Ocean Observatories and the Role of Federal Ocean Education Networks

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***Abstract*- Recommendations of the Integrated Ocean Observing System (IOOS) and Ocean Research Interactive Observatory Networks (ORION) education communities for coordination of ocean observing education efforts include collaborations with existing ocean and coastal educational networks. The ocean observing systems provide a focus around which the efforts of various Federally-funded ocean education networks can be coordinated. This paper explores the connections that exist and highlights opportunities for collaboration. The education networks addressed include the National Oceanic and Atmospheric Administration's (NOAA) National Estuarine Research Reserve System (NERRS), the National Marine Sanctuaries Program (NMSP), Sea Grant Educators Network (SGEN), and the National Science Foundation's (NSF) Centers for Ocean Sciences Education Excellence (COSEE). Some initial collaborations among these networks exist. For example, NERRS and NMSP are working together with the IOOS and ORION to bring the NERRS data to the education community. The COSEE network is also beginning to coordinate with NASA and NOAA networks on a national level.**

This cross-network collaboration will strengthen overall national efforts to promote ocean and coastal education and will lead to a far greater educational impact on the general public and on our nation's formal educational system. Successful use of the ocean observing systems for educational and public outreach purposes will also amplify the value of these systems to our nation.

I. Introduction

A number of existing national ocean, coastal and Great Lakes education networks are beginning to use data produced from ocean observing platforms for educational purposes. The data collected from various platforms, including physical, chemical, geological and biological parameters, are used by educators to stimulate interest in science, technology engineering and mathematics (STEM), specifically in ocean and coastal sciences. In addition, it is recognized that important information about the technology used to collect, store and process the data and the people who service the platforms will stimulate student and public interest in technology and cyberinfrastructure [1, 2]. The sustained nature of these platforms and continuous access to the data generated about the ocean means that children, educators, adults, and family groups will be able to participate in hands-on citizen science projects in their *backyard* or on the other side of the world, view dynamic visuals and visualizations that allow them to encounter the oceans and coasts in four-dimensions, and engineer their own instruments, platforms, or remote vehicles. These activities will only be possible through a focused effort among educators and scientists to consider the role of ocean observing systems in the education programs of existing ocean and coastal educational networks and implement coordinated projects that bring these data to the classroom and to the public [1, 3].

As the operation of existing and planned ocean observing platforms are organized via national and international governmental efforts such as the Integrated Ocean Observing System (IOOS) and the Global Ocean Observing System

(GOOS), educational use of the platforms and data will also become more organized. In the report "Proceedings of the Second IOOS Implementation Conference," conferees outlined how the educational efforts associated with ocean observing systems could be organized. The report recommends development of a regionally dispersed network of educators coordinated by a central site, and also states "The end result is the transparent linkage of multiple sites within a region and linkage of those regions to form a national network. Therefore, the COSEE, NERRS (education and coastal training program), Sea Grant (education and extension), and National Marine Sanctuaries Program (NMSP), Global Learning and Observations to Benefit the Environment (GLOBE) Program, and EPA National Estuary Program (NEP) education networks should be incorporated. Over the long-term, other Earth system science and environmental education networks would be linked-in using the best available practices [4]." In other words, ocean observing systems should be used to bring existing networks of ocean educators together to form a "network-of-networks" focused on the use of observing system data and information in classrooms and in informal education settings such as aquariums and museums.

The goal of this paper is to highlight what several education networks contribute to the education and outreach potential of the ocean observing system by exploring how current programs may be connected and identifying new opportunities for collaboration. Identifying these connections and synergies will help to avoid duplication of effort and contribute to greater impact. Federal agencies have also been tasked with coordinating their ocean research and education enterprises. In response to a recent Presidential Commission report that was focused on improving the Federal oversight of the oceans, the President issued the "U.S. Ocean Action Plan" (OAP). This plan charges all Federal agencies that fund ocean-related programs with increasing the coordination of Federal and State ocean education efforts. The effort described in this paper is an initial attempt to coordinate the activities of various Federal agencies in support of IOOS and is in direct response to the mandate in OAP to "coordinate Federal education and outreach activities."...with the specific task of ensuring "that data collected through ocean and Earth observations are translated into useable forms for teachers, students, and the general public; [5]."

We recognize that the programs described here do not include all of the potentially relevant partners and programs. Potential partners include the American Meteorological Society's (AMS) Local Implementation Teams, EPA's National Estuaries Program (NEP) community educators, Coastal America's Coastal Ecosystem Learning Centers (CELC), the Remotely Operated Vehicle (ROV) regional network, the National Ocean Science Bowl (NOSB) Regional Organizations and NASA's Earth Explorers network. However, we believe the connections we describe for four federally funded programs, including NERRS, NMSP, Sea Grant and COSEE, provide an initial scaffold for future connections and opportunities to expand and collaborate among programs.

