

Progress Report

Advancing the Caribbean Coastal Ocean Observing System

Reporting Period: 12/01/2014 - 5/31/2015

Project title: Advancing the Caribbean Coastal Ocean Observing System

Award number: NA11NOS0120035

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Program Office: NOS Integrated Ocean Observations Systems (IOOS)

Award Period: 06/01/2011 - 05/31/2016

Project Web Site: <http://www.caricoos.org>

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1. Introduction

CariCOOS's development plan offered to meet prioritized stakeholder needs for coastal information through an efficient design minimizing permanent observing assets while developing complementary modeling tools. Its initial implementation phase proved effective in providing coawind, wave and current data products as well as forecasts supporting numerical modeling of these for the Atlantic and Caribbean insular shelves. Additional initiatives included development of a storm surge modeling system as well as remotely sensed water quality products. A Data Management and Communication subsystem, including web based data and product interfaces was also emplaced.

In its second phase, CariCOOS proposed the continued operation of the initial phase and the development of observing, modeling and skill assessment assets and tools required for the shoreward extension of the CariCOOS product domains. Said extension responds to the need for supporting decision-making by specific nearshore dependent activities/sectors such as port and harbor operations (navigation safety and rapid response), recreational activities, as well as coastal hazards and resource management.

Here we report progress toward milestones set for the current program year. CariCOOS has been effective in maintaining operational status of all observing assets including five data buoys, one wave buoy, one Ocean Acidification (OA) monitoring buoy, two HF radars, a 15 Mesonet stations as well as continued operation of current, wave and weather models.

Major milestones accomplished by the modelling subsystem team include 1) extending the high resolution wave model domains so that every single meter of inhabited coastline in the US Caribbean is finally covered by a high-resolution wave model grid within the CariCOOS Nearshore Wave Model; 2) The operational deployment of WRF weather model at 1 km resolution for the region 3) finalization of the Storm Surge Maps (Atlas) for Puerto Rico (PR) ; these along with the maps issued last year for the US Virgin Islands (USVI), provide for appropriate urban development and response planning for the CariCOOS archipelago (excluding the uninhabited Navassa) 4) The CariCOOS-Sea Grant Nearshore Breaker Model is now fully operational and the breaker height predictions are provided to NWS San Juan for use in their rip current risk prediction for PR and the USVI system 5) The first CariCOOS project funded by the private sector (Buckeye Global LLC) for the development of an operational very high resolution wave model for under the keel clearance management in Yabucoa Port is well underway.

The observing subsystem has also been significantly enhanced: The acquisition and deployment of two range HF Radars (CODAR) now provide real time surface current data up to sixty nautical miles offshore the southern coast of PR, a collaborative effort with NOAA's AOML has allowed for the operational deployment of gliders off the

Atlantic and Caribbean coasts and the commencement of a low cost drifter development and release effort is already providing real time Lagrangian surface current observations. Data acquired from these efforts provides an unique and essential insight of this hydrodynamic-rich region and also for the enhancement of numerical modelling initiatives.

The advances reported above have allowed for significant contribution to safety in the nearshore domain by providing decision supporting products for planning and emergency response activities in the region. CariCOOS assistance in SAR includes providing expertise on surface wind and current model interpretation and deployment of low cost drifters in SAR events. Also, CariCOOS storm surge maps and the CariCOOS - Sea Grant Nearshore Breaker Model have become formal response-planning tools of the PR State Emergency Management Office.

Furthermore, the CariCOOS DMAC team has met all requirements set by the IOOS program and continued to diversify their data product offer and distribution alternatives including smartphone apps and social media.

In addition to advances in the technical areas outlined above, this project continues to support the Caribbean Regional Association (CaRA) in its mission. CaRA's Stakeholder Council met on November 2014, identified steps required for certification as a RICE as set forth in the Ocean Observing Act and agreed to incorporate as a nonprofit corporation consistent with of § 501(c)(3) of the United States Internal Revenue Code of 1986 (the "US Code") and §1101.01(a)(2) of the Puerto Rico Internal Revenue Code of 2011. Said recommendations were ratified by CaRA stakeholders during its 2015 General Assembly and CaRA is formally evolving to CariCOOS Inc. while undertaking the required steps for submission of a formal request for certification. The Director's report as well as GA agenda and presentations are available at <http://cara.uprm.edu>.

