SURA's Coastal and Environmental Research Program (CERP): The First 15 Years

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Introduction

SURA's interest and involvement in Coastal and Environmental Research dates back over 15 years to the late 1990s. Over this period, the program has evolved significantly and the program participants have shifted. But from the outset, the centerpiece of SURA's facilitation has remained consistent: *multi-institutional collaborations to enable transformational scientific advances via a distributed community approach that transcends the resources and capabilities of any single institution.* The overarching *scientific goals* that guided SURA's coastal and environmental science pursuits include the following:

Goal 1- Enable discovery of diverse and trans-disciplinary coastal phenomena;
Goal 2- Couple observation and modeling of processes across science domains;
Goal 3- Enable high- resolution studies of multi-scale coastal phenomena;
Goal 4- Advance information and predicting services for basic and applied scientific research and innovative education and outreach.

SURA recognized from the beginning that new understandings that are truly transformational will be followed by new solutions to societal problems *only if* there is effective engagement of and communication among scientists and end users. Over the years, SURA has worked effectively to enable the dialogue that is essential to real interoperability.

Inception-1999-2003: A Vision of the Presidents of SURA's Member Universities

Within the background of SURA's overall mission of advancing collaborative research and education, several of the presidents of SURA's member institutions began, in the late 1990s, to explore new scientific realms, beyond nuclear physics and information technology, where SURA could have a transformational impact and also serve the interests of its members. Since most Southeastern universities are located on or near the coast and most host some level of coastal marine science research and education, coastal research emerged as an attractive candidate for a new thrust.

Over the two-year period from 1999-2001, SURA leaders held discussions with coastal scientists at several SURA member universities seeking a unifying theme that might underpin a multi-institutional SURA program. Over the same period, SURA made investments of its own resources to support a few pilot projects and a series of workshops, the first of which was hosted by NOAA's Coastal Services Center in Charleston, SC. Dr. Margaret Davidson was Director of that facility. Several thematic possibilities were explored initially but eventually abandoned.

Among these was the possibility of support design of a new generation coastal research vessel, deploying fiber optic cable beneath coastal waters to connect oceanographic sensors to shore and acquisition and deployment of innovative sensor arrays. Subsequent to the Charleston workshop, follow up workshops were held at Stennis Space Center and the University of South Florida, St. Petersburg. In the end, it was determined that what made the most sense was to build on SURA's existing strengths: in this case information technology and experience in forging multi-institutional alliances to facilitate collaborative and transformational science.

The central theme that ultimately emerged from the early SURA-sponsored deliberations was, in a very broad sense, promotion of ***a cyber-enabled virtual organization of scientists, data systems, numerical models, and computing resources to advance scientific discovery and support applications.*** The importance of such a program to ensuring the security of East Coast naval facilities against future storm surges and waves motivated Senator John Warner of Virginia, then chair of the Senate Armed Services Committee, to authorize funding within the DoD budget. The appropriation materialized the following year within the Office of Naval Research. Less than one year later, a comparable appropriation was approved within NOAA's budget and was originally administered through Dr. Margaret Davidson's Coastal Services Center. In 2001, the SURA Board of Trustees voted to establish a formal Coastal Research Committee (CRC) and SURA's coastal program was born backed by significant federal funding support. In 2009, the Board approved extension of the committee's role and the name evolved into the Coastal and Environmental Research Committee (CERC).

SURA Coastal and Ocean Observing and Predicting Program (SCOOP)- 2003-2009

In 2003, beginning with funding from the Office of Naval Research (ONR) later supplemented by NOAA, the SURA Coastal Research Committee established a program to develop the supporting cyberinfrastructure (CI) of a prototype *distributed coastal laboratory (DCL)* that had some features of a community modeling test bed. The SURA Coastal Ocean Observing and Prediction (SCOOP) program used a distributed system architecture for predicting and analyzing coastal inundation (Bogden, et. al, 2007). SCOOP leveraged SURA's expertise in IT to demonstrate a revolutionary open-access network of distributed ocean sensors, observations, and computer models for the east coast and Gulf of Mexico. From 2004 until program completion in 2009, SCOOP was directed by Dr. Philip Bogden, who was also the Director of the Gulf of Maine Ocean Observing System (GoMOOS). The late Dr. Joanne Bintz was SCOOP Program Manager. Participating institutions included UAH, UF, USF, VIMS/Wm&M, UNC, TAMU, LSU, BIO (CA) and GoMOOS.