II. Strengths and Capabilities of Four Key Education Networks That Participate in IOOS

Four federally funded programs, NERRS, NMSP, Sea Grant, and COSEE, have an important role in leveraging IOOS data to advance science, technology and ocean literacy in the United States. Although considerable synergy exists between these organizations, effort must be made to enhance their ability to function in unison, with full recognition of the goals, geographic distribution, and unique characteristics of each organization.

Following is a brief description of each of the key education networks participating in IOOS. This section will enhance understanding about some of these characteristics and assets offered by each network.

A. The National Estuarine Research Reserve System

NOAA's National Estuarine Research Reserves System (NERRS) is a network of 27 reserves on the nation's coasts established for education, long-term monitoring, research, and coastal stewardship. NERRS is a partnership program between NOAA and the coastal states which protects more than one million acres of estuarine waters, adjoining wetlands, and uplands in coastal regions across the continental United States, Alaska, and Puerto Rico.

This national network of field-based "living laboratories" provides place-based opportunities for students and teachers to learn about estuarine systems and processes. Each NERRS is staffed with educators and scientists who work to deliver relevant and timely scientific information to support informed decision making and increase public understanding of the importance of protecting estuarine and coastal habitats. NERRS is an example of a program that provides a fully operational network of integrated observing systems, called the System-wide Monitoring Program (SWMP), that is focused on monitoring short-term variability and long-term changes in estuaries and coastal systems. SWMP is in operation at all 27 reserves and has been collecting physical, chemical water quality indicators, nutrients and weather data since 1995[3]. NERRS also makes water quality and weather data available in near real time by means of satellite telemetry (http://nerrs.noaa.gov/monitoring/data.html). Current plans include adding a biological monitoring component and tracking changes in land use through remote sensing.

SWMP is identified as a national backbone component for IOOS due to the Reserve System's broad coverage of estuarine and coastal habitats, which complement the suite of operational coastal ocean observations. In the context of IOOS education, SWMP provides a unique focus on estuaries and the land-sea-human and weather connections. This estuarine and coastal focus is an important complement to the development of educational products with an Earth systems science approach.

B. The National Marine Sanctuary Program

The 13 National Marine Sanctuaries are distributed along the east, west and Gulf coasts, the Great Lakes, Hawaii and American Samoa. Most recently, the program was given management authority over marine resources of the newly designated Northwestern Hawaiian Islands Marine National Monument. Established under the National Marine Sanctuaries Act, the mission of NOAA's National Marine Sanctuaries is to serve as the trustee for the nation's system of marine protected areas, to conserve, protect, and enhance their biodiversity, ecological integrity and cultural legacy. The Sanctuaries host a robust scientific community involved in site characterization, monitoring and research. Each of the sites is also staffed with education and outreach coordinators who bring the sanctuaries to life to numerous teachers and students, as well as the general public.

The Sanctuaries Program is developing a System-Wide Monitoring Program to coordinate monitoring at the sanctuaries in a consistent way at multiple spatial scales and for multiple resource users. A sanctuary observing network was established consistent with the regional structure of IOOS, focusing initially on the west coast.

The West Coast Observation Project coordinates monitoring at four of the five sanctuary sites located on the west coast. The sites involved include Olympic Coast, Gulf of the Farallones, Monterey Bay, and Channel Islands. The project will focus on various data streams including ocean temperature, current speed, oxygen, salinity, and chlorophyll collected at numerous new instrument moorings to be installed within each of the four sanctuaries. The program partnered with the academic consortium Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO) to develop a model end-to-end system of collecting, processing and publishing data. The web based interface for this effort is called SIMoN, or Sanctuary Integrated Monitoring Network. SIMoN provides data, images and interactive mapping capabilities for users, including students and teachers.

C. The National Sea Grant Educators Network

The Sea Grant Educators Network is the formal organization connecting the professional educators within the 32 Sea Grant programs across the United States. Sea Grant education programs are designed to provide educators, students, and free-choice learners with a greater awareness and understanding of marine and aquatic science research, resources, and issues. Because Sea Grant operates from universities and research institutions within each state and regional Sea Grant program, collaborations between ocean scientists and Sea Grant educators are built into the system. Ocean observing data is one of the sources of information used by Sea Grant educators to interpret current ocean science.

