

The Southeastern University Research Association Coastal Ocean Observing and Prediction Program: Integrating Marine Science and Information Technology

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Abstract - The Southeastern University Research Association (SURA) Coastal Ocean Observing and Prediction (SCOOP) program includes university, government, and private sector partners working together to implement Information Technology solutions. The SCOOP program goal is a modular and distributed system for predicting and visualizing the coastal response to extreme atmospheric events, including the damaging and catastrophic effects of storm surge, inundation and wind waves. SCOOP program partners are creating the “IT glue” for this interoperable system of systems by modularizing critical components and standardizing the interfaces between the modules. SCOOP emphasizes the transition of “pre-operational” research activities to operational status, and uses the real-time prediction system as an innovative research tool. SCOOP partners are turning environmental measurement and prediction into a community effort and a real-time collaboration between research institutions and operational agencies.

Coastal Ocean Observing and Prediction (SCOOP) program. The SCOOP program is developing community information services and technologies to advance the sciences of environmental prediction and hazard planning for our nation’s coasts. To achieve this vision, the first step is to help integrate the diverse data flows from a variety of ongoing efforts in coastal ocean observing. The second step is to incorporate these data flows into an open-access, scalable, modular and distributed real-time environmental prediction system.

To this end, coastal and computer scientists at seven SURA universities have partnered within the SCOOP program to create the “SCOOP Grid.” The SCOOP Grid will be a “virtual organization” that supports both research and applications, and enables an ever broader community of scientists to address the coastal science and computer science issues involved in real-time prediction. SCOOP is enabling a community modeling approach, as distinct from developing or applying a single community model. The SCOOP program will build from a variety of existing modeling activities to allow communities of scientists to share the tools, resources, and ideas necessary to pursue new knowledge and to support practical applications. The

INTRODUCTION

The most recent major initiative at the Southeastern Universities Research Association (SURA) is the SURA

interfaces that interconnect the modules will support a broad array of uses and users.

SCOOP program goals align with the broad recommendations of the U. S. Commission on Ocean Policy for an Integrated Ocean Observing System (IOOS) and will support implementation of the President's associated U.S. Ocean Action Plan. The IOOS will involve ongoing partnerships between Federal agencies, the private sector, and the research community. The SCOOP design criteria – modular and scalable systems interconnected with standardized interfaces – will support effective integration of the research community in this partnership. In this sense, SURA is applying the design and development principals that underlie the World Wide Web to create a system that will facilitate the transition of new ideas and new technologies from research to operations.

The SCOOP Grid architecture will support a new paradigm to improve prediction of the coastal ocean's response to storms and hurricanes. The sensitivities and nonlinearities of environmental dynamics make environmental prediction a problem in probability and statistics. Thus, rather than focus solely on producing the single best prediction, early versions of the SCOOP Grid will enable prediction of an ensemble of plausible outcomes based on the best available information. The approach, which is relatively widely used in meteorology, is called ensemble modeling. The enormous technical challenges involved in developing a real-time, ensemble prediction system present formidable barriers to studying these problems. Moreover, many of the challenges fall outside the realm of coastal science, and are best addressed by experts in computer science. A successful SCOOP Grid will empower a broad community of researchers with the requisite tools to advance the science of prediction. It will also support federal and private-sector partners charged with producing operational forecasts, with the ultimate goal of serving the general public that needs advanced warning of hazardous events.

This paper introduces the SCOOP program elements and describes their relationship to the U.S. plans for an integrated ocean observing system.

BACKGROUND

National and international efforts are underway to create the Global Earth Observing System of Systems (GEOSS), of which the IOOS will be the ocean component. SCOOP is focusing on the coastal component of the IOOS. The vision for U.S. coasts involves a national backbone of observations augmented by a federation of linked regional systems. Regional systems will augment the national backbone by contributing data and information optimized to address regional priorities. Integrating the regional and national systems into a single "system of systems" will provide a seamless tapestry of observations and predictions of marine events.

