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1 Background

The Caribbean Regional Association for Ocean Observing (CaRA) and its Stakeholders Council, was formally organized in 2007 with the mission of providing guidance and advice towards the design and implementation of a need-driven coastal observing system in the US Caribbean archipelago: Puerto Rico (PR), the US Virgin Islands (USVI) and Navassa. CaRA's Stakeholders Council and its collective expertise, infused with a region-wide stakeholder need assessment, prompted the establishment of the Caribbean Coastal Ocean Observing System (CariCOOS) to emplace and operate an observing system capable of providing unquestionably high-priority information to sea-goers; agencies responsible for marine and coastal safety; maritime operators, and regional resource managers.

Since inception, CariCOOS was directed to provide data and predictions regarding sea state (wind and waves), currents, storm-surge inundation, and an assessment of impact by land-borne sediments threatening sea grass and reef ecosystems. In addition, CariCOOS has "adopted" data streams and forecasting products from national (i.e. satellite imagery and hydrodynamic models) and regional (e.g. PR Seismic Network sea level gages) sources. Much of CariCOOS growth has been achieved through partnerships in attuned initiatives with the public (i.e. NOAA's Ocean Acidification Program, NOAA-AOML's Hurricane Underwater Gliders Project, CariCOOS-Sea Grant Nearshore Breaker model; NOAA's Coral Reef Conservation Program, CSR-DHS ship detections using HF radar studies, and PR-CZMP storm inundation initiative, among others) and the private sector (e.g. Buckeye LLC-sponsored data for UKC management and port dredging impact). Unprecedented milestones have been achieved towards coastal and marine safety through partnerships with the NWS-SJ-WFO, US Coast Guard, and the PR Emergency Management Agency. Strategically located "upstream" of the continental US, CariCOOS also provides data to "fill the gaps" in national and global observational databases, supporting operational forecasting and research in the hurricane alley and the Caribbean surface current system.

A continuously upgraded subsystem for data acquisition, management, archival and dissemination (CariCOOS DMAC) became a critical vector for information delivery to a wide range of users, while meeting applicable IOOS and existing technical standards. Also, an effort to seize the opportunity to enhance student awareness about our surrounding oceanic backyard resulted in a significant milestone for CariCOOS education and outreach subsystem: the design, construction and publication of a coastal climate module for middle and high school students.

In the following document CariCOOS Inc., now an entity integrating its governance structure with all subsystems, and collaborators, propose to continue its above well-defined trajectory. As a prelude to the activities defining its evolution, CariCOOS Inc. emplaced a thorough need assessment process including direct consultation with critical agencies, industries and sectors. It also issued a request for Expressions of Interest towards identifying potential collaborators to its mission, which also served to identify still unrecognized needs in the region. Based on the above input, and aware of the requirements under the FFO here addressed, the CariCOOS Board of Directors (CBOD) recommended a prioritized approach fully responsive to potential funding scenarios, with the overarching goals of sustaining the existing system and enhancing our observational, modeling, outreach and DMAC efforts, in support of coastal and marine safety, cost-effectiveness of maritime operations and appropriate management of coastal resources. Furthermore, the CBOD has requested that available observations and forecasting products be synthesized into meaningful, user-defined tools. We hereby propose the integration of new and existing data and models into coastal intelligence sources in support safe, efficient, and sustainable decision-making in the US Caribbean archipelago.

Our proposal is organized as follows: a thorough description of goals and objectives for each of the CariCOOS' focus areas and subsystems is given in Section 2. We then describe how we connect with stakeholders in Section 3, and how we plan to achieve our goals and objectives in Section 4. An abbreviated budget and list of milestones are given in Sections 5. Throughout the proposal, superscripts (^{T1,T2,T3}) will indicate the funding level at which specific objectives, products and assets will be carried out based on a prioritization process conducted

Legend: T1 = Tier 1 Funding Level; T2 = Tier 2 Funding Level; T3 = Tier 3 Funding Level

by CariCOOS and the CBOD. T1 refers to components to be carried out under a Tier 1 base funding scenario, corresponding to a $1.7M/year funding level, which is the minimum amount that would allow for effective RA governance, continued operation (but no enhancements) of all ocean observing assets, operational and modest enhancement of the modeling subsystem, and growth of the DMAC and outreach subsystems. An enhanced funding level of $2.5M/yr (Tier 2) would allow for significant growth in modeling and observing capabilities, while a Tier 3 scenario will constitute optimal HF Radar coverage, additional buoy emplacements and biodiversity monitoring.

2 Goals and objectives

Through continuous and enhanced observational and modeling capabilities for the US Caribbean coastal waters, CariCOOS seeks to integrate new and existing data streams into practical tools for information delivery to stakeholders at different levels of ocean literacy and expertise, ranging from everyday commercial fishermen, to beachgoers, researchers, and vessel operators. The goal is to provide comprehensible and accessible coastal intelligence to satisfy user-specific needs, while still serving as the source of reliable and timely ocean data in the region. Specific goals for the next five years of operation are aligned into the following directives:

2.1 Support safe and efficient maritime operations

Since the early ages insular societies have lived on the oceans edge, depending on it for essential functions and services, ranging from transportation and nourishment to recreation. The CariCOOS region is no exception. Here, the shipping and ferry industries represent essential lifelines, providing the main means of food and fuel transportation. Recreational operations and activities, ranging from luxury cruising to individual paddleboarding, constitute a crucial component of the tourism industry and a major economic driver for the region. Often times these services are also accompanied by the risks posed by hazardous winds, waves, currents, storm surge, among many others. Recent technological and scientific advances have made it possible to detect and even predict with reasonable accuracy almost all major threats (and opportunities) presented by the ocean. In CariCOOS our goal is to provide ocean information and decision-support tools to enhance safety and efficiency of the full range of maritime operations taking place in the region. Our specific objectives are:

- To support port and harbor operations, as well as inter-island shipping and cruising operations, by providing observations and models of coastal weather, waves, winds, currents, and water levels.
- To provide recreational operators and users with decision-support tools to aid planning and minimize risk.
- To aid the USCG and other incident response agencies by providing the best available surface current and coastal weather data in support of search & rescue and rapid response operations.

2.2 Minimizing impacts from coastal hazards

The CariCOOS region is constantly threatened by storm surge inundation, strong winds and severe waves resulting from tropical and extratropical storms in the Caribbean and Atlantic. Our complex shelf and coastal morphology, along with the characteristic wave forcing of the region, result in additional coastal threats, accounting for one of the highest per capita drowning rates in the U.S. Furthermore, the recurrent presence of potentially pathogenic organisms in coastal waters and the geological/geographical potential for a tsunami landfall represent unique challenges and opportunities for the region. The goal of this focus area is to support coastal hazard prevention, preparedness, mitigation and adaptation by providing the best available coastal information and decision-support products while continuing to expand the network of platforms and capabilities that provide information on coastal weather, waves, currents, water quality, and storm surge inundation. Our specific objectives include:

- Delivering accurate wave forecasts and decision-support tools to help improve beach safety in the region.
- Collaborating with state and federal agencies to address storm surge hazards in the region.
- Providing data and products to agencies and industry in order to assess regional coastal erosion problems.
- Increase monitoring and develop forecasts to address beach pathogen contamination.

