The Census of Marine Life: Bringing a Decade of Global Research Into the Classroom

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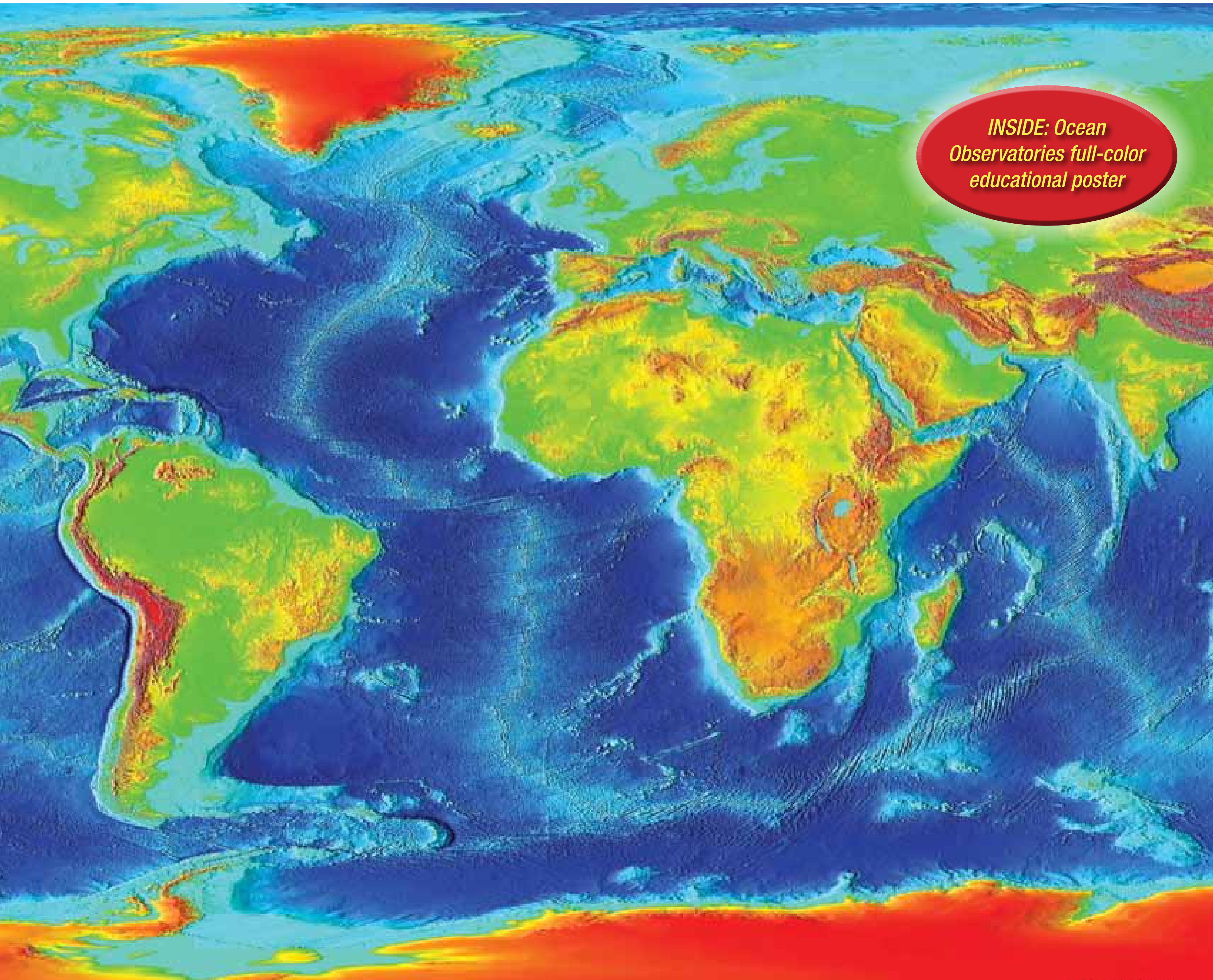

Credit: NOAA NGDC

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INSIDE THIS SPECIAL ISSUE

This themed issue is sponsored by CICOR at the Woods Hole Oceanographic Institution

From the President

Your Future in/the Future of Earth Science Education

by Dr. Michael J. Passow, NESTA President 2008 - 2010

This is almost my final President's Message in TES, but I'll follow the wise advice of many—Never Look Back, because you may not like what's gaining on you—and I'll focus on what's coming ahead for NESTA. Your Board of Directors has been meeting via teleconferencing every two weeks, and sometimes more frequently, to plan for exciting programs that NESTA will offer you. Among these are another great set of events at the NSTA Conference in Philadelphia—more about these elsewhere in this issue.

The more I scroll through the ever-expanding NESTA website, http://nestanet.org, the more I see its potential to become one of the most useful resources for ES educators. For this to happen, we need as many NESTA members as possible to start contributing images, lesson plans, information about meetings, etc. If you haven't done so yet, please do log on through your account, and share something.

Looking further ahead, NESTA is one of the sponsoring organizations at next fall's USA Science and Engineering Fair (www.usasciencefestival.org/). This celebration will take place on the National Mall in Washington, DC on Sunday, 24 Oct. There will be hundreds of exhibit booths highlighting all aspects of Science teaching, research, and society interactions. We'll be glad to have NESTA members help staff our booth at this unique event. Watch for more information as it approaches.

Finally, this issue is another example of the synergy that can result when NESTA partners with other science organizations. Enjoy the articles, and then create your own contributions to ES.

Dr. Michael J. Passow

From the Executive Director

Dear NESTA Members,

I hope you enjoy this special issue of *The Earth Scientist*, which focuses on ocean sciences, sponsored by the Woods Hole Oceanographic Institution (WHOI). The issue is full of articles describing activities that you can use in your classroom to bring ocean science alive for your students. NESTA gratefully acknowledges the support of WHOI for this special issue!

As I write this letter, the NESTA leadership team is completing finishing touches on the schedule for our events at NSTA in Philadelphia. This issue includes a schedule of events for the conference, and we hope to see you there!

In addition to these events, NESTA will be offering a Field Trip on Wednesday, March 16, in advance of the NSTA Conference. The field trip will provide an overview of Pennsylvania geology, and will be led by Dr. Jane Dmochowski of the Department of Earth and Environmental Science of the University of Pennsylvania and Dr. Michael Smith of the Wilmington Friends School. The trip will include exploration of the geology of the Wissahickon Valley and Valley Forge National Park, Pennsylvania. Philadelphia's geology records the story of the formation and rifting apart of Pangaea with extraordinary examples of the many stages in this process. Visible at the surface within just miles of Philadelphia are schist and gneiss outcrops formed during subduction 450 million years ago, sandstones that collected in basins formed during rifting 200 million years ago, and surface features formed by weathering and erosion, including karst topography. The trip will feature a wide range of geological features and formations, including the metamorphic geology of the Wissahickon Valley (schists, gneiss, migmatite, quartzite, chlorite veins and more), as well as Ordovician dolostones and Triassic red shales and sandstones in Valley Forge. Attention will also be given to geomorphology, sinkholes, urban parks, and history of local mining. Participants will receive a guidebook and have opportunities to collect specimens at selected stops.

Those of you interested in joining us on this exciting field trip are welcome to sign up in advance – preferably by 10 March. Information is available on the NESTA website at www.nestanet.org/cms/content/trips/upcoming. You can either send in a form with check payment (download the form at www.nestanet.org/cms/system/files/documents/FieldTripRegistration2010.pdf) or sign up and pay online at www.nestanet.org/cms/content/conferences/register. The fee for the field trip is $50.

Finally, I would like to thank the generous sponsors of our events at the NSTA in Philadelphia. Carolina Biological has been a long time supporter of NESTA, and provides numerous quality specimens to our Rock and Mineral Raffles around the country every year, in addition to classroom kits and other resources. The American Geophysical Union, also a long-time supporter of NESTA, underwrites our ads in NSTA Reports and the NSTA Program, and also this year provided matching support to our year-end fund-raising drive! Through the generosity of 24 individuals and organizations, and AGU's matching support, NESTA was able to raise $6620 in support of its programs! I'm also very happy to announce that Pennsylvania State University has generously agreed to provide partial support for NESTA for our Friends of Earth Science Reception at NSTA on Friday evening. We're excited that the American Geological Institute will be presenting the Edward C. Roy, Jr. Award for Excellence in K-8 Earth Science Teaching at our reception! Of course, we need to also thank the National Center for Atmospheric Research, the University Corporation for Atmospheric Research, and the Windows to the Universe project for their continuing support of NESTA as well. Thanks so much to all of these organizations for their support – without these contributions and the support and effort of the people involved, it would not be possible to bring the services NESTA brings to its members and other Earth and space science teachers across the country.

Cheers!

Dr. Roberta Johnson
Executive Director, NESTA

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In a rare moment in 2006 when all three WHOI research vessels were in port at the Iselin Marine Facility at the Woods Hole Oceanographic Institution. The Oceanographic has been a center of oceanic research since 1930 when it joined an already thriving scientific community in the village of Woods Hole. (The Marine Biological Laboratory and the NOAA's North East Fisheries Science Center are also pictured here to the left.)

Introductory Notes on the Ocean Observatories issue of *TES*

The ocean is central to the habitability of our planet, yet, because it is a vast and often hostile environment for humans to work in, less than five percent of it has been explored. With new gains in technology, ocean exploration is on the brink of a sweeping transformation, from ship-based expeditionary research to long-term observatory science.

This special issue of *The Earth Scientist* is sponsored by the Cooperative Institute for Climate and Ocean Research (CICOR) at the Woods Hole Oceanographic Institution (WHOI) and is designed to provide a variety of resources to teachers and students to learn more about the world's oceans. The articles, by teachers and writers from Alaska to Florida, Maine to Hawaii, California to Cape Cod, and Montana to Arkansas, cover a range of topics including polar research, coral reefs, ocean acidification, air-sea interactions, climate research, the Census of Marine Life, ocean drilling, and information on cutting edge observatory initiatives, which are changing the way information on the ocean is collected and shared.

The research projects highlighted here represent a broad sampling aimed at enticing teachers and students into greater awareness of the ocean, the health of which is critical for people everywhere, not just for coast-dwellers. These projects also demonstrate that science, particularly today's ocean and environmental science, is a multi-disciplinary and collaborative activity requiring teams of individuals with diverse backgrounds, training, and expertise.

This Earth Scientist issue, despite its expanded length, cannot possibly address all ocean observatory efforts of note. For information on additional ocean topics, please see a more comprehensive list of ocean science web resources for educators at: http://www.whoi.edu/CICOR.

We wish to thank all the contributing authors, NOAA Education and the Consortium for Ocean Leadership for their involvement. We also wish to acknowledge the team at the University of Washington's Center for Environmental Visualization, (CEV), which excels at producing compelling visual representations of complex earth systems. With input from a broad oceanographic community CEV developed the poster insert, which we hope readers and students enjoy along with the rest of this issue.

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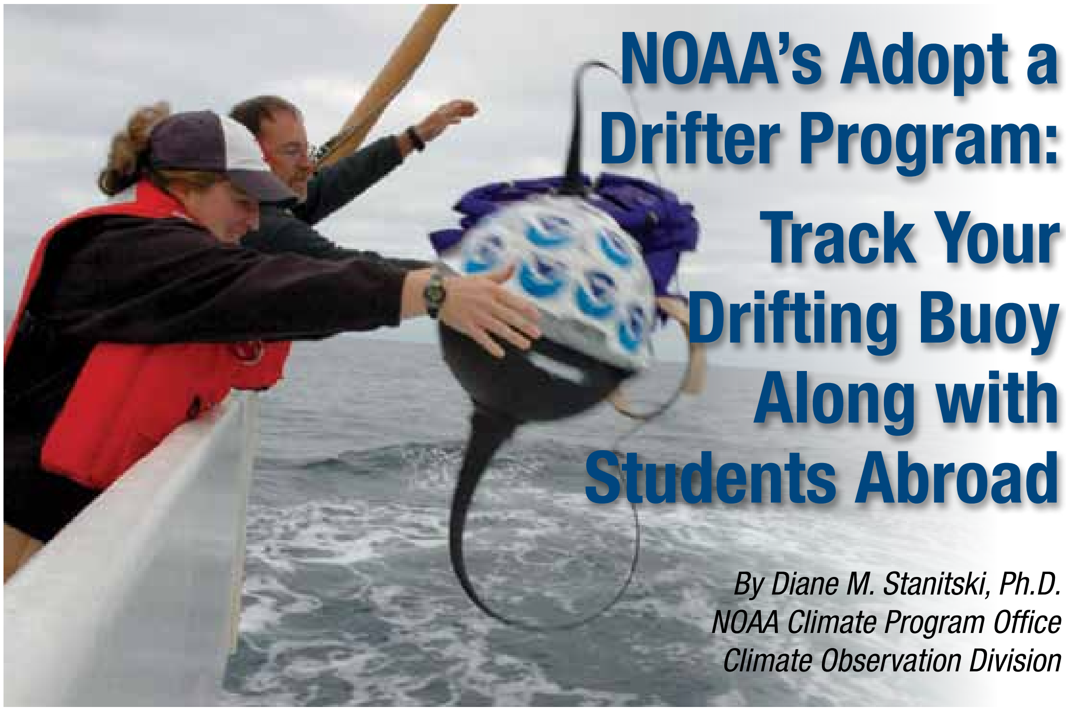

NOAA's Adopt a Drifter Program: Track Your Drifting Buoy Along with Students Abroad

By Diane M. Stanitski, Ph.D.
NOAA Climate Program Office
Climate Observation Division

NOAA Teacher at Sea Megan O'Leary and Jeff Lord, Mooring Specialist from the Woods Hole Oceanographic Institution deploy a drifting buoy as part of the Adopt a Drifter Program. The drifter was adopted by Ana Maria Varela's classes at St. Matthew's College in Argentina, and Todd Toth's class at Waynesboro High School, Waynesboro, PA

Credit: Sean Whelan, WHOI

Abstract

In December 2004, the National Oceanic and Atmospheric Administration (NOAA) ***Adopt a Drifter Program*** (ADP) was established. Teachers and students of all ages have co-adopted a drifting buoy and collaborated with educators and students at schools abroad. Each drifting buoy is equipped with a sea surface temperature sensor and GPS unit (and occasionally an atmospheric pressure sensor), and the drifter's data are sent to satellites and then to data collecting centers where it can be readily accessed on-line. Educators develop lessons using the drifting buoy data and, just as importantly, tools to communicate effectively with their partnering students abroad. Students in the teachers' classes use drifter tracking charts to observe and plot the coordinates of the drifter as it moves freely in the surface ocean currents. Through the ADP, teachers and students can more easily make connections between the sea surface temperature data accessed on line and other processes connected to the oceans and atmosphere, including ocean circulation and wind patterns. The Program provides teachers with the opportunity to infuse ocean observations into their curriculum and communicate with schools abroad. The *Adopt a Drifter Program* website and application to participate can be accessed at www.adp.noaa.gov/index.html. No costs are involved for the participating schools.

