Year Five of Southeast Atlantic Coastal Ocean Observing System (SEACOOS) Implementation

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LONG-TERM GOALS

To significantly increase the quantity and quality of environmental information from the coastal ocean of the SE U.S. and make this readily available for a range of societal, scientific and educational applications.

OBJECTIVES

Explore the components and interactions necessary to create a vital regional coastal ocean observing system (RCOOS) in the southeast U.S. Assist the development of the coastal component of the U.S. Integrated Ocean Observing System (IOOS).

APPROACH

A consortium of universities with existing observing system components worked together to construct a functional regional coastal ocean observing system. Through practical application, best practices for further development of the regional (and national) COOS network were identified and documented.

WORK COMPLETED

In its fifth and final year SEACOOS operated on a much reduced budget and therefore limited the scope of activities to documenting the regional coastal ocean observing system (RCOOS) devleopment and lessons learned and to maintaining a limited number of the observing system elements. SEACOOS sought to document the program's experiences as a mechanism to inform future ocean observing efforts in the region and around the country, as strongly recommended in its external evaluation during the third year of the program (http://seacoos.org/documents/evaluation) and by its Office of Naval Research Program Manager. Eight SEACOOS investigators each received a month of salary support to lead summary and synthesis manuscripts on the main components of the program: the observing subsystem, the modeling subsystem, the information management subsystem, and the extension and education subsystem. Additionally, manuscripts on an overall RCOOS design, program management, the high-frequency radar system and the surface wave observing subsystem were produced.

Draft reports for each element were prepared during summer 2007 and presented at the 10th and final SEACOOS open workshop (http://seacoos.org/General%20Information/Folder.SEACOOS%20Workshops/fall07/), which was held in St. Petersberg, Florida, in conjunction with the 2nd annual IOOS Regional Workshop. The workshop attracted 84 participants from around the country and from a variety of work sectors. SEACOOS was able to support the national meeting by providing travel funds for representatives from each of the 11 regional assocations around the US. In this way the SEACOOS program was able to share its experiences and lessons learned with similar programs from around the country. In addition to reviewing the documentation, workshop breakout sessions addressed information management, an IOOS-wide concept of operations, and supporting applications as important topics that regional ocean observing systems must consider as they develop into operational programs.

Based on feedback from the workshop the manuscripts were further refined and versions were drafted for inclusion in a special volume of the Marine Technology Society (MTS) Journal entitled “Global Lessons learned from Regional Coastal Ocean Observing Systems”, published in fall 2008. Dr. Seim was the guest editor of the volume which includes nine contirbutions from SEACOOS investigators as well as articles on a national perspective on regional development, on the European Union’s regional ocean observing programs, and articles on the Gulf of Maine Ocean Observing System (GoMOOS) and on an observing efforts in the Gulf of Mexio and Lake Erie. The MTS Journal was chosen for the special volume because if its ability to quickly get the volume to press and therefore help ensure that the SEACOOS documentation effort is available to the broader community in a timely and meaningful way.

In addition to these articles that focus on the development and lessons learned from the SEACOOS program’s regional coastal ocean observing system experience, more than 120 refereed science publications have been authored by SEACOOS investigators during the lifetime of the project. The articles, included in the publicaiton list for this report, demonstrate the remarkable breadth of activities undertaken by the program. They address topics of basic science, augmenting our understanding of the physical, chemical and biological oceanography of the SE US coastal ocean, as well as topics of more applied science, with an emphasis on ecosystem studies and the ways in which ocean observing systems can provide information critical to the understanding of ecosystem functioning. There are also a number of articles on extension and education that describe ways in which the information generated by ocean observing can be used to better inform students and the public of the functioning of the world’s oceans and its relevance to our daily lives.

The other main objective of the fifth year of the program was to maintain to the extent possible the observing systems elements that SEACOOS had developed in the first four years of the program. SEACOOS began as a pilot RCOOS based on an expectation that the national program (IOOS) would

begin in earnest in the early part of this decade, hence there was a desire to see those elements of SEACOOS that were viable become part of the formal SE regional component of IOOS.
Funding in year five was restricted to maintaining existing elements, and of these funds the vast majority went to supporting key personnel. Priority was given to the observing and information management components, which each received approximately 40% of the available funding, with the remainder split between modeling and extension and education. Though a number of the observing system elements are still active today and supported by other means, the majority have been mothballed, awaiting a time when funding levels may permit them to be operated again. Unfortunately, key personnel have been lost and as time passes and funding levels remain low, more of them will be lost from the endeavor.