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2.3 Coastal resources: monitoring and management

The archipelagic nature of the CariCOOS region results in a marked dependency on coastal resources vital for the region's well being. Such resources include fisheries, coastal ecosystems, beaches, among many others. Major threats to coastal ecosystems in the region include sedimentation of coral reefs, extreme SST events leading to coral bleaching, ocean acidification and overfishing. Our goal is to provide data products and services to aid coastal managers in their mission of supporting ecosystems' health, fish and coastal water quality. Our specific objectives are:

- To aid coastal decision-making groups by providing data products in support of fisheries management.
- To gather information and develop the understanding required to implement ecological forecasting tools in support of ecosystems health, safe swimming conditions, and rapid response to environmental emergencies.
- To develop early warning systems for Caribbean's vulnerable ecosystems.
- To aid in the conservation of natural coastal resources documenting marine biodiversity.

2.4 Monitoring climate variability

Our goal in this area is to document and report variations in ocean properties attributable to regional and extra-regional climate processes, and which may impact operations and coastal resources, or increase coastal hazards. Our objectives include:

- Contributing information to national data sets through continuous operation of regular observing assets.
- Providing technical and logistic support to large-scale investigations, such as NOAA's ocean acidification and hurricane glider programs.
- Collaborating with the local National Estuarine Research Reserve to gather, analyze, and assess data pertinent to climatic trends and variability thus fully exploiting NOAA's NERRS observing investment in the region.

2.5 Sustain and enhance the CariCOOS observing subsystem

The CariCOOS observing subsystem consists of a network of five ocean data buoys, one directional wave buoy, and one ocean acidification monitoring buoy, the CariCOOS Operational High-Frequency Radar (HFR) Network consisting of four HFR antennas, the CariCOOS Mesonet and Windnet, the CariCOOS Lagrangian Drifter Program, and deep sea gliders, operated in collaboration with NOAA-AOML. The current buoy arrangement was designed taking into account stakeholder needs and is aligned with the National Operational Wave Observation Plan. The goal is to operate an observational subsystem capable of providing timely ocean data and data products in support of coastal intelligence for maritime operations; coastal hazard awareness, prevention, and mitigation; coastal resources management; and climate monitoring. The specific objectives are to:

- Provide point oceanographic observations to relevant users within the US Caribbean Exclusive Economic Zone.
- Provide real-time information of ocean surface currents for the entire EEZ and contiguous waters.
- Provide atmospheric data in support of San Juan NWS-Weather Forecasting Office, assimilation of WMO-Global Telecommunication System, and CariCOOS Weather Research and Forecasting (WRF) Model.
- Provide data in support of HF radar validation, search and rescue, eddy detection, and oil spill response.
- Monitor beach evolution, benthic ecosystems and water quality.

2.6 Maintain and augment the CariCOOS modeling subsystem

CariCOOS currently provides in-house operational forecasts of waves (Simulating WAves Nearshore, SWAN) and winds (WRF), as well as external modeling tools such as AMSEAS and Wave Watch, among others. Our goal is to develop a redundant ocean modeling and prediction subsystem capable of timely and accurate forecasting of ocean conditions. The specific objectives are to:

- Provide accurate and timely wave, wind, and current predictions for the entire EEZ.
- Provide operational water level predictions for strategic locations along the coast.
- Assimilate data into models, as required, to achieve the most accurate results possible.
- Operate, maintain and enhance state of the art high-performance computing facilities.

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2.7 Operate an efficient CariCOOS DMAC subsystem

The wealth of data generated by CariCOOS and its partners require extensive manipulation and quality control in order to achieve the best possible standards of information storage and delivery. The goal of this subsystem is to perform essential steps to create and host user-friendly tools for data browsing and discovery and development of effective core products. The specific objectives are to:

- Perform essential steps that allow provision of data and data products via the web.
- Maintain constant communication with national DMAC efforts and respond to guidance and requirements.

2.8 Support an effective education and outreach subsystem

CariCOOS recognizes that a key component for successful coastal intelligence lies in effective delivery of information. The goals of this subsystem are: to establish effective communication pathways and strategies with stakeholders in order to enhance awareness and encourage appropriate utilization of CariCOOS products and services; evaluate these products and services; and further develop products and services based on stakeholder's needs. The specific objectives are to:

- Outreach effectively to a wide and diverse set of stakeholders through iterative, participatory processes.
- Procure adequate data accessibility to the general public and facilitate informed decision-making and interpretation of data and products via information transfer and stakeholder engagement.
- Aid in shaping the next generation of Caribbean ocean scientists and engineers.

2.9 The effective operation of a governance subsystem

The Caribbean Coastal Ocean Observing System, Inc. (CariCOOS Inc.) is a not-for-profit organization incorporated under the laws of Puerto Rico, and one of eleven Regional Associations (RAs) comprising the coastal component of the U.S. Integrated Ocean Observing System (IOOS). This proposal is submitted by the University of Puerto Rico at Mayaguez (UPRM) on behalf of CariCOOS Inc. The geographical extent of CariCOOS is the coastal zone and the Exclusive Economic Zone in the region of Puerto Rico, the U.S. Virgin Islands and Navassa Island. Consistent with the requirements for a Regional Information Coordinating Entity (RICE) as defined in the ICOOS Act (2009), a status actively pursued by CariCOOS, it has become a distinct observing and modeling system tailored to focus on regional and local priorities as defined by regional managers, government agencies, academia, industry, non-governmental organizations and members of the general public most connected to the coasts and ocean.

CariCOOS will operate under a management structure following a strategic operational plan that will ensure the efficient and effective administration of programs and assets to support observations for integration into the Integrated Coastal and Ocean Observation System. It will work cooperatively with governmental and non-governmental entities at all levels to identify and provide information products of the System for multiple users. CariCOOS will continue providing information about the U.S. Caribbean coastal region for timely use by a diverse range of stakeholders including federal and state agencies, researchers, the maritime sector and recreational sectors, individuals, educators, and others seeking to know current and foreseeable ocean conditions; to understand this coastal environment; to manage ocean coastal resources; and to develop commercial uses of marine resources, data, and information.

3 Connection to stakeholders

CariCOOS constantly assesses user needs from a variety of sectors: In collaboration with Sea Grant and UPRM's Interdisciplinary Center for Coastal Studies, CariCOOS conducted a need assessment survey on stakeholders from the recreational sector to evaluate the reach of CARICOOS products and services; needs met (and not met) by CARICOOS products and services; and preferred methods of communication. UVI-CaRA (now to be VINCOO) also conducted a need/awareness assessment survey for the US Virgin Islands stakeholders. CARICOOS scientists also conduct regular one-on-one assessments with key stakeholders from public (24), private (14), and non-governmental (13) sectors, as well as neighboring nations (3). CariCOOS categorizes these

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sectors as recreational, resource management, SAR-Rapid Response and maritime operations, all identifying waves, currents, and winds as their most pressing data and forecasting needs. Additional data needs include water quality (recreational & resource management sectors) and storm surge maps (resource management). With this information, and approval from the CBOD, CariCOOS established priorities for the next five years of operation and expansion, including but not limited to maintaining the current ocean observing and modeling subsystems; integrating data and predictions into user-oriented products; and improving data dissemination through better visualizations and user-friendly tools.