Program Goals and Criteria

The NOAA Adopt a Drifter Program was established to enable students to:

1) access, monitor, and manipulate real world oceanographic data and make connections between these data and local, regional, and global-scale oceanic and atmospheric processes, and

2) collaborate with students in schools abroad to establish a science-based relationship where email and other interaction enables scientific discussions and cultural connections between the students.

Criteria used to accept teachers into the *Adopt a Drifter Program* include the willingness to participate in a collaborative effort with a school or group abroad, the development of lesson plan ideas that will be implemented in the school year during or immediately following the drifter deployment, and the technology necessary to track the drifter using the ADP website.

ADP Logistics

Collaborating schools that are accepted to participate in the *Adopt a Drifter Program* receive NOAA stickers that the students sign and send to the ship where the drifter will be deployed. NOAA Corps officers, scientists, and/or crew members on board attach the signed stickers to a drifting buoy and then photograph the drifter launch. Photos and information about the buoy are placed on the ADP drifter tracking page at www.adp.noaa.gov/track_drifting_buoys.html.

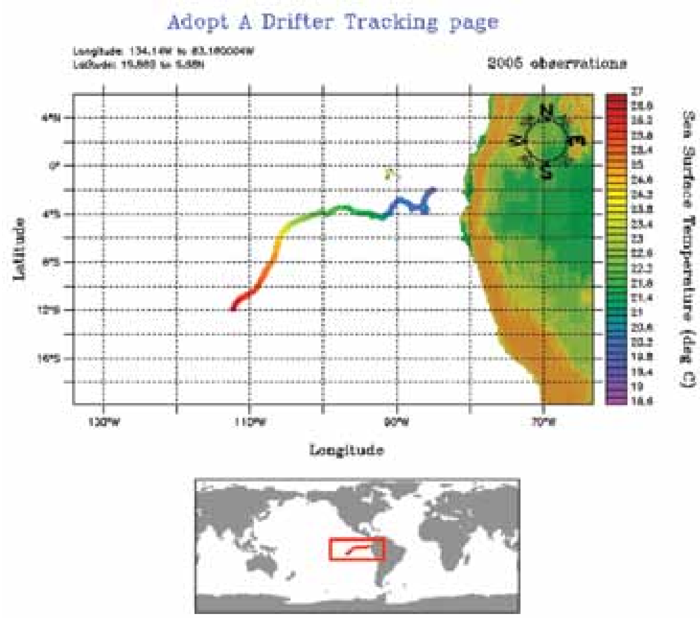

Figure 1. Students can track their drifter's sea surface temperature as the drifting buoy moves with the ocean currents. The *Adopt a Drifter Program* tracking page can be accessed at www.adp.noaa.gov/track_drifting_buoys.html.

Importance of Drifter Data

Drifter data are used to track major ocean currents and eddies globally, ground truth data from satellites, build models of climate and weather patterns, predict the movement of pollutants dumped or accidentally spilled into the sea, and assist with the forecast path of approaching hurricanes. For scientists and students, it is important to understand how the data are measured, how often data are downloaded, and what data are available for schools and the general public to access. Through the ADP, students have access to their adopted drifter's data (e.g., latitude/longitude coordinates, time, date, sea surface temperature) in near real-time as well as access to data from other select drifting buoys deployed as part of the global ocean observing system. Students can access, retrieve, and create a time series plot of various subsets of drifting buoy data (e.g., SST). They can also track and map each adopted drifting buoy for short and long time periods (e.g., one day, one month, one year). See Figure 1 for an example of a drifter's path as displayed on the NOAA *Adopt a Drifter Program* tracking page.

Drifter Recovery

On occasion, a drifting buoy is recovered after its deployment. For example, after a 521-day journey across the Atlantic Ocean, Global Drifter 1250 was recovered on 21 February 2007 near Brest, France. The buoy's sea surface temperature and atmospheric pressure sensors were still functioning perfectly at the time of recovery.

This special buoy's odyssey began on 18 September 2005, in Halifax, Canada, when a ceremony was held aboard the Tall Ship Silva with eighty-seven representatives from 16 countries gathered to celebrate the deployment of Global Drifter 1250. With this deployment, the global drifting buoy array achieved its design goal of 1250 data buoys in sustained service, becoming the first component of the Global Ocean Observing System (GOOS) to be fully implemented. The requirement of 1250 drifting buoys consistently crossing our oceans is driven by the need for buoy measurements of sea surface temperature across the globe in combination with satellite measurements.

The French Naval vessel RHM Tenace, an open ocean tug, retrieved the buoy. The recovery was in itself a special event, since drifting buoys have seldom been recovered in the past. They often disappear at sea. The average life expectancy of drifting buoys is 400 days. Yet 521 days after deployment and at the time of recovery, Global Drifter 1250 was still dutifully reporting its ocean observations via satellite communications to meteorological-ocean centers around the world.

Lesson Plans Using Drifter Data

Participating teachers have assimilated drifter data into their lessons in a number of unique ways. Lessons involve making connections between the ocean and atmosphere to provide students with examples of the integrated earth system. Table 1 includes a sample of available lesson plans and accompanying objectives.

Table 1. Sample Lesson Plans and Objectives created by Teacher Participants in the *Adopt a Drifter Program*

Lesson Plan Title	Lesson Plan Objectives
A Laboratory Simulation of Ocean Surface Currents	Students will identify the forces that cause ocean surface currents.
Do Ocean Surface Currents Influence Climate?	Students will construct climographs for three coastal cities. Students will describe how ocean surface currents affect climate on land.
"Where's Bob?": Tracking a Drifting Buoy	Students will use the Adopt a Drifter Program website to locate and track a drifting buoy. Students will utilize their map skills to plot data from a table onto a map. Students will identify the current in which each drifter is moving.
Comparing Drifters in Different Oceans	Students will graph temperature vs. time. Students will evaluate graphs and compare sea surface temperature in different oceans. Students will convert Celsius temperatures into Fahrenheit temperatures.
Sea Surface Temperature (SST): Ground Truthing Satellite Imagery with Drifting Buoy Data	Students construct tables containing sea surface temperature data from drifting buoys and satellite data. Students will compare drifting buoy data with satellite imagery to ground truth the satellite images.
Ocean Currents Using an Adopted Drifter	Students will observe, collect, and interpret real time data from an adopted drifting buoy.
Graphing and Comparing Data using our Drifting Buoy	Students will participate in a group activity to graph and discuss ocean temperature data from the drifter buoy.
Graphing and Working with Position Data from our Drifting Buoy	Students will participate in a group activity to plot and work with position data from the drifter buoy.
Discovering Currents	Students will participate in a group activity to learn about and discuss ocean currents and the class drifter buoy.

These and other lessons can be accessed on the Adopt a Drifter Program website at www.adp.noaa.gov/lesson_plans.html

Teachers may have the opportunity to deploy their school's own drifting buoy from a ship at sea. If a teacher is accepted to be a participant in the NOAA Teacher at Sea Program (see *NOAA's Teacher at Sea Program: Living and Learning at Sea*, in this issue), and is aboard a ship where drifter deployments take place, it is possible that teachers can deploy their school's buoy while at sea.

How to Participate

The *Adopt a Drifter Program* website and application to participate can be accessed at www.adp.noaa.gov/adopt_a_drifter.html. No costs are involved for the participating schools.

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NOAA Teacher at Sea, Nicole Macias, assists in tagging a white-tipped reef shark while aboard NOAA Ship *Oscar Elton Sette.*

NOAA's Teacher at Sea Program: Living and Learning at Sea

By Elizabeth McMahon, Deputy Director, NOAA's Teacher at Sea Program and Jennifer Hammond, Director, NOAA's Teacher at Sea Program

Abstract

Since 1990, The National Oceanic and Atmospheric Administration's (NOAA) Teacher at Sea (TAS) program (*at http://teacheratsea.noaa.gov*) has enabled over 550 teachers to participate in hands-on scientific research at sea aboard NOAA ships. By participating in the program, teachers gain a clearer insight into our ocean planet, a greater understanding of maritime work and studies, and a higher level of environmental literacy through an interdisciplinary research experience. The program provides a unique environment for learning and teaching by sending kindergarten through college-level teachers to sea to work under the tutelage of scientists and crew. Teachers are then able to bring this knowledge back to their classrooms, generating among their students increased enthusiasm for learning more about our oceans and atmosphere. The TAS program goals, criteria for applying and expectations are presented here as well as unique reflections and lesson ideas from several TAS participants.

Program Goals

The goals of NOAA's Teacher at Sea (TAS) program are: first, to increase environmental literacy, and second, to help to build a workforce for STEM-related careers. A recent groundbreaking study published in the journal *Science* proves that teachers who participate in real-world scientific research positively impact their students' achievement (Silverstein, Dubner, Miller, Glied, & Loike, 2009).

Program Criteria

The Teacher at Sea program receives about 200 applications a year and makes a selection of about 30 participants. Teachers are required to submit the application along with two letters of recommendation and a health form. Other criteria are available on the TAS website.

Program Activities and Expectations

Most participants spend an average of two weeks at sea. Some cruises are only a week and some are over a month, but most last between 12 and 16 days.

The TAS program oversees all logistics and funding for teachers' travel to and from their home to the location of the ship. Once on board, depending on the type of research being conducted, teachers do everything from sorting and dissecting fish, to installing a tidal benchmark, to helping navigate the ship.

Teachers must agree to a statement of work which includes among other things, submitting logs and photos while at sea (which are posted on the Teacher at Sea website), and creating an in-depth lesson plan based on their experience to use in their classroom the following school year. They are also asked to give a presentation or write an article about their experience.

After returning from their cruise, teachers have up to a year to fulfill their statement of work. Once that is completed, teachers become part of the NOAA Teacher at Sea Alumni Association, through which they are encouraged to continue their relationship with NOAA.

Reference

Silverstein, S.C., Dubner, J., Miller, J., Glied, S., & Loike, J.D. (2009). Teachers' participation in research programs improves their students' achievement in science. *Science*, 326, 440. doi: 10.1126/science.1177344

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A Teacher's Reflections on Her Teacher at Sea Experience

By Mary Esther Cook, Ahlf Jr. High School, 308 W. Vine, Searcy, AR 72143, esthercookie@yahoo.com

Real-world field experiences can bring an entirely new and exciting perspective to teachers and their students when discussing ocean science concepts and research in the classroom. I share my experience as a NOAA Teacher at Sea and the positive influence it exerts upon my teaching and my students' learning of the oceanic sciences.

Figure 1. Mary Cook (on right), a junior high science teacher from Searcy, Arkansas, deployed the first adopted drifting buoy in the Pacific Ocean from the NOAA ship Ronald H. Brown. The buoy was released off the coast of Chile in December 2004. Mary's students adopted this buoy and nicknamed it "Bob".

While aboard the research vessel Ronald H. Brown during a Stratus cruise off the coast of Chile, I worked in close association with Chief Scientist, Dr. Robert Weller, of the Woods Hole Oceanographic Institution, and my mentor, Dr. Diane Stanitski, climatologist and coordinator of the NOAA Adopt a Drifter Program. My students and school were the first to adopt a drifting buoy that I deployed during my journey.

