Opening a Window to the Sea: The Potential of the Ocean Observatories for Education

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Abstract- **A major goal of our education and outreach group is to bring observatory data to a variety of users. COSEE-MA is working on a plan for developing web products and programs that facilitate timely connections and exchange of information between ocean scientists and educators. One such program is centered on the Lagrangian Transport and Transformation Experiment (LaTTE), an NSF funded project focused on the Hudson River outflow. LaTTE is a multi-disciplinary, multi-institutional project with a strong linkage between the scientists engaged in the research and the educators bringing the research to the students and the general public. One example of this interaction grew out of a partnership Rutgers developed with the Liberty Science Center (LSC) in Jersey City, NJ. Through this partnership a pilot program "On the Hudson River", a professional development workshop for 12 educators in August of 2005. Participants interacted with Rutgers scientists and COSEE-MA educators for 3 days to learn about the Hudson River estuary and related resources they can use with their students. With these new and innovative projects, public outreach and education has become an important component of research in the Hudson River Estuary. An additional effort is focused on training the next generation of operational oceanographers. The Rutgers University Graduate Program in Oceanography (GPO) has initiated a new Masters Degree in Oceanographic Technologies. The program was designed with input from a pair of AMS Interactive Workshops on Operational Oceanography, and with comments requested from experienced employees of both Navy and NOAA operational centers. Within the collaborative setting of the Rutgers University (R.U.) Coastal Ocean Observation Lab's (COOL) Operations Center, students will receive hands on training in the use of advanced ocean observing technologies and will participate in the year-round field activities supported by the Center. Course work includes three of the core courses in physical, biological, chemical or geological oceanography and three hands-on courses to support the technology training in data analysis, platforms and sensors, and in atmospheric and oceanic modeling. Completion of a full Master thesis including its defense to demonstrate both written and oral communication skills was considered essential by all potential employers. Potential Masters thesis topics include improvements to the capabilities of sensors and sampling platforms, the analysis of the observatory datasets for a wide spectrum of applications, and atmospheric and ocean modeling applications. Graduates will be able to directly support the rapidly expanding sustained technology needs of the Ocean Observing Initiative and the Integrated Ocean Observing System.**

I. THE RESEARCH ADVENTURE AND THE POTENTIAL OUTREACH POSSIBILITIES

The ocean's continental shelves, the narrow area between major land masses and the deep ocean basins, cover only about 10% of the surface of the Earth but are some of the world's most productive ecosystems and are home to most of the world's fish species. Across the continental shelves, there is transport of sediments, organic particles and chemicals supplied by rivers and beaches. This material is transformed as it travels to the deep sea carrying material into the deep ocean basins where it can remain for thousands to millions of years. The rate at which this material is transported is influenced by energy provided by atmospheric winds pushing the surface ocean, currents from the deep ocean basins, and freshwater inputs from the land. The biology in the ocean is continually changing the material in the water as it is transported. Understanding all these processes is extremely difficult. Historically, oceanographers use ships to study the transport and transformation of material on continental shelves; however most ships are slow, moving at the speed of a ten speed bicycle (15-25 mph), and therefore it is difficult to collect the data that is required.

Developing new approaches to study the ocean is now especially critical. Human populations continue to expand and concentrate along the coastlines. Human activity is increasing atmospheric concentrations of carbon dioxide, nitrogen and other elements which are altering climate. Additionally, humans are altering the shelves by harvesting material for food and releasing waste that changes the water chemistry. Continental shelves are affected by these increasing human pressures; however documenting specific impacts is difficult as scientists need to differentiate between natural cycles, global climate change, and specific local impacts associated with the expanding coastal populations. Quoting the U.S. Commission on Ocean Policy, we need "sound science for wise decisions" to ensure the sustainable use of our coastal oceans for this and future generations. These needs have motivated many to start building ocean observatories to study the ocean. One such observatory that has been developed is the Coastal Ocean Observation Lab (COOL).

COOL is an integrated network of instruments that continuously measure/monitor the physical, chemical and biological components of the ocean. It serves as a test-bed for technologies that are the backbone for the ocean observatories. It was developed to allow scientists, environmental managers, and society to maintain a continuous presence in the ocean. The goal is to allow humans to explore the oceans for sustained periods of time whether they sitting at their desk in New Jersey, California, Kansas, or another country. Ultimately the hope is to expand the systems to provide a global capability. The COOL system consists currently of several technologies that provide a global capability (Fig, 1 and 2). Data is collected