RESULTS

Selected examples of achievements documented in the special volume of the MTS Journal are given below. For information on these and other aspects of the program, see the project website (www.seacoos.org) and the publications listed below.

The observing subsystem of SEACOOS employed a number of different platforms and sensing techniques. The acquisition, testing, deployment and maintenance of a number of high-frequency radar installations in the SE US remains a significant accomplishment of SEACOOS (Shay et al., 2008). Based on extensive deliberations within SEACOOS, we decided to assess the two differing types of coastal ocean current radars within the southeast that were on the commercial market. The long-range, SeaSondes (SS) were deployed to sense surface currents at hourly intervals and a 6 km resolution along the West Florida Shelf and the North Carolina Shelf. The medium and long-range Wellen Radars (WERA) were deployed along the Florida Straits and along the South Atlantic Bight with spatial resolutions of 1.2 to 3 km sampling at time scales of minutes (Figure 1).

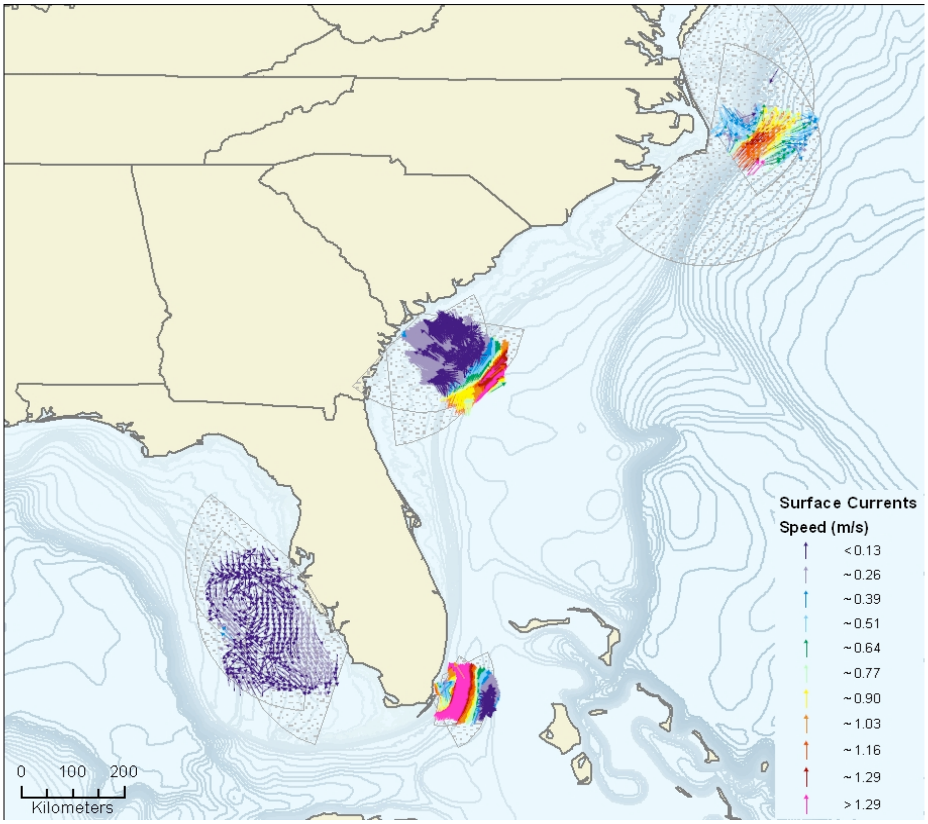

Figure 1. HF radar deployments (and radial coverage) with surface current vectors in April 2007 (EFS and MAB) and Oct 2007 (WFS) in the SEACOOS domain relative to bottom terrain (from Shay et al., 2008).

A common theme in these deployments was to sense the Loop Current, Florida Current and the Gulf Stream which transport heat poleward as part of the gyre circulation. SEACOOS experiences with HF radars were generally positive as it allowed us to assess system performances of both systems under differing venues with large differences in the dynamic ranges and horizontal scales of surface current variability. Collectively, a near real-time surface velocity measurement system was developed where data were visualized on the SEACOOS website. The two radar groups using WERA, the first such deployments in the continental US, were in general pleased with the wealth of data provided by this system, including the possibility of near real-time directional wave capabilities. These measurements are not only important to modeling programs, but are needed to interpret radar-derived surface velocity fields and directional waves in strongly sheared ocean regimes (i.e. Florida Current). In collaboration with our European colleagues, more significant inroads must be made in this area of radar-derived directional waves as it is an exciting area of scientific and research inquiry that has operational potential. This remote sensing capability is a plus in regimes such as the Gulf Stream and Florida Current where surface buoys are difficult to deploy and maintain over long periods.

