

Distributed Coastal Laboratory¹

Need for an IT enabled Distributed System

For the safety and welfare of our nation, its coastal waters must be monitored and their interactions with the ocean, land, and atmosphere must be understood. For this, we propose creating a *Distributed Coastal Laboratory* (DCL) to support research and engineering studies on multi-faceted coastal processes, promote public education and outreach on the importance of coastal phenomena, and facilitate numerous practical applications (including national security). This vision is underpinned by a basic tenet that better science yields better applications, and that the intellectual capacity and leadership for future generations either resides in or passes through our nation's research universities. The vision will be enabled by a robust information technology (IT) infrastructure that links existing resources, owned and operated by a variety of stakeholders, into a whole that is greater than the sum of its parts. It will be the coastal sciences substantiation of a service-oriented architecture (SOA).

The proposed DCL will build upon what is already in place. It must engage government, the academic community, and private sector partners. The DCL will be a system of systems that links and integrates geographically distributed resources by means of the next-generation optical network that the academic community is currently building. Further, it will take full advantage of the evolving regional optical networks (RONs) that are focused on empowering time-and-distance independent research and practical applications. It will be consistent with the coastal ocean component for the Global Earth Observing System of Systems (GEOSS). It will embrace the goals of the U.S. Integrated Ocean Observing System (IOOS; NOAA), the Ocean Research Integrated Observatory Network (ORION; NSF), and the NSF Ocean Observatories Initiative (OOI) that is a component of ORION and numerous regional, state, military, private sector, and international programs. Indeed, the DCL will complement the IOOS, which is driven primarily by societal needs and emphasizes timely decision-making, as well as ORION and the OOI, which are motivated by fundamental scientific questions that target improved predictions of oceanic processes, by taking advantage of what they offer while adding to their reach. .

The DCL will facilitate operational services while enabling transformational research. It should be a shared community resource that blurs unnecessary distinctions between research and practical applications. As we envision a DCL *to support science and engineering, education, and practical applications*, we consider all of these products to be too closely entwined to permit the activities and goals associated with them to be rationally segregated. Science underpins them all. Coordination among multiple programs and uses must involve interoperable strategies for the collection, management, and dissemination of information as well as for education and outreach. The DCL can stimulate and must target integration across initiatives that might otherwise be isolated. It is our expectation that the DCL's suite of integrating technologies and protocols can be exported to other applications that are likewise inherently distributed in their nature. SURA's prototype DCL, which has evolved over the past four years, is SCOOP, the SURA Coastal Ocean Observing and Prediction (SCOOP) Program. While the envisioned DCL will build on SCOOP, it will extend well beyond as a community managed and operated facility for our nation.

¹ Offered by SURA as a logical next step in advancing the SURA Coastal Ocean Observing and Prediction program (SCOOP), which is a prototype DCL, towards a super-regional (aka, national program) with the identified mission, vision and goals.

Vision – Safe and healthy coasts through better science and education

Mission – *For the nation's coasts:*

1. Integrate real-time observing systems;
2. Understand and predict environmental phenomena;
3. Advance information services for safety, security, and commerce.

Goals – *For the proposed DCL:*

1. Enhance and support nationwide capabilities in coastal observing and predicting;
2. Facilitate and manage effective, multi-institutional and interagency partnerships;
3. Design and distribute standards-compliant tools for research and engineering studies;
4. Coordinate the scientific and user communities to set system requirements;
5. Ensure reliability of the evolving systems, offering reliable 24/7 operational support;
6. Build and nurture community support for and involvement in the coastal enterprise;
7. Engage the academic community and support their science and education mission;
8. Facilitate the use of the distributed systems for education and training at all levels;
9. Promote methodologies that are exportable for military and international applications.

What is “A Distributed Coastal Laboratory”?

To advance science as intended, the “Distributed Coastal Laboratory” must be much more than a mere federation of local or regional observatories. Existing and planned coastal observatories are intended to provide high resolution time series of specific parameters within a specified coastal region. These observatories will advance scientific understanding of coastal phenomena that occur in particular coastal regions or estuaries. However, they are typically not intended to elucidate connections among different phenomena, across different regions, or between the coast and the deep sea. In this sense, regional observatories are *not* distributed laboratories. The idea of the Distributed Coastal Laboratory only begins to take shape when information from multiple observatories, observing platforms (i.e. those operated by NOAA, NASA, ONR, USGS, the private sector or universities), and numerical model outputs are integrated and made widely accessible in standardized formats that allow phenomena operating on spatial scales of thousands of kilometers to be described and understood. Doing this successfully lies jointly within the domains of information technology (IT) and cutting edge interdisciplinary coastal science. SURA and its member institutions possess exceptional capability in both domains. The (virtual) distributed laboratory will involve a network of data systems, forecast models, and supercomputers geographically distributed throughout the country. These system components will interact across standardized interfaces in ways analogous to the World Wide Web and will be networked to provide redundancy and reliability. The “Distributed Coastal Laboratory” that SURA envisions will be a national asset that provides timely, high quality information on the shelf, coastal and estuarine realms of the entire U.S. Eastern Seaboard and Gulf of Mexico. The information will no longer be disparate. One system will serve researchers, providers and end users.

