SUMMARY OF PROPOSED WORK

This is a CREST Partnership Supplement submitted under NSF 18-509

Implementing Unique Sensor Systems to Measure, Visualize and Communicate Urban Water Issues

Overview: The FIU CREST Center for Aquatic Chemistry and Environment (CREST-CAChE) is designed to measure the levels of contaminants in fragile aquatic ecosystems and develop appropriate remediation strategies for them. Specifically, CREST-CAChE is characterizing and quantifying contaminants, measuring their transport and transformations, and modeling their likely impacts on ecosystem services of coastal wetland ecosystems. In 2016 and 2017, we expanded our scope by creating formal partnerships with the recently renewed University of Puerto Rico (UPR) CREST and LTER programs with the specific goal of comparing coastal mangrove ecosystems, creating a student exchange program between UPR and FIU, and investigating the role of contaminants and other pollutants on freshwater, estuary and coral reef ecosystems.

In this Supplement, we seek to **further expand our research and education and public engagement capacity** by exploring our complex ***urban aquatic ecosystems***, visualizing our observations/results, and partnering with local museums and municipalities to translate these results into outreach products for public audiences. We will create interdisciplinary teams of natural scientists, designers, architects, and outreach professionals to design novel instrumentation/sensing platforms to visualize and understand the complexity of water throughout the urban landscape.

Specifically, this supplement will: 1) initiate new, collaborative research projects, which add the dimension of investigating Miami's urban river, canal and stormwater network using innovative scientific instrument design and development; 2) expand our collaborative partnerships to include FIU's School of Communication, Architecture, & the Arts; 3) enable cross-training among students, post-docs, and faculty from disparate disciplines; 4) provide data visualization applications to enhance research discoveries, and 5) create public outreach products with **new local museum and municipal partners:** including the Frost Science Museum in Miami, The Coral Gables Museum, as well as local municipalities in Miami-Dade County.

Intellectual Merit: Advances in remote sensing, data storage and processing, and visualization technologies are enhancing scientists' ability to generate, analyze, and visualize large amounts of data. In addition, the new developments in 3D printing and digital fabrication technologies are creating new possibilities for design, innovation and production of low cost in-house, customized scientific tools. Scientists are now enabled to rethink their tools in ways never imagined before. Our faculty and students at CREST-CAChE will build on these new opportunities to design, prototype, test and develop novel instrumentation platforms in partnership with FIU's architects and designers. Developing new tools to study urban ecosystems is critical as this research is often limited by existing instruments and technology, as well as access and security constraints on data gathering at relevant scales. Specifically, this supplement will initiate new collaborative research projects that enhance investigating Miami's urban river, canal and stormwater network using innovative scientific instruments. This will enable cross-training of students, post-docs, and faculty from disparate disciplines.

Broader Impacts: This Partnership supplement will enhance the broader impacts of the originally proposed CREST Center by adding opportunities for students and faculty to participate in CREST-CAChE community engagement and education activities. The FIU center will also be greatly enhanced by having technological and design expertise from architect designers and community partners. In addition, it will expand our university partners and create public outreach products with new local museum and municipal partners: including the Frost Science Museum in Miami, The Coral Gables Museum, as well as local municipalities in and around Miami-Dade County. FIU is a majority, minority institution that provides unique opportunities and approaches to training and mentoring underrepresented students in STEM careers. Merging interdisciplinary approaches to create convergent discoveries among students and faculty from natural sciences, technological, and design disciplines will provide opportunities for enhanced understanding and improved data collection, visualization, and communication of urban aquatic ecosystems.