D. The Centers for Ocean Sciences Education Excellence

COSEE (www.cosee.net) is a network of centers that have as their primary mission the development of collaborations between ocean and Great Lakes scientists, formal educators and informal educators. The focus on development of connections between scientists and educators is an important strength of this network. COSEE partners include public and private informal science providers, primarily associated with aquariums and museums. The COSEE network exists as an open and diffuse network, reaching broadly to scientists and educators nation-wide and helping individuals and groups to make connections with each other to promote ocean literacy. This element provides ready access to scientists and educators outside prescribed networks for IOOS outreach.

On the other hand, many of the scientists involved in the regional IOOS efforts are also associated with a COSEE Center, helping to provide direct links between acquisition and application of IOOS data. Some of the COSEE Centers are running professional development programs for teachers so that real time data from ocean observing systems may be used in the classroom.

COSEE members are currently working closely with various efforts to define Ocean Research Interactive Observatory Networks (ORION) educational goals and structure. As a research-based piece of the overall IOOS effort, ORION presents unique opportunities and challenges. The ORION Education Advisory Committee is considering how, given available resources, to exploit most effectively the unique capabilities of ocean observatories to enhance science education and public awareness of the oceans. Recommendations of this advisory committee will be important to the future development of educational networks (http://www.orionprogram.org/PDFs/Advisory/ToR_EPAC.pdf).

III. Scope & Reach of The Four Education Networks in IOOS

Eleven Regional Coastal Ocean Observing Systems (RCOOS) are operated and improved by Regional Associations (RAs) to provide data, information and products on marine and estuarine systems deemed necessary by user groups […] in the region [6]. Table 1 shows how many Reserves, Sanctuaries, Sea Grant and COSEE offices are located within an IOOS region.

While there is representation of most networks in all regions, it is clear that there is an uneven representation of networks across the regions. A brief analysis of the networks here described also shows that the level of participation in the RAs varies considerably. Uneven representation of the education community in IOOS RAs calls for increased efforts to ensure coordinated participation at the regional level.

TABLE 1. Overlap of IOOS Regional Associations with NERRS, NMS, Sea Grant and COSEE education networks

Alaska Ocean Observing System
Kachemak Bay NERR
Alaska Sea Grant

Pacific Islands Integrated Ocean Observing System
Northwestern Hawaiian Islands Marine National Monument
Hawaiian Isl. Humpback Whale NMS
Fagatele Bay NMS (American Samoa)
Hawaii Sea Grant

Northwest Association of Networked Ocean Observing Systems
Padilla Bay NERR (Washington)
South Slough NERR (Oregon)
Olympic Coast NMS (Washington)
Oregon Sea Grant
Washington Sea Grant
COSEE Ocean Learning Communities

Central and Northern California Ocean Observing System
San Francisco NERR
Elkhorn Slough NERR (California)
Cordell Bank NMS
Gulf of Farralones NMS
Monterey Bay NMS
California Sea Grant
COSEE California

Southern California Coastal Ocean Observing System
Tijuana River NERR
Channel Islands NMS
Southern California Sea Grant
COSEE California
COSEE West (Los Angeles)

Great Lakes Observing System
Old Woman Creek NERR (Ohio)
Thunder Bay NMS (Michigan)
Illinois-Indiana Sea Grant
Lake Champlain Sea Grant
Michigan Sea Grant
New York Sea Grant
Minnesota Sea Grant
Ohio Sea Grant
Pennsylvania Sea Grant
Wisconsin Sea Grant
COSEE Great Lakes

Gulf of Mexico Coastal Ocean Observing System
Mission-Aransas NERR (Texas)
Grand Bay NERR (Mississippi)
Weeks Bay NERR (Alabama)
Apalachicola NERR (Florida)
Rookery Bay NERR (Florida)
Flower Garden Banks NMS (Texas)
Louisiana Sea Grant
Mississippi-Alabama Sea Grant
Texas Sea Grant
COSEE Central Gulf of Mexico

Caribbean Regional Association
Jobos Bay NERR (Puerto Rico)
Puerto Rico Sea Grant

SouthEast Coastal Ocean Observing Regional Association
Guana Tolomato Matanzas NERR (Florida)
Sapelo Island NERR (Georgia)
ACE Basin NERR (South Carolina)
North Inlet-Winyah Bay NERR (South Carolina)
North Carolina NERR
Florida Keys NMS
Gray's Reef NMS (Georgia)
Florida Sea Grant
Georgia Sea Grant
North Carolina Sea Grant
South Carolina Sea Grant
COSEE Florida
COSEE South East