To help achieve this vision, SCOOP is leveraging SURA's experience at representing over 60 of the top U.S. universities in major community science initiatives. The first such initiative, launched over 20 years ago, has given rise to the Thomas Jefferson National Accelerator Facility (JLab). SURA subsequently established leadership in Information Technology (IT) by creating SURAnet, one of the first non-military Internets in the U.S. SURA universities contain the expertise, innovation potential, and research and development (R&D) capacity to achieve SCOOP goals. The Southern Governors' Association (SGA) produced a formal resolution in support of SURA and SCOOP in "the creation of an open-access network of distributed sensors, linked via an ultra-fast network to state-of-the-art computing systems that track and model the southeastern coastal zone in real time and provide components of a more comprehensive coastal security infrastructure."

The Office of Naval Research (ONR) provided funding to SURA with an assurance that any capabilities developed by SCOOP will not be limited to the southeast, but will support the goals for a national system. SCOOP is intended to complement and support the local and sub-regional efforts and will not duplicate, replace or subsume any existing or planned initiatives. The program is currently funded jointly by the ONR and the National Oceanic and Atmospheric Administration (NOAA) through its Coastal Services Center, Coastal Observation Technology System (COTS) program.

SCOOP PROGRAM ELEMENTS

The SCOOP program will achieve its goals for environmental prediction by creating the SCOOP Grid, which will leverage other SURA initiatives, notably in IT. Grid implementations generalize the same concepts of interoperability that underlie the World Wide Web (WWW). However, whereas the WWW comprises a network of shared text and images, Grids comprise a network of shared resources of all kinds, including computing power, databases, instruments, applications, storage, and more. The challenges to creating a grid are both technical and cultural; grid technologies will only help a community that is already interoperable with itself. Grid middleware, such as the Globus toolkit (www.globus.org) are commonly associated with grid applications, but they provide only part of the solution. The ability to apply these technologies effectively relies upon the community agreements for information exchange. Such challenges prompted SURA to take an incremental approach with four sub initiatives working in parallel to make progress on (1) data-access standards, (2) a data Grid demo (3) a model Grid demo, and (4) community building, education, and outreach. The eventual merging of these initiatives will give rise to the SCOOP Grid.

A. DATA-ACCESS STANDARDS

As clearly demonstrated by the WWW, standards enable innovation. The Web relies largely on two key standards, namely, the HyperText Markup Language (HTML) for organizing data (text and images), and the Hypertext Transfer Protocol (HTTP) for exchanging those data. The relatively complex resource sharing involved in grid applications brings correspondingly complex requirements for standardization. In this sense, the standards provide the language of interoperability.

The SCOOP program relies on existing standards whenever possible; developing internal standards only when absolutely necessary. This philosophy is consistent with that expressed by the Ocean.US Data Management and Communications (DMAC) Steering Team, in their guidance document, available on the Ocean.US website at: <http://dmac.ocean.us/dacsc/guidance02.jsp>. The general approach taken within SCOOP is to first develop a set of service requirements and then design an appropriate subsystem and/or service interface. For example, under the leadership of the University of Alabama at Huntsville (UAH) and Texas A&M University (TAMU), SCOOP partners are creating the SCOOP catalog as a subsystem that provides program-wide descriptions of available data collections, archives, models, and their output. The catalog itself is a relational database containing extensive metadata descriptions of the variety of data collections, data sources, community models and archives that exist within the overall program. One of the planned Catalog services includes publication of Federal Geographic Data Committee (FGDC) compliant metadata records to national clearinghouses. The catalog will also support coordination between web portals, distributed archives, various modeling activities, and more.

The SCOOP program relies on distributed data systems at other programs and agencies, and the SCOOP partners are working on mechanisms to facilitate the crosswalk between the wide variety of existing standards. Toward this goal, the SCOOP program is supporting the Marine Metadata Interoperability (MMI) initiative (<http://www.marinemetadata.org>). TAMU, UAH and Woods Hole Oceanographic Institution (WHOI) and the Gulf of Maine Ocean Observing System (GoMOOS) are actively participating on the MMI Steering Team and related activities, which include workshops, demos and outreach efforts.

To facilitate data transport and access, the SCOOP program is deploying a variety of standard Web services and related technologies. Interfaces between various system modules are being created with the Simple Object Access Protocol (SOAP) and other W3C-compliant standards based on the eXtensible Markup Language (XML). To accommodate real-time data-flow requirements for prediction, SCOOP partners are testing an altogether different data-push technology with the Local Data Manager (LDM) software developed by Unidata. The LDM is in operational use for similar purposes by the National Weather Service.