CREST Partnership Supplement
Implementing Unique Sensor Systems to Measure, Visualize and Communicate Urban Water Issues

JUSTIFICATION FOR SUPPLEMENT

Background and Purpose: Answers to questions at the frontiers of scientific advances are often limited by existing instruments and technology. This is particularly true in urban ecosystems where access and security pose constraints on data gathering at relevant scales. In urban ecosystems, human activities and their complexity increase with spatiotemporal scales in novel, diverse, and predictable, and often, unpredictable combinations (Kaushal and Belt 2012, Hale et al. 2015, Rose et al. 2017). Although urban ecology has advanced beyond the "urban stream syndrome" (Paul and Meyer 2001, Walsh et al. 2005) that predicts consistent responses or aquatic ecosystems to urbanization, capturing variability to diverse conditions in urban ecosystems remains a 21st Century challenge (Grimm et al. 2008). The SpatioTemporal Anthropogenic Rescaling (STAR) hypothesis predicts how human activities are generating new scaling relationships for ecological patterns and processes by "expanding", "shrinking", "speeding up" and "slowing down" (Rose et al. 2017) in urban ecosystems. New technologies in passive and remote sampling have increased the frequency and detectability of ecological information, but instrument design is rarely custom-built or tailored to specific scientific questions. Bringing together sensing technology, digital fabrication, and design with ecological expertise is critical to advancing studies from understanding the ecology "in" to the ecology "of" urban ecosystems (*sensu* Grimm et al. 2008).

Rationale

Advances in remote sensing, data storage and processing, and visualization technologies are enhancing scientists' ability to generate, analyze, and visualize large amounts of data. In addition, the new developments in 3D printing and digital fabrication technologies are creating new possibilities for design, innovation and production of low cost in-house customized scientific tools. Scientists are now enabled to rethink their tools in ways never imagined before.

FIU's CREST faculty and students have begun research investigations in the greater Miami area, but have encountered numerous site access and equipment deployment challenges in diverse urban ecosystems. Further, how discoveries from this research are communicated has been limited to very discrete sampling events and locations. A greater collaborative and interdisciplinary approach will result in significant cross-fertilization of ideas, approaches, and innovative solutions to measuring, visualizing, and understanding urban ecosystems. This CREST supplement will expand collaborations among the natural sciences (biology, chemistry) and technological and design disciplines, such as architecture, engineering, and computer science, knowledge of Miami's urban river, canal and stormwater network. In addition, fostering new partnerships and outreach to our local museums and municipalities will greatly enhance the distribution of our project findings to the community.

This proposed supplement will further expand the urban water research component of our existing FIU CREST. With this supplement, our CREST-CAChE team will be able to leverage opportunities afforded by new technologies to design, prototype, test and develop novel instrumentation platforms in partnership with FIU's architects and engineers. Developing new tools to study urban ecosystems will be critical as our research has been limited by existing instruments and technology, as well as access and security constraints on data gathering at relevant scales.

With the passing of the Career and Technical Education bill in 2018 (H.R.2353 – Strengthening Career and Technical Education for the 21st Century Act), Architecture is now recognized as a STEM discipline. Thus, we will integrate faculty and students from Architecture and engineering to our CREST Center for Aquatic Chemistry and Environment (CREST-CAChE) and formally begin collaboration with the College's newly formed Robotics and Digital Fabrication lab (RDF) as well as their Integrated Computer Augmented Virtual Environment (I-CAVE). These labs use high-end digital design, industrial and small-scale robotics, digital fabrication, and visualization technologies to support development of new processes, tools and products.

We will leverage the capabilities of RDF (Figure 3) and I-CAVE (Figure 4) to support visualization of large datasets, as well as design, prototyping, testing and manufacturing of low-cost water quality sensors to conduct our research. These facilities will enable us to work on an iterative process of building, testing and

improving the functionality the water quality sensors. We will create maps illustrating ecological interactions throughout Miami's urban river, canal and stormwater network and stream these data to the CREST-CAChE website. This will enable us to detect unique habitats and species interactions throughout Miami in ways that haven't been previously possible to visualize.