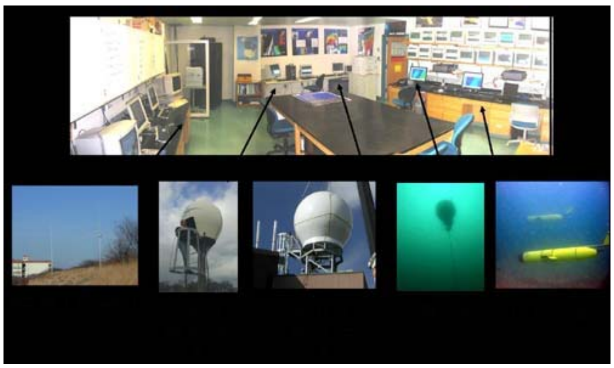

Figure 1. The COOL room, the shore-based brain that controls the ocean observatory. The observatory is the combined data from satellites, shore-based radars, cables, and fleets of autonomous robots. The observatory has been collecting data for over a decade.

from 1) the international constellation of satellites used to measure the physics, chemistry, and biology from space, 2) shore-based radar networks that continually measure surface currents by bouncing radio signals off waves to measure the speed at which they are moving towards or away from the shore, 3) propeller-driven underwater robots that patrol the

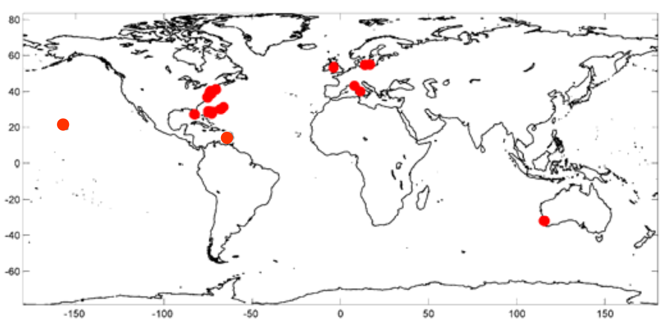

Figure 2. The global deployments of Rutgers gliders in the ocean. Despite that the gliders have been flying world-wide they have been controlled from the COOL room in New Jersey.

ocean collecting high resolution data for short periods of time, 4) sea-floor instrument packages that are connected by cables that allow data to be instantly delivered back to shore, and 5) fleets of unmanned smart non-propeller robots that glider in the sea for months at a time. This data is then "fed" into numerical models which are used to forecast the future. If the forecast does not look like the future then you can ask the exciting question of "why" the model did not work (Did we have wrong assumptions about how the ocean physics works? What do we not understand?).

II. K-12 EDUCATION OUTREACH

The real-time data has great scientific value but it also has great potential for outreach and education. The COSSEE program at the National Science Foundation is focused on increasing scientific literacy by studying the oceans. In the Mid-Atlantic States, there is the COSEE-MA program focused on using observations from COOL in the K-12 classroom. One of the major goals of COSEE is to improve communication between educators and ocean scientists for the benefit of educators, their students, and ultimately the scientists themselves, as public understanding and appreciation for ocean research grows. COSEE MA is working on developing a plan for the development of a web product and programs that efficiently facilitate timely connections and exchange of information between ocean scientists and educators. In addition, COSEE-MA is contributing to the National Oceanography Curriculum. These efforts are expanding and new education partners are actively being engaged leveraging off the existing ocean observatory.

The synergy between COOL and COSEE has allowed individual projects to establish unique education and outreach programs. A current example of this is the Lagrangian Transport and Transformation Experiment (LaTTE), an NSF funded project focused on the Hudson River outflow. LaTTE is a multi-disciplinary, multi-institutional project with a strong linkage between the scientists engaged in the research and the educators bringing the research to the students and the general public. On example of this interaction grew out of a partnership Rutgers developed with the Liberty Science Center (LSC) in Jersey City, NJ.

Close to 30% of the US population lives in northeast United States and the majority live within 50 miles of the coast. Buoyant coastal currents extend along much of the US east coast and consist of a series of estuarine plumes that are fed by rivers with typical maximum discharge rates on the order of 1000 m3/s. Among these rivers the Hudson's flow rate is typical, yet it may dominate the transport of nutrients and chemical contaminants to the coastal ocean. For well over 100 years it has been the most urbanized estuary in the US. For example, only recently has Los Angeles's population exceeded what New York's was in 1900, and today over 20 million people live in its watershed. Currently 100 m3/s of treated sewage flow into the lower estuary and 90% of the associated inorganic nitrogen is exported unassimilated to the coastal ocean. It is arguably the most contaminated estuary on the east coast. NY-NJ harbor sediments, despite only accounting for 4% of the area in the EPA's designated Virginian Province (area from Cape Code to, and including, Chesapeake Bay), are responsible for 90% of sediments in this Province that exceed the EPA Effects Range Medium (ERM) standard for total

PCBs and 69% of those that exceed the mercury ERM standard. In fact, 58 of the 59 chemicals measured by the EPA in the Harbor had higher levels than the Virginian Provinces average.