B. THE SCOOP DATA GRID

The SCOOP data grid initiative began with a proof-of-concept demonstration of data aggregation and visualization using Web service specifications from the Open Geospatial Consortium (OGC) called OpenIoos.org (<http://openioos.org>). These W3C-compliant Web service specifications define an interface with all the metadata necessary to support distributed Web-based mapping capabilities of Geographic Information Systems (GIS), including things like spatial extents and geographic projections.

At first sight, the OpenIOOS web site looks a lot like other Web-mapping sites. However, it is a proof of concept for some rather remarkable aspects that occur behind the scenes. First, the underlying data systems are fully distributed. Over a dozen organizations contribute real-time and historical data to OpenIOOS, with all the data residing at those organizations. The OpenIOOS creates aggregated data maps by connecting to the data hosts via OGC-compliant Web service interfaces. The interface specifies the information necessary to make the aggregated data maps, and most of the communications occur on demand by the users of the OpenIOOS web site. The OpenIOOS site does have a relational database that acts as a real-time cache, but this is really only designed only to improve performance of some of the OpenIOOS web-based GIS mapping tools.

Another remarkable aspect of the demonstration is the ease with which the first implementation took place, despite the variety of software platforms and data management systems in place at the data contributors. The first implementation in the fall of 2003 occurred in less than a month and involved the SouthEast Atlantic Coastal Ocean Observing System (SEACOOS) and GoMOOS. More recent upgrades to the OpenIOOS site allow users to access a retrospective of 2004 hurricanes as well as real-time observations from the 2005 hurricane season. Data for the retrospective are currently provided by NOAA (via the National Hurricane Center, National Ocean Service, National Data Buoy Center, Hurricane Research); the U.S. Geological Survey (USGS) (winds and Waterwatch); the National Aeronautics and Space Administration (NASA) (satellites and JPL); GoMOOS, SEACOOS, the New York Harbor Observing and Prediction System (NYHOPS), TAMU (Mesonet Weather Radar), and the Navy (ONR/CBLAST). Many of these partners had no previous experience implementing OGC-compliant services; yet, after as little as three months of part-time effort, over a dozen partners were contributing satellite imagery and *in situ* observations to a single coordinated display. The data systems that became interoperable ranged from expensive and sophisticated legacy GIS to free and open-source academic systems, all communicating across the OGC-compliant interface.

The community initiative has grown and is currently known as the OpenIOOS Interoperability Test-bed, which involves a growing number of contributors. Planned upgrades to the demonstration will add new data layers and more sophisticated search and query capabilities. It will

leverage progress on metadata and data access, with the ultimate goal of showcasing regional priorities in ocean observing as part of a national effort.

In general, there are huge benefits to standardizing interfaces. In the context of OGC-compliant interfaces, the approach makes sense because more and more state and federal agencies are serving their GIS data sets to the Web via OGC specifications. This means that OpenIOOS.org and other sites can instantly leverage the enormous repositories of geospatial framework data residing in legacy government data systems, while they spend relatively large efforts focusing on incorporating data from the growing number of cutting-edge ocean observing systems. The practical benefits will be realized when client interfaces are implemented on decision support tools that use GIS. In anticipation of such practical applications, the SCOOP prediction systems will include OGC-compliant interfaces.

C. THE SCOOP MODEL GRID

The concept of standardizing interfaces has other benefits that extend into the design criteria for the SCOOP model grid. The SCOOP Model Grid initiative is focused on developing a modular, scalable system to enable prediction and visualization of coastal response to storms and hurricanes. The early emphasis is on real-time prediction of wind-waves and storm surge. The focus on defining and standardizing interfaces cannot be overemphasized. SCOOP partners engaged in the components of the creating the model grid (Table 1) believe that this approach will not only enable efficient communication between the various modules of the overall prediction system, but the modular systems approach will also enable the transition from research to operations. This is a design objective that program managers at ONR have indicated is difficult to attain in practice.

The technical hurdles of creating, maintaining, and operating a real-time, prediction system are challenging, and can become a distraction from many of the interesting research problems in coastal science. The benefits of real-time prediction become questionable when a scientist spends the majority of his/her time setting up the real-time technical capability, leaving only a fraction of time to concentrate the science.