In addition, through this supplement, we will develop new outreach and dissemination partnership activities with the community partners documented in the attached letters from the Coral Gables Museum and the Frost Museum of Science. The recent release of County-level reports revealing significant water quality issues correlating with large-scale seagrass die-off in Biscayne Bay has renewed interest in efforts to prioritize remediation efforts. However, the current monitoring networks operated by Miami-Dade Department of Environmental Resource Management (DERM) and NOAA are not sufficient to identify nor prioritize remediation opportunities.

Both the City of Miami and the City of Coral Gables are focusing new water quality efforts towards reducing contaminants in their waterways. FIU already engages with the City of Miami and the City of Coral Gables on water quality monitoring through its Sea Level Solutions Center's programs. This Supplement request will accelerate the transition of science and data to management applications that remediate contaminants entering Biscayne Bay – a win-win for local municipalities, FIU, and other community partners that rely on the Bay for economic growth from strong tourism and property values. Leveraging and expanding to County-level partners, including the collaborations enabled by Miami-Dade County Commissioner Eileen Higgins (letter attached), whose District includes areas of North Miami and Miami Beach, will enable us to consider deployments in areas outside of the Cities of Miami and Coral Gables.

One of the challenges of using sensor networks in urban waterways centers on deployment and the ability to place the arrays in areas where the data are most needed. This presents particular challenges with other operations in the area (boats, etc.) as well as the ability to maintain the equipment *in situ* safely. We are collaborating with our local police departments (see the letter from City of Miami Police Chief Colina in the supplementary documents) to help us deploy and maintain our sensor arrays in heavy boating areas such as the Miami River and associated canals.

<u>Scope</u>: Miami's urban river, canal and stormwater network

Question 1: At what spatiotemporal scales of variability do ecological patterns and processes change in urban aquatic ecosystems and how are they mediated by human influences?

Question 2: How are human activities that "expand", "shrink", "speed up" and/or "slow down" the flows of fresh water contributing to variability in ecological patterns, water quality, and processes throughout Miami's urban river, canal and stormwater network?

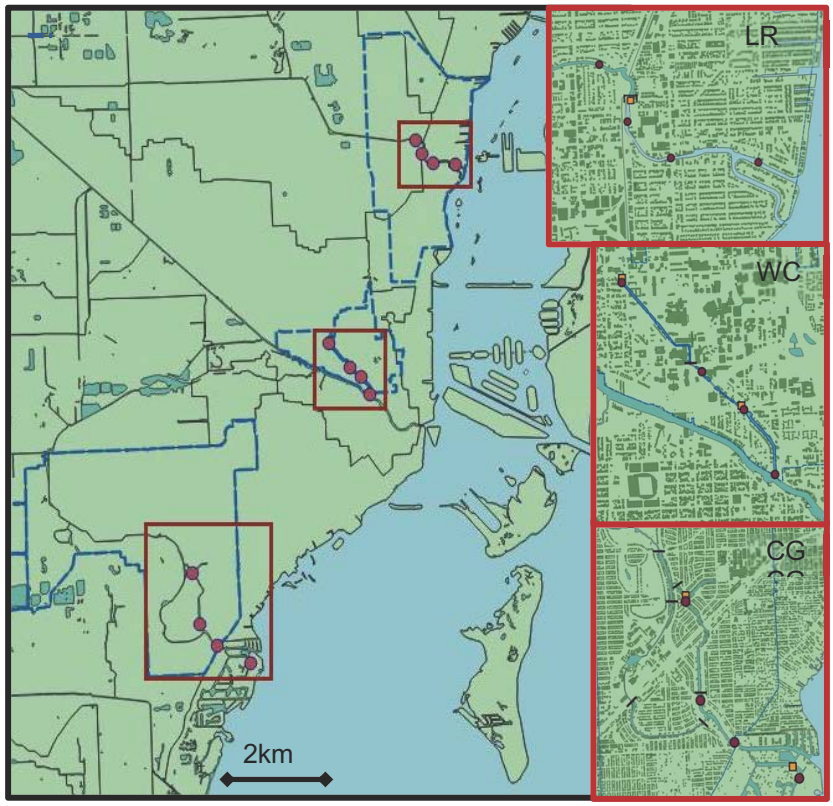

Figure 1. Study locations in three urban drainage basins including Little River (LR), Wagner Creek (WC) and Coral Gables Canal (CG). Dashed blue lines represent spatial extent of sub-basin area and red outline represents study location extent. Existing sampling locations are indicated by red circles.