Funding Strategy

A robust and diverse funding strategy is essential to accomplishing the missions and goals set out above. The design and pursuit of such a strategy must emerge from, and be supported by, the research community at large. It cannot be the exclusive domain of a single agency, organization, or institution. There are numerous funding sources available for an overarching initiative that plays broadly to the needs of those interested in coastal phenomena. Most programs to date have relied on the federal government for funding. NOAA is envisioned to be the lead agency for Congressional appropriations directed to the IOOS. However, other federal agencies, notably NSF through ORION and OOI, as well as ONR and NASA have made substantial commitments to research-focused, broad-based, ocean observing programs. The USGS stream gauging and shoreline monitoring programs and EPA efforts to monitor coastal and estuarine water quality are all potential data sources for the DCL. Other federal agencies with an interest in coastal waters include Homeland Security (including US Coast Guard). Investments by multiple agencies should be promoted. However, effective coordination, from outside any single agency, is essential to realizing the vision of coastal and ocean data integration and real-time cutting-edge environmental predictions.

While federal agencies remain among the target funding sources for the proposed DCL, other sources of capital must also make significant contributions to its success. Among these are the state governments. Some coastal states (e.g. CA and FL) are already investing heavily in ocean observing and have agencies in place to study and manage their coasts. But these entities recognize a critical need to interconnect and integrate their data sources, models, and analysis with others from across the country. Private non-profit research foundations must also play a role in the funding strategy. Finally and perhaps most uniquely, the for-profit private sector should be expected to provide capital for the growth and ultimate utilization of a DCL. The operational aspects and real-time data from across states and regions will enable those in weather prediction, tourism, fishing, energy (oil and gas), and others to make better, more cost-effective decisions about everything from off-shore platform location to product marketing. Finally, it is important to note that each of these funding sources is envisioned to be additive to the current coastal and ocean funding for individual researchers, their institutions and the regional associations, since the proposed DCL will aim at integration and larger-scale modeling and prediction that will be dependent upon the infrastructure and science already taking place.

Governance

Effective and fully enfranchised governance is essential to realizing the vision of the DCL. The governance structure that is adopted must enable ocean and coastal observing and modeling assets, including those related to IOOS, ORION, regional and state programs, military programs, and private sector activities to be integrated. The governance structure must facilitate and expedite the integration of diverse capabilities and systems while accommodating the needs of a broad spectrum of contributor, investor, and user stakeholders.

We propose a shared governance model led by an independent Board of Directors with representation keyed to programmatic and operational drivers, supported through advisory groups that are representative of stakeholder communities. Further, we recommend that the DCL be seen primarily as a government-supported, contractor-operated utility where the contractor is

an academic-industry partnership team that will be expected to deliver best-in-class science (academe) and best-in-class operations (industry). While effective program management will be critical, so will strong science and its associated education and outreach responsibilities.

This is neither a new nor a novel concept. Many of our Nation's existing laboratories, both single and multi-purpose, operate effectively under a structure of this type. What is new and what will be a major challenge for the DCL, is to establish and manage an effective/efficient distributed laboratory whose support is based on multiple funding sources, and whose programmatic impact requires the integration of diverse facilities and peoples, each with their own mission and culture. So integration, across programmatic elements and between and among diverse populations and stakeholders, will be critical. On the "facilities" side one would typically manage this through "service interfaces" – not demanding sameness of the underlying systems, but allowing for, and even encouraging differences that get resolved when necessary through translation facilities at system interfaces. Likewise with "people", the challenge will be to let what works locally flourish with an expectation that when federated with others the language of choice will be "group speak" with translators to assist those in need of assistance. This is the big challenge; but it is not unlike challenges of the global economy in which we all live. The DCL will be expected to prove a principle of "strength in diversity" within the coastal community.

Supporting Science and Engineering

The Integrated Ocean Observing System (IOOS) is intended to provide timely information to directly address societal needs in areas ranging from monitoring climate change to safe routing of oil tankers to optimal management of our nation's fisheries. The operational requirements for the IOOS have been extensively articulated and are accepted as providing its primary justification. Those requirements overlap significantly with those of the academic research community, which could use the IOOS as a tool to advance coastal science and engineering. However, the research community has additional needs that can be accommodated with the same set of assets provided that the data can be accessed at a higher level of detail. The requirements of interoperability will enable a more productive interplay between research and operations. When IOOS information is combined with that from the myriad other observing and predicting programs, the potential exists for the research community to have open access to unprecedented capability for enabling scientific paradigm shifts and for addressing complex engineering challenges. At the lowest level, scientists and engineers will benefit from having ready and continuous access to synoptic scale background time series information to supplement more intensive regionally-specific field experiments. The science and engineering goals for spatially-distributed coastal information should be to:

- enable identification of spatial scales of coherence of important physical, biological, and biogeochemical ocean and coastal phenomena;
- provide reliable, synchronized and standardized time series of important physical, biological, and biogeochemical ocean and coastal phenomena at spatially distributed sites over the U.S continental shelves and from the deep sea;
- conform to a uniform and accepted set of standards for resolution and data accuracy against which new technologies can be evaluated.