2. Progress and Accomplishments

Progress toward proposed ***tasks*** and ***milestones*** (in *italics*).

2.1. Observational Subsystem

2.1.1. Operate and maintain the CariCOOS 5 data buoy network including UVI's buoy

The CariCOOS data buoy network was successfully refurbished in April 2015 by University of Maine personnel in collaboration with CariCOOS and Commercial Divers Inc.

2.1.2. Operate and maintain the CariCOOS Rincón Wave Buoy

Like previous years, maintenance of the Rincón Waverider Buoy is scheduled for late June 2015.

2.1.3. Operate and maintain WeatherFlow MESONET and CariCOOS WindNet

All weather stations have been operated and maintained successfully. Recently, the Rincón wind station has suffered from intermittent downtime due to issues with faulty batteries. Batteries were replaced in late May 2015.

2.1.4. Operate and Maintain HF Radar Mona Passage surface current monitoring system

Both of the original HFR sites (FURA & CDDO) have performed satisfactorily during the last year. A new antenna pattern will be performed in June 2015 to improve coverage and data quality for the CDDO site.

2.1.5. Pre-installation activities (acquisition, siting & permitting) and operational deployment of 5 Mhz HF system for the southern coast of PR

A new HF Radar antenna was installed in the Cabo Rojo Lighthouse (FARO) in January 2015. A second antenna was installed in Ponce Yacht Club (PYFC) in March 2015. QA/QC of data from both sites as well as antenna patterns were completed in late May 2015, and data from both new sites should be released to the national HFR network by mid June 2015.

2.1.6. Operation and maintenance of MAP CO₂ buoy and continue discrete sampling program under NOAA's Ocean Acidification program

The MAP CO₂ buoy has been kept in operation albeit suffering impact by an unknown vessel which required an unscheduled retrieval and replacement of the hull. Related routine water sampling/analysis has also continued. Malfunction of the titrator used for alkalinity measurements has required sending samples to UHN for analysis.

2.1.7. Acquire, refit and operate an outboard powered vessel capable of supporting routine nearshore water quality sampling and discrete observing as well as fast response in case of emergencies including search and rescue, pollutant spills or other environmental emergencies

Several candidate vessels were surveyed but none was found to be appropriate given the limited budget. The purchasing of this vessel has been delayed for year 5.

2.1.8. Continued dissemination of remotely sensed water quality products (Chl a, Kd 490) for the region and Eastern Caribbean.

The daily publication of Chl a and Kd 490 imagery, from MODIS and VIIRS space-borne sensors has continued for the benefit of offshore anglers and scientists.

2.1.9. Development of observational techniques for inshore water quality (CDOM, Chl-a and suspended sediments) based in situ CTD/optical measurements and initial implementation of inshore sampling program.

Four stations along the offshore-nearshore gradient in La Parguera Marine Reserve were sampled on a monthly basis. CDOM, Chl a and T&S data confirm the periodical occurrence of negative estuarine condition and the export of high CDOM salty waters from inshore mangrove line canals and lagoon to mid shelf reefs. Further sampling with increased spatial coverage, using a flow thru system, has been scheduled for February 2016. Results from this spatial assessment will provide for the final design of an operational monitoring effort toward understanding and quantifying carbon export from nearshore to shelf ecosystem which may prove to result in heterotrophic events in the latter and drive increased PCO₂ and increased acidification.

2.1.10. Assess the technical feasibility of implementing a beach pathogen forecasting program: revision of existing operational systems in other regions.

Ongoing efforts towards pathogen forecasting in other IOOS regions include probabilistic and coupled hydrodynamic/water quality numerical models. We have

begun exploring the feasibility of developing a predictive model using EPA's Virtual Beach at a local beach. Additionally, conversations between our region and NOAA's Ecological Forecasting Roadmap and NOAA's NCCOS have been initiated.

2.1.11. Deployments and recoveries of 2 SEAGLIDER AUVs for upper water column heat monitoring and water column structure characterization off the Atlantic and Caribbean coasts of Puerto Rico and the Dominican Republic.