Approach: We propose three sampling regions that vary in human activity and complexity: Miami River, Little River Canal, Coral Gables Canal (Figure 1). These sites represent different influences of the urban domain, representative of the "stormwater", "domestic wastewater" and "tidal flooding" water source endpoints. We will test how location within the urban river, canal and stormwater network changes the "water pulse" and "water fingerprint".

Water pulses

We will utilize the existing data on water level, water quality, and flow routing from the South Florida Water Management District and Miami-Dade DERM, as well as CREST-CAChE Research Buoys (Figure 2). We will use passive and active acoustic sensors to create localized, high-resolution monitoring of environmental soundscapes and quantify water flow and animal movements within Miami's urban river, canal and stormwater network and compare these to baseline information from open water (Biscayne Bay) and coastal wetland habitats (Everglades). These data will capture variation in habitats, water flow, species interactions, and spatial connectivity. We propose to integrate these sensors into an existing autonomous surface vessel (SeaRobotics) which has been configured to operate in shallow coastal habitats to non-invasively sample these complex habitats.

Figure 2. CREST-CAChE Research Buoys are deployed in freshwater and near-shore marine aquatic ecosystems. Buoys are arrayed with high-tech sensors to collect general water quality data at high sampling frequency.

Water fingerprints

Given a single water sample, and assessing some basic bulk (nutrients, optical properties, contaminants) and discrete parameters (ultra high-resolution mass spectrometry), we may be able to identify water provenance and to preserve additional chemical information to provide future interpretations. We will create

Figure 3. FIU's Robotics and Digital Fabrication Lab is a state-of-the-art facility that includes robotic arms, 3D scanners and printers, laser cutters, and programmable objects.

maps of water quality composition and complexity (fluorescence) as well as source, using established biomarkers of dissolved organic matter from endmembers, such as rain, surface water, groundwater, wastewaters and marine-estuarine water.

Visualizing urban water issues

Engaging partners: Two design charrettes will be held to maximize co-production of the sensor systems design and management approaches for remediation of contaminants. The first charrette will be held at FIU and will focus on sensor system design. Using maps and other information about available data, FIU faculty, students and community partners will identify data collection opportunities. The second series of charrettes will focus on sharing data visualizations and exploring how information from the data collection efforts illustrate potential remediation opportunities.

