that manual was updated to reflect the changes and edits to GulfMAP. Stevens has also been working with a development team to standardize definitions and results parameters for future modules of the database. Stevens documented and assisted with troubleshooting database issues as well. Last year, protocols to standardize necropsy data and samples collected and analyzed were provided to network agencies, this year Stevens updated these protocols and began to collecting and filling data collected from these protocols.

Between July 2017 and April 2017, 160 cetacean strandings were entered and audited in GulfMAP. Bottlenose dolphins were the most common species that stranded representing 70% of all strandings. Three mass stranding events of offshore species occurred, ten pilot whales stranded between June 29 to July 2, 2017, seven Fraser's dolphins on July 29, 2017, and 13 Clymene dolphins between October 7, 2017 and October 8, 2017. A small mass stranding of three bottlenose dolphins also occurred shortly after landfall of hurricane Irma. Nineteen strandings had signs of human interaction. Necropsies were completed on 96 strandings, 42 were complete necropsies and 54 were limited necropsies.

Research Performance Measure:

Objectives were met. 1) Three additional stranding network agencies in Louisiana and Mississippi were trained on GulfMAP. 2) The GulfMAP manual was 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 for future GulfMAP modules.

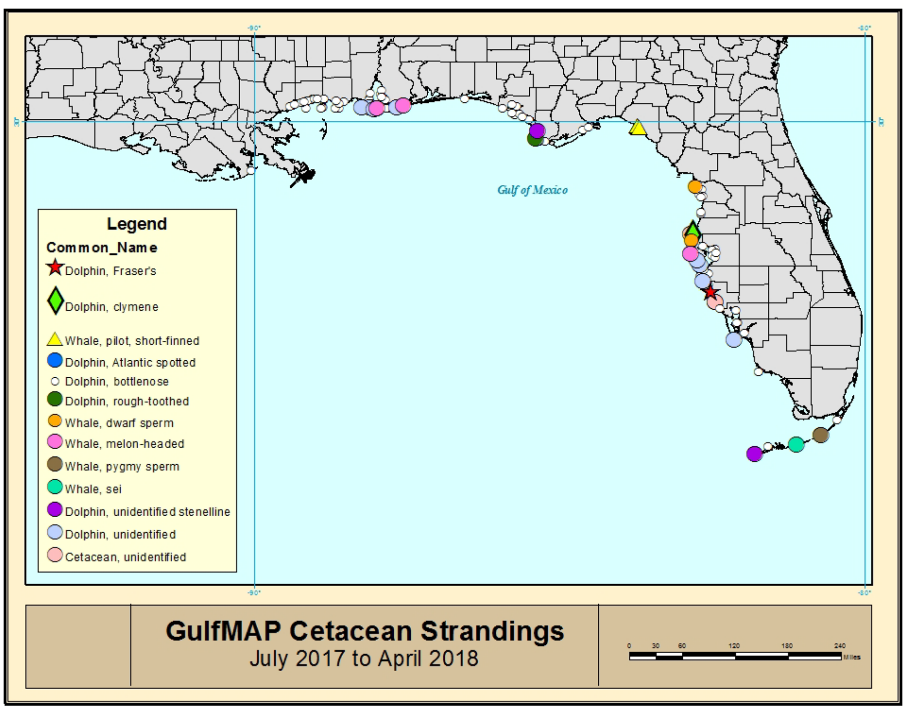

Figure 1: Location of cetacean strandings entered into GulfMAP from July 2017 to April 2017. Common name of cetaceans are represented by different colors. The red star, green diamond, and yellow triangle represent the three mass stranding events.

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 empower NOAA regional offices and fishery management council members to investigate the impact of alternative management strategies in maximizing sustainable ACL's. This will provide regional offices with dynamic real-time feedback during the management planning stage and eliminate the bottleneck of requesting assessment updates from SEFSC scientists.

***Strategy*:** To achieve this goal a graphical tool has been developed in R shiny to automatically edit stock synthesis assessment files and recalculate catch projection results. This will allow users to dynamically investigate the impacts of management action on forecast allocation quotas using simple graphical interfaces such as slider bars and text input boxes.

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 A decision-support tool (DST) development project was proposed and supervised by NOAA personnel over the last year. The objective of this project has been to design and build a DST product that represents a dynamic link between the stock assessment models of the Southeast Fisheries Science Center (SEFSC) and the management decision needs of the Southeast Regional Office (SERO). A user-friendly software interface for the DST has been developed to translate simple user inputs such as slider bars and catch input boxes into automated editing of stock assessment files and model projection of new catch forecasts. The DST was recently applied to answer a Gulf of Mexico Fishery Management Council (GMFMC) inquiry. The GMFMC requested the SEFSC to assess the impact of a future reduction in discard mortality rates, due to recreational use of descender devices, on projected catch allocations in the red snapper fishery. The presentation of these results at the upcoming GMFMC Scientific Steering Committee (SSC) meeting will provide an opportunity for feedback on the currently available capabilities of the DST and further SSC desired capabilities. In addition to the question of changing discard mortality rates the DST is currently capable of adjusting recent catch history, allocation fraction between fleets, minimum retention size, and maximum retention rate. All of these changes as well as projections of those impacts can be made in real-time without requiring any interaction with the underlying stock assessment files. The intended future use of the DST is to provide managers a means to obtain dynamic stock assessment projections which reflect their proposed management decisions throughout the decision-making process, allowing for both maximized yields and mitigated risk of overfishing.

Research Performance Measure: The project is currently on track with the decision support tool being recently applied to its first stock assessment to forecast red snapper catch rates under scenarios of reduced discard mortality. The current working version of the decision support software will be presented to NOAA Southeast Regional Office and Gulf of Mexico Fishery Management Council personnel at an introductory workshop on May 30th 2018. Ongoing activities include continued incorporation of additional functionality as identified as desirable by users and potential upgrading to function with assessments performed in Stock Synthesis v3.30.

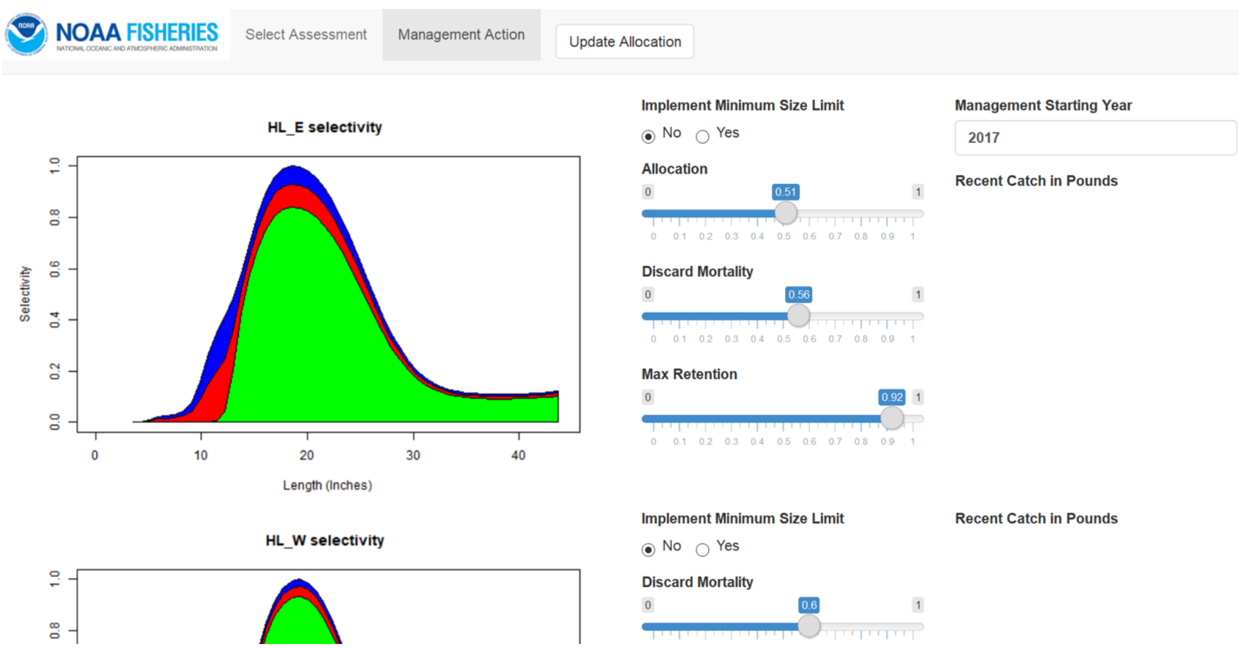

Figure 1: Graphic of the management action pane in the decision support tool. The contents of this panel is developed dynamically depending on the structure of the specific assessment chosen. Here you see the selectivity, retention, and discard curves for the red snapper eastern hand line commercial fleet. Slider bars are available to adjust future allocation, discard mortality rate, and retention rate. If implement minimum size was checked to yes another slider would also be available. If management starting year is increased beyond 2017 input boxes will also become available to input past catch.

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 and the Marine Mammal Program by supporting field projects and data management.

Strategy**:** To perform field work and data management during marine mammal field studies in the Gulf of Mexico and Atlantic Ocean. To lead field and collect data on the abundance, habitat, and spatial distribution of cetaceans within U.S. waters. To support the Atlantic Marine Assessment Program for Protected Species (AMAPPS) & Gulf of Mexico Marine Assessment Program for Protected Species (GOMMAPPS) by collecting biopsy samples, photographic data, acoustic data and visual data. To assist on the Biscayne Bay's bottlenose dolphin population long term photo-identification study.

CIMAS Research Theme:

Theme 7**:** Protection and Restoration of Resources (*Primary*)
Theme 3**:** Regional Coastal Ecosystem Processes (*Secondary*)

Link to NOAA Strategic Goals:

Goal 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 814 marine mammal sightings, and over 28,000 (km) of visual survey effort.

During summer 2017 and winter 2018, I participated in large vessel surveys as part of the Gulf of Mexico Marine Assessment Program for Protected Species (GOMMAPPS) which assessed the abundance, habitat and spatial distribution of marine mammals through visual and passive acoustic monitoring.

In the Fall of 2017, I participated in the Atlantic Marine Assessment Program for Protected Species (AMAPPS) aerial survey of continental shelf and slope waters along the US east coast from New Jersey to South Carolina. This survey was conducted aboard a NOAA Twin Otter aircraft.

In January 2018, I participated as an observer in the GOMMAPPS aerial survey, which main goal was to collect data on the distribution and abundance of cetaceans and sea turtles in the US Gulf Mexico waters. This survey was flown between Texas and Florida aboard a NOAA Twin Otter aircraft.