Mid-Atlantic Coastal Observatories Regional Association
Chesapeake Bay NERR (Virginia and Maryland)
Delaware NERR
Hudson River NERR (New York)
Jacques Cousteau NERR (New Jersey)
Narragansett Bay NERR (Rhode Island)
Monitor NMS (Virginia)
Connecticut Sea Grant
Delaware Sea Grant
Maryland Sea Grant
New Jersey Sea Grant
New York Sea Grant
Pennsylvania Sea Grant
Rhode Island Sea Grant
Virginia Sea Grant
COSEE Mid-Atlantic

Northeastern Regional Association
Waquoit Bay NERR (Massachusetts)
Great Bay NERR (New Hampshire)
Wells NERR (Maine)
Stellwagen Bank NMS (Massachusetts)
Connecticut Sea Grant
Maine Sea Grant
MIT Sea Grant
New Hampshire Sea Grant
Rhode Island Sea Grant
Woods Hole Sea Grant
COSEE North East
COSEE Ocean Systems

NERRS scientists and educators are collaborating in different ways with the Regional Associations. For example, Padilla Bay NERR is leading a pilot project to demonstrate applications of real-time and near real-time water quality data for shellfish farmers in the Pacific Northwest. Data and information will be displayed on NANOOS and AOOS websites. Weeks Bay NERR in Alabama is assisting in development of an Alabama Ocean Observing System web interface, tied in with the Gulf Coast Ocean Observing System (GCOOS). NERRS has also worked to deliver SWMP data to all RAs.

The west coast sanctuaries together with the Central and Northern California Ocean Observing System (CeNCOOS) and the National Coastal Data Development Center (NCDDC) are working to manage information on central and northern California ocean observing activities. This effort, available at www.oceanobs.org, provides select information from ocean observing programs across the region through a public web-based interface. This information includes the locations of specific data sensors and how to access data products.

A survey of Sea Grant educators conducted by the chair of the Sea Grant Educators Network in 2005 revealed that 11 of the 16 responding programs were directly involved in some way with regional ocean observing associations. The nature of the educators' involvement varied from participation in regional planning and stakeholder meetings to the design and production of brochures, posters, lesson plans, website content, and outreach-education-business plans [7]. For example, Sea Grant educators working as partners in COSEE Southeast have helped design and distribute education products on hurricanes and waves using data from SEACOOS (South East U.S. Atlantic Coastal Ocean Observing System, http://www.seacoos.org). Alaska Sea Grant Education Services recently produced an award-winning promotional brochure for the Alaska Ocean Observing System. In addition, Alaska Sea Grant conducted a community-based review of the new Cordova/Prince William Sound section of the AOOS website (www.aoos.org), which provides a central source for marine weather and other information, and has begun development of an AOOS education, outreach, and public awareness plan.

COSEE provides a network for disseminating these products through their NERRS, NMSP and SGEN connections and partnerships. In addition, COSEE scientists and educators are contributing directly to the development of exhibits, curriculum, and teacher professional development programs focused on the use of real-time data (e.g. COSEE MA "Taking the Pulse of Our Planet").

IV. Education networks Participate in Moving the IOOS Agenda Forward

Development of curricula and other educational materials must reflect new learning strategies and technology to ensure their effectiveness. Some of the steps required include assessment of target audiences, use of best educational practices to inform the approach taken to design and develop an educational product or program, and inclusion of appropriate evaluation strategies. The education networks have taken important steps to marshal the information required to inform the development, approach and implementation of a future national ocean observing educational product.

A. Audience Research

To support teacher and student use of current and emerging technologies, product developers need to have a clear sense of the needs, gaps, and challenges presented by infusing technology and data in the classroom. NERRS has taken a systemic approach to conducting a series of audience assessments to better understand and meet the needs of different user groups. Specifically, the program held a series of regional workshops in 2006 to assess K-12 teacher capabilities, needs, interest and concerns, about using IOOS-SWMP data resources. The results of this assessment (available October 2006) is helping the Reserves better package the stories around the SWMP data, identify region specific recommendations that will contribute to the framework for the potential development of national ocean observing education products and help guide the production of NERRS quality materials that will make it relevant and easy for teachers to infuse estuarine topics and data in their classrooms [3].

B. Design and Development of Education Products following a Rigorous Education Research Approach

In an attempt to analyze what works and what doesn't and define the minimum tool set that enables non-scientific users to intuitively explore, display, and analyze NOAA observing systems data, the National Estuarine Research Reserve System, National Marine Sanctuaries Program and the National Oceanographic Data Center have partnered to develop a demonstration project which they have called *NOAA's Data Education (NODE)* Portal [8]. The goal of this demonstration project is to (1) test how different data parameters can be integrated to tell a compelling story about the ocean and coastal ecosystem, (2) provide a test-bed for development of educational applications of IOOS data, and (3) analyze the usability of IOOS data by the non-scientific public. Project results are expected by the end of 2007.