4 Work plan

4.1 Support safe and efficient maritime operations

In support of planning efforts related to pilot boarding/disembarking, navigation of harbor channels and approaches, docking maneuvers, and incident response, CariCOOS will continue to implement very high-resolution wind (WRF)[T1], wave (SWAN)[T1] and hydrodynamic (FVCOM)[T1] models in several critical ports and approaches across the region and provide customized, user-friendly web products (see the CariCOOS Safe Navigation Tool[T1]) to facilitate decision-making by the maritime sector. The private industry (e.g. Buckeye LLC) has supported a pilot project for UKC and dredging strategy identification. CariCOOS will continue to engage the private shipping industry to meet their data needs.

CariCOOS' recent inclusion into SAR operations has allowed for identification of products and services to be offered towards more efficient and successful operations. Observational data from CariCOOS HF Radars, already being ingested into the USCG EDS, and drifters will continue to inform operations and assess the effectiveness of models available to USCG SAROPS (see letter of support). In fact, CariCOOS will continue to deploy[T1] drifters all across the region in order to validate both CariCOOS circulation models and USCG-SAROPS derived trajectories. We will continue to share this information with the USCG Sector San Juan SAR team, who has agreed to deploy CariCOOS' low cost drifters from their own vessels. CariCOOS will host[T1] a SAR community meeting with the purpose of sharing the assessments of hydrodynamic models in use by them, inform about pertinent enhancements to the observing subsystem, and provide, as appropriate, technical advice towards more efficient SAR operations.

4.2 Minimizing impacts from coastal hazards

Drowning prevention. PR has a strongly seasonal cycle of wave heights and marine conditions that can suddenly change as intense swells arrive. Surf zone currents caused by wave-induced pressure gradients pose a threat to beachgoers at hundreds of beaches across the region. This, added to the fact that more than half of the Puerto Ricans do not swim, plus lifeguards are almost inexistent, account for an average of 25 beach drownings per year. CariCOOS will continue to operate and further enhance the Nearshore Breaker Model[T1] (NBM) that, under the existing cooperative agreement, is being utilized by San Juan NWS WFO as part of their operational Surf Zone Forecast. The NBM, which currently provides breaker forecasts for ~90 beaches in PR/USVI, will be extended to more than two hundred beaches[T1], optimized to output results at twice the temporal frequency, and further validated and refined through field experiments and improvements in the resolution and model physics.

Beach Pathogens. Beach water quality has become a frequent problem for PR and the USVI, to the point of challenging not only the public health but our strong tourist-driven industry. Just within this year, 85% of the beaches sampled by PR state agencies exceeded, at least once, the allowable limits for fecal indicator bacteria (FIB). Furthermore, the current sampling frequency (once every other week) and warning system (communication of unallowable FIB levels after collection of two consecutive positive samples) prevents the current operational system to yield a true representation of the actual state of the site. To assess this pressing need in light of NOAA's Ecological Forecasting Roadmap, we propose to develop the CariCOOS Beach Water Quality Grade System[T1] (BWQGS), a forecasting tool to predict the potential for unallowable bacteria levels in beach water, and therefore assess safe swimming conditions on a daily basis. Inspired by California's Beach Report Card, the proposed tool

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will gather information from probabilistic and deterministic models, as well as in situ sampling to provide beach grades based on forecasted and observed bacteria levels at pilot[T1] and additional[T2,T3] beaches.

Probabilistic models will be developed using EPA's Virtual Beach statistical tools fed with new and existing site-specific meteorological, oceanographic, and FIB data. Due to the available microbiological sampling infrastructure (provided by the CARICOOS-Surfrider Enterococci monitoring program), the proposed beach sites will be located in the west coast of PR. While these data-driven approaches will make use of existing data sources, they will also require new data streams including: increased (2X[T1], 3X[T2]) microbial sampling, rainfall, and stream flow. The deterministic model will assess FIB concentrations at temporal and spatial resolutions finer than those allowed by the probabilistic model. Nearshore hydrodynamics and fate and transport of FIB will be modeled using Delft3D suite of models (FLOW and WAQ) coupled with CariCOOS' SWAN to resolve time and space variations of FIB across and along the beach at a pilot site.

Coastal Intelligence: The CariCOOS Safe Navigation Tool[T1]

This interactive tool will be an integrated marine navigation product to be developed by CariCOOS and Candela Creative Group beginning in year 1 with expected completion by year 2. This tool will allow users to obtain timely and accurate wind and sea state forecasts along their planned navigation routes, using model predictions from the CariCOOS WRF and SWAN operational models. Users will input either waypoints and estimated time of departure and arrival from each waypoint, or waypoints and estimated vessel speed. Besides the ability to design custom routes, the tool will also have pre-computed forecasts for the major navigation routes in the region (PR-Dominican Republic Ferry, St. Thomas-St.Croix ferry, fuel shipping routes, etc., as shown below). Stakeholders to benefit from this product: major shipping companies, recreational and commercial anglers, law enforcement agencies, all boat and ship captains.

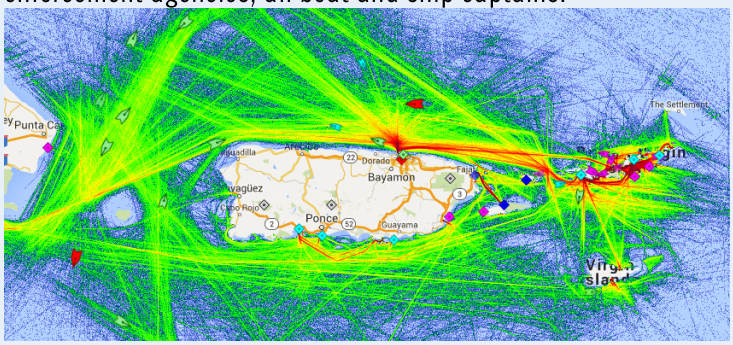

Figure 1. AIS ship traffic density map showing major shipping lanes in the region (source: marinetraffic.com).

CariCOOS will continue to support regular FIB monitoring as part of Surfrider Foundation's volunteer efforts in the northwest[T1] coast of PR, and will expand said initiative to other beaches in the region[T2,T3]. By spatially and temporally expanding the monitoring program, we expect to help identify potential sources of contamination, and assess their nature as point/non-point sources. To address the need for more rapid, continuous, and automatic detection of harmful bacteria levels, CariCOOS will provide support to P. Resto (UPRM), who will develop a prototype of a cost-effective portable in-situ biosensor[T2] using commercially available bio-detection assays, microcontrollers, and Android devices.

Storm surge. In light of NOAA's Storm Surge Roadmap, CariCOOS will collaborate with state/federal agencies to continue addressing the storm surge hazard in the region. The CariCOOS Storm Surge Atlas[T1], delivered in FY14, will be updated to combine storm surge maps with freshwater inundation estimates (FIRM maps) to depict total inundation via a new graphical interface in the new CariCOOS website. Additionally[T3], CariCOOS will undertake an effort to simulate the interaction between freshwater inundation and coastal storm surge in order to provide dynamically consistent water elevations. These maps will continue to be revised periodically through the COMT-SURA project and other efforts, and will be formally shared with state agencies (e.g. PREMA, VITEMA) for long-term and pre-incident planning purposes.

Coastal erosion. Coastal erosion has become a significant threat to the major tourism hubs in the region (San Juan, Rincón, etc.), and CariCOOS will continue to support state and federal agencies dealing with the coastal erosion issue in PR/USVI. Historical CariCOOS wave model data is currently being used to examine the

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hydrodynamic regimes at beaches with the largest erosion rate in Puerto Rico and how these correlate with the observed morphological changes. We also propose a pilot study to evaluate the feasibility of using remotely-sensed video data to monitor shoreline changes at erosion-prone beaches in Puerto Rico[T2]. The system, consisting of 2-3 cameras spanning a 180° view, will allow for full coverage of the selected site, and will provide spatial and temporal coverage of beach morphology previously unavailable in the region. This quasi-real-time monitoring asset will be publicly available through the CariCOOS website, and will provide additional support to other areas of interest such as beachgoer safety, storm damage assessment, and beach water quality.