The SCOOP CI supported products and services that included: 1) a coastal data network with over 1000 platforms from 15 different organizations delivering real-time observations with standards-compliant web services, 2) real-time model-data

comparisons for wave and water-level models along the east coast and Gulf of Mexico, 3) retrospective model visualizations of coastal inundation and waves along the East Coast and Gulf of Mexico; 4) direct comparisons of two different modeling running in the Chesapeake Bay, and 5) a prototype decision support tool for predicting coastal storm damage on the coast of Maine. All of these products are supported by distributed system components connected by web services that conform to Open Geospatial Consortium (OGC) standards (OGC 2008). Underpinning SCOOP was a Service Oriented Architecture (SOA) in which a collection of standards-compliant services in the "Service Layer" supported a variety of multi-disciplinary capabilities in the "Science Applications Layer" by connecting them to a common "Resource Layer." Shared resources in this last layer included distributed, Web-accessible data systems, models, sensor networks, and computing resources.

Crucial to SCOOP, and subsequent testbed efforts, were rigorous and generally accepted standards and SCOOP adopted the standards of the Open Geospatial Consortium (OGC). The OGC (http://www.OpenGeospatial.org) played a prominent role in SCOOP for several reasons. First and foremost, the OGC was and is an established consensus standards organization. The OGC is an international consortium of 371 companies, government agencies (including NOAA), and universities that develop publicly available interface standards that make complex spatial information and data services accessible, interoperable and useful with multiple applications. The OGC standards (also known as OpenGIS® standards) are helped to "geo-enable" the Web.

Prior to the formal establishment in 2007, within NOAA, of the Integrated Ocean Observing System (IOOS) Office, the SCOOP program co-led an OGC process known as an "Interoperability Experiment" to create the ocean-data network on the early OpenIOOS website (no longer existent), and to develop open-source software tools on www.OOSTethys.org. The Oceans Interoperability Experiment (Oceans IE) broadened participation beyond those funded by the SCOOP project. Participants in the Oceans IE created, implemented, and tested OGC-compliant services in the Sensor Web Enablement initiative. The NOAA/IOOS Program Office participated in the Oceans IE; when the NOAA National Data Buoy Center (NDBC) and the NOAA National Water Level Observing Network (NWLON) adopted the OGC standards in 2008, their data services instantly integrated into the real-time data network.

Some accomplishment highlights of the SCOOP Program include the following:

- The SCOOP architecture consisted of several component modules that enabled distributed coastal modeling across the southeastern U.S., including the Atlantic and the Gulf of Mexico coasts.
- The model runs were performed on a variety of supercomputers available in a "grid-enabled" network (e.g., SURAgrid).
- The SCOOP program emphasized web-based mapping standards and Geographic Information Systems (GIS) that facilitated the display of high-resolution base layers needed to support SCOOP products.

- A SCOOP Education Virtual Appliance developed by the University of Florida via SCOOP support enabled scientists and non-scientists to better understand the capabilities of SCOOP and to learn about coastal and estuarine science.
- The infrastructure capability to deliver Web Feature Service (WFS) translation services enabled access to the data for automated QA/QC procedures to ensure data quality and reliability.
- The original OpenIOOS web site served as both a community-building tool and a technology demonstration for the ocean observing community.
- The OOSTethys Project evolved as an open-source collaboration that created and adapted tools to help developing observing system components (Bermudez et al, 2006).
- The OGC Interoperability Experiment completed in 2007 provided a wealth of cookbooks and best practices examples that allow widespread community participation in interoperable data sharing of various in-situ observation data for the IOOS.
- The SCOOP Program participants produced over 40 publications, including student theses, book chapters, journal articles, and proceedings.