Two SeaGliders deployed on February 2015 as part of the NOAA sponsored project “*Sustained and Targeted Ocean Observations for Improving Tropical Cyclone Intensity and Hurricane Seasonal Forecasts*” were retrieved for maintenance and are scheduled for redeployment in July 2015. Further information may be found at <http://www.aoml.noaa.gov/phod/goos/gliders/index.php>

2.1.12. CTD cast at CaTS (bi-monthly) and USVI shelf stations (monthly)

In conjunction with the Rapid Status Assessment of coral (RaStA) program at the UVI-CaRA has completed monthly CTD measurements of 15 monitored coral reefs sites around St. Thomas, USVI. For each site a CTD sensor package is used to collect a full water column cast of variables including conductivity, temperature, pH, depth, turbidity, dissolved oxygen, chlorophyll fluorescence, salinity, and density.

CTD casts at CaTS have been cancelled since water column structure data acquired by SEAGLIDER AUV's (see above) are sufficient to validate the baroclinic structure of 3D circulation models as well as for monitoring for anomalies resulting from remote climate forcing and mesoscale processes.

2.1.13. Acquisition and installation of thermistor array in UVI-EPSCoR buoy

This milestone has been delayed and modified. Rather than including a thermistor array in the existing UVI-EPSCoR buoy, a standalone mooring (with telemetry) will be deployed by UVI in year 5.

2.1.14. Continued engagement of private enterprises in the navigation and energy sector as potential sponsors of observing assets required for their marine operations: follow up existing negotiations

A proposal was funded by Buckeye Global LLC for the development of an operational wave model for Yabucoa Port. A second proposal which contemplates the

deployment of a buoy equipped with a downward looking ADCP is still being evaluated for funding by AES Corporation.

2.1.15. Deployment of Lagrangian drifters (in collaboration with NOAA AOML) as part of ROMS and AMSEAS model validation experiments. Deployments scheduled for August/September and March/April

Fifteen (15) drifters have been released from south and western Puerto Rico and the results have been used for ROMS / AMSEAS validation.

2.1.16. Deployment of an ADCP in West Gregory Channel and related data analysis by UVI personnel in response to a request by Charlotte Amalie (St. Thomas-USVI) harbor pilots who have expressed the need for assistance in identifying intense currents in the channel which hamper safe navigation in the area.

This milestone has been delayed for execution by UVI in year 5.

2.2. Modeling Subsystem

2.2.1. Maintain currently operational high resolution (HR) WRF (weather) and SWAN (wave) model implementations

- WRF: CariCOOS WRF implementations at 1 km and 2 km have remained operational.
- SWAN: All SWAN wave model implementations have remained operational and have been fully duplicated in two separate high-performance computers.

2.2.2. Implementation of very high resolution (VHR) WRF and SWAN model at San Juan, Charlotte Amalie, Guayanilla and Yabucoa

Four new operational SWAN grids have been added in FY14, marking an important milestone: every single meter of inhabited coastline in the US Caribbean is now covered by a very high-resolution SWAN grid. Work on high-resolution WRF grids is ongoing.

2.2.3. Operational deployment and enhancement of CariCOOS - Sea Grant Nearshore Breaker Model

The CariCOOS Sea Grant Nearshore Breaker Model is now fully operational and redundant and available at: http://www.caricoos.org/Nearshore_Breaker_Model/.

2.2.4. Continue the development and validation of regional high-resolution (HR) CariCOOS-ROMS hydrodynamic model and assessment of potential HFR data assimilation schemes

Model validation has continued during FY14 using drifters, HFR and buoy data, and data from ADCP deployments.

2.2.5. Initiate the implementation of a unstructured hydrodynamic model (FVCOM) for nearshore waters

Preliminary FVCOM simulations have been conducted for San Juan Bay, and model validation is ongoing.

2.2.6. Continue development of very high-resolution (VHR) ROMS implementations for critical coastal areas including major ports

Development of nested ROMS domains has been delayed until further validation of the regional scale model is completed.

2.2.7. Finalization of Storm Surge Inundation (SSI) Map Catalog for all hurricane categories

The SSI Map catalogs for Puerto Rico and the USVI have been finished and Google Earth files (kmz) are available through CariCOOS.org. The PR SSI maps have been formally adopted by the P.R. State Emergency and Management Agency (AEMEAD).

2.2.8. Construct and disseminate SSI maps and provide training to pertinent agencies

A training course on the appropriate use of SSI Maps was held at the U. of Puerto Rico, Mayaguez Campus on January 14, 2015 for over 50 state and municipal emergency managers.