Teacher Research Experiences at Sea

When I reflect upon my voyage as a NOAA Teacher at Sea, I consider it from the perspectives of how it has impacted my own life and how it impacts my students. Even though my TAS cruise took place a few years ago, it continues to be the potent force in my teaching about oceanic and atmospheric sciences today. Being a NOAA Teacher at Sea changed me. It took me out of my comfort zone into the world of real oceanic research. Becoming the "learner" enabled me to be a better teacher for my students. Before Teacher at Sea, my total experience of the ocean was obtained at the beach while on vacation. However, observing tides, feeling the power of a breaking wave and getting carried along by longshore currents, gave me more familiarity with the ocean than most of my central Arkansas 8th graders. Less than 50% of them have met the ocean face to face and it is an intangible concept to most of them. So, how do you teach tides and waves and the magnitude of the ocean's influence on the Earth so that it becomes part of their body of knowing, not just a regurgitation of facts? It's nearly impossible!

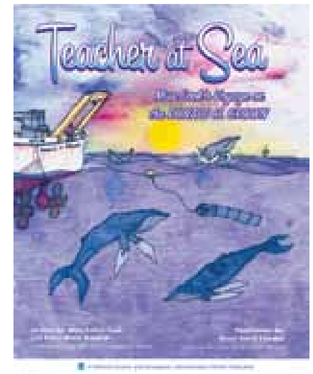
Figure 2. Scientists and technicians deploy Stratus X buoy in 4440m (over 2.75 miles) of water off the coast of Chile, where a deck of stratus clouds make sea surface measurements from satellite impossible. The importance of teamwork and safety can not be overestimated.

Having firsthand experience, however, carries a lot of weight with 8th graders. Being a Teacher at Sea provided me with a multitude of firsthand experiences, from working with real scientists and engineers to living at sea aboard a scientific research vessel. It is absolutely the best way to learn, especially for understanding the complexities and sheer magnitude of oceanic and atmospheric observations. As my knowledge increased, my amazement increased, too. I was astonished to learn about the colossal efforts put forth to monitor the ocean-atmosphere interface using instruments such as drifting buoys, Argo floats, and the moored Stratus buoy off the coast of Chile. It was thrilling to learn about the special designs and techniques employed by the scientists and engineers on the cutting-edge of oceanic and atmospheric research. Learning how the buoys work while collecting and transmitting information was a real eye-opener for me. With each passing day I became more enthusiastic about teaching and involving my students. Beyond telling them about the science, I wanted each one of them to have a personal investment in their own learning. Adopting a drifting buoy through the NOAA Adopt a Drifter Program (ADP) was the clincher. Their level of interest skyrocketed. My students had their own buoy adrift, which we named "Bob", that housed an ocean temperature sensor and Global Positioning System (GPS) unit, enabling them to track Bob's path and to monitor sea surface temperature and ocean currents for two years. Every day they wanted to access their buoy's location and temperature data. They were motivated to learn detailed mapping techniques in order to accurately plot the buoy on a daily basis. Longitude, latitude, degrees, minutes, and seconds became particularly important to them (see Fig. 3). They were self-motivated because they had a personal interest.

Figure 3. "Bob" the drifter awaiting deployment (left) and students tracking its path in the Pacific Ocean (right).

Even though the Stratus project and the Adopt a Drifter Program were the main events onboard, other important projects were being conducted such as releasing weather balloons to collect atmospheric data, conducting CTD casts, deploying a tsunami buoy in conjunction with the Chilean Navy, mapping the ocean floor, and deploying

Argo floats. All of this great science happening before my very eyes provided a golden opportunity to write a science storybook which Dr. Stanitski and I did for my students! *Teacher at Sea: Miss Cook's Voyage on the Ronald H. Brown* highlights the major science work carried out during my TAS cruise. The ship's boatswain, Bruce Cowden, provided beautiful illustrations that accurately depict the ship and all the instrumentation on board. Teachers can request a free copy in an email to NOAA-OUTREACH@noaa.gov. I use this book every year during our ocean studies and it has opened the door for cross-curricular collaboration between our Science and English Departments. The *Teacher at Sea* book is now on our Accelerated Reading list and testing center where many of my students earn a score that can also be used for their literacy goals.



Cover of the book *Teacher At Sea Miss Cook's Voyage aboard the Ronald H. Brown*. You can view this book and accompanying lesson plans online at http://teacheratsea .noaa .gov/books/index .html .Read further about Mary Cook's experience at sea and her students' experiences tracking their adopted drifter in NOAA's Teacher at Sea Program: Living and Learning at Sea. A pdf copy of this book is available at: http://oceanservice.noaa.gov/education/yos/resource/09A_tas_book1.pdf

Impacts in the Classroom

My new students this year have adopted another drifter and are just as enthusiastic about tracking their own buoy and collecting and examining the same drifter data that real scientists analyze. In having the opportunity to come in contact with real scientists doing authentic research, the students are learning lessons beyond the science itself; hey are internalizing the concepts and context of scientific research process.. The Adopt a Drifter Program enables this level of participation and understanding for each student. The ADP also encourages cross-cultural interaction.. This year our school is co-adopting a drifting buoy with a school in Costa Rica. Besides comparing drifter data and predictions, both classes of students are writing and creating PowerPoint presentations for each other, ranging from comparing our climates to sharing facts about school life in our different countries.

A further result of the NOAA Teacher at Sea and Adopt a Drifter Programs seems to be that my students have an increased awareness of the realm of career possibilities open to them in the fields of science and engineering.

My Month Aboard the Ronald H. Brown on the Stratus Cruise as a Teacher at Sea

By Megan O'Leary, Truro Central School. PO Box 2029, Truro, MA 02666, MeganOLeary1@gmail.com

I had the extraordinary opportunity to spend a month aboard the Ronald H. Brown on the Stratus Cruise as a Teacher at Sea, and upon my return I created a WebQuest for my students. Our quest takes students on a virtual journey allowing them to become oceanographers, meteorologists, marine biologists and navigators. The marine biologists identified and studied certain animals of the deep along with unique tortoises and iguanas of the Galapagos Islands. "I thought it was pretty amazing how the gooseneck barnacles on the bottom of the Stratus Buoy wouldn't come off unless you used a little force.",

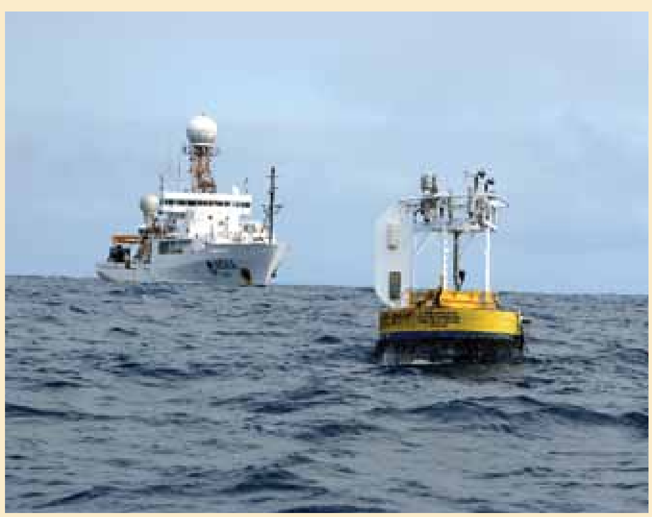


Figure 4. The Stratus Buoy prior to its retrieval with the Ronald H. Brown in the background.

Figure 5. (left) Truro Central School fifth grade class's decorated styrofoam cups prior to their swim with the CTD 4,000 meters below the ocean's surface.

Figure 6. (right) Truro Central School fifth grade class's styrofoam cups after their swim with the CTD 4,000 meters below the ocean's surface.

Cameron conveyed and Briana thought, "it was pretty interesting because we got to learn how some species of whales have teeth and some have baleen". The meteorologists spent a week attempting to predict the weather on Cape Cod, not an easy job even for professional meteorologists! Daniel commented, "I was a meteorologist and it was amazing to watch how the weather changes so much over time." Our navigators needed to steer our course through the Gulf Stream, around the loop current to arrive at the Panama Canal in time for our transit across to the Pacific Ocean. Shannon told us, "I learned a lot about navigation, especially how the ocean currents and weather can impact the shipping lanes." The oceanographers on the team discovered many new species aboard the AUVs and even discovered a Revolutionary era shipwreck. Silas found "the OCEAN QUEST to be an exciting, intriguing project on exploring the deep sea."; while Jonathan thought "the OCEAN QUEST was amazing because we were able to discover sunken ships from so long ago." A wonderful experience was had by all. I have completed this WebQuest in subsequent years and it is always a favorite project of fifth graders. Please feel free to take the quest with your class at: http://www.truromass.org/media/OCEANQUEST.htm

Two Montanan Teachers at Sea

By Art Bangert, Associate Professor of Education, Montana State University, Bozeman, Montana, abangert@montana.edu and Rick Jones, Earth Science teacher, Billings Senior Freshman Academy, Billings, Montana, jonesr@billings.k12.mt.us

The Teacher at Sea Program places teachers on various scientific NOAA projects. In January 2010 two Montanan teachers, Art Bangert and Richard Jones went on an active research cruise aboard the NOAA Ship Ka`Imimoana. Here they describe the science conducted and how the experience augments what they have to offer students.

The Ka`Imimoana or KA, Hawaiian for Ocean Seeker, is the only NOAA ship with the sole mission of climate research, through its support of NOAA's Tropical Atmosphere-Ocean (TAO) Project. This project is designed to improve our understanding of the role of the tropical ocean in modifying the world's climate (NOAA, 2009). The ship deploys, recovers, and services deep-sea moorings that measure ocean currents, ocean temperatures, and atmospheric variables in the equatorial Pacific Ocean. The TAO buoy array consists of approximately 70 moorings in the tropical Pacific Ocean, telemetering oceanographic and meteorological data to shore in real-time via the Argos satellite system (Office of Climate Observation, 2009).

The Teacher at Sea experience helps classroom teachers realize a deeper understanding of the complexities associated with collecting data that climate scientists need to produce predictive models of weather patterns (e.g., El Nino and La Nina) that can potentially impact humans and and their environment. The extreme efforts of NOAA scientists, technical specialists, and dedicated crews from NOAA ships are geared to making this data available. This TAS experience is the second for Rick Jones, an Earth Science teacher from Billings who sailed for 65 days on a similar cruise on the KA in 1998, Art Bangert, professor of education at Montana State University is new to the program and like many people he was aware of El Nino in general but didn't really understand how scientists gathered data to produce models of those weather patterns. After his participation in his first buoy recovery and deployment, Art commented, "I had no idea of how involved and complex the process was for deploying and collecting probes that provide the data that climatologists use to predict the weather".

It is this level of involvement in real science that draws Rick again to the tropical Pacific. "Most of my students are amazed that their teacher has ever done anything like this. These experiences have given me first hand knowledge of how science is conducted and when students ask when are we ever going to need this, I can give them concrete examples based on my time as a TAS. Being a TAS gives a teacher a unique opportunity to do science, not just teach it.

Figure 7. Rick and Art place fairings on the Nielspin (a plastic coated conductive wire) to help reduce drag on the anchor line from strong currents at the Equator. (A. Bangert)

In addition to the science learning that the teachers in the TAS program gain, working side by side with the NOAA crew also helps to create a better awareness of the career opportunities that are available for students. NOAA scientists are trained to be officers that can wear many hats. Some become "Chief Scientists" who are responsible for leading the deployment and retrieval of buoys and other scientific equipment designed to collect climate data. However, other NOAA officers command or oversee the operations of the ships that transport scientists to their data collection sites. It is often the case that NOAA officers have experience as both a "Chief Scientist and as a research ship's commanding officer. What wonderful career opportunities for students to know about when considering a diverse range of careers related to science, technology, engineering and math (STEM).

To see pictures and read Rick and Art's daily blog from the ship visit: http://www.montanateachersatsea.blogspot.com/

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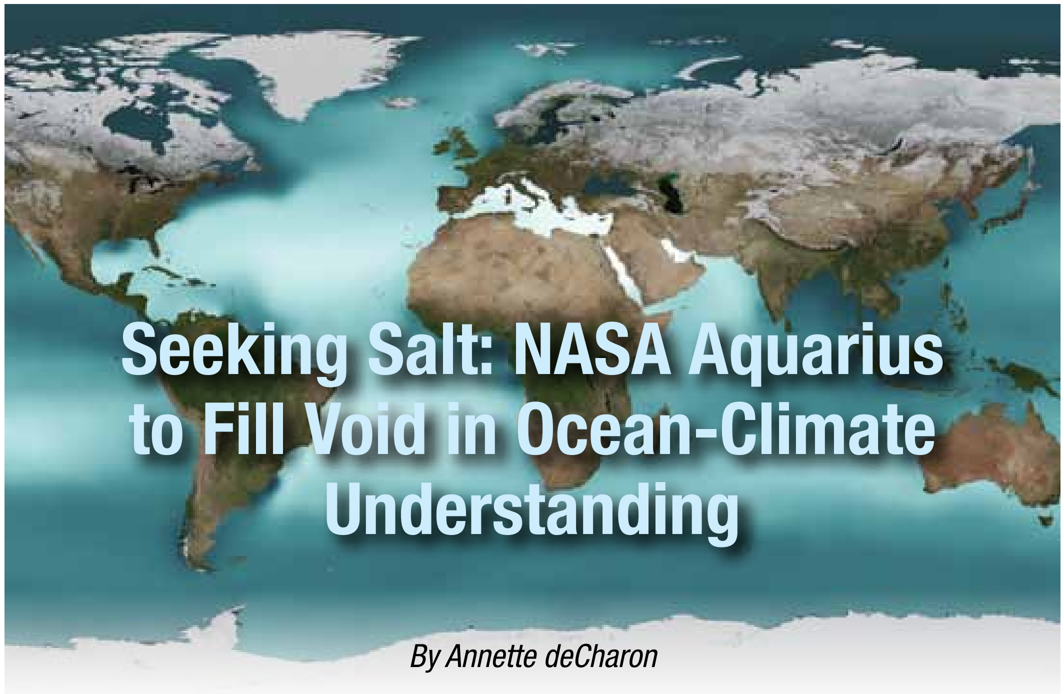

Seeking Salt: NASA Aquarius to Fill Void in Ocean-Climate Understanding

By Annette deCharon

Abstract

For something so fundamental, very little is known about the ocean's salinity. The Aquarius/Satélite Aplicaciones Cientificas-D (SAC-D) satellite mission will soon measure sea surface salinity from space. These new data will help researchers better understand ocean circulation, water cycle, and climate processes. Aquarius educational activities, tools, and materials will give educators and students access to data and insights made possible by this 21st century technology.