4.3 Coastal resources: monitoring and management

Fisheries. CariCOOS will continue to aid the fisheries sector in assessing the effectiveness of existing and potentially new Marine Protected Areas (MPA) as sources of fish larvae to reefs in the region. To this end, CariCOOS will continue to document hydrodynamic connectivity using real time data (buoy and HF radars) numerical simulations[T1,T2] using a biophysical model of larval dispersal[T2] to simulate larval flux for coral and fish species at local, management and regional scales (D. Holstein, UVI). CariCOOS will also continue routine Lagrangian drifter deployments[T1] using biodegradable drifters in collaboration with the Caribbean Fisheries Management Council (CFMC) and others. A pilot project under the leadership of R. Appeldorn[T2] will use passive acoustic techniques on an ocean wave glider to locate fish spawning aggregations in waters surrounding PR.

Coastal Intelligence: The CariCOOS Beach App

Providing accessible data to beachgoers: Integration of several nearshore data streams and modeling products will be achieved through the CariCOOS Beach App[T1,T2] (CBA), a beach-specific tool to be developed in collaboration with Candela Creative Group. The CBA will provide site-specific information on wave height (NBN)[T1], water quality (BWQGS)[T1], wind speed and direction (buoy, mesonet & windnet)[T1], water temperature (buoys)[T1], rain forecast (from external sources)[T1], tidal phase[T1], number of beachgoers and beach width (beach cams)[T2], Sargasso coverage, and more. The CBA will also include a crowd-sourced component, which will provide beachgoers with the possibility of uploading photos and describe beach conditions in real time.

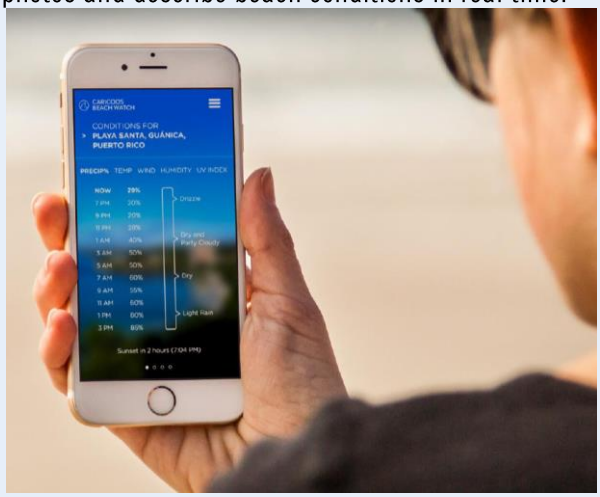

Figure 2. The CariCOOS beach APP.

Ciguatera fish poisoning. Ciguatera Fish Poisoning (CFP) is the most common non-bacterial seafood-related illness worldwide. It is highly prevalent in the US Caribbean, as thousands of people are afflicted annually via the consumption of coral reef fish containing ciguatoxins. Besides the health issue this represents, fisheries efficiency is also severely impacted . CFP results from the benthic dinoflagellate *Gambierdiscus* spp. (GB), which creates gambiertoxins that are ingested by grazing fish, and transformed into ciguatoxins throughout the food web. Ciguatoxins are concentrated in the flesh of commercially important top fish predators. The main reasons responsible for the large geographic variability in ciguatoxin fish concentrations are unclear. Under the leadership of T. Smith from UVI, CariCOOS proposes a pilot project[T2] to examine the hypothesis that coral reefs and hardbottom habitats that are experiencing low turbulence and higher temperatures will have increased populations of GB and therefore a higher amount of contaminated fish. Pending favorable results from the pilot project, high-resolution oceanographic data from CariCOOS model climatology will be used to define habitats

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favorable for GB proliferation and confirm model predictions. The end goal of this effort is to provide stakeholders with predictive maps of potentially high ciguatera risk levels.

Whale tracking. To document sperm whale distribution and abundance within the region, CariCOOS, under the leadership of G. Rodriguez from DNER, will undertake a pilot project[T2] that seeks to describe important sperm whale feeding and mating habitats by acoustically identifying and tracking sperm whales using animal telemetry. This data will be used to build a fluke catalog of sperm whales in the Caribbean, and a database of sperm whale sightings.

Water quality. CariCOOS has addressed the need for assessing the chronicity of sediment loading of reef/sea grass areas through the calibration and use of 5 years of remotely sensed imagery. A suspended sediment database will be derived from MODIS-A & MODIS-T imagery and the assessment will be revised[T1] and published in years 1 & 4.

The threat of elevated near surface SST will be monitored by construction of a graphical application[T1] depicting existing near surface temperature measurements in the region and subsurface anomalies detected by comparing temperature sections collected by the SeaGliders with the WOA 2009 climatology. CariCOOS will support[T1] UVI's efforts to monitor temperature through a thermistor chain mooring off St. Thomas. Derived real time temperature data at depth would be implemented into an early warning system for USVI coral bleaching and the data would also be used to understand more about coral bleaching thresholds and degree heating weeks. Collected data will also allow for detection of oceanographic processes, such as internal waves, affecting the coral reef communities in the USVI.

Coastal Intelligence: The CariCOOS Sargasso Watch[T1]

Big Sargasso events have become the norm in the Caribbean. While providing for convenient fishing spots offshore, excess quantities of Sargasso can become a nuisance to beachgoers and cause fish kills when its decomposition reaches anoxic conditions. The CariCOOS Sargasso Watch will combine satellite imagery, surface currents observations (HF radar) and predictions to generate an integrated product that seeks to locate, define, and predict trajectories of Sargasso patches in the Caribbean.

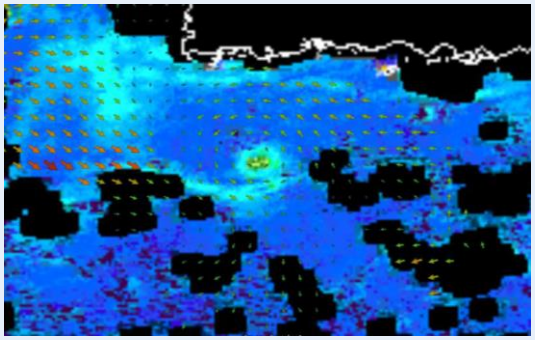

Figure 3. HFR currents over AFAI Sargasso imagery from USF.

Marine Biodiversity Observation Network[T3]: Although services provided by the coral reef-seagrass-mangrove continuum have been well documented, monitoring their state and functions requires an effective approach that yields information on key species critical to the above communities while assessing cross gradient interaction which can provide essential insight into connectivity. To this end, a biodiversity monitoring program is here proposed as a pilot project for the southwest coast of PR. Marine biodiversity will be assessed by a characterization of benthic and pelagic/planktonic communities across a coastal/neritic - oceanic gradient off La Parguera, Lajas, hosting some of the best developed coral reef ecosystems of PR. Replicate transects will be established on five localities targeting the main reef sections of the shelf and shelf-edge. Benthic characterizations will include a qualitative and quantitative assessment of the sessile-benthic, motile-megabenthic and demersal fish communities resident at each reef station across the gradient. Likewise a series of replicate plankton tows will be run 3, 5, 7, 10 and 15 NM from the coastline in order to provide an assessment of the main fish taxa that characterize the waters off La Parguera across a coastal/neritic - oceanic gradient. The resulting database will be available through our DMAC services and periodically revised.