Coastal and Ocean Modeling Testbed (COMT) 2010-2012

Coastal ocean and estuarine environments along with adjacent shorelines, wetlands and lowlands are threatened by climate change, sea-level rise, storm-induced flooding, oxygen depleted "dead zones", oil spills and unforeseen disasters. Recognizing these threats, particularly in the southeastern U.S., the omnibus spending bill that passed the U.S. Senate in December 2009 included $4.0 M in the NOAA/IOOS budget to support a super regional modeling testbed for the U.S. Atlantic and Gulf Coasts. In anticipation that SURA would lead and facilitate a multi-institutional proposal, an invitation to express interest was sent to all members of the Coastal and Environmental Research Committee (CERC), to previous partners and to other members of the modeling community. SURA staff received positive expressions of interest from over 70 scientists including some the nation's most prominent coastal modelers. A rigorous screening process was conducted and in February, 2010 SURA submitted a proposal to the NOAA IOOS Office entitled: ***A SUPER-REGIONAL TESTBED TO IMPROVE MODELS OF ENVIRONMENTAL PROCESSES ON THE U.S. ATLANTIC AND GULF OF MEXICO COASTS.*** The proposal was successful and the project began officially in June, 2010.

The original NOAA award number was NA10NOS0120063. Dr. Rick Luettich, (UNC-CH) was the principal investigator and Liz Smith (ODU) was project manager. By way of the testbed, SURA facilitated strong and strategic collaborations among experts from academia, federal operational centers and industry and guided the U.S. IOOS Super-Regional Modeling Testbed through its first highly productive phase. Partner institutions in the initial two years included: Applied Science Associates, Inc.; Bedford Institute of Oceanography; Chesapeake Research Consortium; University of Colorado at Boulder; Dalhousie University; Deltares USA, Inc; Florida State University;

Gulf of Maine Research Institute; Louisiana State University; Mississippi State University; Naval Research Laboratory; NOAA IOOS Office; NOAA National Center for Environmental Prediction; NOAA NOS/OCS/CSDL; Old Dominion University; Rutgers University; Texas A&M University; University of Delaware; University of Alabama – Huntsville; University of Florida; University of Massachusetts-Dartmouth; University of Maryland's Center for Environmental Science; University of South Florida, College of Marine Science; The University of North Carolina at Chapel Hill; University of Notre Dame; US Army Corps of Engineers/ Research and Development Center; University of Southern Mississippi; Virginia Institute of Marine Science, College of William & Mary. *Unfunded (pro bono) Federal Participants/Advisors* included: EPA Chesapeake Bay Monitoring Program; US Coast Guard; US Geological Survey; NOAA National Hurricane Center; Naval Oceanographic Office (NAVOCEANO); NASA Jet Propulsion Laboratory.

In June 2008, the U.S. IOOS program office sponsored a Modeling and Analysis Steering Team (MAST) Workshop to identify specific steps to advance the modeling subsystem (Ocean.US, 2008). One of the leading recommendations of the Workshop report was to develop a coastal and ocean modeling testbed to advance joint activities and develop the modeling and analysis strategy of the U.S. IOOS enterprise [Ocean.US, 2008] including standards-based cyberinfrastructure. Prior to COMT, there had been limited success integrating the research and user communities into a coherent, multi-institutional program that targets research and development activities such as systematic model inter-comparisons; model skill assessment; algorithmic/parameterization improvements; model implementation guidance; cyberinfrastructure analytical and visualization tools; data standards; and data archives to aid the development and operational use of these models.

The mission of the Testbed has been *targeted research and development to accelerate the transition of scientific and technical advances from the coastal ocean modeling research community to improved operational ocean products and services.* The long-range vision of the program is *to increase the accuracy, reliability, and scope of the federal suite of operational ocean modeling forecast products to meet the needs of a diverse user community. We consider operational use to cover a wide range of society-critical applications including forecasts, hindcasts (e.g., event based forensic studies), risk assessment, and design and system management (e.g., nutrient management regulations).* The Testbed has served NOAA's mission to protect, restore and manage coastal resources through an ecosystem approach, as well as to improve NOAA's capability to serve society's needs for weather and water information. The initial two years of the COMT addressed three coastal and ocean prediction challenges of great societal importance: ***estuarine hypoxia, shelf hypoxia, and coastal inundation.*** A fourth effort concentrated on providing and refining the ***cyberinfrastructure*** and cyber tools to support the modeling work and to advance interoperability and community access to the COMT archive.