The long-term monitoring of Biscayne Bay bottlenose dolphins (*Tursiops truncatus*) continued during 2017-2018 season. I participated in project planning and leading the field work, which included to 15 field days and 40 sightings for that time period.

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 marine mammal observer/small boat coxswain onboard NOAA ship Gordon Gunter GOMMAPPS Summer 2017 and Winter 2018 surveys.
- 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 & GOMMAPPS onboard a NOAA Twin Otter plane during 2017-2018.

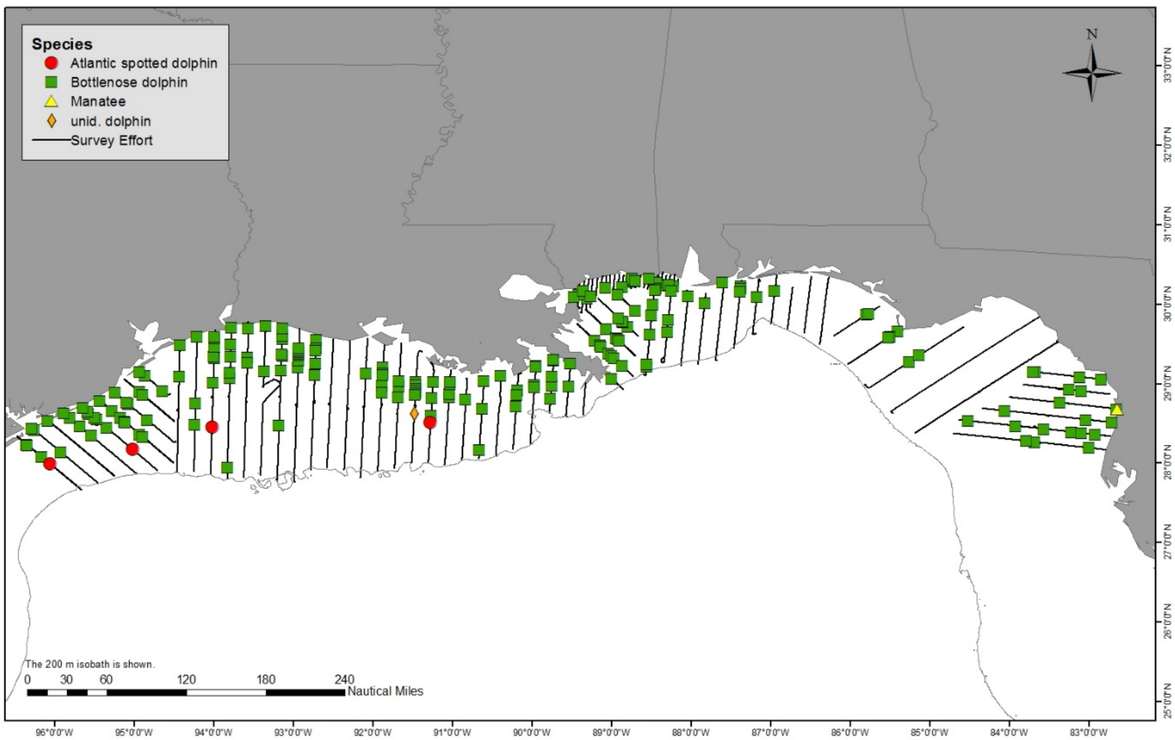

Figure 1: GOMMAPPS – Aerial

Coral Restoration and Recovery

Project Personnel: D. Williams, A. Bright and A. Peterson (UM/CIMAS)
NOAA Collaborators: L. Grove (NOAA/SEFSC)
Other Collaborators: FKNMS, FIU, FWC, 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 listed under the U.S. Endangered Species Act protection as threatened species. The first component involves studies related to spawning, larval and post-settlement ecology of broadcast-spawning coral species *Acropora palmata* (elkhorn coral) and *Orbicella faveolata* (mountainous star coral). Both species spawned well in 2017 allowing sufficient collection of gametes for fertilization experiments and larval production. Fertilization rates were high for *O. faveolata* while rates were low for *A. palmata.* Low fertilization rates coupled with the implementation of new, novel culture chambers (methods developed by CARMABI) resulted in challenges during the larval culture stages. However, sufficient numbers of larvae were produced to execute the final replication of planned experiments: 1) characterize larval longevity and settlement competence and 2) in collaboration with FIU, examine settlement preference on different degrees of algal turf and sediment-laden habitat types. At the beginning of September 2017, Hurricane Irma caused a mandatory evacuation of the Florida Keys resulting in premature termination of the larval longevity and settlement competence assays.

A second component evaluated performance of nursery-cultured elkhorn coral (*Acropora palmata*) outplanted to natural reef habitat beginning in 2014. Experiments examining the effects of fragment size, genotype, and habitat on restored coral success (survivorship, growth, and bleaching) have been completed and results were accepted for publication (Pausch et al. 2018).

A third component of this project, initiated in the summer of 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, yet one published research study found that ~ 6% of genotypes of *A. cervicornis* (staghorn coral) showed innate disease resistance. Following a developed protocol (Miller and Williams 2016), we continued screening stocks of *A. cervicornis* (14 genotypes) and *A. palmata* (6 genotypes) resulting in the identification of three additional disease resistant genotypes (nursery fragments acquired from UM, FWC and CRF) (Fig. 1-2). Furthermore, samples were collected from each fragment to determine gene expression patterns between resistant and susceptible genotypes (Serrano CIMAS, and Traylor-Knowles, MBE). The data gathered from the 2016 and 2017 trials is the first step in understanding how resistance to disease is accomplished, and can be applied in the design of coral restoration techniques promoting more resilient restocked coral populations.

Research Performance Measure: Intensive field work is involved with each project component. We were successful in implementing the genotypic disease resistance experiment (July-August 2017) and the larval experiments (August 2017) as planned. However, Hurricane Irma forced us to end the larval longevity and settlement competency assays early.

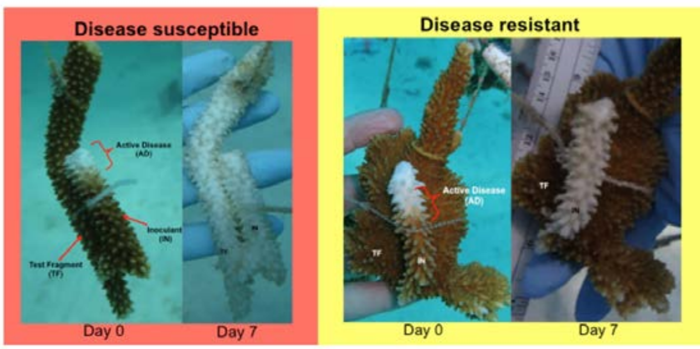

Figure 1: Illustration of outcomes for the standardized, 7-day field disease resistance assay. A diseased inoculant fragment is attached to the healthy fragment to be screened. The assays are monitored every other day to document the initiation of transmission (tissue loss) and the rate of tissue loss (disease severity) in transmitted fragments. Replicate fragments of each genotype were assayed so genotypes can be ranked according to their relative resistance (% of replicates in which transmission was observed).

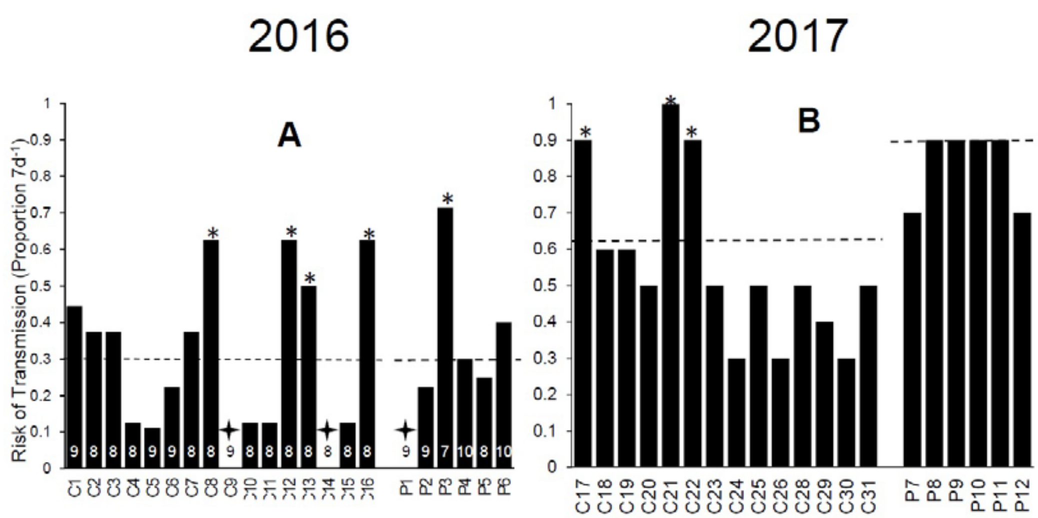

Figure 2: Graphic representation of the risk of disease transmission for each coral genotype during assays conducted in (A) 2016 and (B) 2017. One of six A. palmata genotypes (represented by the letter P) and two of 16 A. cervicornis genotypes (represented by the letter C) screened in summer 2016 were resistant (C9, C14, P1), showing no transmission in n=7-10 replicates. In 2017, three of the 14 tested A. cervicornis genotypes had a significant higher risk of transmission than the tested population (C17, C21, C22), while an additional three had a low transmission rate of 30% of replicates (C24, C26, C30).

Nearshore salinity and juvenile pink shrimp (Farfantepenaeus duorarum): Integrating field observations, laboratory trials, and habitat suitability simulations

Project Personnel: I. Zink (UM/CIMAS); D. Die (UM/RSMAS)
NOAA Collaborators: J. Browder (NOAA/SEFSC)

Long Term Research Objectives and Strategy to Achieve Them:

Objectives: To investigate salinity influences on juvenile pink shrimp in central and southern Biscayne Bay shallow, nearshore areas. To develop a model of juvenile pink shrimp habitat suitability and use it to predict potential impacts of Biscayne Bay Coastal Wetlands project implementation on Biscayne Bay nearshore pink shrimp habitat suitability.

***Strategy*:** To achieve these objectives, 10 years of pink shrimp abundance data was extracted from an epifaunal community monitoring program dataset. The pink shrimp abundance data were analyzed with respect to habitat predictors using quantile regression and multivariate techniques. These analyses were then used in conjunction with modeled salinity predictions under two alternative canal discharge scenarios (base-case and high-flow) to predict potential changes in pink shrimp habitat suitability under the high-flow scenario, which would be expected to reduce salinities broadly across the nearshore area, possibly approximating desired mesohaline conditions.