A surface wave measurement initiative within SEACOOS led to the establishment of directional wave measurement stations at several new locations, evaluation of the employed systems, and the transfer of a number of these systems or data streams to new programs (Voulgaris et al., 2008). These data have been invaluable in providing nearshore wave climatologies for the deployment sites (Figure 2).

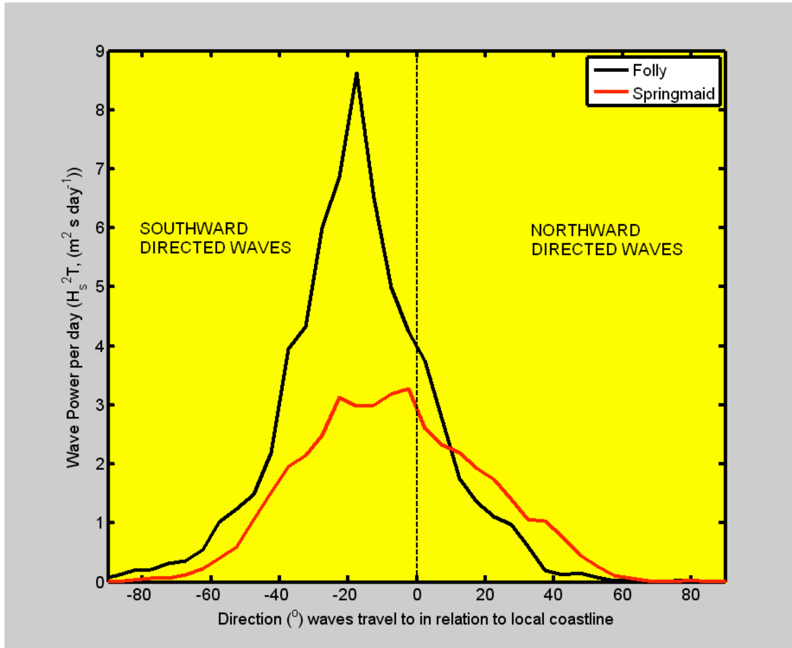

Figure 2. Nearshore wave climatology for two cabled ADCP stations (Folly Beach and Springmaid Pier) along the coast of South Carolina. Under the same wind regime, the site at Folly Beach receives significantly more energy than the site on Springmaid Pier. At both sites the wave energy is directed southward, indicating a southward dominated longshore sediment transport (from Voulgaris et al., 2008)

Furthermore, NOAA/NWS have been utilizing these data for guidance on nearshore forecasting activities. Expertise was established throughout the region in using ADCPs for wave measurements. A particular success was the creation of data display results for ADCP directional wave measurements. These were widely disseminated to various partners within SEACOOS but also were shared with other RCOOS programs. Comparisons of ADCP- and buoy-obtained wave parameters have shown that the two systems are in very good agreement and different sensors can be integrated in a wave observation program.

The research and development efforts in the area of using radars for estimating wave conditions with a high spatial resolution has established the region as the pioneer in these activities. The SEACOOS-sponsored radar experiment demonstrated that the WERA technology holds the promise of providing wave height estimates and led to identification of areas that need further research. This activity fostered collaboration between different institutions and has provided the basis for the development of a new waves program under the auspices of the Regional Coastal Ocean Observing Associations. Furthermore, long-range HF Radars installed on along the Georgia and South Carolina coasts (Figure 1) are currently undergoing upgrades to provide offshore wave information.

In addition to HF radar and wave measurement programs, SEACOOS obtained near real-time observations from buoys, offshore towers, pier and shore stations, and mobile platforms (ships, gliders and drifters) using several communications techniques. These assets more than doubled the number of fixed observing platforms in the SEACOOS region (Figures 3 and 4). More importantly, the SEACOOS observation subsystem established the first network of subsurface observing locations (of temperature and salinity) and shelf current observations. The program also initiated a pilot program in regional remote sensing that utilized established capabilities at partner institutions to deliver tailored satellite products in near real-time. Another unusual component of the observing system was the *Explorer of the Seas*, a Royal Caribbean Cruise Liner that has been outfitted with a variety of atmosphere and ocean sensors which collect observations continuously while the vessel is underway. It followed a weekly track through the West and East Caribbean, repeatedly crossing the Florida Straits. These crossings provide a measure of the transport and structure of the Florida Current, a dominant feature of the regional oceanography and which carries a signal of climate variability that directly impacts the SE coastal ocean.