4.4 Monitoring climate variability

Toward understanding the main processes driving and/or buffering ocean acidification in the coral reef-sea grass-mangrove complex ecosystem, CariCOOS will continue operation of the MAPCO2 buoy and related routine

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water sampling/analysis[T1] with funding from NOAA's Coral Reef Monitoring Program. This effort will be paralleled by a CariCOOS-sponsored regional assessment of dissolved and particulate carbon fluxes required for the proper interpretation of the MAP CO2 buoy/discrete water sample data. A project for assessing the spatial variability of the carbonate chemistry of the mangrove – seagrass - reef ecotone will be implemented [T2] for the identification of potential refugia for corals from acidification and potential management approaches to preserve these.

Aware of the potential impacts of ocean climate variability to insular regions, CariCOOS proposes to continue offshore water monitoring efforts through a funding collaboration with NOAA-AOML to operate 2 SEAGLIDER AUVs for monitoring salinity, temperature and dissolved oxygen in the upper 1000m of the Atlantic and Caribbean coasts[T1]. Observations are expected to result in improvement of tropical cyclone intensification and seasonal hurricane forecasts. Moreover, glider observations will serve for documenting the response of the oceanic environment to regional and remote climatic forcing (i.e eddies, SST trends, continental riverine influence).

4.5 Sustain and enhance the CariCOOS observing subsystem

CariCOOS will continue to operate its core observing assets[T1] including: a network of five ocean data buoys, one directional wave buoy, and one ocean acidification monitoring buoy; the CariCOOS HFR Network consisting of four HFR antennas; the CariCOOS Mesonet and Windnet, a network of 16 coastal weather stations, and the CariCOOS Lagrangian Drifter Program. An expansion of the CariCOOS buoy network to the oceanic domain, critical for obtaining full ocean current profiles in support of fisheries and for model assimilation, is also here proposed. In response to stakeholder needs for nearshore surface current observations, in year one the Rincón wave buoy (operated in collaboration with Julie Thomas at CDIP and SCCOOS) will be upgraded[T3] to the new Datawell Waverider DWR4, capable of measuring surface currents.

The recently expanded CariCOOS HFR network is providing real-time observations of coastal and offshore circulation patterns off western and southwestern PR. Responding to stakeholder needs and the National Surface Current Mapping Plan, during the next cycle we expect to install four[T2] (nine[T3]) antennas, and begin assimilation of HFR output[T1] into the CariCOOS-ROMS forecasting system. Given the documented inaccuracy of models currently available via the USCG EDS for SAROPS, the results of this integrated effort will be of precious use to SAR and response operations (see USCG's letter of support). We will also continue to expand the CariCOOS drifter program to further validate and enhance existing hydrodynamic models (AMSEAS, CariCOOS ROMS and CariCOOS FVCOM), as well evaluate SAR tools currently in use within the region. Details are provided in Appendix 1.

CariCOOS will continue collaboration with NOAA-AOML/RSMAS in an IOOS funded collaborative project (Morell Co-PI) entitled "Sustained and Targeted Ocean Observations for Improving Atlantic Tropical Cyclone Intensity and Hurricane Seasonal Forecasts" focused on improving hurricane forecasts utilizing data from SeaGliders[T1]. This initiative is consistent with the IOOS Underwater Glider Network Plan.

In order to better resolve small-scale convective processes resulting in local weather patterns, CariCOOS will support operation and maintenance of the PR Weather Radar Network[T2], an existing system consisting of three Dual-Polarimetric Doppler X-band weather radars located in the west coast of PR. These radars have proven to resolve processes as fine and spontaneous as water sprouts. The information to be gathered will support safe and efficient marine operations, as well as forecasts of beach water quality. Radar output will be served to stakeholders through the new CariCOOS website. This effort will be led by J. Colom from UPRM.

CariCOOS will also support new initiatives on affordable instrument development for water quality observations[T3]. S. Habtes will lead this effort, which seeks to develop the Rainbow Sensor Mooring, a cost effective mooring to monitor dissolved organic matter content, temperature, and ultraviolet light in the water column using Hobo loggers and other low cost technologies.

4.6 Maintain and augment the CariCOOS multi-scale modeling subsystem

With the goal of developing an ocean modeling and prediction subsystem capable of timely and accurate forecasting of ocean conditions, CariCOOS has implemented and validated very high-resolution wave and

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weather models utilized by agencies (e.g. NWS, PREMA, USCG, Fish and Wildlife Service) and operators all across the region.

Wave modeling: The CariCOOS Nearshore Wave Model (CNWM) is a SWAN-based operational wave modeling system, which provides 120-hour forecasts of the nearshore wave climate at 11 nested nearshore grids with spatial resolution raging from 30m to 240m throughout the region. As of August 2015, CariCOOS reached an important milestone: every single meter of inhabited coastline in the US Caribbean is now covered by a very high resolution SWAN grid. Throughout the five year performance period of the present project CariCOOS will continue[T1] to fine tune and validate the model; will improve the wind forcing provided to SWAN; further validate SWAN in the surf zone; and improve model physics as necessary in response to the results from model validation field experiments. The operational implementation of unstructured SWAN will also be explored[T1] and implemented if predictions improve over the structured version currently in use. The CNWM is the numerical engine that provides sea state forecasts seaward of the surfzone to the CariCOOS-Sea Grant Nearshore Breaker Model (NBM) described earlier. The NBM uses empirical relationships for estimating breaker heights using the available wave energy flux (from SWAN) just seaward of the surf zone. CariCOOS will continue[T1] validation of the NBM, including calibration of the empirical relationships being used for breaker height estimation as a function of beach slope, wave parameters, etc. As previously mentioned, the CariCOOS-Sea Grant Nearshore Breaker Model is now fully operational and in use by the general public, municipal emergency management offices in PR and by the San Juan National Weather Service Weather Forecast Office for issuing their beach hazard forecast. CariCOOS will work with Candela Creative to develop[T1] much-improved graphical interfaces to both the CNWM and the NBM.

Circulation modeling: CariCOOS circulation modeling efforts have focused on implementing ROMS for the region at sub-kilometer spatial resolution under the leadership of S. Leonardi from UTD in collaboration with CariCOOS UPRM personnel. Extensive model validation has shown that the model provides an improvement over existing AMSEAS predictions for the region, but has also suggested that model performance could significantly improve with data assimilation given the recent expansion of the CariCOOS HFR network. Over the first three years of the proposed project CariCOOS will work with A. Moore (UCSC)[T1,T2] and H. Arango (Rutgers)[T1] to implement 4D-VAR assimilation techniques into the existing ROMS implemented by Leonardi and CariCOOS. It is expected that the assimilation of satellite, HFR, glider, and buoy data into ROMS will lead to much-improved ocean current predictions in the region. In parallel, an experimental coupled wave, circulation and atmospheric modeling system using ROMS, WRF and SWAN will be developed by Leonardi (UTD)[T2] for PR/USVI. At smaller scales, CariCOOS has recently begun implementation of the Finite Volume Coastal Ocean Model for San Juan Bay. A major focus of the modeling efforts for the next five years is the implementation of very high resolution FVCOM with tide, wind, wave and baroclinic forcing for major critical ports as well as the implementation of a regional FVCOM model as an independent circulation prediction system for comparison with ROMS predictions. CariCOOS will work with Candela Creative to develop[T1] much-improved graphical interfaces to both ROMS and FVCOM.