2.2.9. Conduct an experimental numerical assessment of the potential role of channelized urban rivers as conduits of storm surge to high-density population areas in Puerto Rico

This milestone was cancelled given the lack of appropriate bathymetric and topographic data of rivers in Puerto Rico. Prof. Aurelio Mercado is seeking external funding to obtain such bathymetry and further explore, via numerical simulations, the role of these rivers in the dynamics of coastal storm surge.

2.2.10. Continued participation in IOOS Coastal and Ocean Modeling Testbed for Puerto Rico and the Virgin Islands.

CariCOOS continues supporting COMT efforts by providing data as well as local expertise to the modelling teams. Also, CariCOOS has provided instrumentation and logistic assistance for short term deployments.

2.2.11. Carry out preliminary bathymetric surveying and hydrodynamic modeling of the San Juan Bay Estuary in support of the Caño Martin Peña dredging project (http://www.dragadomartinpena.org/index_page.html)

Preliminary FVCOM simulations have been conducted for San Juan Bay, and model validation is ongoing. Bathymetric surveys have been delayed until NOAA NGDC completes development of a new 1/9 arc-sec DEM for San Juan.

2.2.12. Carry out a CariCOOS particle tracking drill using ~10-20 GPS-tracked drifters in order to evaluate the performance of existing (NCOM-AMSEAS, RTOHS, HYCOM) and in-development (CariCOS ROMS) circulation models. This drill will also help understand CariCOOS's capabilities of handling such a scenario and help determine which areas must be improved in order for CariCOOS to stand ready to respond to events such as pollutant spills and search and rescue operations.

Experiment will take place in early Fall 2015. However, 15 drifters have already been released from south and western Puerto Rico and the results have been used for ROMS validation.

2.3. DM, Products & Computational Subsystems

2.3.1. Continued development of CariCOOS DMAC subsystem while meeting IOOS requirements

Continued upgrades to our THREDDS/OPenDAP servers, including data set aggregations and improved compliance with IOOS service and data discovery standards. Problem solving through collaboration with fellow DMAC personnel at other RAs has been most fruitful.

2.3.2. Operate and maintain existing CariCOOS data streams, data products and dissemination interfaces

Implemented mirroring of all HF Radar (HFR, CODAR) raw output (4 antennas) at the CID facilities. Processing of HFR antenna radials into total vectors is now conducted locally in one of our DMAC servers. HFR display products have also been enabled locally and are in the parameter optimization and testing phase before being released to the public.

NASA Ocean Color MODIS and VIRRS data are now processed locally and served in our THREDDS/OPeNDAP servers; processed image products are available through our web portal.

Mesonet and Windnet meteo data are also processed locally and served through THREDDS/OPeNDAP.

2.3.3. Development of iPhone smartphone apps

The CariCOOS iPhone App was released to the public at the 2015 General Assembly in March 2015.

2.3.4. Operate, maintain and upgrade computational infrastructure

Storage space has been increased in response to additional demand. Dedicated HPC systems have been acquired for SWAN and WRF model development and execution. An additional HPC server was externally funded in collaboration with the Caribbean Fishery Management Council.

Our internet network is being upgraded by the University of Puerto Rico and through hardware improvements of our Wi-Fi infrastructure.

Improvements have been made to our power supply and backup capabilities at the CID HPC facility.

Computer workstations and software are constantly maintained for use by CariCOOS personnel and student interns.

2.3.5. Develop new specific data products in response to stakeholder needs

Stakeholder needs assessment is being developed by Sea Grant and a survey was conducted during the 2015 General Assembly.

2.3.6. Contracting consultant for upgrading of CariCOOS web pages

Candela Creative Group has been contracted to develop the new CariCOOS website. A final version should be completed by August 2015.

2.4. Outreach and Education Subsystem

2.4.1. Continue O&E formal and informal activities focused on enhancing awareness and appropriate utilization of CariCOOS products and services

Four informational videos were produced by M. Falcón for CariCOOS. These focused on the use of CariCOOS data by diverse sectors including the San Juan NWS WFO Forecasting Office, port pilots and fishers.

2.4.2. Continued assessment of stakeholder/user needs

UPR Sea Grant has conducted a formal need assessment during FY14 with the aim of assisting CariCOOS in shaping the next five year proposal due in August 2015. Results will be provided to CariCOOS in late June 2015.