Introduction

One of the most fundamental properties of seawater is its saltiness or salinity. Measurements of salinity have been taken directly for centuries, yet 24% of the entire ocean's surface has never been measured. Now, three decades of scientific and technical development have made it possible to accurately measure sea-surface salinity (SSS) from a sun-synchronous orbit 657 kilometers (408 miles) above Earth's surface. Scheduled for launch in 2010, the U.S.-Argentine Aquarius/SAC-D satellite mission is designed with SSS as its primary measurement (Figure 1). From the outset, education and public outreach (EPO) has been an important, highly integrated and complementary component of the mission.

Figure 1. Visualization of Aquarius/SAC-D satellite in orbit

Scientific & Technical Importance of Aquarius

A key Aquarius objective is to provide high-quality EPO resources that mirror the mission's scientific and technical program. For example, data from Aquarius will significantly improve understanding of ocean circulation, the water cycle and climate. Also, the cutting-edge nature of Aquarius/SAC-D provides an opportunity to address technical achievement in the 21st century.

Ocean Circulation – Aquarius will be highly complementary to existing satellite programs that monitor sea surface temperature because, together, salinity and temperature control density at the ocean surface. Sea-surface density drives formation of ocean water masses and three-dimensional ocean circulation. Thus better understanding of SSS patterns will improve understanding of the ocean's capacity to store and transport heat.

Water Cycle – Earth's "water cycle" is dominated by ocean-atmosphere exchanges: globally, 86% of evaporation and 78% of precipitation occur over the ocean. SSS is key for understanding the fresh-water fluxes into and out of the ocean system. This is because some parts of the water cycle decrease salinity (e.g., precipitation, groundwater flow to the ocean, river runoff) and some parts increase it (e.g., evaporation and freezing of seawater). With Aquarius data, scientists will be able to relate SSS variations to evaporation and precipitation, providing insight into how the ocean responds to seasonal and annual variability in the water cycle.

Climate – Oceanographers believe that maintaining density-driven ocean circulation is key to keeping ocean heat transport - and Earth's climate - in balance. Increases in SSS in high latitudes can increase seawater density accelerating the deep overturning circulation in the ocean. Conversely, decreases in SSS (e.g., by melting ice) may result in widespread decreases in seawater density, reducing its ability to sink. In a very simple model, decreasing SSS in the North Atlantic would reduce the efficiency of the ocean "global conveyer belt" which helps to regulate global climate by moving heat from the tropics to higher latitudes.

21st Century Technology – Salinity remote sensing is accomplished by measuring microwave emissions from the sea surface in terms of a parameter called brightness temperature (in kelvin), correcting for other natural emission sources and sinks. Ocean brightness temperatures are related to the dielectric properties of seawater, and at lower microwave frequencies, these are modulated by salinity. The principal scientific objective of Aquarius is to take global SSS measurements over the open oceans with 150-km spatial resolution, and to achieve a measurement error less than 0.2 (PSS-78 [practical salinity scale of 1978]) on a 30-day time scale, taking into account all sensor and geophysical random errors and biases (Lagerloef et al, 2008).

TABLE 1: Example Student Outcomes based on alignment of Aquarius mission with NSES, NAAEE & OL standards

	Grades K-4	Grades 5-8	Grades 9-12
Water Cycle	Compare the basic properties of fresh and salt water[1,3]	Explain the effect of temperature on density[1,3]	Explain relationships between fresh water & ocean dynamics*
Ocean Circulation	Describe connections between oceanic salt water & fresh water in the water cycle[1,2,3]	Explain the effect of density on ocean circulation[1,3]	Explain the influence of ocean salinity on the thermohaline circulation*
Climate	Compare climates based on precipitation, temperature & distance from ocean[2,3]	Explain that the ocean holds a large amount of heat and the effect this has on climate[1,2,3]	Describe how changes in ocean circulation can produce large changes in climate[1,2,3]
21st Century Technology	Explain that satellites can be used to make measurements at a distance[1,2]	Gather, analyze, & interpret data about the ocean's effects on climate[1,2]	Explain how new technology can enhance the gathering & use of oceanic data[1,2,3]

** Outcomes that are too new to be found in existing science standards documents*

Alignment with K-12 Student Outcomes

Aquarius is providing hands-on activities, interactive data tools, conceptual visualizations, video of scientists, and scientific articles that can be integrated into classroom settings to address specific student outcomes. Table 1 shows nine of the 23 student outcomes that are addressed by Aquarius EPO materials, aligned with National Science Education Standards (NSES; National Research Council, 1996), North American Association for Environmental Education (NAAEE, 2000) and Ocean Literacy (OL) standards (National Geographic Society et al, 2005). A robust evaluation plan is being implemented to test the efficacy of Aquarius EPO products with respect to these outcomes.

The student outcomes in Table 1 are closely tied to a set of interactive tools that use historical salinity, temperature, and density data sets from the NOAA World Ocean Database (Boyer et al, 2006). Designed and implemented by the Aquarius education technology team, these data are available as three distinct yet complementary tools that highlight: *Spatial Patterns* (long-term data); *Annual Cycle* (monthly mean data); and *Change over Time* (yearly mean data). These are augmented by tutorials and a "Q&A" section that addresses:

1. Is salinity the same everywhere in the oceans?
2. Are there "salt deserts" in the oceans?
3. What are the main sources of fresh water to the oceans?
4. Are there salty and fresh seasons?
5. Were the oceans as salty a hundred years ago?
6. How does salinity affect the deep ocean?

After the Aquarius/SAC-D launch, new features will be added, allowing students and educators – in parallel with scientists -- to use NASA's first-ever salinity data.

International EPO Partnership

In the months leading up to the launch of any satellite mission, collaboration and communication are vitally important. For Aquarius/SAC-D, this includes working closely with the Space Agency of Argentina (Comisión Nacional de Actividades Espaciales, CONAE) on facilitating broader impacts of the mission's goals. Thus far, coordinated EPO products include web resources, English and Spanish language versions of an educational poster, decals, and other printed materials. Be sure to visit http://aquarius.nasa.gov as exciting new EPO products are released to support this pioneering mission!

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The Bridge: An Ocean of Free Education Resources

By Christopher Petrone

So you have to, or even better, you *want* to teach your students some basic concepts about the ocean? The first line of offense is Google, right? Deciding to start your search broadly, you type in *ocean*. This yields in the ballpark of 184 million sites. So you narrow the search term to *ocean science*. Despite better results, roughly 32 million sites, you try to outsmart the internet and type in *important ocean concepts*; how many results could there be? Three million, that's how many.

While you have time to bookmark a few dozen of these sites, promising yourself that you will go back and review them this summer in your "free time," you click on one in particular that caught your eye, called *The Bridge* (http://www.marine-ed.org/bridge). Suddenly, without realizing it, you have found what you have been looking for, all in one place: a free website that contains the internet's best ocean science resources, which have been reviewed for content, educational value and usability by busy, time-limited educators for busy, time-limited educators.

The nationally-recognized resource has been a product of the Virginia Sea Grant marine education team (http://www.vims.edu/adv) since its inception in 1997 and continues to be the first-stop for educators, world-wide, seeking vetted marine education websites. Bridge currently has just over 1000 resources categorized by topic, including: atmosphere; biology; chemistry; geology; habitats; human activities; and physics. It also links to numerous student and professional development opportunities, aquariums and science fair resources. The Bridge email discussion list, *Scuttlebutt*, currently has over 1600 members who post activities, questions about curriculum or unidentified field specimens; and receive information on upcoming professional development opportunities and newly released resources.

Bridge features a section devoted to the use of coastal and ocean observing systems in education. In addition to providing educators with annotated links to observing systems across the country, Bridge has eight Data Analysis Teaching Activities (DATAs) that use observing system data. A part of the Bridge DATA Series, which has over 65 activities, the observing system DATAs are aligned to the National Science Education Standards, and include an introduction, current scientific data, directions on how to use the data and discussion questions. Below are two examples of Bridge DATAs that use coastal and ocean observing system data:

Satellites and Storms: Using Ocean Observing Systems to Investigate Coastal Storms

The atmosphere and the ocean are both dynamic fluids, ever-circulating as they are driven by the uneven heating of the earth and the earth's rotation on its axis. While we often think of the atmosphere and ocean as two separate systems - with weather and wind moving the air, currents and tides affecting the sea - in reality they are two sides of a single air-sea system. The ocean and atmosphere influence and interact with each other in very complex ways.

We can investigate basic atmosphere-ocean interactions using some of modern oceanography's most valuable tools, satellites. Thanks to advancing technology, satellites now collect all kinds of data: ocean temperature; water color (indicating sediment load or phytoplankton density, for example); wind speed and direction; the roughness of the ocean's surface; and more. And we can access this information, plus data from buoys, ships and meteorological stations, using the internet. In this series of activities, students use ocean observing systems to study the formation and impacts of coastal storms.

<http://www2.vims.edu/bridge/DATA.cfm?Bridge_Location=archive1007.html>

Don't Even Sink About it!

Does a pen float? How about a can of soda? Does salt water really make that much difference to how an object floats? What's a Plimsoll mark? What do rubber ducks have to do with all this? Buoyancy can be a difficult concept for students. It's all about density! With this hands-on introduction to teaching buoyancy from the Bridge website and COSEE-NOW, students work through activities and demonstrations that use online resources and ocean observing systems data to investigate the buoyancy considerations of commercial shipping.

<http://www2.vims.edu/bridge/DATA.cfm?Bridge_Location=archive1207.html>

Bridge is a partner of the National Marine Educators Association and is active in NSF's Centers for Ocean Sciences Education Excellence (COSEE) project. It is funded by the National Sea Grant Office and the NOAA.

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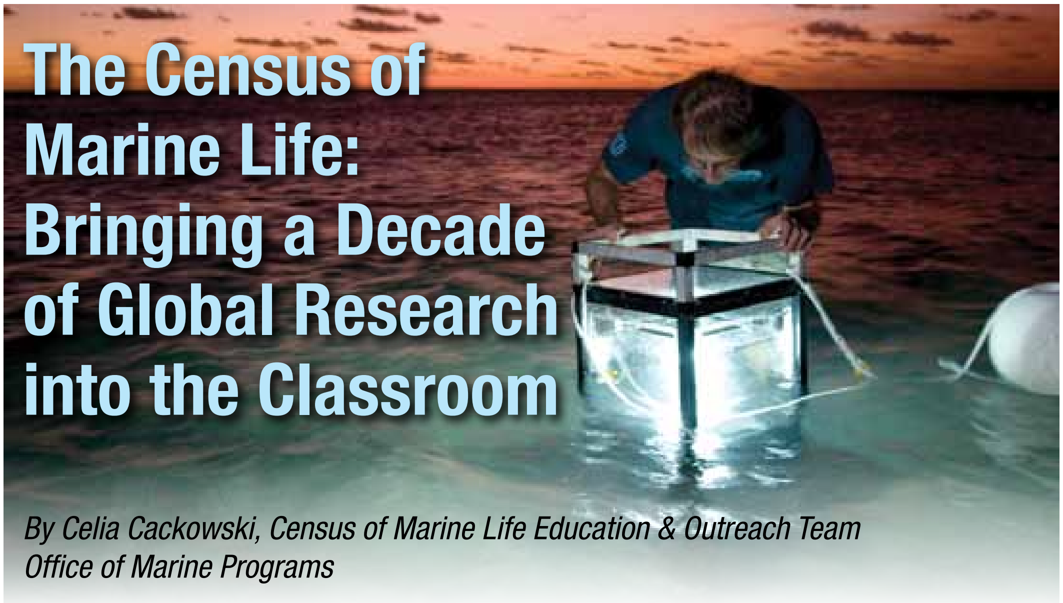

The Census of Marine Life: Bringing a Decade of Global Research into the Classroom

By Celia Cackowski, Census of Marine Life Education & Outreach Team
Office of Marine Programs

Researcher Neil Bruce of the Museum of Tropical Queensland studies specimens in lighted aquarium on Lizard Island Reef.

Photo by Gary Cranitch, Queensland Museum.

Abstract

The Census of Marine Life is an unprecedented undertaking that is significantly contributing to understanding of the marine environment and life in the global ocean. Census researchers are discovering new life forms, finding life in unexpected places, advancing technology to create windows into what was an opaque ocean, and building global partnerships to advance what is known about life below the surface. Outreach materials about new discoveries and emerging technologies, as well as hands-on activities, can help educators illustrate multidisciplinary research to their students.