CIMAS Research Theme:

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

Link to NOAA Strategic Goals:

***Goal 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 impact (Secondary)*

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

Research Summary:

The Comprehensive Everglades Restoration Plan (CERP) intends to restore the quality, quantity, timing, and distribution of freshwater through terrestrial ecosystems to coastal ecosystems. One CERP project, the Biscayne Bay Coastal Wetlands (BBCW) project, is intended to alter the delivery of freshwater to specific nearshore areas of central and southern Biscayne Bay's mainland shoreline. Freshwater will be diverted away from point-source canal discharges for the re-hydration of coastal wetlands via a series of newly constructed culverts and spreader canals. These constructed element and operational changes in freshwater delivery are intended to distribute freshwater discharges over greater spatial and temporal extents while reducing nearshore salinities to reflect pre-alteration oligohaline and mesohaline salinity regimes.

Pink shrimp was previously identified as an ecological indicator for assessment of Comprehensive Everglades Restoration Plan (CERP) implementation. Changes in salinity regime along central and southern Biscayne Bay mainland shoreline were anticipated to benefit wet season pink shrimp populations utilizing those areas. These benefits were to manifest via increases in pink shrimp abundance. To test this hypothesis, 10-yr (2007-2016) of a long-term epifaunal monitoring dataset (Figure 1) was analyzed to investigate pink shrimp spatiotemporal patterns and density limitations with respect to salinity and other environmental conditions.

Salinity conditions at the time of sampling were found to limit pink shrimp densities; a log-linear 90th quantile regression response was observed and salinities <8 ppt resulted in reduced maximal-density observations. Pink shrimp densities were also limited by temperatures below 19 °C and above 33°C, water depths <0.3 m and >1.1 m, and submerged aquatic vegetation cover (SAV) <25%. Spatiotemporal hierarchical clustering of pink shrimp density observations revealed low temporal resolution. While most year-seasons grouped together within one large-membership cluster, one particularly low-density year-season (2013 wet season) with a microalgal bloom event formed a singleton group. More generally, wet season exhibited lower density than was observed during dry season sampling events. Spatially, higher densities of pink shrimp were observed further from canal discharge areas (Figure 1).

Building upon these results, habitat suitability modeling of predicted salinity limitations on pink shrimp density was conducted. This relationship was defined by the quantile regression relationship between pink shrimp density and 35 d antecedent mean salinity, which was used as a more integrative proxy of salinity conditions experienced by shrimps residing in a particular area. Using hind-cast 35 d antecedent mean salinity conditions modeled under base-flow and high-flow (i.e., a doubling of canal discharges) scenarios, changes in pink shrimp habitat suitability were predicted to quantify potential CERP impacts on nearshore Biscayne Bay pink shrimp densities (Figure 2). High-flow scenarios resulted in reductions of pink shrimp habitat suitability along a stretch of coastline impacted by canal discharges (Figure 3). These impacts were exacerbated during the wet season and during years marked by high rainfall, such as water-year 2004 (Figure 2). On average, wet season 'optimal' and 'good' habitat suitability was reduced from 91.8% of the prediction domain to 74.3% of the domain (Figure 3).

The past year's work culminated with the successful defense of Ian Zink's doctoral dissertation; he completed the dissertation in December of 2017. His research focused on assessing pink shrimp abundance in nearshore areas of Biscayne Bay likely to be impacted by BBCW implementation. These results indicated that restoration of low-mesohaline and oligohaline nearshore conditions along southwestern Biscayne Bay shorelines would likely negatively impact pink shrimp densities. Focusing on early wet season salinity conditions for pink shrimp may result in a mismatch in habitat optimization because pink shrimp densities tended to be higher during dry season sampling events. These findings are important with respect to adaptive management, a guiding principal of CERP. These studies offer insight on potential impacts of altered salinity regimes stemming from BBCW and CERP implementation.

Research Performance Measure:

All objectives of this proposal were met or are in progress:

(1) Ian Zink successfully defended and completed his doctoral dissertation.
(2) Spatiotemporal trends in juvenile pink shrimp abundance were identified and related to habitat predictors including temperature, salinity, and total submerged aquatic vegetation cover. This work has been submitted to a respected, peer-reviewed journal for publication and has already been presented to colleagues at scientific conferences.
(3) Pink shrimp-habitat relationships were used to model habitat suitability with respect to modeled salinity predictions under two different freshwater discharge scenarios. This work has already been presented to colleagues at scientific conferences and a draft manuscript is in preparation and will be submitted to a respected, peer-reviewed journal for publication.

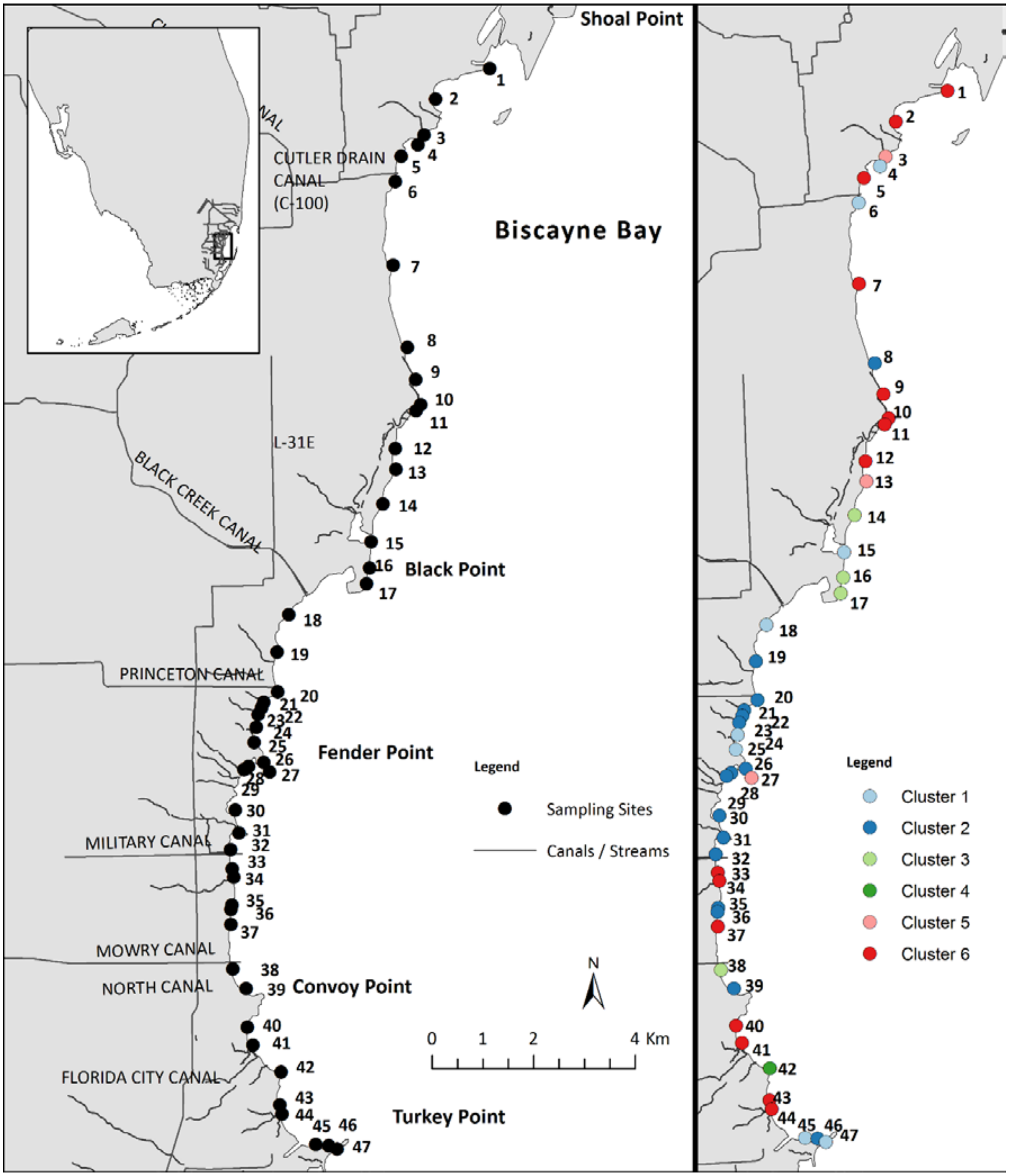

Figure 1: Maps depicting the location of the study site on the southwest coast of Florida (upper left inset), locations of 47 fixed epifuanal monitoring sites located along the mainland shoreline of central and southern Biscayne Bay (left panel) and the grouping of sampling sites based on hierarchical clustering of pink shrimp density observations (right panel). Most higher-density (red) sampling sites were located further from canal mouths and in areas that exhibited higher and less variable salinity regimes.