Following its initiation in June, 2010, the IOOS Testbed developed a flexible and extensible community research framework, including a supporting "cyber-

infrastructure" as well as an interdisciplinary network of scientists and stakeholders, to advance the testing and evaluation of predictive models of key coastal ocean environmental issues. This framework supports integration, comparison, scientific analyses and archiving of data and model output. The cyber-infrastructure that has been developed includes a repository of data assembled from numerous observations and models as well as tools for comparing and assessing the models and data. A less tangible product of this Testbed, but one that will have a significant lasting impact, is the community building that resulted from federal and university-based scientists working together on the shared goal of improving model performance. Several models, tools and techniques are now being incorporated into NOAA's operational framework. Both the IOOS Office and the National Center for Environmental Prediction (NCEP) recognized the Testbed to be a valuable National resource. NCEP is the first operational center to become an "anchor" of the Testbed. The Testbed addresses major NCEP modeling challenges in coastal predictions by enabling the transition of research improvements into NCEP's operational forecast capability. In addition to numerous academic partners, Federal participants include agency representation from NOAA, Navy, EPA and the U.S. Army Corp of Engineers (USACE).

The first two years of the COMT (2010 – 2013) culminated in a special issue of the *Journal of Geophysical Research* (JGR)- Oceans. This special section of JGR contains 17 articles from COMT. (A total of 21 manuscripts were submitted and 17 were accepted and published.) The overview article (Luettich et al., 2013) lays out the rationale for the program and provides a summary of the outcomes of the four main facets. The scientific details can be found in the accompanying 16 technical articles. All are at: http://onlinelibrary.wiley.com/10.1002/%28ISSN%292169-9291/specialsection/USTESTBED1.

Coastal and Ocean Modeling Testbed (COMT) 2013-2015

In February 2013, SURA submitted a proposal in response to a recently released *FY2013 IOOS Community Modeling to Support the Coastal and Ocean Modeling Testbed (COMT)* announcement to pursue the next phase of a COMT (Funding Opportunity Number: NOAA-NOS-IOOS-2013-2003511). Dr. Rick Luettich, University of North Carolina, Chapel Hill was the SURA principal investigator. On September 18, we received official notification from the IOOS office that we would be funded at the level of $1M for the beginning September 1, 2013. We solicited, and received, modified budgets and statements of work (SOWs) from the five sub-award principle investigators (listed below). The COMT includes the following projects in addition to SURA management:

1. "**Transitioning an Estuarine Hypoxia Model to Operations via a COMT in the Chesapeake Bay,"** Principal investigator is Marjy Friedrichs (VIMS/Wm & M). Partners include scientists from WHOI, NOAA, UMCES, PNNL.
2. "**The US West Coast Component of the Coastal Ocean Modeling Testbed (COMT)"** Principal investigator is Alex Kuropov (Oregon State University).

Partners include scientists from UW, UCSC, UMaine, NOAA, NAVOCEANO, UCSD, NRL).

3. "**A Puerto Rico/U.S. Virgin Islands surge and wave inundation model testbed,".** Principal investigator is Andre Van der Westhuysen (NOAA/PR). Partners include scientists from UND, UACOE, UPR. NOAA/NWS.
4. "**Seasonal and Short-term Forecast System and Nutrient Load Scenarios for Hypoxia Prediction in the Northern Gulf of Mexico,".** Principal investigator is Katja Fennel (Dalhousie University). Partners include scientists from TAMU, NOAA, NRL
5. "**ASA contribution to the US IOOS Coastal Ocean Modeling Testbed (COMT) – Cyberinfrastructure,"** Principal investigator is Eoin Howlette (ASA). Partners include UACE, NOAA, NAVOCEANO.