One of the most acknowledged accomplishments of SEACOOS was the establishment of a comprehensive, distributed, information management system (Fletcher et al., 2008). Its initial focus on developing a set of standard for data transport mechanisms, vocabulary and metadata enabled creation of the first truly regional information management system in the country. The protocols developed by SEACOOS are being used by others and are currently being promoted as possible national standards. Data were aggregated into a relational database and considerable effort has gone into optimization of its performance. Visualization has emphasized map-based products, relying on open source tools to create geographical information system (GIS) compatible imagery. The production of map layers that conform to Open Geospatial Consotrium (OGC) standards, each representing a single variable or subset of observations, that can then be combined or shared has proven to be an effective way to promote interoperability with other organizations and was the methodology used to first demonstrate the ability of regions around the country to aggregate their data streams (the openiios.org website was the result). The technology has proven expandable and can now host a number of input conventions and supports a growing number of output data types and data feeds (Figure 5). The SEACOOS data management technology and many of its personnel now form the basis for the SECOORA data management system.

Quality assurance/quality control protocols have been a primary focus of information management within SEACOOS during the last years of the program. Through coordination with other regional data

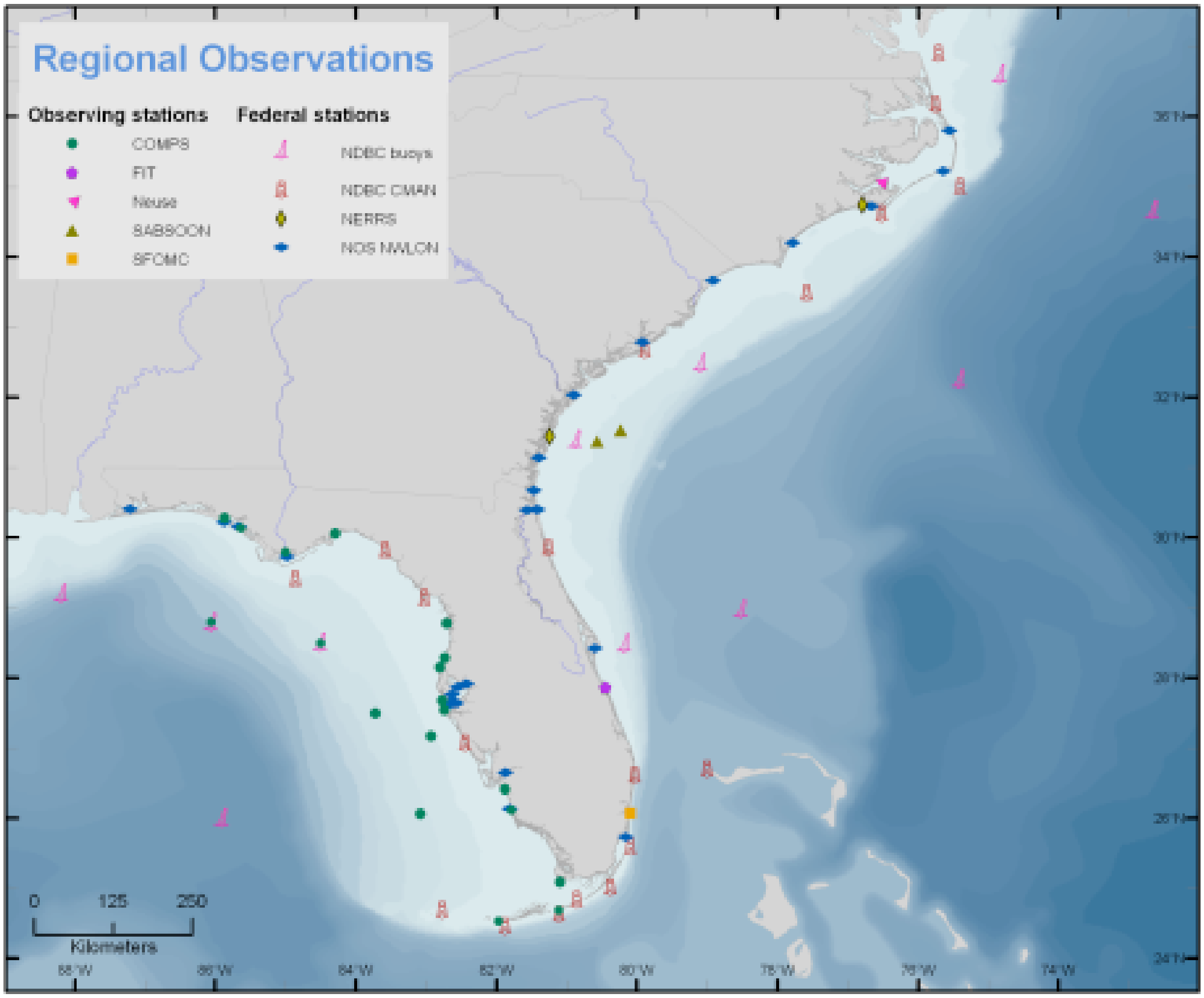

Figure 3 – distribution of coastal and offshore real-time* in-situ *observing stations in the SE coastal ocean in the fall of 2001. Not included are the many onshore meteorological stations and USGS river gauge network (from Nelson et al., 2008)