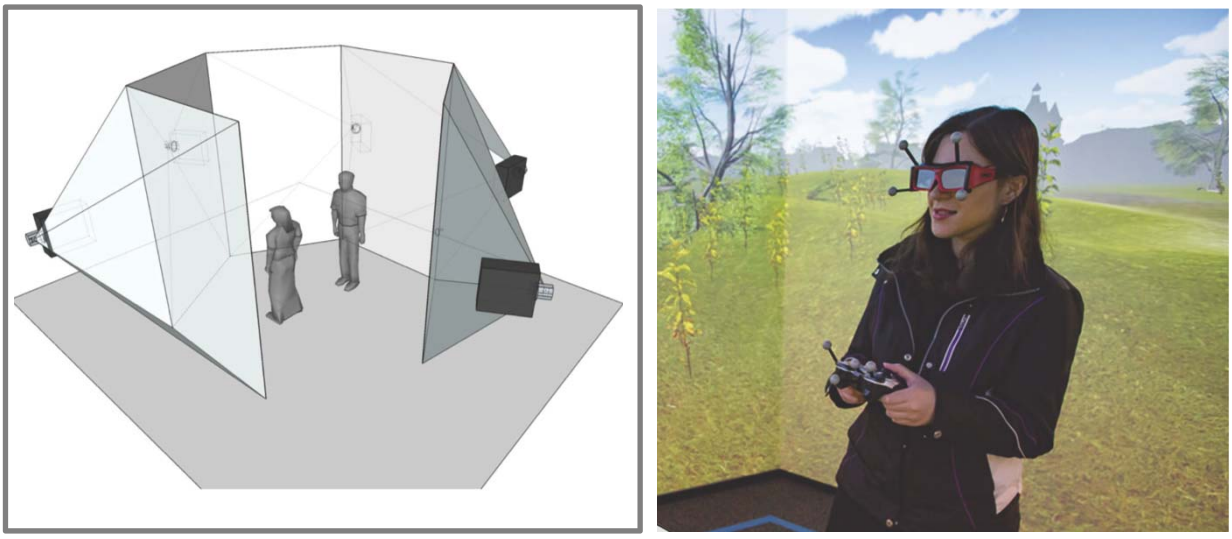

Figure 4. FIU's School of Communication, Architecture & the Arts and College of Engineering and Computing have established the Integrated Computer Virtual Augmented Environment (I-CAVE) to enable the convergence of interdisciplinary data streams through advanced technology and visualization

Proposed 2019 Supplement Management and Activities

The FIU CREST PI (Dr. Todd Crowl) will oversee and coordinate all CREST Center activities. Professors Dr. John Kominoski (ecosystem ecologist), Dr. Shahin Vassigh (architect and urban planner), Dr. Kevin Boswell (marine ecologist and acoustics expert), and Dr. Piero Gardinali (chemist) will coordinate students and faculty in platform design, instrument development, field collection, and data visualization teams. Dr. Tiffany Troxler is the Director of Science for FIU's Sea Level Solutions Center (SLSC) and will coordinate public outreach and engagement with new local museum and municipality partners.

Specific activities include:

1. Identify students and faculty in South Florida that are interested in participating in novel collaborations to explore Miami's urban river, canal and stormwater network.
2. Host a design charrette at FIU with faculty, students and community partners to explore Miami's urban river, canal and stormwater network and map ideas about the types of information we can gather from it.
3. Conduct cross-training workshops where natural scientists, designers, and architects work together to implement the ideas from the charrette; design, development, test, and rebuild instrument platforms.
4. Conduct field sampling trips with students, post-docs, and faculty to deploy instrument platforms and coordinate additional sampling brigades for FIU CREST undergraduate researchers and community partners.

5. Build a 3-dimensional model of Miami's urban canal and stormwater network and project onto it water quality and sensor data streams from the field to visualize differences among urban ecosystems throughout Miami.
6. Host a second set of design charrettes with FIU faculty, students and community partners to explore solutions to water quality management issues using data visualizations produced in a series of events co-hosted by partner organizations.

Broader Impacts

This Partnership supplement will enhance the broader impacts of the originally propose CREST Center by adding opportunities for students and faculty to participate in CREST-CAChE community engagement and education activities. The FIU center will also be greatly enhanced by having technological and design expertise from FIU's School of Communication, Architecture & the Arts and enhanced community outreach and water quality management application through FIU's Sea Level Solution Center. FIU is a majority, minority institution that provides unique opportunities and approaches to training and mentoring underrepresented students in STEM careers. Merging interdisciplinary approaches to create convergent discoveries among students and faculty from natural sciences, technological, and design disciplines will provide opportunities for enhanced understanding and improved data collection, visualization, and communication of urban aquatic ecosystems.

Data Management Plan

Data will be managed in accordance with FIU CREST established data management plans, submitted with our initial NSF proposals.

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http://carta.fiu.edu/roboticslab/

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