Despite these rather alarming statistics, the Hudson river – estuary's water quality has been steadily improving over the last thirty years. To expand knowledge of these local waters the "Home on the Hudson" work shop focused on providing teachers a hands-on experience sampling the aquatic environment (Fig. 3). The goal was illustrate: 1) the estuary is a collection of different habitats with unique characteristics that function collectively as part of a larger ecological system, 2) the ecology of the estuary consists of physical and biological processes, including a diversity of organisms that are intimately connected, 3) The estuary has a long history of human uses and influences, including commerce, transportation and recreation, 4) Scientific research contributes to an improved understanding of how the estuary functions, and provides objective data for effective stewardship and management of the system. This professional development workshop was held for 12 educators in August of 2005. Participants interacted with Rutgers scientists and COSEE-MA educators for 3 days to learn about the Hudson River estuary and related resources they can use with their students. Teachers were introduced to these concepts at sea and were given experience with cutting edge technologies, such Webb gliders, with the goal to allow them to be more comfortable using the expanding suite of science lesson plans that have been developed by Rutgers and are distributed through the "COOL classroom" (Fig. 4).

Figure 3. The Home on the Hudson workshop. Teachers went to sea with scientists and deployed state of the art technologies such as the Webb glider.

Figure 4. The COOL classroom website.

III. GRADUATE EDUCATION AND THE GATHERING STORM

The National Research Council in 2006 released a report "Rising above the Gathering Storm" that suggested the United States economic vitality is facing a highly competitive global environment which threatens to drain the high-quality knowledge intensive jobs that have fueled this countries wage growth over the last century. One of the major recommendations was to "make the United States the most attractive setting in which to study and perform research so that we can develop, recruit, and retain the best and brightest students, scientists, and engineers from within the United States and throughout the world". In the ocean sciences the future will in part rest in developing the capability to, for the first time in human history, have a well sampled ocean. This will allow effective resource and economical management for of the oceans which contributes close to a trillion dollars to the national economy.

Currently the growth of a federation of regional systems is in part limited by the inability to find properly trained people capable of operating the new systems [1]. It has been suggested that not every new student needs to be trained as a Ph.D. research oceanographer. Following the meteorological paradigm, there likely is a cadre of interested students, and now a demonstrated need, to train some as operational oceanographers, probably at the Masters level. Public debates over exactly who is considered an operational oceanographer have taken place [2-4], leading to the conclusion that, depending on the definition, between a few hundred to a few thousand operational oceanographers already exist in the Navy and NOAA. Using the broader definition, assuming 4,000 individuals and a 40 year work career, approximately 100 new operational oceanography graduates are needed annually to fulfill the existing need [2].

Education programs for training those 100 students did not exist until Rutgers developed a new Masters degree in Oceanographic Technologies in 2005. The purpose of the new degree is to produce Masters-level students in oceanography with background technology training and hands-on experience in a modern integrated and sustained research observatory. The program will generate the type of graduates required to operate the rapidly expanding network of research and applied observatories currently being constructed. Duration of the program is that of a standard Masters degree, typically 2-3 years depending on the time required for the Masters thesis. An important feature of the program is direct participation in ongoing research programs. Students will have numerous hands-on training opportunities in the collaborative environment of the R.U. COOL Operations Center. Within the collaborative setting of the Rutgers University (R.U.) Coastal Ocean Observation Lab's (COOL) Operations Center, students will receive hands on training in the use of advanced ocean observing technologies and will participate in the year-round field activities supported by the Center. Course work includes three of the core courses in physical, biological, chemical or geological oceanography and three hands-on courses to support the technology training in data analysis, platforms and sensors, and in atmospheric and oceanic modeling. Completion of a full Master thesis including its defense to demonstrate both written and oral communication skills was considered essential by all potential employers. Potential Masters thesis topics include improvements to the capabilities of sensors and sampling platforms, the analysis of the observatory datasets for a wide spectrum of applications, and atmospheric and ocean modeling applications. It is anticipated that a small cohort of 3-6 students will enter the program each year. Interacting as peers, they will learn from each other in a team oriented environment. The program was developed in collaboration with a similar evolving Masters program in Operational Oceanography at the University of Bergen in Norway. The U.S. side of this collaboration is currently being supported by the G. Unger Vetlesen Foundation. This program will admit it's second student in Fall 2006. The first student of the program graduated in 2005, and has subsequently been hired by the New Jersey Public utilities to provide high-resolution atmospheric forecasts which allow sea breezes to be resolved. Sea breezes impact the entire state of New Jersey as the sea breeze front propagates onshore (Fig. 5). Any predictive skill in sea breeze prediction allows utilities to optimize the purchase and allocation of power on the energy grid. This applied problem required the student to have sufficient understanding of the processes in the ocean that drive the potential of sea breezes to develop. Additionally the student required numerical modeling skills to run models in an operational manner. The program will scale up as demand builds.