providers and federal agency input SEACOOS developed white papers and a schema for encoding QA/QC information within an arbitrary data stream. Though never fully implemented during the lifetime of the program, the structure mocked up by SEACOOS is serving as the starting point for renewed interest in this topic as funded through the QARTOD to OGC (Q2O) grant from the NOAA IOOS Program Office.

Forecasting the time-evolving, three-dimensional fields of the coastal ocean from the estuaries out to the boundaries of the EEZ was the ambitious goal of the SEACOOS modeling group. Tremendous progress was made towards this goal, with the three contributing groups running quasi-operational systems near the end of the funding of the program (http://seacoos.org/General%20Information/Folder.SEACOOS%20Workshops/fall07/docs/model/). Each group used a high-resolution coastal model, nested within a basin scale model to define open

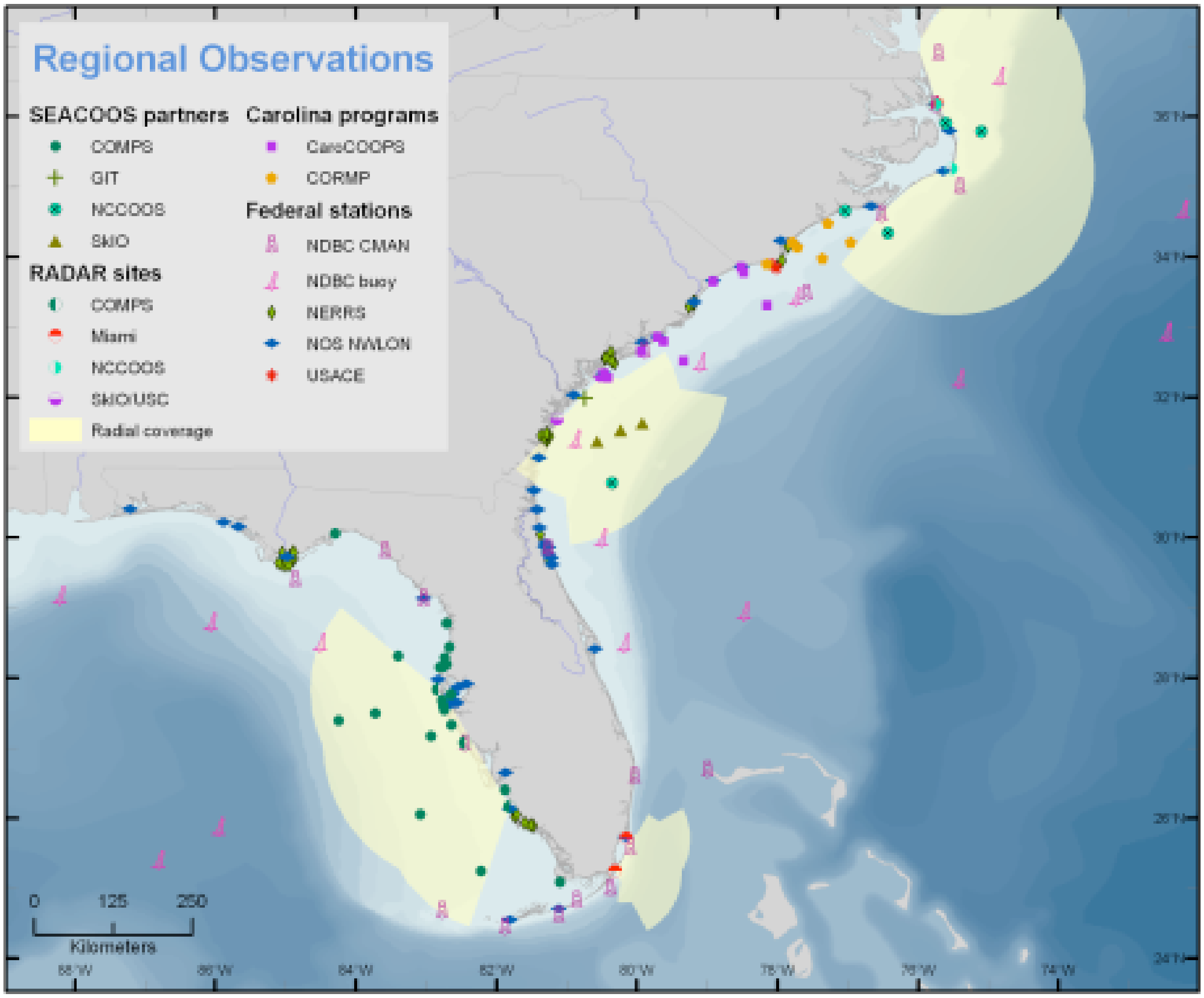

Figure 4 – distribution of real-time* in-situ *observing platforms operating in the SE coastal ocean from 2002-2007 and nominal coverage for surface currents from shore-based HF radar station. A number of inshore water level stations, onshore meteorological stations and USGS river gauge sites are not shown.

boundary conditions, and forced with an atmospheric model and tides (Figure 6). Particularly challenging was the representation of the Loop Current/Florida Current/Gulf Stream in the deeper parts of the model domains and the depiction of the nearshore regime in the shallowest parts of the model domains. Skill assessment of the nested models found generally good agreement with the existing sparse observational array (despite the growth of observing under SEACOOS funding), though the fidelity of the Gulf Stream representation in the basin scale models off the South Atlantic Bight was questionable and, because of a lack of observations, unverifiable. On the West Florida shelf it was found that a second nesting, of estuarine models within the coastal model, was a practical approach to representing the cross-shelf linkage from estuarine waters to the deep ocean.

These circulation models served as the starting point for a variety of coupled models. These included nutrient-phytoplankton-zooplankton models in the Straits of Florida (Fietcher and Mooers, 2007), red tide tracking (Weisberg et al., 2007), larval fish dispersion studies (Edward et al., 2007), and sediment transport models (Feitcher et al., 2006). These studies underscore the value of establishing a basic representation of the ocean circulation as an essential building block for the regional observing systems. An obvious next step in development of modeling subsystems is assimilation of some of the observations. Some assimilation occurs as part of the basin scale modeling and hence it influences the nature of the nested solutions. However, as part of SEACOOS, insufficient resources were available to pursue a region-wide effort. Some groups have begun to implement assimilation schemes, in particular for the HF radar datasets, and results to date are promising (Barth et al., 2008c).