Needs from the maritime sector have been assessed through formal participation on the PR Harbor Safety and Security Committee Meeting. Also, CariCOOS has been called into the Search and Rescue community and presented with specific data and information needs

2.4.3. Education and outreach activities

- Active participation in the following organizations
 - South Puerto Rico Harbor Safety and Security Committee
 - Puerto Rico Climate Change Council (lead team)
 - Jobos Bay National Estuarine Research Reserve (Advisory Board)
 - Sea Grant Puerto Rico (Advisory Board)
- Collaboration with the following organizations
 - NWS- San Juan WFO
 - PR Emergency Management and Disaster Administration Agency
 - Department of Natural and Environmental Resources Coastal Zone Management Program

2.5. IOOS, CaRA and IOOS Association

2.5.1. Participate in IOOS & IOOS Association activities, meetings and teleconferences

- Julio Morell and Miguel Canals participated in the Director's Meeting held in Boulder, CO August 25-28, 2014
- Prof. Morell and Dr. Sylvia Rodriguez attended the Spring IOOS meeting and the IOOS Association meeting in March 2015.

- CaRA/CariCOOS representative(s) have attended all IOOS monthly calls.

2.5.2. Development and execution of a CaRA/CariCOOS certification plan

- Marichal, Juarbe & Hernandez Inc., attorneys at law are fully engaged in finalizing all documentation required for updating CaRA's governance structure into CariCOOS Inc. as required for certification as a RICE.
- Heather Kerkering is coordinating technical and clerical activities required for CariCOOS certification.

2.5.3. Support CaRA activities and provide legal and administrative support

2.5.3.1. Convene Council Meetings

CaRA's council met on November 23, 2014 to discuss and deliberate on its governance structure and steps required for its formalization as a RICE.

2.5.3.2. Convene yearly General Assembly

CariCOOS held its seventh General Assembly on March 20, 2015 at the Club Náutico de San Juan. The CariCOOS team of investigators, students, and collaborators showcased their work interactively in posters and exhibits at the General Assembly to over 170 stakeholders. Also, the assembly ratified CaRA's Council decision to become an independent NGO and become a 501(c)(3) organization. A report of the Agenda is available at http://cara.uprm.edu/sites/default/files/2015_GA_Directors_Report_1.pdf.

2.6. Subawards

- U. Virgin Islands, Paul Jobsis (PI): The limited progress shown by UVI responds to delays in formalizing the subaward. Unspent funding will be rolled over to the year 5 subaward to UVI.
- U. Texas, Dallas, S. Leonardi (PI): Dr. Leonardi's group has demonstrated satisfactory progress in the implementation of CariCOOS-ROMS ocean modelling program. Unspent funds will be rolled over to the year 5 subaward
- U Maine Physical Oceanography Group, N. Pettigrew (PI): UMPHOG has complied with all requirements detailed in the SA in support of CariCOOS buoy operation and maintenance program.

2.7. Partner projects

- IOOS Coastal and Ocean Modeling Testbed for Puerto Rico and the Virgin Islands (<http://testbed.sura.org/node/522>):
 - Modeling efforts (XBeach) have progressed as scheduled.

- Sustained and Targeted Ocean Observations for Improving Atlantic Tropical Cyclone Intensity and Hurricane Seasonal Forecasts.
 - The deployment/recovery/maintenance cycle has proceeded as proposed
- Model and data based hydrodynamic connectivity study for the marine protected area network off western Puerto Rico:
 - As part of this project, several drifters have been deployed off western PR. This data has been very useful for validation of ROMS and AMEAS models

3. Scope of Work for FY15

The scope of work for FY15 is outlined below, with bullets representing specific milestones for each major project task or CariCOOS subsystem.