Introduction

The Census of Marine Life is a global network of researchers in more than 80 nations engaged in a 10-year scientific initiative to assess and explain the diversity, distribution, and abundance of life in the oceans. The world's first comprehensive Census of Marine Life - past, present, and future - will be released in October of 2010.

The scientific framework of the Census of Marine Life comprises a global information system assimilating data and information from 17 field projects. Most of these projects are investigating what now lives in six ocean realms (Human Edges, Hidden Boundaries, Central Waters, Active Geology, Ice Oceans, and Microbes). Some investigate the history of marine animal populations and forecast the future of marine populations and ecosystems.

Nardoa rosea sea star as seen from the underside, Heron Island.

Photo by Gary Cranitch, Queensland Museum.

Census scientists are discovering new species, learning more about marine ecosystems, investigating historical populations and the current abundance and distribution of marine life, and are modeling future trends in marine animal populations.

A mix of curiosity, need-to-know, technology, and scientists willing to investigate the unexplored and undiscovered is resulting in a much clearer picture of what lives and will live below the ocean's surface around the globe.

Bringing the Census to the Classroom

While the Census does not offer traditional teaching materials, the potential application of Census work in the classroom is limited only by the educator's imagination. Students that are easily engaged by emerging technology may enjoy seeing its practical applications. The Census's focus on marine biodiversity in relation to ocean realms and conditions also allows for multidisciplinary discussions.

Three subarctic sunflower stars, *Pycnopodia helianthoides*, crawl along the seafloor in shallow waters off Knight Island in Prince William Sound, Alaska, USA.

Photo by Casey Debenham, University of Alaska.

Most of the Census's projects have their own education and outreach initiatives. Educational materials vary in scope, depth, and format. Most multimedia materials are available online (see materials list) and many are archived on the program's central web portal (www.coml.org), which is hosted and maintained by the Census's Education and Outreach Team in the Office of Marine Programs at the University of Rhode Island's Graduate School of Oceanography.

Following Census Scientists Online

Most of the Census's educational impact comes in the form of online materials. Students can follow the work of Census scientists through video segments and press releases on the program's web portal and by linking to ship's logs and researchers' diaries on individual field project sites.

A particularly ambitious undertaking that is an offshoot of the Census tagging and tracking programs is the global Ocean Tracking Network (OTN) headquartered at Dalhousie University in Halifax, Nova Scotia. The OTN is conducting the world's most comprehensive and revolutionary examination of marine life and ocean conditions, and how they are changing as the earth warms. OTN scientists are tracking thousands of marine fish, birds, and mammals using acoustic telemetry technology and developing a global infrastructure to collect comprehensive data on sea animals in relation to the ocean's changing physical properties. Multimedia galleries on the program website can help educators tie in popular marine biology themes with harder to sell physical oceanography concepts. OTN used Census technology and wherewithal as a model for its innovative observing network.

Another popular classroom tool that demonstrates ocean tracking is the annual Great Turtle Race. After years of putting satellite tags on leatherback turtles as they left their nesting beaches, scientists with the Census's Tagging of Pacific Predators (TOPP) project noticed a distinct pattern in the turtles' behavior and migration patterns. Scientists teamed up with conservation organizations to raise public awareness through an annual online "race," which allows students to track female leatherback turtles over thousands of miles opening up discussions on biology, oceanography, and satellite technology.

Also available for download is a presentation by the Census's Mid-Atlantic Ridge Ecosystem Project (MAR-ECO), which studies patterns and processes of northern Mid-Atlantic ecosystems. Project researchers presented a series of English-language talks geared toward international high school and university students in Kristiansen, Norway in October 2009. The workshops, entitled "Deep Ocean Odyssey," also included slide shows and live music and drew more than 600 high school students.

The striped eye stalks of the jeweled anemone crab. Found in French Frigate Shoals. Anemone hermit crabs differ from other hermits in that they have a commensal (both organisms benefit) relationship with sea anemones attached to their shell. The crabs ever transfer anemones from one shell to another when switching shells, but scientists have yet to figure out how an anemone gets on a newly inhabited shell in the first place.

Photo by Andy Collins, NOAA.

Students as Researchers

Technology and protocols emerging from the Census have also inspired students and educators to team up with scientists, becoming researchers in their own right.

Two New York City high school students, for example, curious about new DNA barcoding technology, discovered that fish at local stores and restaurants were commonly mislabeled and being sold for far more than they would if properly labeled. DNA testing revealed more than being cheated at the marketplace and restaurants. In two cases DNA barcode tests revealed fillets sold as the popular Red Snapper were instead endangered Acadian Redfish. The students' report marked the first marketplace application of the four-year-old DNA barcoding technology and made headlines across the country.

High school students in Florida and Japan have worked closely with scientists from the Census's Natural Geography in Near Shore Areas Project (NaGISA) to gather data on nearshore fauna in their communities using a standardized protocol. This sampling protocol is available online for use by school groups across the globe.

Conclusion

While not in traditional lesson plan form, the potential application of Census research in science classrooms is clear. From YouTube videos to online games to beautiful pictures, the Census can engage students through modern, visual mediums. The first Census will not only advance knowledge about life in the global ocean, including the first ever complete catalog of marine life, but will serve to inform decisions about how to best manage the resources that live below the surface around the world. By engaging students with current and ongoing research, Census participants hope not only to disseminate information but also to inspire the next generation of researchers, policymakers, and citizens to continue that dialogue.

Resources

Census of Marine Life Portal (RSS Feed Available), www.coml.org

Census Galleries and Press Releases, www.coml.org/media-resources

Ocean Tracking Network, ceantrackingnetwork.org/media/index.html

The Great Turtle Race, www.conservation.org/great_turtle_race/Pages/main.aspx

MAR-ECO Deep Ocean Odyssey Webcast, www.mar-eco.no/learning-zone/2009_a_deep_ocean_odyssey

Barcode of Life, phe.rockefeller.edu/barcode/index.php

NaGISA Protocols, www.nagisa.coml.org/Protocols

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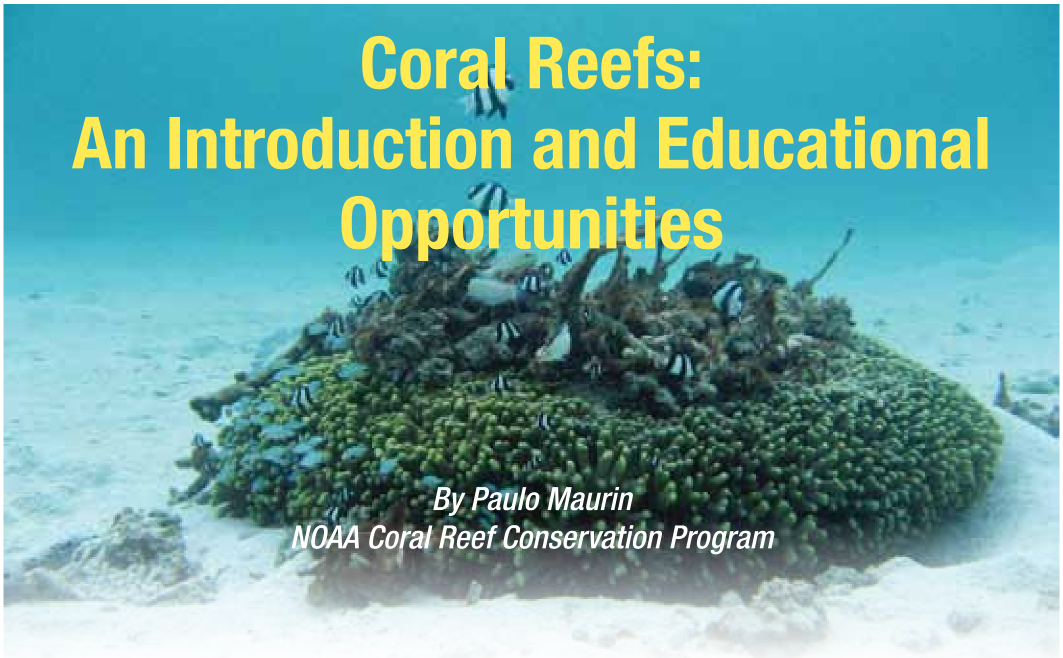


Coral Reefs: An Introduction and Educational Opportunities

By Paulo Maurin
NOAA Coral Reef Conservation Program

Summary

Corals are one of the key indicator species for climate change, and coral reefs are one of the ecosystems most directly jeopardized by climate change. While they occur in warm, tropical waters, we all play a role in each of the top three threats they face: impacts from climate change, fishing and land-based sources of pollution. NOAA's Coral Reef Conservation Program provides educational resources, including professional development course and classroom-ready materials, to help educators teach about coral reefs.

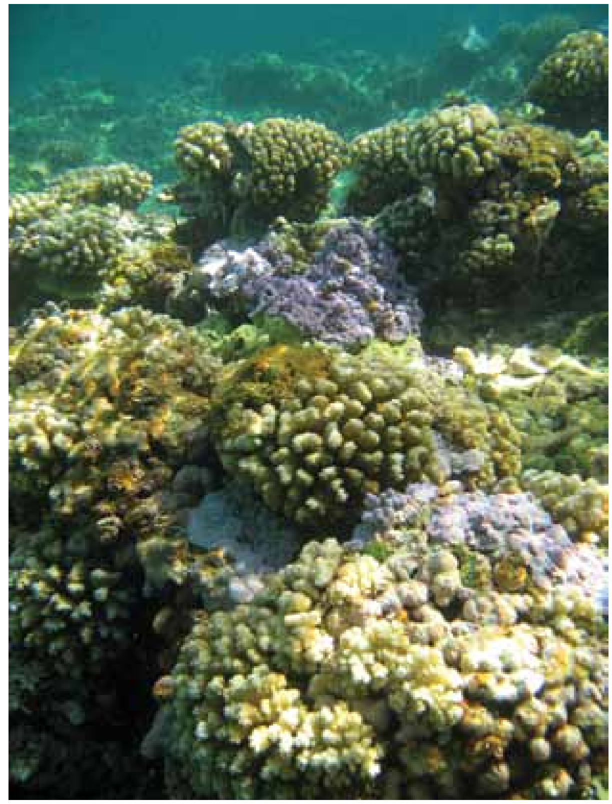
Coral reefs. The term itself evokes paradisiacal beach scenery, underwater wonderment, and the largest parade of marine life. Coral reefs epitomize biodiversity, but public understanding of these ecosystems rarely goes beyond these commonly shared imagery. Coral reefs, however, offer much more if we are willing to dive a little deeper into these complex and wonderfully weird rainforests of the sea. In addition, corals are quickly being adopted as one of the main indicator species for climate change, as they represent, along with the arctic, one of the ecosystems most directly threatened by it. This has placed coral reefs in the public spotlight, and students are becoming increasingly eager to learn more about them in the context of the impacts of human activities on our planet.

Close up of coral polyps.

Photo: G.P. Schmahl, Flower Garden Banks National Marine Sanctuary

Corals themselves are tiny animals, each known as a polyp, and most are no larger than a grain of rice. But they often form colonies, and collectively they build the largest biological structures on Earth – the coral reefs. Related to jellyfish and anemones, coral polyps are stationary predators, with tentacles that capture zooplankton in a similar manner a mobile jellyfish captures fish. Plankton, however, tends to be very limited in the warm and clear tropical waters where we find reef-building corals. To survive and thrive in these nutrient-poor waters, corals have developed a symbiotic relationship with plant-like organism called "zooxanthellae." Living within tissues of the coral polyp, the zooxanthellae have a protected home where they can safely photosynthesize. In return, the algae provide the polyp with food (in the form of glucose, glycerol and amino acids). As a result of this mutually beneficial arrangement, corals have the energy to build large and complex calcium carbonate structures.

The three-dimensional structures corals form becomes essential habitat for many forms of marine life. Indeed, a quarter of all life in the ocean is found in the very small areas (less than one percent) comprised of coral reefs. The relationship between the coral reef and its inhabitants is also a symbiotic relationship, since many herbivore fish eat algae growing next to reefs, and thus competing for space. While reef-building corals depend on the algae they host within in order to survive, they are in perpetual competition for sunlight with larger algae growing outside.



Kure Atoll Corals.

Credit: Paulo Maurin, NOAA

NOAA's Coral Reef Conservation Program (CRCP) works to protect, conserve, and restore coral reef resources by maintaining healthy ecosystem function. The CRCP emphasizes its efforts to understand and address the top three recognized global threats to coral reef ecosystems: climate change impacts, fishing impacts, and impacts from land-based sources of pollution. Each of these threats poses different, and difficult, challenges to coral reefs.

Land-based sources of pollution disrupt the clean and clear waters corals need to survive. Many of our coastal activities, such as building ocean-front houses and shops, roads, and even agriculture, often increase the sediments that reach the ocean and can harm coral reefs. We all live in a watershed, and our rivers are connected to the sea, which carry sediment, pollution and trash to the oceans.

Fishing in coral reef areas, when ecologically unsustainable, can lead to the depletion of key groups of reef species, with impacts on entire coral reef habitats and associated species and ecosystems. Coral reefs depend on associated species (including fish, sea urchins and many others) to keep algae growth in check. When too many of these fish are taken out, algae overgrow coral reefs, and the remaining fish lose their essential habitat.