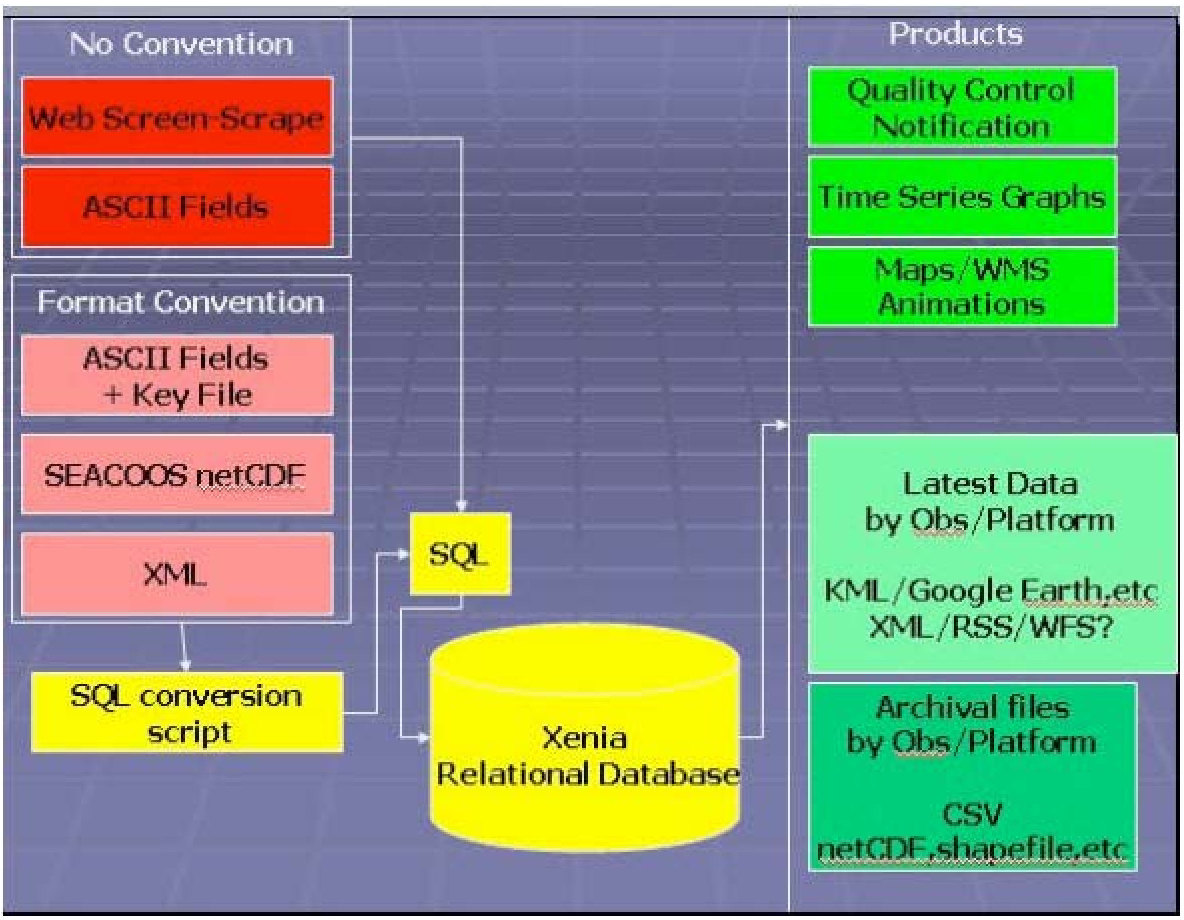

Figure 5 – a schematic representation of the data flow in the SEACOOS information management system and the variety of input and output data formats that are accommodated (Fletcher et al., 2008).

At this time none of the modeling programs have been transitioned to or supported by SECOORA due to budgetary constraints. A significant modeling program has been proposed for SECOORA but funding levels have been too low to begin implementation.

The extension component of the Extension and Education (E&E) subsystem of SEACOOS was operated through the Sea Grant Extension Programs of North Carolina, South Carolina, Georgia and Florida. Education activities were channeled through the three Centers for Ocean Sciences Education Excellence (COSEE) in the SEACOOS domain. Together these formed the E&E working group which undertook the daunting task