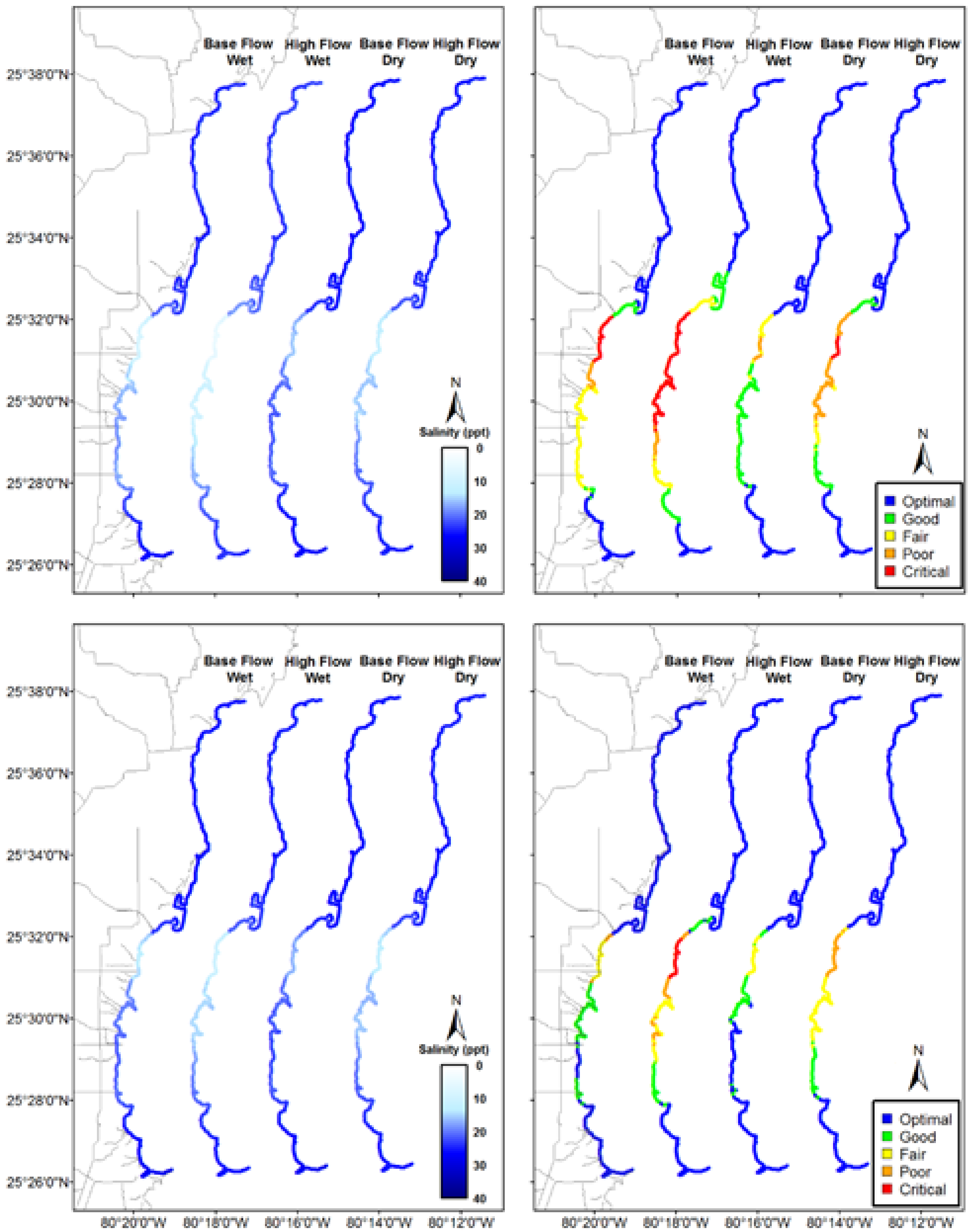

Figure 2: Maps depicting water-year (WYR) 2004 simulated salinities and habitat suitability index levels along the southwestern Biscayne Bay shoreline for each season and freshwater flow model scenario at the 635 interpolated points for WYR 2004 (upper two panels) and Average WYR (lower two panels). Colors in the right two panels represent five habitat suitability levels: optimal (1.0-0.8), good (0.8-0.6), fair (0.6-0.4), poor (0.4-0.2), and critical (0.2-0.0). Canals and creeks are represented by grey lines interior of the shoreline.

VII. EDUCATION AND OUTREACH

CIMAS aims to integrating its core science activities with the educational enterprise of its academic partners' graduate academic programs. Additionally CIMAS encourage all research projects to engage in outreach activities. Such project based activities are reported in the last part of this section.

Education Activities

CIMAS, has strongly invested in being part of the training pipeline for NOAA jobs. CIMAS funds have been a large part of this investment through 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; 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 scientific meetings, such as those associated with the US fishery council process and Regional Fishery Management Organizations (RFMOs) such as ICCAT.

There is CIMAS graduate student fellowship which fully funds a graduate student. This year the student has been Olivia Williamson from RSMAS who studies coral reefs.

Graduate Education

The Rosenstiel School of Marine and Atmospheric Science offers graduate instruction leading to the Doctor of Philosophy (Ph.D.), Master of Science (MS) and Master of Professional Science (MPS) degrees. Degrees are aligned with the five departments of the school: Atmospheric Sciences, Marine Biology and Ecology, Marine Ecosystems and Society, Marine Geosciences, and Ocean Sciences. In addition there is an interdisciplinary, cross-departmental program Meteorology and Physical Oceanography. During the course of 2017-2018 there were close to 200 students enrolled in the RSMAS PhD and MSc programs, 80% of whom are in the Ph.D. programs. About 150 students are registered in the RSMAS MPS program. Many RSMAS graduate students, especially in the PhD and MSc programs, are partially funded through CIMAS research projects and a few receive partial academic fellowships. Students funded through CIMAS research projects are 60% supported by CIMAS and 40% by the UM.

CIMAS also funds and coordinates specialized training activities of interest to NOAA and CIMAS scientists and UM students. National or international experts are invited to cover a methodological topic of special relevance to NOAA science or CIMAS hosts a workshop related to NOAA's research. In October 30th-November 3rd, 2017 CIMAS hosted, a workshop[1] on Recruitment: theory, estimation, and application in fishery stock assessment models Methodology. This workshop was part of the series organized by the Center for the Advancement of Population

[1] Sharma, R. , Porch C., Babcock, E., Maunder M., and Punt A. (editors) 2018. CAPAM Workshop report Recruitment: theory, estimation, and application in fishery stock assessment models. Miami, Fl, October 30th-November 3rd, 2017. http://www.capamresearch.org/sites/default/files/CAPAM_Workshop_Series_Report_3.pdf

Assessment (CAPAM). In June 2018 CIMAS hosted the ICCAT stock assessment of Atlantic blue marlin[2]. In addition to a number of National and International scientists, both of these meetings were attended by selected RSMAS graduate students as well as scientists from NOAA and UM. A few RSMAS students and post-docs funded through CIMAS attended selected ICCAT working group meetings at the ICCAT HQ in Madrid. These experiences provide young 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 or state agencies related to NOAA science[3]. Many such graduates have joined the NOAA AOML, SEFSC laboratories or are at NOAA headquarters. Examples of RSMAS graduates that in 2017 joined other laboratories are Dr. Michelle Sculley who joined JIMAR in Hawaii, and Dr. Dominique Lazarre who joined the Florida Fish and Wildlife Research Institute.

Undergraduate Education

The Rosenstiel School now offers six different undergraduate degree majors:[4] a dual major, BSc in Marine Science and BSc single majors in Meteorology, Marine Biology and Ecology, Oceanography, Geological Sciences and a BA in Marine Affairs. These programs provide enhanced opportunities for undergraduate research associated with upper level courses. 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.

Contributions to local High Schools

RSMAS faculty, graduate students, including CIMAS-linked personnel participates in education-related activities at local high school by delivering lectures and hosting students for internships and teachers for professional experiences.

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 is part of the Living Marine Resources Cooperative Science Center (LMRCSC) and the CIMAS Associate Director, Dr. David Die serves as UM representative in the LMRCSC science committee. That allow coordination between CIMAS and LMRCSC activities that share the same 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,

[2]Anonymous 2018. Report of the 2018 ICCAT blue marlin stock assessment meeting (Miami, United States, 18-22 June 2018). https://www.iccat.int/Documents/Meetings/Docs/2018/REPORTS/2018_BUM_SA_ENG.pdf

[3] Note that only those joining the NOAA associated workforce that are CIMAS employees (as scientists or post-docs) appear in our annual report.
[4] https://www.undergraduate.rsmas.miami.edu/academics/majors/index.html

(3) conduct research on quantitative Fisheries Science, Fisheries socio-economics, Fisheries Habitat and Aquaculture.

Enhancing the education of CIMAS employees

UM CIMAS employees working at the adjacent NOAA laboratories are eligible for tuition remission. Many have obtained MPS and MSc. degrees during their employment period. In all these cases, their internship experience or thesis research overlaps and complements their primary CIMAS duties.

The USF Marine Assessment Graduate Program

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.

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 that have been 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[5] 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)

[5] Course was taught prior to present award as part of the MRA program.

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

This course was taught for the fourth time during Fall 2017 by Chris Stallings and Ernst Peebles of USF-CMS (16 students - 0% agency)

USF students: Alyssa Andres, Jeremy Browning, Makenzie Burrows, Meaghan Faletti**, Greta Helmueller, Jonathan Peake

USFSP students: Anne Burth, Austin Cavanaugh, Sean Hogan, Lindsey Knowlton, Cynthia Lupton, John Moorman, Daniel Morrow, Kelly O'Neil, Ashlee Steinberg, Ian Williams

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, Meagan 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 Ainsworth of USF-CMS (8 students, including 3 agency employees – 38% agency).

USF students: Elizabeth Simpson**, Brianna Michaud, Kaitlyn Colna, Kelly Vasbinder, Melissa Rohal
Florida FWC students: Brittany Combs, Ben Kurth
NOAA students: Walter Ingram (audited)

This course was taught for the third time during Fall 2017 by Cameron Ainsworth of USF-CMS. (12 students, including 10 agency employees - 83% agency)

USF students: Jeremy Browning, Greta Helmueller
Florida FWC student: Shanae Allen
NOAA students: Becky Allee, Kyle Dettloff, Benjamin Duffin, Nicholas Farmer, Michael Larkin, Jennifer Leo, Shannon Martin, Kelli O'Donnell, and Jeffrey Pulver.

Note: The course Ecosystem Modeling 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 students: 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

This course was taught for the fourth time during Fall 2017 by David Jones of USF-CMS (7 students – 0% agency)

USF students: Kyle Amerigan, Alyssa Andres, Meaghan Faletti**, Shaniqua Gladney, Greta Helmueller, Bich Vi Viviane Nguyen, Jonathan Peake
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 NMFS SERO
Beverly Sauls (M.S., Fall 2013); employed by FWC FWRI
Sky Williams (M.S., Fall 2013); independent ecosystem data analyst
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); ecotourism guide
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); employed by FWC FWRI
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); Technical Project Coordinator for Pinellas County, FL
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
Kara Wall (M.S., Summer 2017); employed by FWC FWRI
Joshua Kilborn (Ph.D., Spring 2018); employed as research faculty at USF-CMS
Marcy Cockrell (Ph.D., Spring 2018); employed as postdoc at USF-CMS
Jennifer Granneman (Ph.D., Summer 2018); employed by FWC FWRI

Outreach

CIMAS also conducts National and international level outreach. In 2017 CIMAS produced a video[6] highlighting the reach and breath of research conducted by the program, with a special emphasis of participation of NOAA scientists in CIMAS research. For example this last year some CIMAS scientists (Dr. Ian Enochs, Dr. David Die) participated on the SKYPE a scientist [7] international project which hosts class sessions between students and teachers from primary schools and high school with research active scientists. RSMAS faculty works to engage all of the communities of South Florida through outreach activities, including some citizen scientist projects. RSMAS is engaged with partnerships with the Miami Science Museum and Miami Seaquarium.