In a sense, the goals of SCOOP are to provide an infrastructure that reverses the ratio, allowing a scientist to spend most of their time doing science with real time systems that work equally well in hind-cast mode, with only a fraction of their time spent plugging into the technical infrastructure. Moreover, standardized interfaces will allow the models themselves to be treated as plug-and-play modules in the overall prediction system. In effect, rather than advocate for one model over another, the SCOOP model grid will enable testing and comparison of a variety of models in similar settings, thereby promoting a software evolution that will advance community modeling capabilities

TABLE 1: 2004/2005 Model Grid Elements and Associated SCOOP Partner Institutions

| SCOOP GRID ELEMENTS | SCOOP PARTNER LEAD(S) |
|------------------------------|-----------------------|
| Data Standards | TAMU, UAH |
| Metadata Catalog & Services | UAH |
| Archive & Inventory Services | LSU, TAMU |
| Verification | U Miami |
| Storm Surge Modeling | UNC, VIMS, UF, LSU |
| Wave Modeling | GoMOOS/BIO, LSU, UM |
| Configuration Tool Set | TAMU |
| Visualization Services | LSU, TAMU |
| Verification Services | UM |
| Computing Services | LSU, UF, UNC |
| Security | TAMU |
| Web Mapping | GoMOOS |

on the whole. By working within a real-time prediction system, the computer science community will be presented with interesting scenarios and problems that fully engage their talents and experience.

SCOOP model grid implementation is occurring in an incremental fashion. As of the summer of 2005, the primary modules include:

- A SCOOP Metadata Catalog that documents observational data, models, archives, interfaces on the grid, and serves other modules as appropriate. (Lead institution: UAH);
- Archives that serve as a repository for model output with its own directory that coordinates with the metadata catalog and services retrospective analyses. (Lead institutions: TAMU & Louisiana State University [LSU])
- Coastal Models, including storm surge models (ADCIRC, ELCIRC, CH3D) and wind-wave models (WWIII, WAM and SWAN). (Lead institutions: University of North Carolina [UNC], University of Miami [UM], University of Florida [UF], Virginia Institute of Marine Science [VIMS], LSU, GoMOOS, & Bedford Institute of Oceanography [BIO]);
- Verification and Visualization services that allow real-time aggregation of buoy and NOS data for visualization and model-data comparisons. They include many outside data sources. (Lead institutions: LSU, UM & GoMOOS);
- Observational/Initialization Winds including real-time winds and synthesized hurricane wind ensembles used to drive the various surge and wave models. (Lead institutions: UF, UM); and
- Grid Middleware Demonstrations aiding the development and testing of Grid middleware

solutions that will be transitioned to the SCOOP Grid. (Lead institutions: LSU, UNC, & UF).

The SCOOP program will soon merge the model grid and data grid activities into a single initiative called the SCOOP Grid. The first version of this Grid will provide enabling technologies for a novel approach to predicting surge, waves and inundation during severe storms (Fig. 1). During hurricanes in particular, the largest uncertainties in predicting storm surge and wind-waves at the coast are often traced to uncertainty in the predicted winds. In the final days and hours before a storm hits the coast, surge and wave modelers cannot know the details of the impending landfall. Instead, they have access to statistical descriptions, possible trajectories, and intensities, and are often faced with a variety of different model predictions. These information sources will be used to define the SCOOP wind ensembles. The various SCOOP modelers will run and compare their regional and large-scale wave and/or surge models using these wind ensembles, and will develop statistical measures of predictability, surge, and inundation based on these calculations. The ensemble predictions will run in real time for the 2005 hurricane season, and will be capable of running in retrospective mode for historical storms.

D. COMMUNITY BUILDING, EDUCATION, AND OUTREACH

Community building in the form of communication, cooperation, and coordination may well be one of the most challenging aspects of creating a truly integrated GEOSS, for which the IOOS provides an ocean component. SCOOP partners are committed to enhancing communication at all levels.

1) OOS TECH WORKSHOPS

At the grass-roots level, the SCOOP program has become a major supporter and organizer for the so-called "OOS Tech" workshops. OOS Tech 2003, the first in the series, was an informal gathering of "techies" from GoMOOS, SEACOOS, and other organizations along the U.S. east coast. The initial goal was to gather software developers together to meet one another and start sharing ideas and software. The 2005 OOS Tech workshop will engage the broad coastal community involved in the IT issues associated with building an IOOS. The workshop will provide an opportunity to work with data experts from observing systems around the U.S. to discuss IOOS needs and share strategies and issues in a way that will advance the national effort and build the "open-source" attitude. Engaging this broad community is necessary to identify the best tools available, gaps in required technologies and applications, and opportunities for sharing technologies and solutions. Planning for OOS Tech 2005 meeting is underway at <http://twiki.sura.org>.