of raising awareness among the public about IOOS and its potential benefits to society, of defining stakeholders in the region, of defining their information needs, and how their needs might best be addressed using information from the observing systems (Simoniello et al., 2008). Each of these steps was a challenge but the last step, of identifying how best to address user information needs, was the most challenging because it was essential that the response was consistent with what the RCOOS could provide at its current level of maturity and that there were adequate resources to develop any tailored applications that might be envisioned.

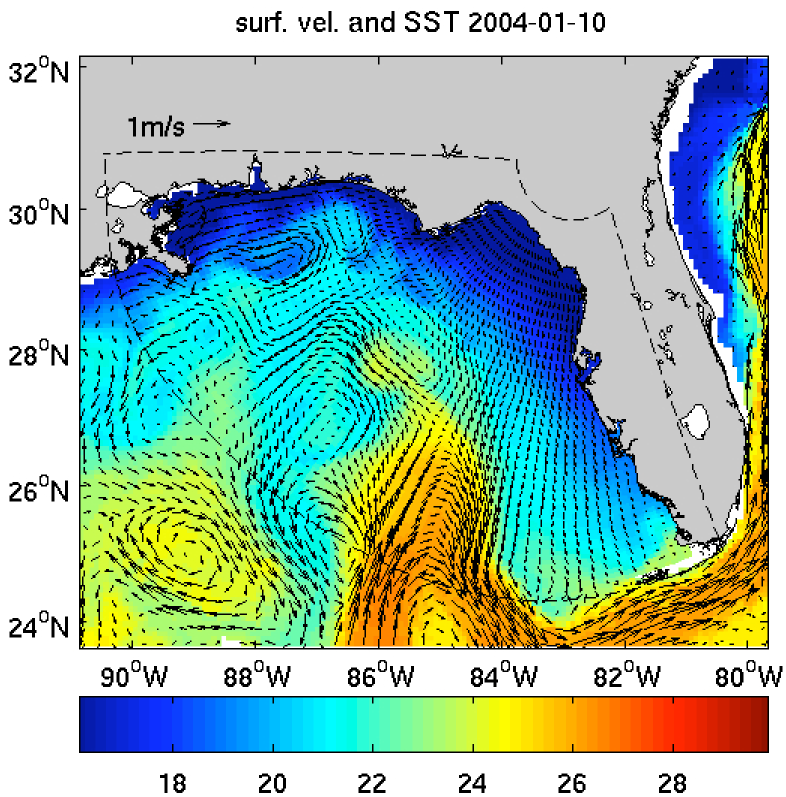

Figure 6 – An example of a coastal ocean model nested within a basin scale model, in this case, the west Florida Shelf ROMS model nested within the HYCOM North Atlantic model (Barth et al., 2008a)