Outreach and educational activities of CIMAS research projects

CIMAS emphasizes that all projects should take advantages of opportunities for reaching users of its science outputs through outreach activities. The following outreach activities are linked to specific research projects listed elsewhere in this report.

Coral Health and Monitoring Program (CHAMP)

- Enochs, Formel, Aguilar, and Morris worked with the Angari Foundation to produce a virtual reality education and outreach piece about their research.
- Enochs and Formel worked with the consulting company Far Outreach to develop STEM lesson plans designed around their autosamplers and ocean acidification research.

Western Boundary Time Series Project

- S. Garzoli and S. Dong are involved in the MPOWIR (Mentoring Physical Oceanography Women to Increase Retention) organization.
- C. Meinen was interviewed by journalists in February 2018 and March 2018 to discuss western boundary flows.
- S. Dong served as a committee member for a Ph.D student from RSMAS (Yu Cheng), University of Miami.

[6] https://youtu.be/lK-2AA2NmmE
[7] https://www.skypeascientist.com/

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.
- E. Valdes participated in Bring Your Child to Work Day.

Southwest Atlantic Meridional Overturning Circulation ("SAM") Project

- C. Meinen and R. Perez are mentoring a CIMAS postdoctoral fellow (Marion Kersalé) under support from a related NOAA Climate Variability & Predictability (CVP) proposal.
- S. Dong is mentoring a CIMAS postdoctoral fellow (Alexandra Gronholz) under support from another related NOAA CVP proposal. S. Garzoli, R. Perez, and S. Dong are involved in the MPOWIR (Mentoring Physical Oceanography Women to Increase Retention) organization.
- C. Meinen was interviewed by journalists in February 2018 and March 2018 to discuss western boundary flows. R. Perez participated in the "Skype-A-Scientist" program which matches K-12 classrooms and scientists around the world.
- In November 2017, R. Perez participated in the Exploring Marine Sciences Day for 5th and 6th grade girls at the University of Miami/RSMAS.
- S. Dong served as a committee member for a Ph.D student from RSMAS (Yu Cheng), University of Miami.

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

- M. Goes participated in the SEEDS workshop "*Mentoring: Making it Count*" on April 6, 2018 9am-4:30pm on the RSMAS Library, organized by RSMAS and Merlin Walberg of Phoenix Consultancy. Goals of the workshop were: 1) To build relationships and understanding between faculty and students; 2)To identify connections between mentoring relationships and the transformation of culture; 3)To learn practical skills and tools for mentoring to use daily.
- M. Goes and S-K. Lee are members of the CLIVAR US AMOC Task Team III: Mechanisms and Predictability, and participate actively in the bi-monthly webinars.

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
- Furthermore, results were presented at the Ocean Science Meeting 2018: 'Variability of the South Atlantic Ocean heat content in an eddy-resolving and a non-eddy-resolving General Circulation Model'
- S. Dong is involved in the MPOWIR (Mentoring Physical Oceanography Women to Increase Retention) organization, and served as a committee member for a Ph.D student from RSMAS (Yu Cheng), University of Miami.

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.

South Atlantic-North Atlantic Meridional Overturning Circulation (MOC) Linkages: Analysis of the Upper and Lower Limbs With In Situ Instruments

- C. Meinen, R. Perez and M. Le Hénaff are mentoring a CIMAS postdoctoral fellow (M. Kersalé) under support from this proposal. S. Garzoli, R. Perez, and S. Dong are involved in the MPOWIR (Mentoring Physical Oceanography Women to Increase Retention) organization.
- In February 2018 and March 2018, C. Meinen was interviewed by journalists to discuss western boundary flows.
- In November 2017, R. Perez participated in the Exploring Marine Sciences Day for 5th and 6th grade girls at the University of Miami/RSMAS. In February and April 2018, R. Perez spoke to K-12 classrooms as part of the "Skype-A-Scientist" program.

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)

Development & Research Activities for the Basin-Scale Hurricane Weather Research and Forecasting (HWRF-B) Model

- NOAA/AOML Open House
- Greater Miami AMS Chapter

NOAA/AOML – CARICOOS Hurricane Underwater Gliders

- Website: http://www.aoml.noaa.gov/phod/goos/gliders/, where 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.
- Several outreach activities included providing tours of the NOAA/AOML facilities during the reporting period.
- Gustavo Goni is a committee member of one PhD student from the University of Puerto Rico Mayaguez.
- Gustavo Goni continues with the setting of oceanographic equipment display at NOAA/AOML, which includes Underwater Gliders.
- R. Domingues, G. Rawson, and U. Rivero participated in the 2018 NOAA/AOML open house held during May 10-12. Their participation included a presentation to visiting schools, and general public about the current underwater glider efforts in support hurricane intensity forecasts.

Improvement to the Tropical Cyclone Genesis Index (TCGI)

- Guest Speaker, Marlborough Elementary School 3rd grade, Marlborough, CT (June 2017)
- Guest Seminar, NASA Marshall Space Flight Center, Huntsville, AL (June 2017): The tropical cyclone diurnal cycle.
- Guest Speaker, Veterans' Memorial School, Norwich, CT (February 2017)

A Twenty One-Year Tropical Cyclone Global Positioning System Dropwindsonde Dataset

- The use of dropwindsondes during NOAA's hurricane field program was presented in an invited talk to the South Florida Explorers club on May 6, 2018.

An Observing System Experiment for the Hurricane Imaging Radiometer

- "An Observing System Experiment Study of the High Altitude Hurricane Imaging Radiometer" was presented at the 33rd American Meteorology Society Tropical Meteorology conference April 17, 2018.

Hurricane Moving Nest for FV3

- NOAA/AOML Open House

The GO-SHIP Repeat Hydrography Program

- Barbero, 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). Volkov lead outreach efforts during I07N including a dedicated blog.

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

- Public awareness: Media mentions of the GOMECC-3 cruise in Spanish language, mentions at UM e-veritas, blog chronicling the cruise in plain language, tweets, and Instagram posts. K-12 outreach: Skype a scientist presentation on OA.

Ship of Opportunity Program

- Several outreach activities included providing tours of the NOAA/AOML facilities including in September 2016 for University of Miami oceanography undergraduate students.
- Project personnel continues with the implementation of project videos hosted on the PHOD web site (NOAA/AOML XBT network, NOAA/AOML Argo, NOAA/AOML SAM, NOAA/AOML Underwater glider projects, etc).
- M. Baringer and S. Dong are members of Mentoring Physical Oceanography Women to Increase Retention (MPOWIR) mentoring groups.
- Gustavo Goni is a committee member of one PhD student from the University of Puerto Rico Mayaguez.
- Gustavo Goni continues with the setting of oceanographic equipment display at NOAA/AOML, which includes XBTs.
- S. Dong, together with R. Perez, mentored a summer intern, Alycia Ciresi. Ms.Ciresi is a teacher at MAST Academy, and plans to attend graduate school at RSMAS, Univ. of Miami, to pursue a doctoral degree in physical oceanography.
- M. Baringer mentored two University of Puerto Rico students, who volunteered to participate in the Western Boundary Time Series cruise, continued mentoring student on use of data for Master Thesis.
- M. Baringer mentored a MAST Academy high school student in Environmental Science to formulate and execute a project that evaluated the impacts of boating use on the local marine environment using nutrient data.
- M. Baringer organized a “My Brother’s Keeper” event and open house at NOAA/AOML with volunteers including encouraging low-income students to pursue STEM fields.
- M. Baringer briefed congressman and staffers on NOAA/AOML research including several Climate Observation Division projects.
- M. Goes mentored the high school student Steve Marrero from MAST Academy during the period of June-August, 2017 on physical oceanography and data analysis.
- M. Goes was a presenter at the “2017 Hurricane Awareness Tour” at the Opa-Locka Airport on May 12, 2017. Event open for the local schools and general public.
- M. Goes was a presenter at the NOAA/NWS open house at the Florida Int’l Campus on March 18, 2017. Event aimed at severe weather awareness for general public.
- R. Domingues was a presenter at the NOAA/AOML open house on May 11-12, 2018.

Calibration/Validation Support for NPP VIIRS Data Product Continuity

- The Sargassum Watch System (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

- In addition to the PI team, this project employed an undergraduate engineering student during his final semester and subsequent months, a recently discharged Army veteran, and contracted to a small business (Computer Servants, Tallahassee, FL). This project was used for a number of outreach activities including: demonstration at the annual COAPS/National High Magnetic Field Laboratory open house, demonstration at the bi-annual FSU Coastal and Marine Laboratory open house (coinciding with the March for

Science), demonstration at FSU Technology Transfer events, and inclusion of an undergraduate researcher through the FSU Research Experience for Undergraduates program. This project also engaged citizen science through volunteer-observations of landings of drift cards that were deployed during the first drifter field experiment. Results of the experiments, locations of drift cards found by volunteers, and other project-related media and press are presented on the website drifters.ocean.fsu.edu.

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

- K-12 outreach: Skype a scientist presentation on OA and CO2 fluxes. Public lectures; guest lectures at schools and universities; members of national and international steering committees.

Ocean technology development: bottom drifter development

- Poster presentation of the Bottom Drifter at the Ocean Science 2018. Presentation and public display of the Bottom Drifter at the FSU Coastal and Marine Lab Conservation Lecture Series.

Marine Optical Buoy (MOBY) Operations and Technology Refresh

- Immaculata La Salle High school career day, Undergraduate physics major seminar explaining the project.

PIRATA Northeast Extension

- During May-August 2018, G. Foltz mentored an intern from ENSTA-ParisTech University in France on Atlantic tropical cyclone-ocean interaction.
- In May 2018, G. Foltz spoke to a class of first-graders at Carver Elementary School about what it is like to go on a PIRATA research cruise and work for NOAA.
- In February and April 2018, R. Perez spoke to K-12 classrooms as part of the "Skype-A-Scientist" program.
- In November 2017, R. Perez participated in the Exploring Marine Sciences Day for 5th and 6th grade girls at the University of Miami/RSMAS.

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 K12 students (IMPACT program for under-represented minorities, UM/RSMAS)

Creel survey of private boat recreational fishing in the US Virgin Islands: phase II

- Went to a number of the FAC (Fishery Advisory Committee) meetings which were attended by a number of charter and recreational fishers to make sure that representatives understood the overall goal of the project. Also teleconferenced into one of those meetings to explain how recreational Allowable Catch Limits (ACLs) would work and how this sampling project would fit in the determination of ACLs.