Water levels and storm surge: Our storm surge modeling program has completed storm surge maps for PR and the USVI, which have been adopted by the PR State Emergency Management Agency and by the USVI emergency management office (VITEMA), respectively. With the aim of improving the accuracy of water level predictions during storm conditions, CariCOOS will embark on a pilot project[T3] similar to the NOAA-funded Coastal and Inland-Flooding Observation and Warning (CI-FLOW) demonstration project in an attempt to combine observations, models and decision support tools to predict total water levels at specific locations.

4.7 Operate an efficient CariCOOS DMAC subsystem

CariCOOS' DMAC subsystem has been developed and implemented over previous funding cycles. It is now fully integrated into the IOOS-DMAC Service Oriented Architecture (SOA), and operating as the Regional Data Assembly Center (DAC). The current operational setup, including locations and physical space, personnel and hardware, as well as standard operating procedures and data end-points, are described in detail in the CariCOOS DMAC SOP. CariCOOS DMAC currently stores and openly distributes data and products through the IOOS

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standards-based Data Access Services. The required enhancement of personnel and technical resources required for adoption of foreseen additional data streams and meeting additional DMAC requirements will be addressed through this proposal.

Our DMAC efforts are principally geared towards: 1) a network of five metocean coastal buoys around PR and the USVI; 2) a network of 15 meteorological stations in PR and the USVI and contributing meteorological station data to the WMO GTS system; 3) managing model outputs (ROMS, WRF, SWAN); and 4) maintaining the flow of data into the Data Access Services and webpage products. CariCOOS DMAC also manages the flow of data from other Federal sources into visualization product endpoints that available through our web portal. These include: 1) data from the ocean acidification effort, including discrete measurements and data from the MAPCO2 buoy; 2) regionally optimized NASA Chla and Kd490 satellite imagery; 3) Jobos Bay National Estuarine Research Reserve climatologies, near-real-time (NRT) data; and 4) coastal zone inundation maps (issued in collaboration with the state the Dept. of Natural and Environmental Resources Coastal Zone Management Program).

By design, DMAC QARTOD procedures and responsibilities are distributed among our data providers. This is currently a contractual condition required from every sub-awardee data provider who supplies CariCOOS with a NRT data stream. CariCOOS DMAC personnel have participated in the communication, distribution, and review process of the various QARTOD manuals; as well as the IOOS-DMAC annual meetings and monthly conference calls. To minimize downtime our THREDDS/OPeNDAP servers are located in physically distant, dual, server locations for duplication and redundancy; our computational server assets (for modeling) are distributed between the two locations. We rely on the IOOS HF Radar and Glider DAC's for the management, initial visualization and archival of CariCOOS HF Radar and Glider data. However, local storage, processing and visualization of HF Radar data from our network of four HF Radar stations serving the west and south coasts of PR are also part of the DMAC data stream.

Responding to CBOD directives, this proposal supports a major investment at the Tier 1 level to generate local expertise, capabilities and data management. We here propose to hire a model specialist, and a specialized contractor (Candela Creative Group) to synthesize and visualize CariCOOS data, which will provide for optimal DMAC functions and future operations. The CariCOOS DMAC subsystem seeks to continue current CariCOOS DMAC and Regional DAC efforts as detailed in the SOP[T1] and to expand into several areas. In addition to non-biological (ATN or MBON) data streams specified at the T3 funding level, we also seek to identify and engage new ATN[T2] and/or MBON[T3] data streams. This effort will follow IOOS guidelines and recommendations set forth in the Strategic Plan and Recommendations for a National Animal Telemetry Network (ATN) and Attaining an Operational Marine Biodiversity Network (MBON) Synthesis Report. Two local fisheries research groups have been identified as potential providers of fish spawning aggregation ATN and are included in this proposal under Tier 2 and Tier 3 scenarios.

The DMAC Team will continue the search for regional data sets that may be included in our DMAC portfolio[T1]. A long-term strategic plan is being developed for the sustained operation of CariCOOS DMAC and the Regional DAC, which takes into consideration personnel changes, equipment replacement due to failure and obsolescence, certification of CariCOOS as a RICE, and new IOOS DMAC directives. CariCOOS entries/holdings/queries in the IOOS Registry and Catalog[T1] will be increased while achieving full compliance with IOOS DMAC metadata, file and data discovery standards and checks. Expertise on various technical subjects, such as state-of the-art programming and scripting languages (or environments), Catalog/Registry issues, data services, etc[T1,T2,T3] will be added into the DMAC subsystem.

4.8 Support an effective education and outreach subsystem

Stakeholder Engagement. Stakeholder needs, communication preferences, and feedback are essential for successful coastal intelligence, and dictate programmatic strategies and operations of the observing system. CariCOOS staff will continue to actively engage stakeholders through recurrent activities including but not limited to: a) Procuring an active presence in pertinent forums, such as Harbor Safety Committees, PR Climate

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Change Council, Caribbean Regional Ocean Partnership, UPR Sea Grant Advisory Board, the Caribbean Landscape Conservation Cooperative, among others; b) Consulting stakeholders via direct communication and interaction at CariCOOS General Assembly meeting; c) Assessing awareness, prioritizing needs, and evaluating product feedback, interpretation and cost-effectiveness through formal surveys; and d) Utilizing the communication and educational strategies mechanisms described below.

CariCOOS has identified the maritime sector, specifically port pilots, and search & rescue authorities as High Engagement Priorities for the upcoming cycle. Port operations are essential to PR and the USVI, as most of the island's goods, fuel, and commodities are imported from elsewhere. Although rare, search and rescue operations cost more $80,000/hour and often times end unsuccessfully. CariCOOS will continue to engage these two sectors, who rely on accurate prediction of surface currents, winds, and waves. The former remains a challenge, and is therefore a programmatic priority for CariCOOS in the upcoming cycle, focusing on accurate modeling of ocean currents and HF radar expansion.

Communications. Providing coastal intelligence is not possible without public awareness, convenient delivery, and effective interpretation of CariCOOS data and products. CariCOOS will continue issuance of quarterly newsletters and its active presence on social media, with the purpose attracting new users and engaging current ones in additional products. Likewise, CariCOOS will continue participating in recreational ocean-related activities (e.g. surfing and SUP contests, fishing tournaments, etc.) to promote safety through the use of CariCOOS products and services. Additionally, CariCOOS will continue to deliver short video clips highlighting products and users.

The new CariCOOS.org[T1]

In response to stakeholder requests for a user-friendly website with improved graphics and products, in FY14 CariCOOS partnered with Candela Creative Group to begin the design of the new CariCOOS website. While this new website is still under development and funded through the current CariCOOS grant, new products and major improvements are scheduled and budgeted for the next five-year performance period. Our new website will be the main tool for delivering coastal intelligence and decision support tools to stakeholders in the region. Final release is expected in December 2015. A sneak preview is available here.