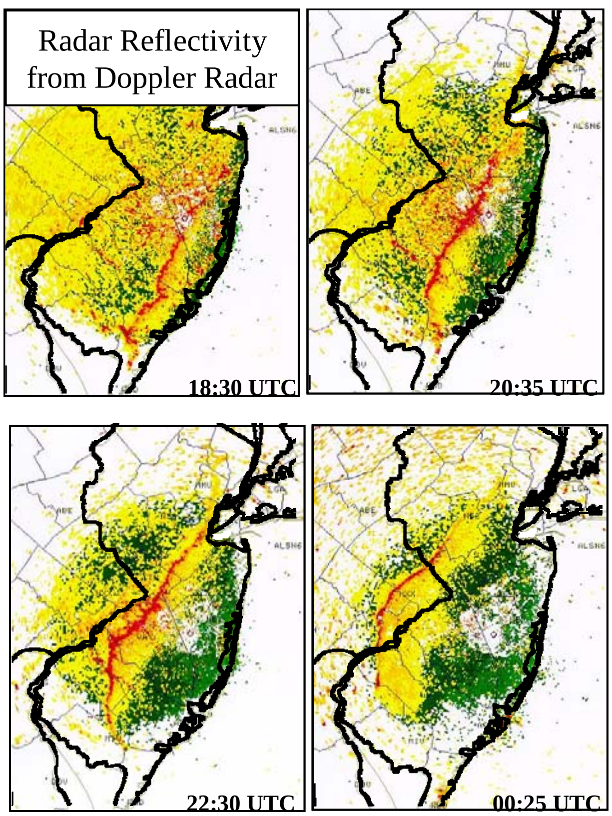

Figure 5. Doppler Radar showing the inland penetration of the sea breeze front across the state of new Jersey. The figure was provided by Louis Bowers and Leonard Bielory.

TABLE 1
The courses and requirements for Rutgers Masters of Operational Oceanography

Courses (3 credits each)

Background Core Courses (9 credits)
Physical Oceanography (PO)
Biological Oceanography (BO)
Chemical Oceanography (CO)
Marine Geology (MG)
Earth System History (ESH)

Operational Core Courses (9 credits)
Coastal Ocean Observing Systems (COOS)
Ocean Data Analysis (ODA)
Coastal Ocean & Estuarine Dynamics (COED)

Optional Courses (6 credits)
Remote Sensing (RS)
Waves, Current & Sediment Transport (WCST)
Estuarine and Sediment Processes (ESP)
Numerical Modeling I & II (NM-I; NM-II)
Microbial Dynamics (MD)
Large Scale Dynamics (LSD)
Radiative Transfer (RT)

Note: 24 Course credits are required.

One unique aspect of the program is that formal partnerships have been established with other Universities. This allows the masters students to partake in a range of hands-on efforts depending on which institution is hosting a field effort on any given year. The partner institutions benefit from having skilled students available during those field efforts. These field efforts occur after the students have completed their course work (Table 1). The cohort of students will be deployed as a team. Within each cohort, students will have sufficient flexibility to specialize in some observing technology (models, AUVs, or remote sensing). Taken together the students provide a wide skill set to benefit the field program.

The current partner institutions include California Polytechnic State University, Mote Marine Laboratory, University of Alaska (Fairbanks), and NAVOCEANO at Stennis Space Center. International partners include the Nansen Environmental & Remote sensing Center, the Institute of Marine Research, and the Norwegian Meteorological Institute. This partnership is expected to grow rapidly n the coming year as the international ocean observing community is developing a community that is built on the open exchange between existing observatories. In the past, information and technology exchange between systems has largely been informal and facilitated by the desire of scientists to work with each other. In an effort to formalize some of these informal collaborations an ocean observatory consortium was established in spring 2005. The consortium, the International Collaborating Ocean Observing Laboratories (ICOOL), represents partnership between several observatories in the United States (from the Northeast to Alaska), Canada, Norway, and England. The primary goal of these labs is the exchange of technology, models, and experience. Examples of such efforts include the successful deployments of COOL gliders at Liverpool (England), Rostock (Germany), and Perth (Australia) to provide these European groups field data to facilitate their efforts to garner funds to purchase gliders. As the global network of coastal observatories evolve, consortia like ICOOL will allow for interoperability, the efficient integration of rapidly evolving technologies throughout the global network, and the expansion of resources that any community can leverage from. Additionally the Masters of Operational Oceanography will benefit from having access to full international ocean observing community.

In conclusion, the ocean observatories will be extremely useful platforms for education and outreach. The observatory can provide understanding of the local environment such as the Hudson River while simultaneously providing the platform for training the technologists of the future.

IV. REFERENCES

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