2) REGIONAL ASSOCIATIONS AND OCEAN OBSERVING SYSTEMS

SURA is engaging at the policy and decision-making level by coordinating with the developing National

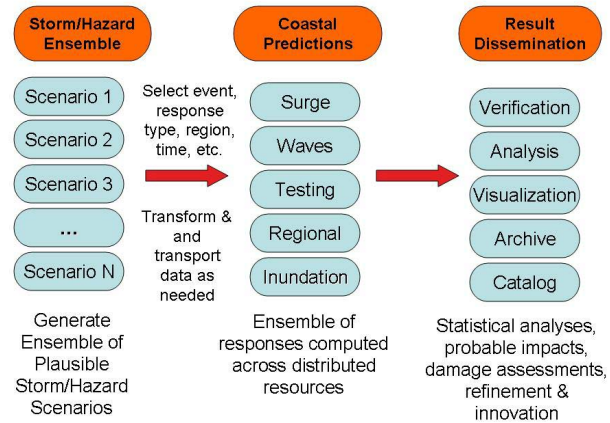


Fig. 1: Ensemble Modeling Architecture for the SCOOP Grid: SCOOP is setting up a modular system that will allow a statistical approach to environmental prediction by simulation a range of scenarios. This approach allows application of multiple models to be applied by large community of scientists focused on coastal inundation and other hazards.

Association of Regional Associations (NFRA). The national system is being conceived as a federation of regional associations and observing systems, and these regional entities involve participation from an increasing number of university partners. The SCOOP program began by supporting GoMOOS, the Gulf of Mexico Coastal Ocean Observing System (GCOOS), the Mid-Atlantic Coastal Ocean Observing Regional Association (MACOORA), and the South East Coastal Ocean Observing Regional Association (SECOORA). These observing systems and associations are responsible for assessing the needs of their regional users, assessing the ability of the available data/systems in the region to assess those needs, and meeting the objective of having advancing a pilot project in the region that would demonstrate that the user needs are being met.

3) SCOOP WIKI

To facilitate communication at the implementation level, SURA has been maintaining a public wiki site (<http://twiki.sura.org>) that is being used for a variety of purposes, including planning for the OOSTech Workshop and the OpenIOOS Interoperability Test Bed.

4) OCEAN EDUCATION

The Centers for Ocean Sciences Excellence in Education (COSEE) network was established in 2002 to encourage ocean scientists to become more active in education and outreach at multiple levels, to develop high-quality educational resources and to foster national coordination of local regional ocean education. COSEE's web presence is currently a disparate collection of seven individually designed and maintained regional websites, a password-protected administrative site, and a web page maintained by

the Central Coordinating Office (CCO) that links to all other sites (<http://www.cosee.net/>). SCOOP partnered with the Consortium for Oceanographic Research and Education (CORE) to develop a unified and coherent web presence in the COSEE.net portal. This portal will integrate web-based resources from each Center, the Bridge Ocean Science Teacher Resource Center, and the Digital Library of Earth Systems Education (DLESE).

SCOOP AND THE OCEAN.US DMAC PLAN

Ocean.US distinguishes three basic subsystems involved in creating the IOOS; 1) the data acquisition subsystem; 2) the DMAC subsystem; and 3) the modeling and analysis subsystem. In the Fall of 2004, the first DMAC Steering Committee produced the Ocean.US DMAC plan, which provided a strategic approach to creating the DMAC subsystems, and concrete guidance toward making progress while awaiting policy decisions that will impact overall funding. A recent reorganization of the Ocean.US DMAC Steering Committee gave rise to a revised concrete guidance document. All of these documents can be found on the Ocean.US website (<http://ocean.us/>).