Among the forms of raising awareness of IOOS, the information kiosk proved quite popular. It was used in a number of venues, including the *Explorer of the Seas* (a commercial cruise liner), at aquaria and science centers, and at fishing piers. The kiosks took on a variety of forms but always included an interactive computer terminal that allowed the user to explore the components of observing systems and the many uses for the information. Some were directly connected to real-time data streams and/or the SEACOOS data portal, and some were designed to give users a clear notion of a particular instrument system (Figure 7). Most other forms of raising awareness involved presentations, at boat shows, on board the *Explorer of the Seas*, or at targeted meetings (e.g. state emergency managers), with the notable exception of the production of several DVDs that described the structure and challenges of coastal ocean observing systems.

The early work of the E&E group in identifying stakeholders led to a critical early distinction between users who were accustomed to ingesting and using large amounts of ocean information, or superusers, and those users who required a more refined form of information delivery to make it meaningful to

Figure 7 - Scaled model of SEACOOS buoy with supporting computer kiosk located at Roper Mountain Science Center, Greenville, SC.

them. SEACOOS choose to preferentially focus on developing information streams for superusers because of their ability to utilize essentially raw data feeds and therefore avoid the cost associated with developing custom applications. This choice minimized the role for broad extension in the later years of the program. Providing support for US Coast Guard Search and Rescue operations and for fisheries managers became the targeted applications of SEACOOS, from which flowed requirements that impacted the objectives of the RCOOS in its later years.

Education activities were led by the COSEE programs and followed two paths: direct teacher engagement in developing lesson plans that tapped directly into the SEACOOS information outlets; and a poster series that focused on specific topics of interest and which were supplemented by a variety of online activities. The lesson planning took place in each state to ensure that the curriculum met with state standards and resulted in a range of classroom activities related to the oceans and ocean observing. A total of four posters were developed, which were of high production quality and mass produced (5,000-10,000 copies) and were widely distributed in the southeast and to some extent across the country. The associated online activities on the SEACOOS website have been among the most popular and suggest that the poster series was an excellent mechanism to engage students of all ages.

The program management of SEACOOS was also an important development. The partners involved in SEACOOS were many and from a variety of backgrounds and establishing a framework in which all could contribute took time (Seim et al., 2008). SEACOOS developed a formal consortium that defined its governance, drafted strategic and implementation plans through interactions with the partnership, and subjected itself to an external evaluation which helped clarify its mission. The program also hosted a total of ten community workshops that played a critical role in building the community of interest that led to the creation of SECOORA, the regional association for the SE US. SEACOOS was a large organization; at its height SEACOOS employed over 100 technical staff in part-time and full time capacities and more than 30 investigators. It trained 28 advanced degree students over the lifetime of the program. The single most challenging aspect of managing the program was promoting adequate communications. The distributed nature of the RCOOS is inherently isolating and constant attention to communications among all parties is vital.

IMPACT/APPLICATIONS

SEACOOS may be considered a pilot regional coastal ocean observing system. It tested recommended methods of measurement, modeling and data exchange to establish their viability in sustained operation and developed some new methods of its own. It also developed the operational structure and coordination of policies needed by the RCOOS to provide broad-based participation. The most significant local impact has been the leverage SEACOOS has provided for SECOORA to stand up its own RCOOS. A number of the program elements have been transitioned to SECOORA and many more are proposed to become part of SECOORA should funding levels increase. Perhaps more importantly, many of the developments made within SEACOOS have impacted development of RCOOSs around the US, and it has provided a model of collaboration for others. We are proud of the final special volume and its focus on best practices and lessons learned and we trust that it will help the US develop a robust coastal ocean observing system in a timely and efficient manner.

RELATED PROJECTS

An abbreviated list of programs associated with SEACOOS that receive other funding include: SECOORA (http://www.secoora.org); USF COMPS (http://comps.marine.usf.edu/index.html), SABSOON (http://www.skio.peachnet.edu/research/sabsoon) , Caro-COOPS (http://carocoops.org), Explorer of the Seas (http://oceanlab.rsmas.miami.edu), the Southeast COSEE (http://www.scseagrant.org/se-cosee/), and the Florida COSEE (http://floridacosee.net).

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