Many human activities contribute to the release of CO_2, affecting the Earth's climate. Increased ocean temperature linked to climate change threatens coral reef ecosystems through more common mass coral bleaching and disease, sea level rise, and storm activity. Additionally, increasing CO_2 from human activities is changing the chemistry of the sea water, making it more acidic, reducing growth rates in corals and marine organisms with shells. Climate change is one of the most urgent threats to the long-term survival of coral reefs.

While many of us live far away from coral reefs, and perhaps even the ocean, these three top threats to coral reefs are still linked to all of us. Climate change is the great equalizer, in the sense that our individual contributions are equally weighted, regardless of where we do our carbon emissions: be it in the south Pacific island of Guam or in coral reef-less Georgia. And while most of us do not routinely fish in a coral ecosystem, most people are seafood consumers whose choices affect far-off ecosystems. Similarly, we do not need to own a beach front house to add sediment and trash to the sea- our watersheds and rivers do that for us.

The CRCP has an educational program to assist educators to teach about coral reefs. The Program has formed a partnership with the National Science Teacher Association, and at its yearly confer-

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ence CRCP offers a half-day symposium (eligible for professional development credit), along with related conference presentations and web seminars related to coral reefs and climate change. Additionally, we offer a compilation of educational resources, in the form of a CD, for educators, with 50 lesson plans, curricula, many classroom activities, background materials, and slideshows that are ready for presentations. These resources are available at http://coralreef.noaa.gov/education/educators/resourcecd/. A physical copy of the CD can be requested at no charge by sending us an email to coralreef@noaa.gov .

For high school use, we are in the process of developing two scalable classroom curricula on coral reefs and bleaching and ocean acidification that using real-time data generated by the CRCP. We hope to have these modules ready for classroom use before the end of 2010.

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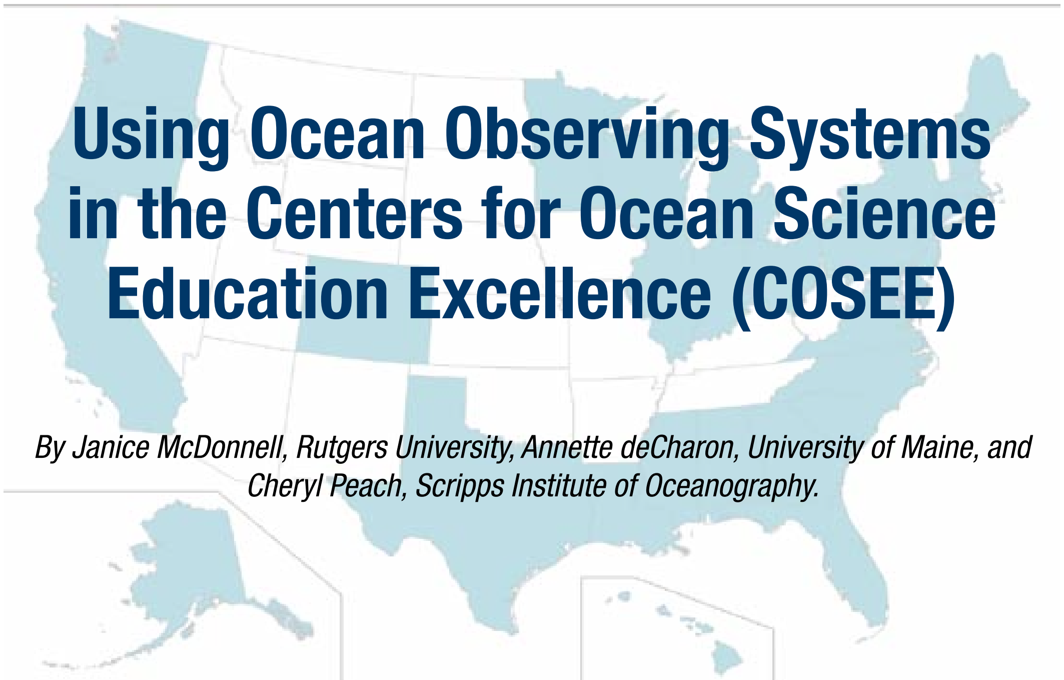

Using Ocean Observing Systems in the Centers for Ocean Science Education Excellence (COSEE)

By Janice McDonnell, Rutgers University, Annette deCharon, University of Maine, and Cheryl Peach, Scripps Institute of Oceanography.

Abstract

Scientists and educators participating in the National Science Foundation's Centers for Ocean Science Education Excellence (COSEE) are working together to improve ocean literacy of students, teachers and the general public using the unique resources of the evolving Ocean Observing Systems. Oceanography is augmenting ship-based expeditionary science of the last two centuries with a distributed, observatory-based approach in which scientists continuously interact with instruments, facilities and other scientists to explore the earth-ocean-atmosphere system remotely. This article explores how three Centers are using the unique real time and near real time data assets of ocean observing systems to support Ocean Literacy. COSEE Network Ocean World (COSEE NOW) offers a robust website that includes a series of online seminars, blogs, and educational resources for both formal and informal education professionals. COSEE Ocean Systems (COSEE OS) is creating and evaluating tools and processes that broaden understanding of the ocean's role in the climate and earth systems. Finally, COSEE California (COSEE CA) is using emerging information, communications and teaching technologies to bring cutting edge science to teachers, students and the public in both formal and informal learning environments. What follows are three articles combined under this COSEE title.

The Centers for Ocean Science Education Excellence: A Background

By Janice McDonnell

The Centers for Ocean Sciences Education Excellence (COSEE, see www.cosee.net) is a national network with the collective purpose to engage scientists and educators to transform ocean sciences education for all. Each Center has either a regional focus or a thematic mission.

The COSEE program, which is funded primarily by the National Science Foundation with support from the National Oceanic and Atmospheric Administration, engages in Network-level activities to promote Ocean Literacy, or a deeper understanding of the ocean and its influence on each person's quality of life and our national prosperity. Many reports have documented that the oceans are

CENTERS FOR OCEAN SCIENCES EDUCATION EXCELLENCE

With 12 Centers and a Central Coordinating Office located throughout the United States, each Center is a consortium of one or more ocean science research institutions, informal science education organizations, and formal education entities.

- **COSEE Ocean Learning Communities:** OR, WA, CA, HI
- **COSEE Pacific Partnerships:** OR, WA, CA, HI
- **COSEE California:** CA HI, VA
- **COSEE West:** CA, CO
- **COSEE Great Lakes:** IL, WI, MI, OH, NY, PA, MN, IN
- **COSEE Ocean Systems:** ME, NH
- **COSEE New England:** CT, ME, MA, NH, RI
- **COSEE Central Coordinating Office:** RI, ME, MA
- **COSEE Networked Ocean World:** NJ, MA, VA, NY, CA
- **COSEE Coastal Trends:** MD, DE, VA
- **COSEE SouthEast:** NC, SC, GA
- **COSEE Central Gulf of Mexico:** MI, AL, FL, LA, TX
- **COSEE Alaska:** AK

changing from the depletion of global fisheries (Myers & Worm ,2003: Worm et al., 2006), receding sea ice in the Arctic and Antarctic (Vaughan et al., 2003; Francis & Hunter, 2006), changing sea level (Miller & Douglas, 2004), altered biogeochemistry (Vitousek et al., 1997; Orr et al., 2005), and expanding oxygen poor zones (Rabalais et al., 2000; Grantham et al., 2004). It is critical for the ocean sciences community to improve our understanding of climate change and communication of results to the public and policy makers. All Centers support Ocean Literacy through the integration of ocean research into high-quality educational materials for use by scientists, informal and formal educators alike.

Ocean Observing Systems and COSEE

The COSEE Network is using all available tools and resources to meet the ever increasing need for ocean awareness and public understanding. Oceanography is augmenting ship-based expeditionary science of the last two centuries with a distributed, observatory-based approach in which scientists continuously interact with instruments, facilities, and other scientists to explore the earth-ocean-atmosphere system remotely. Routine, long-term measurements that can also resolve episodic oceanic processes on a wide range of spatial and temporal scales is crucial to resolving scientific questions related to Earth's climate, geodynamics, and marine ecosystems. These globally distributed ocean networks are being constructed throughout the world's oceans to improve our understanding of the ocean as the planet's climate flywheel while improving long term predictions.

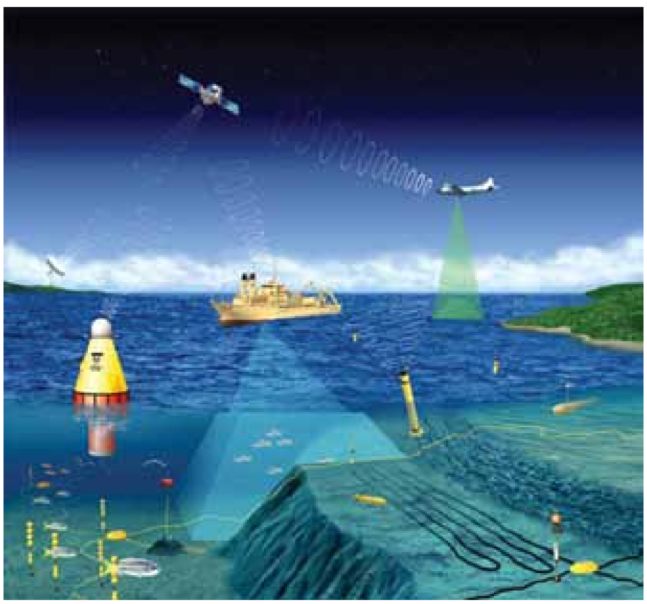

Figure 2. Ocean Observing Systems are revolutionizing how oceanographic data is collected and accessed by scientists, educators, and the public.
Credit: NOAA

In the United States, ocean observatories are being deployed by federal agencies including the National Science Foundation (Ocean Observing Initiative, OOI), and the National Oceanic and Atmospheric Administration (Integrated Ocean Observing System, IOOS), providing access to the oceans and allowing us to strengthen our efforts to build collaborations that address societal needs. Observatories are also highlighted in the National Science and Technology Council plan (2007) which calls on the ocean observatories to "fundamentally alter society's view of the ocean" and the National Research Council's report "Preparing for the Gathering Storm" which highlights the need to entrain the next generation of scientists and engineers to maintain the future economic vitality of the United States.

All COSEE Centers are using the unique real time and near real time data assets of ocean observing systems to support Ocean Literacy. Highlighted here, are the efforts of three centers, to use Ocean Observing Systems in COSEE programming and content development.

Building a Virtual Community through the Centers for Ocean Science Education Excellence Networked Ocean World (COSEE NOW)

The Centers for Ocean Sciences Education Excellence Networked Ocean World (COSEE NOW) is exploring new ways to virtually bring together scientists and educators involved in Ocean Observing Systems (OOS). It is focused on using ocean research and effective education practices to inspire students and the general public in ocean exploration, discovery, and stewardship. COSEE NOW offers a robust website (www.coseenow.net) that includes a series of online seminars, blogs, and educational resources for both formal and informal education professionals. Currently there are approximately 200 COSEE NOW registered members. It is expanding the COSEE virtual network while developing additional prototype new media that bring together a diverse community of scientists and educators.

The COSEE-NOW website is a gathering place for scientists and educators of all kinds to come together and share their questions and resources about Ocean Observing Systems. Its objective is to encourage collaboration on common themes and products through the creation of a learning community. Its vision is that this learning community will encourage collaborative connections and partnerships and increase the overall efficiency and coherency of education and public outreach related to OOS science and technology. The outcome of this effort would be a set of curriculum and resources that could be utilized and shared by all members of the OOS network. By providing the tools for collaboration, COSEE NOW is encouraging scientists and educators to discuss a variety of topics including:

- K-16 Ocean Observing and Real Time Data education
- Incorporation of ocean literacy standards and essential principles
- Establishment of criteria for effective professional development and lesson plan design
- Development of an information pipeline on careers/workforce within the Ocean Observing community
- Data visualization challenges and solutions
- Evaluation of collaboration technologies

The approach of COSEE NOW is to create blended learning opportunities where educators and scientists meet in face-to–face workshops complimented by online webinars and blogs designed to extend the collaboration among scientists and educators. COSEE NOW piloted a new series of online seminars in which classroom teachers learned how to use ocean observing systems data in their teaching and scientists have learned more about writing effective broader impact statements and implement effective education and public outreach programs. More recently, COSEE NOW paired exhibit design and development experts with a group of informal educators working within the Integrated Ocean Observing Systems (IOOS) network. To encourage communication, COSEE NOW is building a community of blogs – tied together under one umbrella with the same membership base.

Telling Ocean Stories

Because OOS represent such an innovation and paradigm shift in the oceanographic community, COSEE NOW has put significant effort into developing our community's capacity to tell "stories" about experiences with ocean observing systems from both the perspective of the scientists and educators involved. COSEE NOW hosted a number of successful workshops on effective storytelling techniques in an effort to capture the development and evolving history of the OOS technology. These workshops were conducted under the guidance of Andy Goodman, a former Hollywood screenwriter and author.

Figure 3. Rutgers University's autonomous glider, RU 27 nicknamed the Scarlet Knight, completed its 221 day and 7,409 mile journey from New Jersey to Baiona, Spain.