Effects of Nitrogen sources and plankton food-web dynamics on habitat quality for the larvae of Atlantic bluefin tuna in the Gulf of Mexico.

- Undergraduate students from the University of Miami's RSMAS participated in the project in research cruises, sample and laboratory processing. The students provided valuable research support in the early life history unit laboratory in various projects and facilitated technical assistance while having the opportunity for hands-on learning.
- Websites with educational information regarding the project and research survey:
  http://nfchroniclesnoaa.blogspot.com/
  https://restoreactscienceprogram.noaa.gov/projects/bluefin-tuna-larvae
- During our port stop a large group of nature lovers from the FL Master Naturalist Program, NW Panhandle Chapter and students from Ms. Willi's science classes at Milton High School visited our "open house" in Pensacola, FL on May 11 with over 50 individuals of all ages in attendance.

Reef Visual Census (RVC): Reef fish monitoring in the Florida reef tract and US Caribbean

- Scientists with this project conducted multiple outreach activities reaching thousands of individuals through the outreach activities of each of the partner organization. Specifically, NOAA PIs and Collaborators conducted outreach activities specific to this project at the Miami-Dade County Youth Fair, several local elementary schools, an invited speaking engagement with the Dauphin Island Sea Lab, and the NOAA (AOML/SEFSC) Open House.

Caribbean Reef Ecosystem Research, USVI Larval Distribution and Supply

- During the NF1803 survey in June 2018, graduate students from the University of Virgin Islands, University of Puerto Rico-Mayaguez, and City University of New York participated in the sampling effort. In addition, we had a high school student participate as well.
- 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.
- During these surveys, a blog was updated written by the survey participants to share with the public educational information regarding the project and research survey for the survey carried out in 2013, 2015, 2016, 2017 and 2018: http://nfchroniclesnoaa.blogspot.com/

2016 National Coral Reef Monitoring Program – SEFCRI Benthic Sampling

- This data is being used in the creation of the Florida Coral Reef Report Card (*in preparation*), which is intended to provide information about the state of Florida's coral reef resources to a broad audience.

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

- Two oral and one poster presentation utilizing samples collected from previous surveys that are under this project's umbrella were presented at the XX Reunion Nacional de la

Sociedad Mexicana de Planctología in Merida, Mexico. One of the oral talks was presented by a graduate student, as well as the poster presentation.

- Two graduate students will acquire a Master's degree utilizing datasets collected from this project at the university El Colegio de la Frontera Sur.
- Four undergraduate students are currently carrying out their undergraduate thesis which is a requirement to obtain their degrees also utilizing samples collected from this project at the university El Colegio de la Frontera Sur.
- A NOAA Hollings Intern from Eckerd College aged otoliths for larval blue marlin from Caribbean collections in 2015 and 2016. This data was presented at Ocean Sciences Meeting in Portland, OR.
- 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

Net Revenues of the Federal Fin-Fish Commercial Fisheries in the Southeast

- Presentations:WRFC8 (World Recreational Fishing Conference) 2017 conference, July 16-20 2017, Victoria, British Columbia, Canada and Crowdsourcing For-Hire Sportfishing Trip Price Data from Websites

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

- http://www.marine.usf.edu/students/48
- http://www.marine.usf.edu/ainsworthecology/
- http://www.marine.usf.edu/fishecology/
- St. Petersburg ScienceFest – MRA faculty and students organized multiple activities at ScienceFest, which is a large multi-agency sponsored science-related festival that was attended by ~25,000 people in October, 2017. MRA personnel demonstrated sampling techniques and discussed fisheries and marine-related research, including directing class activities for invited schools.

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

- Participated in NOAA Open House (May 10-12, 2018) engaging Miami Dade County public school students, and members of the general public.

Support of the National Coral Reef Management Fellowship Program

- **American Samoa:** The two main successes for the 2016-2018 coral fellows in American Samoa were creating a Climate Change and Resiliency Glossary and teaching partner organizations about stormwater issues and rain garden installations. Her work included outreach events at various schools, including Manulele Elementary, where she installed two gardens in order to reduce the volume of stormwater and its pollutants reaching nearshore waters of the Nu'uuli Pala priority watershed. Other areas for raingardens included Vatia, Nu'uuli, and Faga'alu. Sabrina completed 13 raingardens in total during her two years in American Samoa. She also provided hands-on watershed and stormwater interpretation for elementary and high school students during a camp with NOAA's National Marine Sanctuaries.

- **CNMI:** The CNMI fellow 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 coral fellow staffed and ran outreach booths with the FL DEP at 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 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 Fellowship for distribution by environmental publications and is creating a newsletter about the fellowship, which will be distributed on the NOAA and NSU fellowship web pages.
- **Guam:** In 2017, the Guam coral fellow 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 summer 2017, the Guam fellow assisted NOAA colleagues with a "Training the Trainers" session for EOR at the Bureau of Environmental and Coastal Quality in Saipan, CNMI. She also 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.
- Following the second leg of the NOAA Mariana Archipelago Reef Assessment and Monitoring Program cruise in May 2017, the Guam Fellow 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:** In Summer 2017, the coral fellow 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 coral fellow provided critical support for the revision of maps for the updated Recreational Guide to the East End Marine Park as well as the recently installed Visitor Center phase 1. She further contributed to the climate change and watershed panels of the Visitor Center, as well as layout and design support for the entire phase 1. The fellow also oversaw two summer interns at the Park who conducted seagrass surveys and is training new volunteers for the upcoming second season of turtle monitoring in beaches

along the Park. In addition, she was a valuable partner with the local agency in the aftermath of the 2017 hurricanes. She remained on island and was instrumental in helping with the cleanup and aiding in getting the East End Marine Park back up and running.

Marine Mammal Research

- In 2018, I presented a 1-hour lecture about NOAA's Biscayne Bay dolphin photo-id, genetic biopsy, and stranding programs to a group of eighteen 8th grade students from Sidwell Friends School (Washington DC) at the Mote Marine Laboratory in Summerland Key, FL. I also assisted in the three-day Open House event held at NOAA's SEFSC in May.

Mandatory Ship Reporting System

- The Mandatory Ship Reporting system website: https://www.rightwhalesmsr.aoml.noaa.gov/
- News item about the Mandatory Ship Reporting system at AOML's Physical Oceanography Division website: http://www.aoml.noaa.gov/phod/news/load.php?pFullStory=20140416_20140515_MSR.html
- Article about the Mandatory Ship Reporting system at AOML's Newsletter, issue of March-April 2014: http://www.aoml.noaa.gov/keynotes/PDF-Files/Mar-Apr14.pdf
- Detailed information about the Mandatory Ship Reporting system at the NMFS website: http://www.nmfs.noaa.gov/pr/shipstrike/msr.htm
- Detailed information about the Mandatory Ship Reporting system at AOML/PhOD website: http://www.aoml.noaa.gov/phod/research/ecosystems/msr/

Gulf of Mexico Marine Mammal Stranding Database "GulfMAP"- data diplomat position

- Stevens has participated in providing content for a website that will display the visual aspects of GulfMAP to the general public.
- May 10th-12th the SEFSC had an open house event were children from the local schools and public visitors learned about the different programs and research done at the SEFSC. Stevens participated all three days discussing the marine mammal program at NOAA, whale and dolphin biology, and marine conservation.

A dynamic decision support tool for management

- The decision support tool is being presented to the Gulf of Mexico Fishery Management Council on 31st of May 2018 as a method of projecting expected OFL changes for Red snapper under potential scenarios of reduced discard mortality through the use of descender devices.

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	**NOAA/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

Analysis of kinetic energy and structure functions from along-track and crossover altimeter data

- Don Chambers was elected a Fellow of the American Geophysical Union in 2017 for: "Outstanding contributions to sea level research and ocean dynamics using satellite observations." He was also awarded a USF Outstanding Faculty Award in 2018 for his research on ocean dynamics using satellites.

Improvement to the Tropical Cyclone Genesis Index (TCGI)

- Co-Recipient: 2018 Banner I. Miller Award, American Meteorological Society: for their paper "The tropical cyclone diurnal cycle of mature hurricanes, which identified a fundamental process in tropical cyclones and elegantly defined its properties and potential implications using observational data."

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

- Florida State University GAP Commercialization Grant Program award to co-PI N. Wienders

Surface water partial pressure of CO_2 (pCO_2) measurements from ships

- Dr. Frank Millero, Rosenstiel Award 2018

Ingesting Sea Surface Height Anomalies from the Jason-3 and Sentinel 3A Missions to Enhance the NESDIS Operational Ocean Heat Content Product Suite

- Elected to the Gulf of Mexico Coastal Ocean Observing Regional Association Board of Directors. GCOOS-RA is sponsored by NOAA's Integrated Ocean Observing System Office.

Net Revenues of the Federal Fin-Fish Commercial Fisheries in the Southeast

- Due largely to the success of this project, the NOAA Collaborator C. Liese was nominated and selected as the NOAA employee of the month for March 2018.

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

- Marcy Cockrell – National Academy of Science's Gulf Research Program Science Policy Fellowship
- Meaghan Faletti – Florida Chapter of the American Fisheries Society, Rottman Memorial Scholarship ($1,000)
- Meaghan Faletti – USFCMS Endowed Fellowship Program, Tampa Bay Parrothead Fellowship ($10,000)
- Meaghan Faletti – Florida Forage Fish Research Fellowship (collaboration with FWRI, Pew Charitable Trusts, and International Game Fish Association), ($10,000)
- Meaghan Faletti – Fish Florida! Scholarship ($5,000).
- Jonathan Peake – USFCMS Endowed Fellowship Program, Linton Tibbetts Endowed Graduate Student Fellowship ($10,000)

- Garrett Miller – USFCMS Endowed Fellowship Program, Wells Fargo Fellowship in Marine Science ($10,000)

X. POSTDOCTORAL FELLOWS AND GRADUATE STUDENTS

CIMAS-Supported Postdoctoral Fellows and Graduate Students

Postdoctoral Fellows

Aguilar, Catalina
Chakravorty, Soumi
Forrestal, Francesca
Germineaud, Cyril
Gronholz, Alexandra
Gruss, Arnaud
Harper, Kirsten
Jones, Paul
Kersale, Marion
Majumder, Sudip
Rudko, Mykhailo
Trifonova, Neda
Vaughan, Nathan
Zink, Ian

Graduate Students, Task I

Cain, Erin
Camposano, Samantha
Denson, Latreese
Hoenig, Lillian
Kiest, Kristina
Morris, John
Nuttall, Matthew
Rider, Mitchell
Sarkis, Sierra
Simmons, Victoria
Souza, Philip
Stoltz, Amanda
Varkony, Matthew
Williamson, Olivia