The FY 14 NOAA budget included $1.05 M in the IOOS allocation specifically targeted to support continuation of the testbed. Negotiations with NOAA-IOOS for funding through 2015 were completed and a revised Year 2 Budget was submitted on August 27, 2014. The Annual IOOS Coastal and Ocean Modeling Testbed (COMT) Principal Investigator and Partner Meeting was held on August 6-7, 2014 at the NOAA Center for Weather and Climate Prediction in College Park, MD. The meeting was very well attended and the PI reports were excellent and demonstrated impressive progress. Zdenka Willis, the director of IOOS expressed support for SURA and COMT as did other members of the NOAA community. At this writing, the COMT project is just entering its second year and is making excellent progress. Some highlights include:

- A significantly updated COMT website is now available at: http://testbed.sura.org
- The latest COMT Progress Report was submitted on April 10, 2014 for the period September 2013-February 2014: http://testbed.sura.org/node/755
- Several COMT-related papers were given at the April 16-18 NOAA Testbeds and Proving Grounds Workshop: http://testbed.sura.org/node/743
- The 2nd year of COMT funding from the IOOS Program has been distributed and contracts are being updated:
- We expect funding at the ~ $1M level to continue for the next few years without an annual re-compete.

Some Dead Ends

The foregoing sections have described programs that succeeded in obtaining funding and eventually yielded substantive results. However, for each funding success, there were multiple declines. Among these, were proposals submitted to NOAA, NSF, DHS, foundations and the private sector as well as unsuccessful attempts to further advance a *distributed coastal laboratory (DCL)* program, of which SCOOP was a prototype. Although these various submissions involved substantial commitments of time and effort that, on the face of it, led to naught, in reality those efforts were far from wasted. In each case, we were able to pull together teams of scientists that had not

previously attempted to work together. And along the way we expanded our experience in collaborative team building and community engagement.

New Horizons

A new research initiative now being explored by SURA, is engaging a diverse group of scientists, managers and legal scholars with interests in collaborating on an interdisciplinary research agenda to integrate across the natural and social sciences. The aim is to improve the resilience of coastal communities in the face of societal and climate change. The importance of including the social sciences in future environmental forecasting programs was recently emphasized in a special synthesis of the U.S. Globec Program (Haidvogel, et al., 2013, *Oceanography 26(4),* 128-135). The International Geosphere Biosphere Programme (www.igbp.net) has also emphasized the mutual interdependence of human (i.e. socioeconomic) and natural systems (e.g. ecosystems, biophysical and biogeophysical systems), and this will be a paramount concern as IGBP transitions to "Future Earth." We are taking guidance from the IGBP and pursuing a similar set of goals focused, initially on four ***complex coastal systems:*** (1) Chesapeake Bay and Middle Atlantic Bight; (2) West Florida shelf and Tampa Bay; (3) Louisiana Coast and shelf; and (4) the Miami-Dade County urban center of southeast Florida. We consider a ***complex systems*** approach to offer a substantive means of cross-disciplinary integration consistent with the IGBP. The societal issues that we hope to address include not only responses to storm events and attendant *inundation and erosion*, but also long-term degradation of coastal *water quality*, *fisheries and ecosystem services.*

As a first step in launching this initiative, SURA will host a workshop on October 29 &30, 2014 focused on ***Understanding and Modeling Risk and Resilience in Complex Coastal Systems.*** A long-range, overarching outcome that we envision emerging from this initiative is the establishment within SURA of an official organizational framework such as a ***SURA Consortium for Coastal and Environmental Resilience***. Such a consortium (or alliance?) would involve supporting partner membership agreements and would be designed to integrate natural and social sciences and engineering research expertise to understand and respond to complex coastal and environmental problems and opportunities of high societal priority. Central to this undertaking is the task of large data management and the development of data products that enhance environmental prediction and response success.

References Cited

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Appendix: CERC Chairs

Chair	**Institution**	**Years**
Otis Brown	University of Miami	2001-2003
Carolyn Thoroughgood	University of Delaware	2004-2009
Harvey Seim	University of North Carolina	2009-2012
Chris D'Elia	Louisiana State University	2013- 2015
David Shaw	Mississippi State University	2015-Present

SURA-CERC Timeline