Figure 4. Undergraduate students from Rutgers, the University of the Azores, and Platforma Oceanica de Canarias (PLOCAN) collaborated with Drs. Scott Glenn, Oscar Schofield, and Josh Kohut to pilot the glider on its Trans-Atlantic journey.

The Coastal Ocean Observation Laboratory (COOL) at Rutgers University practiced these storytelling techniques by documenting the historic mission of an autonomous underwater glider's journey across the Atlantic Ocean. K-12 students from across the United States submitted more then 200 letters to be included inside the glider, named the Scarlet Knight. Students followed the progress of the glider via the scientist's blog to see if their letters would make it across. On the other side of the Atlantic Ocean, students in Spain wrote their own letters back to the U.S. students, scientists and approximately 30 undergraduate students at Rutgers University involved in the mission. Students from both sides participated in the historic event as the glider landed in Baiona, Spain, home of Columbus's legendary Pinta.

COSEE-NOW's newest team member, Ari Shapiro, has been capturing the personal stories of scientists and their work in his new biweekly podcast called Ocean Gazing. The Ocean Gazing podcast is one of COSEE NOW's primary educational outreach tools. The aim is to provide scientists with a forum for telling their stories about ocean observing science and the broader impacts that science is having on people beyond academic institutions. In each biweekly episode, Ocean Gazing integrates interviews, ambient sounds gathered in the field and in the lab, music, audio recordings from listeners (from children to adults), and the unveiling of a mystery sound. The scientists have said they enjoy participating in the podcast as a mechanism for making their science accessible and promoting the work they do in an engaging and accurate manner. We have between 200 and 250 downloads for each episode, and we are actively promoting Ocean Gazing on Facebook and Twitter. We are developing high school curriculum companion pieces for some of the podcasts to encourage educators to use the podcasts in the classroom setting.

COSEE NOW looks forward to launching its new website in 2010 and encouraging broader participation and collaboration on the site. Please contact Janice McDonnell <mcdonnel@marine.rutgers.edu> for more information.

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COSEE-Ocean Systems: Collaborative Mapping to Clarify Concepts in Ocean Observing

By Annette deCharon

One Center, COSEE-Ocean Systems (OS), creates and evaluates tools and processes that broaden understanding of the ocean's role in the climate and earth systems. To promote systems thinking, COSEE-OS applies the technique of concept mapping with demonstrated effectiveness in helping scientists and educators "get on the same page" (deCharon et al, 2009).

COSEE-OS Application of Concept Mapping

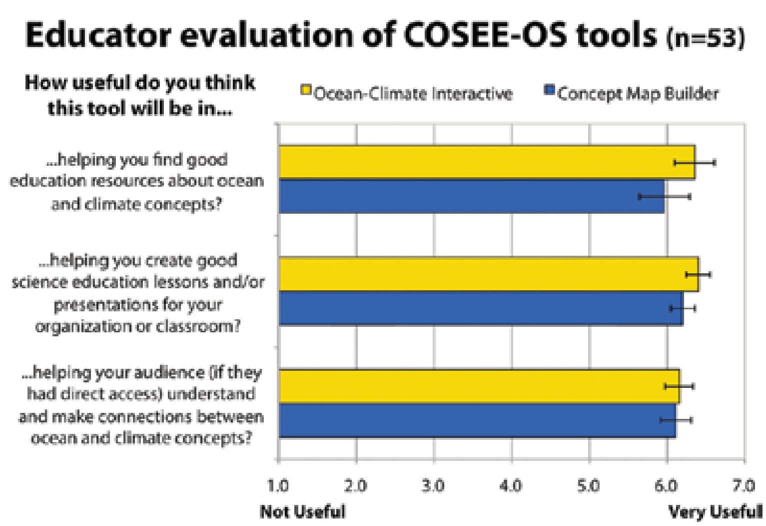
Traditionally, concept maps are used as "formative assessment products that promote dialogue and focused feedback among students, and between teacher and students" (Mintzes, Wandersee, and Novak, 2004). However, concept maps can also be used to capture how experts in science "organize, represent, and interpret information in their environment" (Bransford et al., 1999). In its series of model workshops from November 2008 – October 2009, COSEE-OS included concept map training for scientists. This proved worthwhile because although 100% of 53 participating workshop educators had used concept mapping, only 5% of 20 scientists had previous experience with the technique.

One goal of COSEE-OS model workshops was fostering high-quality interactions between scientists and educators. 91% of educators agreed that concept mapping helped them think through the topics they learned during the workshop. In post-workshop interviews, an equally high percentage of participating scientists agreed that concept mapping helped them share their understanding of connections with educators. Evaluation data also revealed that, on average, educators rated the quality of their interactions with scientists 6.7 on a 7.0 Likert scale.

Ocean Climate Interactive and Concept Map Builder

At the core of the COSEE-OS model is research and development (R&D) of online tools that support scientist-educator collaboration, both during and after the workshops. These cost-free tools – the Ocean Climate Interactive (OCI) and Concept Map Builder (CMB) – have been incrementally developed, tested, and refined over the course of the workshops.

Figure 5. Average Likert values (and standard error) from 53 educators who attended four COSEE-OS model workshops (Nov. 2008 – Oct. 2009)



The OCI application merges complex science content with online concept-mapping technology (http://cosee.umaine.edu/cfuser). Users can access a large, scientist-vetted database containing images, videos, news items and teaching resources. The CMB allows registered users to create their own interactive, computer-based concept maps (http://cosee.umaine.edu/cfuser/cmb). It surpasses traditional concept map software by allowing users to search for and embed ocean-climate assets from the OCI database in their customized maps. The maps can also be shared with colleagues, students, and peers.

During the model workshops, educators provided feedback about the usefulness of the OCI and CMB for: finding good education resources, helping

Figure 6. Examples of ocean observing concept maps that have been developed in COSEE-OS workshops

Examples of on-line ocean observing concept maps developed in COSEE OS workshops include:

- How do we take the pulse of the earth?
- What is the evidence for climate change?
- How do watersheds influence our oceans and climate?
- How does water movement affect the movement of organisms?
- How do we follow river pollution's path with computer models?

create good lessons and/or presentations, and helping their students understand and make connections between ocean and climate concepts. In general, educators' reactions were very positive.

Connections to Ocean Observing & Future Plans

Consensus-based concept maps – including those related to ocean observing (Figure 6) – are key outputs of COSEE-OS model workshops. Web visitors can view the maps at various stages of development: from the scientists' first maps through the consensus versions developed by scientist-educator teams. Videos of these maps being presented using the OCI are available online (http://cosee.umaine.edu/coseeos/workshops/workshops.htm). Individuals can also download workshop maps into their personal CMB accounts by registering with COSEE-OS.

Thanks to improvements made during the yearlong testing and improvement program, the COSEE-OS concept-mapping model is now transferrable to new venues, including online workshops. In the near term, it will be used at other COSEE Centers, including pilot projects that team faculty researchers with graduate and undergraduate students.

Over the long term, COSEE-OS will bring its R&D model to targeted pre-college classrooms. These pilot case studies will follow content "through the pipeline" from ocean researchers to educators to students. COSEE-OS will study how scientists' original messages evolve based on their interaction with educators, how students modify the educators' concept maps and, finally, how students' maps can help scientists better communicate their research to non-scientists.

For additional information, please contact Annette deCharon <annette.decharon@maine.edu>

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Teaching Ocean Science in the 21st Century Classroom with COSEE California (COSEE CA)

By Cheryl Peach

Introduction

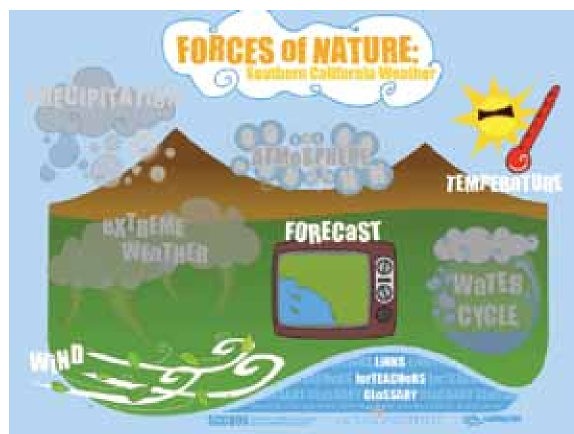
Scripps Institution of Oceanography (Scripps) is a partner in COSEE CA, a COSEE dedicated to engaging researchers in ocean science education and outreach. The focus of the work at Scripps is two-fold: 1) using emerging information, communications and teaching technologies to bring cutting edge science to teachers, students and the public in both formal and informal learning environments; and 2) facilitating partnerships between scientists and educators to advance ocean science education. Among its many activities in these two areas, COSEE CA has focused considerable effort on ocean observatories and observatory-based science, a rapidly evolving field in which ocean researchers and technologists are using sensors and sensor networks coupled to powerful computing networks to establish a permanent, real-time, 24/7/365 presence in the world ocean. In what some are calling a major paradigm shift in ocean sciences, data that would once have been exclusively in the domain of the investigating researchers are, through observatory networks, immediately available to anyone, anytime, anywhere. COSEE CA has been working to develop, or facilitate development of, educational tools that promote non-scientist interest and engagement in this important new approach to ocean science research.

Two examples of COSEE CA contributions to observatory education and outreach include: 1) facilitating a partnership that resulted in educational learning modules based on Southern California Coastal Ocean Observing System data; and 2) developing an Xbox ocean exploration "serious" game in partnership with the NSF Ocean Observatories Initiative (OOI) Cyberinfrastructure Team.

Teaching with Observatory Data

COSEE CA facilitated a collaborative partnership between the Southern California Coastal Ocean Observing System (SCCOOS), the Ocean Institute in Dana Point, CA and EarthGuide at Scripps, to create educational products that promote student use of SCCOOS data to learn basic science content and better understand the process of science. Two key products were created by this team: 1) a set of EarthGuide online, interactive education modules designed to allow students to use data to investigate the effects of the marine environment on air temperature and weather in the Southern California region (*Forces of Nature*); and 2) an Ocean Institute advanced, 5th grade science curriculum centered on using real-time data from the SCCOOS website in the classroom (*Weather and Water*; supported by a subsequent grant to the Ocean Institute by the Beckman Foundation). Both products can be accessed on the "especially for teachers" section of the SCCOOS website (http://www.sccoos.org/cc-EspTeachers.html).

Figure 7. Forces of Nature site currently home to three of seven planned interactive learning modules for elementary and middle school students (earthguide.ucsd.edu/weather/).



Serious Gaming in Formal and Informal Learning Environments

Serious gaming is emerging as a promising new field of teaching and learning in both formal and informal environments (Fostering Learning in a Networked World: The Cyberlearning Opportunity and Challenge, 2008). As ocean observatories evolve, ocean science education faces many of the challenges that have faced NASA outreach in Mars exploration, that is the extreme nature of the environment being investigated and the difficulties with visualizing that environment. Visualizations and animations are powerful teaching tools and as an extension, teaching using a highly visual gaming environment holds promise for engaging today's students, so called "digital natives", in experiences that both teach and engage. The Deep Sea-Extreme Environment Pilot (DEEP) game is a prototype that is being developed to assess the efficacy of this medium for elevating awareness about ocean observatories and for engaging students in learning about observatory science, both in the classroom and at science centers.

For additional information about these projects and other COSEE CA initiatives, please contact Cheryl Peach <cpeach@ucsd.edu>

Importantly, this work, and the work of many of the COSEEs, is occurring concurrently with the creation and integration of ocean observatory networks so that observatory education will keep pace with the rapid advances in observatory science, technology and data delivery.

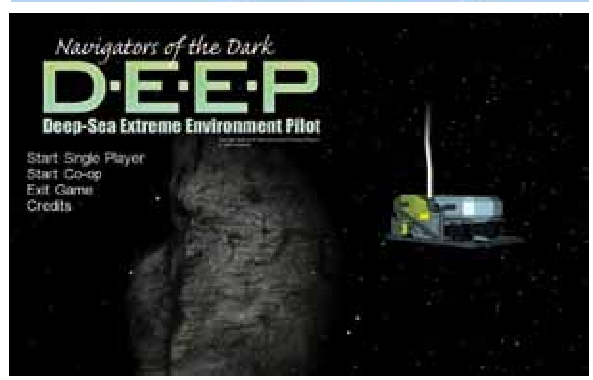


Figure 8. Start-up page for the prototype Xbox game Deep-Sea Extreme Environment Pilot, an educational game designed for use in science centers.

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Students retrieve their remotely operated vehicle (ROV) from the pool after participating in the MATE Center's ROV competition.

The MATE Center Prepares Students for Ocean-Related Technology Careers

By Jill Zande, Co-PI, Associate Director & Competition Coordinator, MATE Center and Caroline Brown, Science and Technology Writer for the MATE Center

Abstract

The Marine Advanced Technology Education (MATE) Center is a national partnership of community colleges, universities, high schools, employers, and working professionals whose mission is to enhance marine technical education and increase the number of skilled marine technology professionals. MATE conducts workforce research and uses this information to improve and develop marine technology-focused educational programs, including an international underwater robot competition that uses remotely-operated vehicles (ROVs) to help students improve their STEM skills and prepare them for ocean-related careers, and an ocean drifter project that helps community college and university partners develop curriculum and activities incorporating ocean observing and data collection technologies that are aligned with workforce needs.