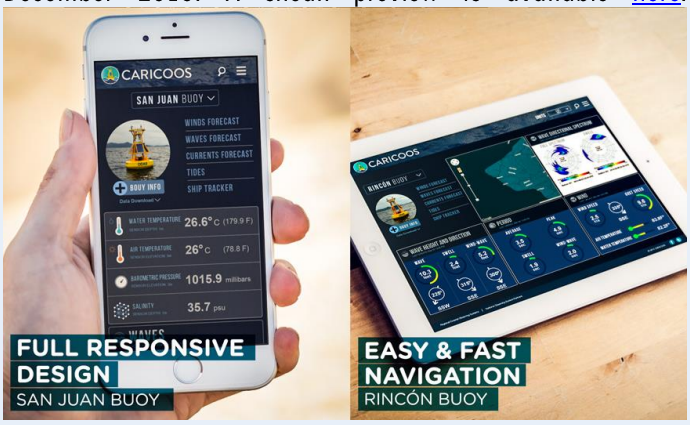

Figure 4. Features of the new CariCOOS.org to be released in Fall 2015 (more details in Appendix 1).

Recognizing the crucial need for timely and accessible delivery of information, CariCOOS has teamed up with Candela Creative Group (CCG) to develop and maintain a new user-friendly webpage (link here) to provide real time data and forecast to users. The new webpage will be fully responsive to fit space restrictions for mobile devices, and will feature new data visualization products and user-defined capabilities (APPENDIX 2). This webpage will be fully translated to Spanish in order to satisfy a need overwhelmingly identified by stakeholders. Additionally, CariCOOS will continue to maintain the Google and iOS apps, and through CCG develop new user-oriented apps (e.g. the Beach App). Further delivery methods will include the CariCOOS FRIGATE BIRD, who will concisely communicate current conditions, new products, and asset status via Twitter and other platforms.

To ensure an accurate and seamless data interpretation, CariCOOS will continue to host general and targeted training workshops for stakeholders and local authorities, from teachers to emergency management agencies, to facilitate interpretation of data and products and obtain essential feedback. Other information

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transfer efforts include internet-based (e.g. YouTube channel) courses on data and product interpretation, and the new data visualization products to be developed in collaboration with CCG.

Education. CariCOOS will continue to operate and update its Outreach and Education webpage (include link); procure an active presence in partnering educational efforts (such as those from Jobos Bay Natural Estuarine Research Reserve, PR Sea Grant program, Marine Technology Society-UPRM Chapter, among others); support a critical mass of outstanding students whose research work become essential parts of CariCOOS' products and services; and host a summer internship program. CariCOOS has also partnered with OCEANICA to include a CARICOOS permanent booth at this interactive educational exhibition located in Plaza Las Americas, the most attended shopping center in the region.

CariCOOS will also feature new educational efforts to promote marine safety, such as the "Out on the Water? Check CARICOOS Before You Go!" pilot program in which CARICOOS tablets will be placed at strategic locations (e.g. beach convenience stores, beach equipment rentals, hotels, etc.) for the general public to access caricoos.org. The goal is to prevent drowning-related deaths by reaching the public that is not yet familiar with CARICOOS, many of which are tourists. Additionally, we will partner with Sea Grant to develop the "Equípate" campaign, which aims at educating the public about affordable ways to aid in their own search and rescue operation in the unfortunately case of a lost-at-sea event (e.g. by bringing streamers that can be easily detected from aircraft).

CariCOOS will continue to sensitize the next generations on current ocean issues, including marine conservation, aquatic safety, and applied ocean sciences and engineering. We will continue to foster higher education and unique research opportunities through UPRM's Center for Applied Ocean Sciences and Engineering (CAOSE), to foster the next critical mass of ocean scientist and engineers. We will also undertake new K12 efforts including: 1) The CariCOOS Drifter Day, a high-school competition in which students design and track their own drifters; 2) The Partnership for Beach Water Quality, a crowd sourcing initiative in which students help collect beach water quality samples to help develop CariCOOS' probabilistic models, while learning about water quality problems and sensitive ways to assess them, and 3) The Track Your Eddy Project, a semester-long project that seeks to involve students in ocean observing while tracking the size, strength, location, and characteristics of nearby eddies.

4.9 The effective operation of a governance subsystem

Need Prioritization. Through the CBOD, we will continue to gather the needs and carefully match them with the capabilities and resources of the CariCOOS enterprise in order to create a cost-effective, successful, and operational observing system for the Caribbean. The CBOD will meet annually to review completed activities and shape future activities to best meet stakeholder requirements in line with available resources. The input received from the broader community will shape priority setting and influence the annual program plans and budgets submitted to IOOS. The mechanism is as follows: CariCOOS will carry out a need assessment via direct consultation with stakeholders, web based surveys, and others. The results will be brought to the CBOD for deliberation and prioritization. Once priorities are established by CariCOOS Inc., the capabilities within the region (and if not available, outside the region) are explored through either an RFP or a call for EOIs. Proposals are scrutinized by the CariCOOS scientific leadership and recommendations issued to the CBOD for approval.

Reporting. The CariCOOS team will continue to evaluate and ensemble mid-year reports from key personnel and subawardees, in order to assess satisfactory progress towards annual milestones. End-of-year reporting will help assess success in achieving yearly milestones. After evaluation of end of year reports, the CariCOOS team, in consultation with the CBOD, will prioritize the work plan and milestones for the next year.

Funding. CariCOOS needs significant, sustained, and consistent annual support to provide for basic operations and allow for successful execution of strategic activities. To date, the IOOS program has provided such support; however, CariCOOS will continue to seek out and obtain funding from partner agencies and

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organizations, while at the same time working with elected officials, federal agency personnel, and members of the IOOS community to sustain and grow support for the IOOS program within the federal budget process. Funding from the private sector will be actively sought.

5 Project budget and milestone list

The base funding level (T1) has been set at ~$1.7M/yr, which is the minimum amount that would allow for effective RA governance, continued operation (but no enhancements) of all ocean observing assets, operational modeling and modest enhancement of these models, and growth of the DMAC and outreach subsystems. An enhanced funding level of $2.5M/yr (Tier 2) would allow for significant growth in modeling capabilities as well as a significant expansion of the CariCOOS HF Radar network (as explicitly required by the USCG). Funding at the Tier 3 level (between $2.5 and $3.8M) would allow for near-full HF Radar coverage of coastal areas in PR/USVI as well as the addition of nearshore and deep water buoys. Project costs for the full five-year period are discussed below following the cost categories included in the main SF 424A form for UPRM, CariCOOS' fiscal agent. Further budget details are included in the table in Appendix 3, the attached SF-424A and budget justification forms.

Personnel: $3.1 M are requested for salary support for UPRM for the CariCOOS Executive Director[T1] (Julio Morell, 0.73FTE), Technical Director[T1] (Miguel Canals, 0.47FTE), Research Coordinator[T1] (Sylvia Rodriguez, 0.22FTE), a WRF modeler (Luis Aponte, 0.22FTE), a numerical modeler[T1] (0.75FTE), an observing system engineer[T1] (0.75FTE), and five additional FTEs: a high performance computing specialist[T1], a webmaster [T1], a marine technician[T1], an outreach coordinator[T1], and an administrative assistant[T1]. Additional support is requested for other UPRM faculty and technical personnel at Tier 2 and 3 funding levels (see appendix 7).

Fringe Benefits: $1M are requested for fringe benefits at the UPRM-established rates (more details in attached documentation). **Travel:** A five-year total of $189k will allow the CariCOOS team participation in IOOS, IOOS Association and CariCOOS Inc. meetings and activities as required by the IOOS office, as well as other scientific conferences and local travel related to field work or stakeholder engagement in the CariCOOS region.