Task II *Employees*

Jugovich, Amelia
Christophersen, Jonathan
Halsall, Patrick

Other Participants in CIMAS Projects

Postdoctoral Fellows

Barnes, Brian
Ghosh, Tirthankar
Hancock, C
He, Bian
Roa, Camilo
Shulze, Lena
Hu, Wenting
Min, Dughong
Nag, Bappaditya
Poterjoy, Jonathan
Speer, Kevin
Swalethorp, Rasmus

Graduate Students

Aviles-Diaz, Ana
Barton, Mark
Bilo, Tiago
Binder, Benjamin
Chen, Shuangling
Cockrell, Marcy
Colburn, Philip
Dominguez-Nava, Anahi
Fisco, Dana
Granneman, Jennifer
Grasso, Peter
Hansen, Kurt
Hepner, Megan
Jermain, Robert
Kelly, Thomas
Kilborn, Joshua
Knowles, Morgan
Lopez, Omar
Mehta, Chris
Monk, Sam
Morales, Selene
Mostowy, Jason
Palacio, Ana
Patranella, Allison
Peter, Szandra
Pomales, Luis
Quiquempois, Vincent
Roper, Zola
Seijo, Giovanni
Shropshire, Taylor
Sinnickson, Dylan
Suca, Justin
Sukhdeo, Raymond
Thomas, Rachel
Tolan, Michael
Valla, Daniel
Vandine, Benjamin
Vidotto, Egla
Wall, Kara
Wang, Mengqiu
Wickes, Marissa
Zavadoff, Breanna
Zhang, Yang
Zhang, Yingjun

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
Brossard, Amy	Research Associate II
Bucci, Lisa	Senior Research Associate II
Casey, Sean	Associate Scientist
Chakravorty, Soumi	Postdoctoral Associate
Chomiak, Leah	Research Associate I
Christophersen, Hui	Assistant Scientist
Christophersen, Johnathan	Research Associate II
Dahl, Brittany	Research Associate I
Davies, Stephen	Research Associate II
Debich, Amanda	Senior Research Associate I
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	Senior Research Associate II
Dunion, Jason	Associate Scientist

Dutra, Elizabeth	Research Associate I
Ehrbar, Elizabeth	Programmer, Intermediate
Enochs, Ian	Associate Scientist
Festa, John	Senior Research Associate III (PT)
Foley, Katherine	Senior Research Associate II (PT)
Formel, Nathan	Research Associate II
Forrestal, Francesca	Postdoctoral Associate
Forteza, Elizabeth	Research Associate III
Garcia, Rigoberto	Senior Research Associate III
Garzoli, Silvia	Scientist (PT)
Germineaud, Cyril	Postdoctoral Associate
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	Associate Scientist
Harper, Kirsten	Postdoctoral Associate
Hazelton, Andrew	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
Kren, Andrew	Assistant Scientist
Langwiser, Caitlin	Research Associate I
Le Henaff, Matthieu	Assistant Scientist

Leighton, Hua	Assistant Scientist
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 III
Overstreet, Elizabeth	Senior Research Associate II
Perez, Renellys	Associate Scientist
Peterson, Annabeth	Research Associate II
Pierrot, Denis	Associate Scientist
Privoznik, Sarah	Research Associate II
Quenee, Charline	Research Associate I
Rawson, Grant	Research Associate III
Roddy, Robert	Research Associate III (PT)
Rosales, Stephanie	Senior Research Associate II
Rudko, Mykhailo	Postdoctoral Associate
Ryan, Kelly	Senior Research Associate II
Sabina, Reyna	Research Associate III (PT)
Sellwood, Kathryn	Research Associate III
Serrano, Xaymara	Assistant Scientist
Sevilla, Thomas	Electrical Engineer
Shideler, Allison	Senior Research Associate II
Shiroza, Akihiro	Senior Research Associate I
Shulzitski, Kathryn	Assistant Scientist
Smith, Ian	Research Associate I
Sprehn, Charlotte	Senior Research Associate I
Stevens, Sabrina	Senior Research Associate I
St. Fleur, Russell	Programmer, Intermediate
Sullivan, Kevin	Senior Research Associate III
Trifonova, Neda	Postdoctoral Associate
Ugaz, Diego	Electrical Engineer

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
Zawislak, Jonathan	Assistant Scientist
Zhang, Jun	Scientist
Zhang, Xuejin	Scientist
Zink, Ian	Postdoctoral Associate

XII. VISITING SCIENTISTS

Mr. Julien Fornasari – May 7 – August 3, 2018
ENSTA ParisTech University
Palaiseau, France

Dr. Andrew Hazelton – May 28-31, 2018
Geophysical Fluid Dynamics Laboratory
Princeton, NJ

High-Resolution fvGFS Forecasts of Atlantic Tropical Cyclones: Structural Analysis and Evaluation of the 2017 Atlantic Hurricane Season

Dr. Jeffrey D. Kepert – April 23, 25, 2018
Weather and Enviromental Predictions
Centre for Australian Weather and Climate Research
Melbourne, Australia

"Bias correction of tropical cyclone size and structure in the ECMWF global ensemble prediction system"

Dr. Nancy Maynard – October 1, 2012 (to continue through December 2018)
NASA Emeritus
NASA Goddard Space Flight Center
Greenbelt, MD

Dr. Shyama Mohanty – May 1, 2017 (4 months)
School of Earth Ocean and Climate Sciences
Indian Institute of Technology Bhubaneswar
Odisha, India

Dr. Alain Muñoz Caravaca – July 18 – August 21, 2017 (observer on cruise)
Grupo de Modelacion y Geomatica
Centro de Estudios Ambientales de Cienfuegos
Cienfuegos, Cuba

XIII. PUBLICATIONS

Table 1: Publication Record 2017-2018 for Cooperative Agreement NA15OAR4320064

	Institute Lead Author 2017-2018	NOAA Lead Author 2017-2018	Other Lead Author 2017-2018
Peer Reviewed	22	16	40
Non-Peer Reviewed	16	3	3

Refereed Journal Articles

Aberson, S. D., K. J. Sellwood, and P. A. Leighton (2017), Calculating Dropwindsonde Location and Time from TEMP-DROP Messages for Accurate Assimilation and Analysis, *J. Atmos. Oceanic Technol.*, 34, 1673-1678, doi:10.1175/JTECH-D-17-0023.1.

Ainsworth, C. H., C. Paris, N. Perlin, L. N. Dornberger, W. Patterson, E. Chancellor, S. Murawski, D. Hollander, K. Daly, I. Romero, F. Coleman, and H. Perryman (2018), Impacts of the Deepwater Horizon oil spill evaluated using an end-to-end ecosystem model, *PLoS ONE*, 13(1): e0190840, doi:10.1371/journal.pone.0190840.

Baringer, M. O., D. A. Smeed, J. Willis, M. Lankhorst, W. R. Hobbs, S. Dong, G. McCarthy, D. Rayner, W. E. Johns, G. Goni, and U. Send (2017), Meridional overturning and oceanic heat transport circulation observations in the North Atlantic Ocean [in "State of the Climate in 2016"], *Bull. Amer. Meteor. Soc.*, 98 (8): S84-S87, doi:10.1175/2017BAMSStateoftheClimate.1.

Bell, R. J., and B. P. Kirtman (2018), Seasonal forecasting of winds, waves and currents in the North Pacific, *J. Operational Ocean*., 11, 11-26, doi:10.1080/1755876X.2018.1438342.

Boukabara, S.-A., K. Ide, N. Shahroudi, Y. Zhou, T. Zhu, R. Li, L. Cucurull, R. Atlas, S. P. F. Casey, and R. N. Hoffman (2018), Community Global Observing System Simulation Experiment (OSSE) Package (CGOP): Perfect Observations Simulation Validation, *J. Atmos. Oceanic Technol.*, 35, 207–226, doi:10.1175/JTECH-D-17-0077.1.

Bumbeer, J., R. M. da Rocha, H. Bornatowski, M. de Castro Robert, and C. Ainsworth (2017), Predicting impacts of lionfish (*Pterois volitans*) invasion in a coastal ecosystem of southern Brazil, *Biological Invasions*, 1-18, doi:10.1007/s10530-017-1625-8.

Cai, W.-J., W.-J. Huang, G. W. Luther, D. Pierrot, M. Li, J. Testa, M. Xue, A. Joesoef, R. Mann, J. Brodeur, Y.-Y. Xu, B. Chen, N. Hussain, G. G. Waldbusser, J. Cornwell, and W. M. Kemp (2017), Redox reactions and weak buffering capacity lead to acidification in the Chesapeake Bay, *Nature Communications*, 8:369, s41467-41017, doi:10.1038/s41467-017-00417-7.

Chambers, D. P. (2018), Using kinetic energy from altimetry to detect shifts in the positions of fronts in the Southern Ocean, *Ocean Sci.*, 14, 105–116, doi:10.5194/os-14-105-2018.

Cyronak, T., A. J. Andersson, C. Langdon, R. Albright, N. R. Bates, et al. (2018), Taking the Metabolic Pulse of the World's Coral Reefs, *PLoS ONE,* 13(1): e0190872, doi:10.1371/journal.pone.0190872.

Dole, R. J., et al. (2018), Advancing science and services during the 2015-16 El Niño: the NOAA El Niño Rapid Response Field Campaign, *Bull. Amer. Meteor. Soc.*, 99, 975-1001, doi:10.1175/BAMS-D-16-0219.

Doyle, J. D., et al. (2017), A View of Tropical Cyclones from Above: The Tropical Cyclone Intensity (TCI) Experiment, *Bull. Amer. Meteor. Soc.*, 98, 2113-2134, doi:10.1175/BAMS-D-16-0055.1.

Feely, R. A., R. Wanninkhof, P. Landschützer, B. Carter, and J. A. Trinanes (2017), Global ocean carbon cycle [in "State of the Climate in 2016"], *Bull. Amer. Meteor. Soc.*, 98(8):S89-S92, doi:10.1175/2017BAMSStateoftheClimate.

Fogg, A. Q., and M. E. Faletti (2018), Invasive lionfish (*Pterois* spp.) agonistic behavior observations, *Bull. Mar. Sci*., 94, 1-2, doi:10.5343/bms.2017.1129.