3.1. Observing subsystem:

- Operate and maintain the CariCOOS 5 data buoy network including UVI's buoy.
- Operate and maintain the CariCOOS Rincón Wave Buoy
- Operate and maintain WeatherFlow MESONET and CariCOOS WindNet
- Operate and Maintain CariCOOS HF Radar surface current monitoring system
- Enhance the CariCOOS HF Radar network by:
 - moving the FURA antenna to Rincón Lighthouse, if the site is deemed as a feasible HFR location
 - rental of additional HFR unit from Rutgers and installation at site in St. Croix, assuming that a suitable secure location is found there
- Operate and maintain MAP CO₂ buoy and continue discrete sampling program under NOAA's Ocean Acidification program
- Continued dissemination of remotely sensed water quality products for the region
- Deployment of SEAGLIDER AUVs as part of the IOOS NOAA-AOML project entitled *Sustained and Targeted Ocean Observations for Improving Atlantic Tropical Cyclone Intensity and Hurricane Seasonal Forecasts*
- Deployment of Lagrangian drifters, both surface and SVP
- Deployment of side-looking Aquadopp at Port of Charlotte Amalie by UVI personnel

3.2. Modeling subsystem:

- Maintain and enhance operational high resolution WRF (weather) and SWAN (wave) model implementations
- Maintain and enhance the operational CariCOOS - Sea Grant Nearshore Breaker Model
- Continue validation of CariCOOS-ROMS hydrodynamic model
- Continue implementation of FVCOM for San Juan Bay
- Commence FVCOM simulations for Parguera
- Evaluation of EPA's Virtual Beach as a pathogen forecasting tool for public beaches in Puerto Rico. A pilot study will be conducted for beaches in Rincón, PR to assess the feasibility of adopting EPA's Virtual Beach as a statistical tool to develop local predictive models for occurrence of beach pathogens.
- Exploration of the Delft3D suite of models as a potential tool for 3D simulation of nearshore hydrodynamics and water quality
- Implement the WRF-ARW wind model for improved representation of sea breeze dynamics
- Implement WRF wind forcing in SWAN and compare performance vs. NDFD
- Further improve the CariCOOS ROMS by:
 - Securing a technical review of the current CariCOOS implementation by external consultant
 - transitioning ROMS operations from UTD to UPRM
 - beginning 4D-VAR assimilation experiments
- Continued participation in IOOS Coastal and Ocean Modeling Testbed for Puerto Rico and the Virgin Islands

3.3. Data management and dissemination subsystem:

- Continued development of CariCOOS DMAC subsystem while meeting IOOS requirements
- Operate and maintain CariCOOS data streams, data products and dissemination interfaces
- Operate, maintain and upgrade computational infrastructure
- Develop new specific data products in response to stakeholder needs
- Operational deployment of new website
- Historic metadata archival

3.4. Outreach and Education (O&E) subsystem:

- Continue O&E formal and informal activities focused on enhancing awareness and appropriate utilization of CariCOOS products and services
- Continued assessment of stakeholder/user needs
- Continue and enhance communication and consultation between CariCOOS, CaRA, regional programs, IOOS and IOOS Association
- Provide support to CaRA membership and council and provide logistical and administrative support as required for accomplishment of their mission and meeting requirements for certification as a regional information coordination entity (RICE) as defined under the ICOOS Act.
- Training and tutorials for the new website

4. Leadership Personnel and Organizational Structure

M. Canals has assumed the position of CariCOOS Technical Director. Y. Detrés has ceased collaborating with CariCOOS. Outreach and Education responsibilities are now shared by Directors Morell and Canals, CariCOOS Investigator Dr. Sylvia Rodriguez, Mr. Adolfo Gonzalez and student intern Carlos García. Dr. Sylvia Rodriguez from UPRM, who joined CariCOOS during FY14, collaborates with Morell in the CariCOOS nearshore water quality program and leads the CariCOOS pathogen forecasting efforts.

5. Budget

Required modifications to the proposed budget are detailed below:

5.1. Personnel

- Y. Detrés has ceased working for CariCOOS. Outreach and Education responsibilities are now shared by Directors Morell and Canals, Dr. Sylvia Rodriguez, Adolfo Gonzalez and student intern Carlos Garcia

5.2. Subawards

- U. Maine: P.I. N. Pettigrew confirmed expenditure of all allotted funds. Pettigrew's team has, as before, satisfactorily accomplished all proposed tasks. A detailed progress report has been submitted.
- U. of Texas: (P.I. S. Leonardi) Progress towards operational implementation of CariCOOS-ROMS has met expectations as evidence in the detailed progress report submitted. Unspent yr. 4 funds will be rolled over to the yr. 5 subaward.

- U. of the Virgin Islands: (P.I. P. Jobsis) UVI activities were significantly delayed due to a temporal disqualification of the institution as a recipient of federal funds. Unspent funds and corresponding activities are reassigned to year 5.

6. Issues

No issues worth reporting for this performance period.