Equipment: $1.97M over 5 years is requested for the purchase of oceanographic and computing equipment to support the operation and enhancement of observing, modeling and DMAC subsystems (see appendix).

Contractual: ~$9M over five years is requested for contracts and subawards. This figure includes subawards to the following institutions: (1) A subaward to the University of Maine (PI Neal Pettigrew) for the maintenance, monitoring and data management[T1] of the real-time CariCOOS Ocean Data buoy network, and construction of additional buoys at the Tier 3 level. (2) A subaward to CariCOOS Inc. (formerly CaRA) totaling $304k/yr will support its development, certification and function as a Regional Information Coordination Entity as defined by the ICOOS Act (2009). (3) A subaward[T1,T2] to Rutgers University (PI Roarty) for their continued collaboration in the deployment and operation of CariCOOS HF Radar system. (4) A subaward to UVI (PI Jobsis)[T1] for the operation and maintenance of UVI-owned observing assets: UVI EpsCOR Buoy A, a thermistor chain mooring, and a Nortek AOS real time current meter in Gregerie Channel. (5) A subaward to Rutgers University (PI Arango)[T1] and a second related subaward to UCSC (PI Andy Moore)[T2] under which the PIs will assist CariCOOS researchers and personnel in the set-up and implementation of ROMS 4D-Var Assimilation within the framework of existing configurations of ROMS for the region. (6) A subaward to University of New Hampshire (PI Salisbury)[T2] for ocean acidification (OA) research at the Atlantic OA Test-bed in Parguera, PR. (7) A subaward to the University of Texas at Dallas (PI Leonardi) for the development of a coupled ocean atmosphere modeling system[T2], consisting of a coupling between ROMS, SWAN and WRF. (8) A subaward to UVI (PIs Smith & Holstein)[T2,T3] to develop a ciguatera predictive model and evaluating coral reef larval connectivity among managed and unmanaged coral reef habitats in the USVI. (8) A subaward to UVI (PI Habtes)[T3], under which the PI seeks to develop a cost effective mooring to monitor organic content, temperature, and UV light in seawater using Hobo loggers, etc.

In addition to the subawards, major contracts include: (1) A contract to WeatherFLow Inc.[T1] for the continued operation, maintenance and access to data from 13 coastal Mesonet stations. (2) A contract to the Virgin Islands Network for Coastal Ocean Observing[T1] to support CariCOOS outreach and education efforts in the USVI. (3) A

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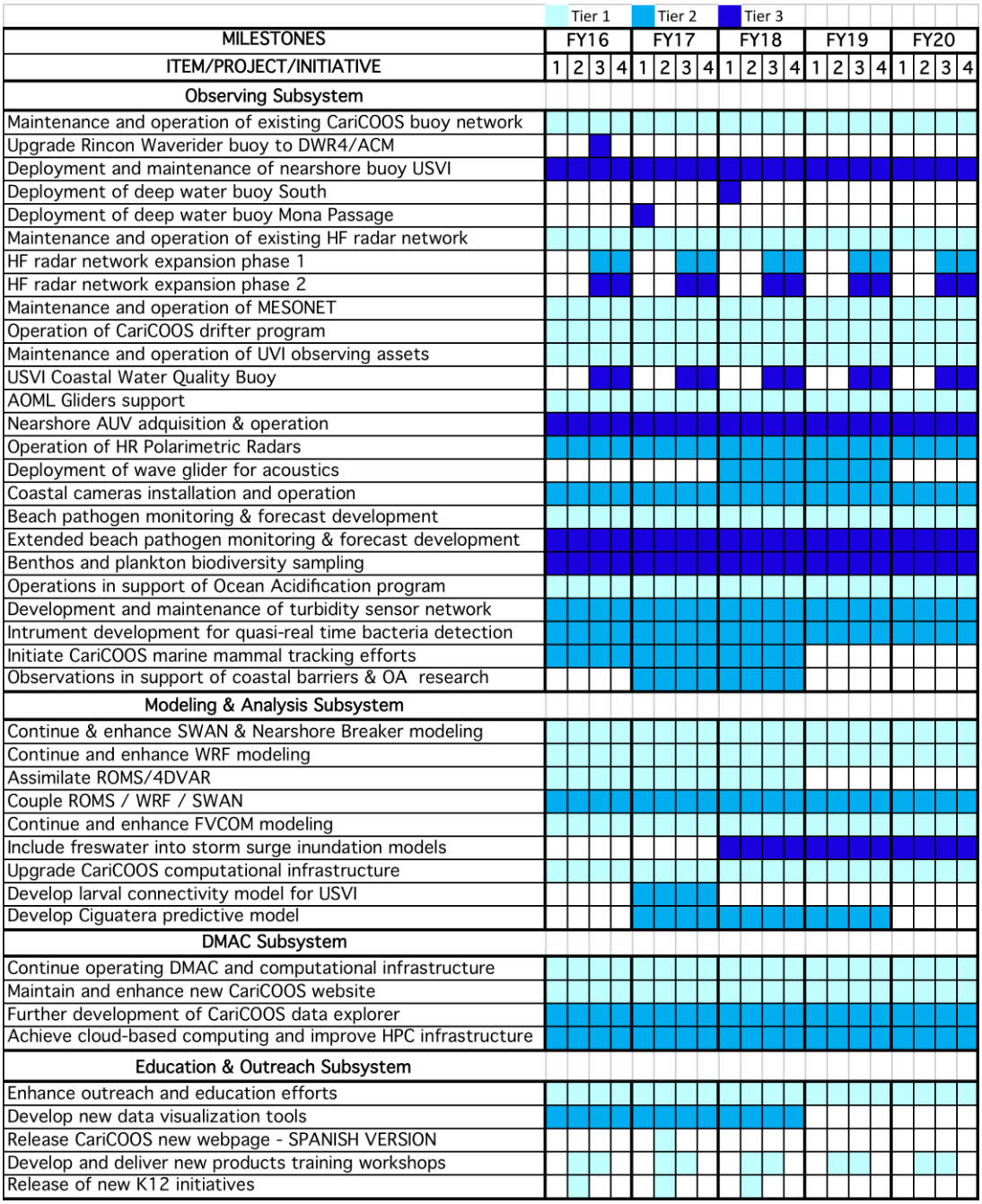
contract to Candela Creative[T1,T2] to maintain and upgrade the new CariCOOS web page, plus an enhancement at the Tier 2 funding scenario for additional web products. (4) A contract to Surfrider Foundation Inc.[T1] to manage a volunteer-based coliform monitoring effort for western PR. (5) A contract to the PR Department of Natural and Environmental Resources[T2] to support a pilot study to determine distribution and migration patterns of Sperm whales off the east coast of PR. (6) A contract to RPS ASA[T2] for the further development and maintenance of the CariCOOS Data Explorer. (7) A contract to private lab for large scale beach pathogen testing[T2] across PR/USVI under tier 2. (8) A contract for Reef Surveys Inc.[T3] for periodic planktonic and benthic monitoring along the oceanic to shelf ecosystem gradient will initiate a biodiversity monitoring in the region.

Other: $102k over five years are requested for tuition support and insurance. **Indirect Costs:** $2.2M in indirect costs are requested at the 26% UPRM off-campus rate.



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