The SCOOP program strives to remain consistent with the strategic goals of the DMAC plan. But SCOOP is actively and consciously blurring the distinction between the DMAC subsystem and the modeling and analysis subsystem, and future initiatives will be directed to blurring the distinction with data acquisition as well (e.g., via smart sensors). In any case, consistency between SCOOP goals and the DMAC plan continues to grow. Whereas the first version of the DMAC concrete guidance did not mention OGC web services, the OGC specifications are strongly endorsed in the more recent guidance documents, so that SCOOP program elements are now in closer alignment than ever. Table 2 attempts to isolate the primary elements of the DMAC guidance, and provides a crosswalk with SCOOP program goals.

TABLE 2: DMAC Crosswalk with the SCOOP Program

| OCEAN.US DMAC UPDATED SHORT TERM GUIDANCE | CORRESPONDING SCOOP PROGRAM ACTIVITIES |
|---|---|
| <i>STANDARDS PROCESS</i> | |
| Create a community-oriented, standards-related resource & Web-based collaboration environment | This is the purpose of the SCOOP Wiki (http://twiki.sura.org) |
| Provide attention & information regarding DMAC data standards | Experiences and Best Practices (OGC & others) published on SCOOP wiki |
| Provide technical assistance resources in key evolving standards areas as they emerge | “How to” documents are being published on the SCOOP wiki |
| Help share related information through existing federal agency programs | SCOOP partners work with NOAA/CSC |
| Participate in Expert Teams | Awaiting their formation; SCOOP Director is on DMAC Steering Committee |
| <i>METADATA</i> | |
| Metadata should be created in an XML-schema with an XML style sheet | SCOOP practices are consistent |
| Create FGDC-compliant metadata | Planned for the SCOOP metadata catalogue Web Service |
| Submit metadata to one of the national spatial data infrastructure nodes | Planned for the SCOOP metadata catalogue Web Service |
| Document data-dictionary used | SCOOP will use once finalized |
| Participate in Expert Teams | Awaiting their formation |
| Metadata resources | SCOOP Director is on the MMI ExCom |
| <i>DATA TRANSPORT AND ACCESS</i> | |
| Gridded data -- install OPeNDAP servers | SCOOP recommends this when appropriate |
| Complex data collections in relational database (RDBMS) should use OPeNDAP | SCOOP recommends Web Services |
| Large collections of data -- use OPeNDAP if a server exists | SCOOP employs LDM |
| Participate in pilot and/or test-bed activities | Openioos.org is a test bed |
| Participate in working group | Awaiting their formation |
| Future interfaces will be SOAP-enabled | SCOOP Partners are already using SOAP |
| Gateway services must be addressed (e.g., register UDDI users) | SCOOP depends on XML & SOAP which simplifies UDDI implementation. |
| | |

| <i>ARCHIVE & ACCESS</i> | |
|---|---|
| Ensure irreplaceable data are archived at a responsible entity | SCOOP provides interoperability & aggregation capabilities as well as real time archives of model-derived fields and Web-service archive access |
| Archives should be searchable | SCOOP metadata catalogue is searchable |
| Regional data centers, model centers and archive centers should coordinate with Federal centers | SCOOP partners are setting up a distributed, secure & integrated center for all but has not coordinated with federal centers |
| Closely coordinate Data transport, access and archive | Inherent in SCOOP model grid |
| Participate in expert teams | Awaiting their formation |
| <i>IT SECURITY</i> | |
| Security roles, challenges and constraints are needed | SCOOP has a Model Grid task to identify & document these issues |
| Participants providing data & forecasts should negotiate use with Federal agencies | SCOOP is communicating via NOAA/CSC |
| Use community-accepted best practices regarding IT security | Inherent in SCOOP approach |
| <i>QUALITY ASSURANCE/QUALITY CONTROL</i> | |
| Delegate QA/QC for buoy & mooring data to NDBC | SCOOP partners (e.g. GoMOOS) do this |
| QA/QC is outside scope of DMAC, look to QARTOD | SCOOP partners overlap with QARTOD activities |
| | SCOOP verification task qualifies as QA/QC for surge & wave prediction |

SUMMARY

Environmental prediction requires real-time data and modeling, which demands ever greater strides in IT, data management, and Grid architecture development. SCOOP will continue to integrate diverse scientific endeavors and empower a virtual community of ocean scientists with the tools, resources, and ideas that enable discovery. SCOOP, through SURA member universities and outreach to other organizations, is stepping up to use available IT technologies in a community driven process to help define the future of the Grid and all its potential for coastal, ocean, and earth science.

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