Sea Grant and COSEE educators have also been part of the ORION education community, and are working with the Monterey Bay Aquarium Research Institute's EARTH project testing the use of near-real-time data from ocean observatories in outreach activities with teachers, students, and the public [2].

C. Advancing Ocean and Estuarine Literacy

"Once mature, the operational component of IOOS, […] will enable the nation to advance seven important societal goals, [some of which deal with improving predictions of climate change and weather and their effects on coastal communities and the nation; mitigating the effects of natural hazards; reducing public health risks; protecting and restoring healthy coastal ecosystems; and enabling the sustained use of ocean and coastal resources]. To achieve these societal goals the public will need to understand and appreciate the ocean's role in each one of them […][1] ." Research-driven and societal-benefits-focused education networks here described are currently playing an important role in catalyzing interactions between scientists and educators, making data accessible and meaningful to a variety of target audiences, and producing educational products that will help advance people's ocean and data literacy.

The NERRS, for example, has moved in a concerted effort to make SWMP data accessible and usable to scientists, as well as coastal decision-makers, the public and the K-12 community [3], both at a national and regional scale. In addition, education coordinators at each of the Reserves are working together to launch a K-12 Estuarine Education Program (KEEP). KEEP aims to increase teachers' and students' understanding of estuaries and coastal system by providing professional teacher training workshops, field-based experiences, and distance learning opportunities. Through KEEP and the development of an Estuaries 101 Curriculum,

Reserve educators also aim to increase teacher's and students' ability to use IOOS/SWMP data in their own investigations of estuarine and coastal conditions and processes. While data can be currently viewed on-line at http://cdmo.baruch.sc.edu/ in student-friendly formats, such as simulated thermometers and gauges, "[t]his program will also generate a […] web-interface for the visualization and interpretation of the SWMP data specifically for a K-12 audience"[8]. This web-interface and educational products developed by Reserves support a number of IOOS goals including: sustaining living marine and estuarine resources, protecting and restoring healthy coastal marine and estuarine ecosystems, improving modeling and predictions about the consequences of coastal climate change, and mitigating the effects of coastal storms and other natural hazards [9].

The NMSP's SIMoN website has data and images for students and teachers and provides links to other education websites with ocean-related material. The dynamic mapping application allows users to create maps by selecting layers of data, the spatial extent, and geographic location for each map. Sanctuaries education programs are also expanding efforts to bring biological and physical data into classrooms, using data collected by students and volunteers as well as by platforms. The Program is also installing underwater cameras to bring live video of underwater resources through telepresence. These videos could be incorporated into IOOS education data products.

The Bridge (www.marine-ed.org/bridge), an online resource center for ocean sciences education supported by the National Sea Grant Office and NOAA, has developed classroom lesson plans incorporating OOS data from a variety of IOOS facilities as well as NOAA and USGS sources.

D. Building the Network

Developing connections and opportunities for collaboration among existing Federal ocean education networks requires considerable attention to defining and aligning the education goals of ocean observatories with individual network goals. The developing COSEE network of scientists, educators, and informal science providers has provided some important lessons about partnership building and the importance of communication. Successful partnerships depend on clearly identified common or synergistic goals and missions. The process of developing the connections between IOOS, the existing ocean education networks, and additional partners should include formative evaluation of the development and functionality of the partnerships. Communication is essential for network success – setting up "a network of networks" for the IOOS program will require establishment of effective communication channels with strong management oversight.

V. Conclusions

Earth and ocean science education are undergoing a remarkable transformation with the application of observational systems. However, education networks, including the ones described in this paper, need to continue working on developing a long-term strategy, ensuring the sustainability of this work, strengthening ties to other fields of science education, and continuously monitoring to ensure that products developed remain relevant and meaningful to target audiences.

The ocean observing systems present a strong unifying theme by which the existing ocean and Great Lakes educational efforts can be connected. As members of the education networks continue to collaborate locally, regionally and nationally, additional opportunities will develop to create new education programs and products using ocean observing data and technology. The strengths and regional contributions of each of these networks must be considered in the development of a "network-of-networks." Uneven representation of the education networks along the coasts in each IOOS region argues for close collaboration, and it is clear that the networks we have discussed do not adequately cover the open ocean. Continued attention to developing strong partnerships and clear lines of communication between existing networks are needed as the ocean observatories and their data become available to the public.

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