Foltz, G. R., C. Schmid, and R. Lumpkin (2018), An Enhanced PIRATA Dataset for tropical Atlantic Ocean - Atmosphere Research, *J. Climate*, 31, 1499-1524, doi:10.1175/JCLI-D-16-0816.1.

Ghosh, T. and T. N. Krishnamurti (2018), Improvements in Hurricane Intensity Forecasts from a Multimodel Superensemble Utilizing a Generalized Neural Network Technique, *Wea. Forecasting,* In Press, doi:10.1175/WAF-D-17-0006.1.

Gintert, B. E., D. P. Manzello, I. C. Enochs, G. Kolodziej, R. Carlton, A. Gleason, and N. Gracias (2018), Marked Annual Coral Bleaching Resilience of an Inshore Patch Reef in the Florida Keys: A Nugget of Hope, Aberrance, or Last Man Standing? *Coral Reefs*, 37(2): 533-547, doi:10.1007/s00338-018-1678-x.

Goes, M., E. Babcock, F. Bringas, P. Ortner, and G. Goni (2017), The Impact of Improved Thermistor Calibration on the Expendable Bathythermograph Profile Data, *J. Atmos. Oceanic Technol.*, 34, 1947-1961, doi:10.1175/JTECH-D-17-0024.1.

Goes, M., S. Dong, G. Goni, and M. Baringer (2018), An updated estimate of salinity for the Atlantic Ocean sector using Temperature-Salinity relationships, *J. Atmos. Oceanic Technol.*, In Press, doi:10.1175/JTECH-D-18-0029.1.

Goni, G. J., J. Knaff, and I.-I. Lin (2017), Tropical Cyclone Heat Potential [in "State of the Climate in 2016"], *Bull. Amer. Meteor. Soc.,* 98 (8), S123 - S126, doi:10.1175/2017BAMSStateoftheClimate.1.

Goni, G. J., R. E. Todd, S. R. Jayne, G. Halliwell, S. Glenn, J. Dong, R. Curry, R. Domingues, F. Bringas, L. Centurioni, S. F. DiMarco, T. Miles, J. Morell, L. Pomales, H.-S. Kim, P. E. Robbins, G. G. Gawarkiewicz, J. Wilkin, J. Heiderich, B. Baltes, J. J. Cione, G. Seroka, K. Knee, and E. R. Sanabia (2017), Autonomous and Lagrangian Ocean Observations for Atlantic Tropical Cyclone Studies and Forecasts, *Oceanography*, 30(2), 92-103, doi: 10.5670/oceanog.2017.227.

Grace, M. A., L. Aichinger Dias, K. Maze-Foley, C. Sinclair, K. D. Mullin, L. Garrison, and L. Noble (2018), Cookiecutter shark bite wounds on cetaceans of the Gulf of Mexico, *Aquatic Mammals*, In Press.

Gravinese, P., I. C. Enochs, D. P. Manzello, and R. van Woesik (2018), Warming and pCO_2 effects on Florida stone crab larvae, *Estuarine, Coastal and Shelf Science*, 204, 193-201, doi:10.1016/j.ecss.2018.02.021.

Groves S. H., D. M. Holstein, I. C. Enochs, G. Kolodziej, D. P. Manello, M. Brandt, and T. B. Smith (2018), Growth rates of *Porites astreoides* and *Orbicella franksi* in mesophotic habitats surrounding St. Thomas, US Virgin Islands, *Coral Reefs*, 37(2), 345-354, doi:10.1007/s00338-018-1660-7.

Gruss, A., M. D. Drexler, C. H. Ainsworth, E. A. Babcock, J. H. Tarnecki, and M. S. Love (2018), Producing Distribution Maps for a Spatially-Explicit Ecosystem Model Using Large Monitoring and Environmental Databases and a Combination of Interpolation and Extrapolation, *Front. Mar. Sci.,* 5, doi:10.3389/fmars.2018.00016.

Halliwell, G. R., M. Mehari, L. K. Shay, V. H. Kourafalou, H. Kang, H. –S. Kim, J. Dong and R. Atlas (2017), OSSE Quantitative Assessment of Rapid-Response Pre-Storm Ocean Surveys to Improve Coupled Tropical Cyclone Prediction, *J. Geophys. Res. Oceans*, 122(7), 5729-5748, doi:10.1002/2017JC012760.

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Herdter, E. S., D. P. Chambers, C. D. Stallings, and S. A. Murawski (2017), Did the Deepwater Horizon oil spill affect growth of Gulf of Mexico Red Snapper? *Fisheries Research*, 191, 60-68, doi:10.1016/j.fishres.2017.03.005.

Hoffman, R. N. (2018), The Effect of Thinning and Superobservations in a Simple One-Dimensional Data Analysis with Mischaracterized Error, *Mon. Wea. Rev.*, 146, 1181–1195, doi:10.1175/MWR-D-17-0363.1.

Hoffman, R. N., N. Privé, and M. Bourassa (2017), Comments on “Reanalyses and Observations: What’s the Difference?”, *Bull. Amer. Meteor. Soc*., 98, 2455–2459, doi:10.1175/BAMS-D-17-0008.1.

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APPENDIX I

Amendment #	Project Title	Funding Amount
Amendment # 87	CIMAS: Evolutionary Reinvention: Subcontractual Award to a CIMAS Consortium Academic Institution: "Florida International University"	$134,248.00
Amendment # 88	CIMAS: Evolutionary Reinvention "Subcontractual Award to a CIMAS Consortium Academic Institution: Nova Southeastern University"	$12,348.00
Amendment # 89	Florida Reef Track Reef Fish Monitoring & Assessment	$144,060.00
Amendment # 90	CIMAS: Evolutionary Reinvention: Subcontractual Award to a CIMAS Consortium Academic Institution: "University of South Florida"	$279,887.00
Amendment # 91	AOML-SWFSC-JCVI-MBARI Collaboration: Marine 'Omics and eAUV Technology to Support Ecosystems Understanding and Fisheries Assessments	$180,781.00
Amendment # 92	CIMAS: Evolutionay Reinvention "Subcontractual Award to a CIMAS Consortium Academic Institution: Florida International University"	$44,197.00
Amendment # 93	CIMAS Evolutionary Reinvention: Task II "AOML Work Force Activities"	$5,064,261.00
Amendment # 94	Inclusion of Jason-3 and Sentinel-3A Missions Into Three Operational Ocean Heat Content Products	$108,045.00
Amendment # 95	CIMAS: Evolutionary Reinvention "AOML Task I Education/Outreach and Research Infrastructure Activities"	$1,517,001.00
Amendment # 96	Remote Sensing and In-Situ Observations for Operational and Climate Applications	$123,434.00
Amendment # 97	Biogeochemical Measurements Task III	$116,301.00
Amendment # 98	CIMAS: Evolutionary Reinvention: "Subcontractual Award to a CIMAS Consortium Academic Institution: University of South Florida"	$86,250.00
Amendment # 99	Ocean OSSE development for Quantitative Observing System Assessment	$77,175.00
Amendment # 100	Are Eastern Tropical Pacific coral reefs becoming more resilient to ENSO?	$28,596.00
Amendment # 101	CIMAS Evolutionary Reinvention "Subcontractual Award to a CIMAS Consortium Academic Institution: Nova Southeastern University"	$380,727.00
Amendment # 102	CIMAS: Evolutionary Reinvention "AOML/SEFSC Administrative Support"	$104,027.00
Amendment # 103	CIMAS: Evolutionary Reinvention: "Subcontractual Award to a CIMAS Consortium Academic Institution: University of South Florida"	$148,972.00
Amendment # 104	CIMAS Evolutionary Reinvention: Task II "AOML Work Force Activities"	$3,587,110.00
Amendment # 105	Surface Water pC02 Measurements from Ships	$477,252.00
Amendment # 106	CIMAS Evolutionary Reinvention: Task II "AOML Work Force Activities"	$395,806.00
Amendment # 107	CIMAS Evolutionary Reinvention: Task II "AOML Work Force Activities"	$33,000.00
Amendment # 108	CIMAS: Evolutionary Reinvention "AOML Task I Education/Outreach and Research Infrastructure Activities"	$26,944.00
Amendment # 109	CIMAS: Evolutionary Reinvention "Task II SEFSC Work Force Activities	$2,887,968.00
Amendment # 110	CIMAS: Evolutionary Reinvention "SEFSC Task I Education/Outreach and Research Infrastructure Activities"	$381,274.00
Amendment # 111	ECOA 2018	$33,000.00
Amendment # 112	CIMAS: Evolutionary Reinvention: "Subcontractual Award to a CIMAS Consortium Academic Institution: Nova Southeastern University"	$14,987.00
Amendment # 113	CIMAS: Evolutionary Reinvention: Subcontractual Award to a CIMAS Consortium Academic Institution: "Florida State University"	$121,250.00
Amendment # 114	CIMAS Evolutionary Reinvention: Task II "AOML Work Force Activities"	$148,617.00
Amendment # 115	CIMAS: Evolutionay Reinvention "Subcontractual Award to a CIMAS Consortium Academic Institution: Florida International University"	$145,082.00

Amendment # 116	CIMAS: Evolutionary Reinvention "SEFSC Task I Education/Outreach and Research Infrastructure Activities"	$99,280.00
Amendment # 117	CIMAS: Evolutionary Reinvention "Task II SEFSC Work Force Activities	$1,030,735.00
Amendment # 118	CIMAS Evolutionary Reinvention: Task II "AOML Work Force Activities"	$352,333.00
Amendment # 119	CIMAS: Evolutionary Reinvention "AOML Task I Education/Outreach and Research Infrastructure Activities"	$694,812.00
Amendment # 120	CIMAS Evolutionary Reinvention: Task II "AOML Work Force Activities"	$719,825.00
Amendment # 121	Marine debris motion	$68,186.00
Amendment # 122	Inclusion of Jason-3 and Sentinel-3A Missions into Three Operational Oceanic Heat Content Products	$50,000.00
Amendment # 123	Ocean OSSE development for Quantitative Observing System Assessment	$77,175.00
Amendment # 124	Marine Optical Buoy (MOBY) Operations and Technology Refresh	$2,487,750.00
Amendment # 125	CIMAS: Evolutionary Reinvention: "Subcontractual Award to a CIMAS Consortium Academic Institution: Florida State University"	$178,578.00
Amendment # 126	CIMAS Evolutionary Reinvention: Task II "AOML Work Force Activities"	$998,233.00
Amendment # 127	CIMAS: Evolutionary Reinvention "AOML/SEFSC Administrative Support"	$27,400.00
	TOTAL	**$23,586,907.00**