The “geographically distributed coastal laboratory” will enable advances to be made in the following areas (all of which are tightly interconnected to the societal goals of IOOS).

- Coastal and ocean circulation models
- Estuarine mixing and circulation
- Wave and storm surge modeling
- Climate change research
- Marine boundary layer studies
- Predicting harmful algal blooms
- Predicting chemical dispersal
- Water quality modeling
- Ecosystem dynamics
- Multi-species fisheries research
- Predicting and mitigating coastal hypoxia
- Predicting and mitigating coastal land loss

With interoperable systems, the same suites of sensors, models and data systems can support both operational and research-focused users. The data-service requirements of the research community differ in important respects from those of the operational and resource-management communities. Although requirements differ between operational and research services, interoperability can allow various services to be supported by multi-purpose data. For example, whereas operational products and services often involve summary statistics (i.e. hourly averages), research and development to improve environmental prediction and hazard planning or to design more effective coastal protection structures requires access to “raw” data in real time and archived forms. If the underlying data used in developing summary statistics can be accessed, then they can enable computation of higher order, or derivative, quantities such as turbulent mixing, sediment suspension, rates of primary productivity or shallow water wave transformation. In another example, real-time water-level data developed to support ship operations become valuable tools for climate prediction, provided the data archives are documented and readily accessible. Thus, the IOOS national backbone should provide basic information of potential value to all levels of users, including the academic research community.

Supporting Education at All Levels

Web access to data and model output maps will contribute immediately to K-16 education and to outreach activities. It is expected that the DCL will intersect with and directly support COSEE programs. Web-accessible visualization of real-time data and model output will also contribute to public understanding of coastal and estuarine processes. Links to coastal information will also be made through CORE-supported web resources for high school teachers. On a more fundamental level, the stronger interaction between basic research and practical applications enabled by the DCL could entrain a larger fraction of the student population into the world of science.

Increasingly, graduate education and graduate student dissertation research relies on students having online and real time access to information from coastal and ocean observations and model output. In the future, the DCL may allow students to address research questions about

large-scale (1000's of km) phenomena that have hitherto been beyond the reach of conventional approaches.

Supporting Practical Applications

In return for having access to distributed ocean and coastal data and information, the research community is obliged to bridge the gap between global scientific research and applications of relevance to society, and to do so in immediate time frames. It is taken as axiomatic that academia must “give back” by enhancing the system’s operational support functions. These applications include supporting the security of ports and coastal waters, supporting the management of coastal fisheries, providing accurate predictions of coastal inundation and other hazards and, of course supporting the “seven societal goals” of IOOS as articulated by Ocean.US and NOAA:

- Improve safety & efficiency of marine operations
- Mitigate the effects of natural hazards
- Improve predictions of climate change
- Improve predictions of weather
- Improve national and homeland security
- Reduce public health risks
- Protect and restore healthy ecosystems
- Enable the sustained use of marine resources

These goals are inseparable from the science goals specified earlier. Moreover, operational performance metrics for the longer-term goals, such as predicting climate change, cannot be defined without better science and data. The Distributed Coastal Laboratory can enable these goals to be achieved with a higher level of success than would be the case without the envisioned integration. Increased accuracy of real-time models will facilitate planning for extreme events, improve safety and efficiency of maritime operations and search and rescue, increase security from water-borne threats and enhance readiness to respond to unexpected introductions. The Integrated Ocean Observing System (IOOS), though largely justified on the basis of addressing societal needs, must be tightly woven into the fabric of the DCL. Through the involvement of the research community, the IOOS can be an operational system that enables innovation, and is itself capable of innovation.

The Distributed Coastal Laboratory envisioned here can be expected to bring the resulting advances in coastal science directly and immediately to bear on problems of national security by integrating scientific resources and understanding so as to enable rapid and effective response to potential terrorist threats as well as to episodic natural or accidental hazards, such as severe storms, harmful algal blooms, pathogen dispersal or toxic spills. The DCL also has the potential to provide the Navy with a portable suite of sensors, models and informatics techniques for detection, diagnosis, and predictions of manmade and natural water-borne hazards and threats, including intrusions, water-borne pathogens and toxins in ports, bays and littoral waters. The DCL will support development of robust observing and modeling methodologies as well as methodologies for managing and visualizing observed and modeled information.

Performance Metrics

In general terms, credible metrics for DCL performance must involve a fundamental scientific understanding of coastal phenomena that we do not have today, but that we must gain over the course of the program's existence. The integration that the proposed DCL will facilitate among multiple programs will also enable the operational support functions of IOOS to be far more powerful and effective than would ever be possible without DCL. In more specific and immediate terms, the expectations of beneficiaries of the DCL will revolve around having routine access to minimally processed data from spatially distributed locations. Most importantly ***the data must be discoverable, accessible and documented.*** Data from the DCL will be useful to all, provided that they meet these basic requirements for a hierarchy of multi-use services. The definition of data here includes observations and measurements from sensors, as well as any and all products that might result from processing of those data, including the output of numerical model simulations.