Introduction

Ocean industries account for twenty percent of the U.S. economy and support one in six jobs. Offshore oil and gas industries, telecommunications, underwater archaeology, underwater engineering and construction, shipping, port and harbor security, and ocean research all depend on ocean-related technologies. Recruiting highly-skilled technical professionals to support ocean activities is critical.

Yet, despite the need for a well-prepared technical workforce, students and educators are not always aware of the ocean-related career opportunities because the educational pathways to these careers have not been well mapped out and promoted. There are only a handful of programs whose curricula are clearly aligned with relevant workforce needs, and even fewer articulated pathways that connect middle schools to high schools to community colleges and universities.

What is the MATE Center?

To help address the increasing need for an appropriately-trained and educated ocean workforce, the Marine Advanced Technology Education (MATE) Center was established in 1997 with funding from the National Science Foundation (NSF). MATE is a national partnership of community colleges, universities, high schools, employers, and working professionals whose mission is to enhance marine technical education and increase the number of skilled marine technology professionals.

To achieve its mission of preparing America's workforce for technical positions in ocean-related occupations, MATE conducts workforce research and uses this information to improve and develop marine technology-focused educational programs and pathways to help students improve their STEM skills and prepare them for ocean-related careers. MATE's programs provide the skills, knowledge, and aptitudes needed to succeed in a technically challenging workplace. Examples of successful programs include a student underwater robot competition that focuses on remotely operated vehicles (ROVs) and a pilot project on ocean observing technologies that uses ocean drifters. Both of these activities help educators bring ocean technologies into the classroom.

ROV Competition Simulates Marine Workplace Environment

MATE's international student ROV competition was the first student robotics competition to focus exclusively on ROVs, which are tethered underwater robots that support offshore oil and gas, science, and other marine-related industries. ROVs are typically equipped with cameras and instruments such as sensors and manipulator arms to perform tasks such as collecting data and biological samples.

The competition presents middle school, high school, community college, and university students with the same types of challenges that scientists and engineers face when working in the ocean environment. Using underwater missions that simulate the high-performance workplace, student teams from all over the world compete with ROVs that they design and build. Examples of competition missions include installing and maintaining simulated electronic instruments; maneuvering through the mock-up of a shipwreck; and sampling plastic fishing lures that represent newly-discovered marine species.

In addition to the underwater missions, teams must make oral and written engineering presentations to a panel of judges who represent various aspects of the marine industry. Each team is evaluated on the design, construction, and performance of its ROV; the members' ability to communicate what they learned; and how they put their knowledge to use in designing and building their ROV.

The MATE ROV competition is supported by the NSF, the Marine Technology Society ROV Committee, the National Oceanic and Atmospheric Administration (NOAA), and other ocean- and technology-related organizations. In 2009, more than 300 teams competed in the international competition or a series of regional contests that "feed" into the international event. Since the program's inception in 2002, well over 7,000 students have participated in the competition.

Along with professional development and student outreach workshops, the MATE Center supports the teachers and student teams that participate in the ROV competition with curriculum materials, including *Underwater Robotics: Science, Design & Fabrication*. This new textbook introduces educators and students in advanced high school classes or college and university entry-level courses to subsea technology, with a specific focus on ROVs. Scheduled for release in Spring 2010, *Underwater Robotics* provides all the information needed to design and build underwater vehicles.

Ocean Drifter Project Provides OOS Workforce Skills

MATE's ocean drifter project illustrates its commitment to helping community colleges and universities meet the demands of the rapidly evolving ocean observing system (OOS) workforce. The project helps community colleges and universities develop curriculum and activities that incor-

Students from Cape Fear Community College of Wilmington, NC launch a drifter that collects real-time information about ocean currents.

porate ocean observing and data collection technologies that are critical to the ocean observing workforce.

Ocean drifters are floating platforms equipped with sensors and satellite communication technology that can transmit data on a nearly continuous basis. They provide scientists and the general public with real-time observations relating to ocean properties such as currents and temperature, which have widespread applications in shipping, search and recovery, recreation, and science.

The goal of the ocean drifter project is to incorporate ocean technology, real-time data collection, and data sharing into the curriculum. Faculty participants in the project learn how to work with their students to build and deploy ocean drifters and analyze the data that they collect. This exercise helps students prepare for jobs in the ocean observing workforce, where technical knowledge and skills such as gathering, analyzing, visualizing, and sharing real-time data are essential.

The ocean drifter project was launched as a pilot program in August 2009, with funding from NSF and technical assistance from NOAA and Centers for Ocean Sciences Education Excellence-Networked Ocean World (COSEE-NOW). Ten community college and university partners are currently involved.

Conclusion

The MATE Center's programs provide critical skills and experiences that provide students with the knowledge and skills to work in ocean-related fields. By designing, developing, and working with ocean-related technologies and participating in scenarios modeled after the real-world marine technical workplace, students apply STEM skills in a fun and exciting manner as well as increase their knowledge of marine-related technical careers.

For more information about MATE's student ROV competition, visit http://www.marinetech.org/rov_competition/. Download a flyer about the ROV textbook at http://www.marinetech.org/education/pdf/ROVBookFlyer.Final1a.pdf. To learn more about the ocean drifter project, visit http://coseenow.net/mate/.

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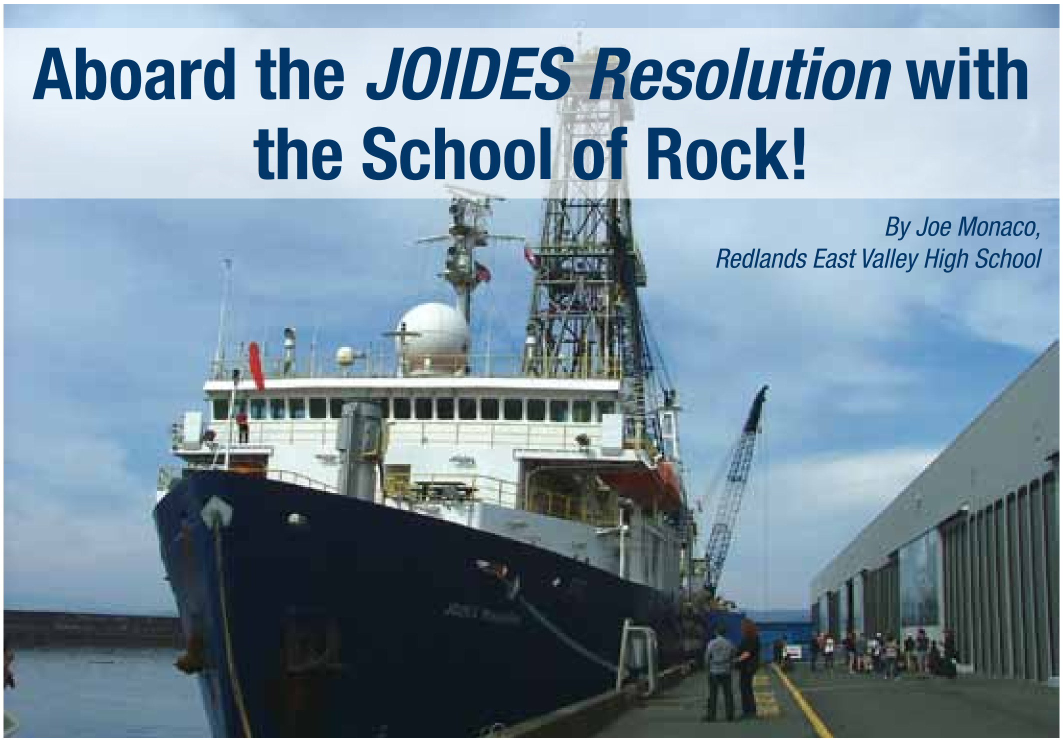
Aboard the *JOIDES Resolution* with the School of Rock!

By Joe Monaco,
Redlands East Valley High School



Abstract

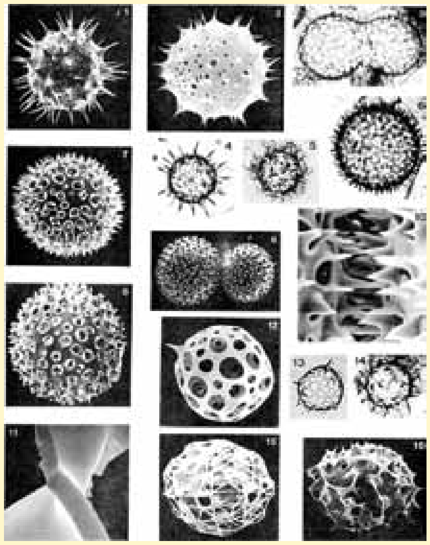
The School of Rock is a program for school teachers funded by the Integrated Ocean Drilling Program (IODP). In 2009 teacher participants spent 11 days out to sea aboard the JOIDES Resolution (Joint Oceanographic Institutions for Deep Earth Sampling), learning about sediment cores. We were participants rather than observers and used much of the same lab equipment used by scientists during a typical research expedition. In addition, we made many microscope slides of microfossils to take back to the classroom. The chief scientist on board had an objective to achieve at the Juan de Fuca plate and as a result we all got to see how the drill floor of the JOIDES Resolution operates. All participants ended the expedition with many classroom ideas and a first-hand experience of how oceanographic research is conducted.

Can anything be better than doing hands-on science? **ABSOLUTELY NOT**! In the summer of 2009 I had the opportunity to travel along the west coast of the United States aboard the oceanographic research ship the *JOIDES Resolution* (Joint Oceanographic Institutions for Deep Earth Sampling) as part of the School of Rock Program for Teachers. The 470-foot long *JOIDES Resolution* is 470 is the largest oceanographic research ship in the United States.

The ship normally sails on 60 day expeditions five or six times a year. It has a 210-foot tall drilling derrick that is used to drill into ocean floor sediments and solid basement rock. Teachers from the United States, Japan, France, and Portugal spent 11 days at sea learning first-hand about ocean floor sediments, the equipment used to gather data, and how to sample cores during Transit 321T. We didn't just hear how all of this is done – we did it!

Each teacher sampled the cores on board the ship and then made smear slides and microfossil slides to take back to the classroom. Typically, scientists look over cores and choose to sample specific places along the length of the core according to their interests; the teachers were free to do the same. We made smear slides by using a toothpick to take a sample and then transferring the tiny amount of sediment to a microscope slide. Once the slide was finished, it was placed under the microscope

Editor's Notes



Radiolarians, mentioned in this article come in many shapes and sizes. Their beauty and geometric designs have captured the interest of scientists and artists alike. See radiolaria.org for more information.

Photo Credit: Takahashi 1991

Here are two images of micro organisms collected by sediment traps as they were falling to the seafloor. Such organisms comprise the majority of biomass in the world ocean. Scientists study them as they fall through the ocean and can learn from their fossils in the sediment as discussed in this article.

Coccoliths, the shells of coccolithophores, seen here, are critically important for ocean acidification in controlling ocean surface alkalinity. They are small compared to foraminifera tests (1/100 to 1/1000). They are fragile and not well preserved in deep sediment so they are collected by sediment traps suspended in the ocean. Coccolithophorids, living coccolithophores, are the most abundant plant on the planet.

Credit: Susumu Honjo, WHOI

Marine particles made of CaCO3 and as they were found settling toward the seafloor. The transparent and opaque, round and comma-shaped objects of 0.3 to 0.6 mm, are planktonic foraminifera and pteropod shells. The dark yellow, long objects are fecal pellets produced by microzooplankton. Coccoliths (previous image) are found in such pellets.

Credit: Susumu Honjo, WHOI

to look for microfossils. A wide variety of fossilized organisms were visible, such as radiolarians and foraminifera. These microfossils can be used to date the sediments. Each teacher now has a nice slide collection to use in classrooms with students.

The paleo lab itself is somewhat envied by all others because it has two large windows – one looks out over the drilling floor while the other offers an unobstructed view of the ocean. In the paleo lab, participants used plastic scoops to take larger samples from the cores. We then logged the samples into the database to track which cores and the specific place within the cores the samples came from. From there the samples were washed, dried, sieved by size, and then viewed under the binocular microscope. The planktonic forams, specifically the *N. pachyderma*, can then be used to determine the climate of the past. Cool water forams produce shells that coil to the left while warm water ones coil to the right. The varieties are counted and a percentage calculated. By studying present day forams and comparing to the fossil record paleontologists can locate areas that experienced upwelling in the past, which in turn gives clues as to the climate of the day. It is amazing to see the variety of shapes considering that the organisms are so small.

In the chemistry lab we tested sediments for the percentage of carbonate contained within the sediments. This can be used by scientists for various studies, including environmental conditions. We used an instrument called a coulometer to make the carbonate measurements. A sample was massed using a balance that sits on a gimbal to isolate it from any ship motion. The sample was transferred to the coulometer where the sample was logged into the database and an automated process completes the titration. A computer monitor then displays the results while also recording them into the database. Every time samples are taken of any core, a record is made in the database. A printed label also follows the sample around. This eliminates any potential identification problems.

In another lab, we observed a whole core being split and then run through a battery of instruments to determine its many physical properties, such as magnetic susceptibility, color, reflectance, natural gamma radiation (an indication of radioactive minerals), sound wave propagation, etc. Some lab setups measure one specific property while others make a variety of measurements as the sample is mechanically pushed along a track. Several of the instruments were built by scientists and technicians so they are one of a kind. It is amazing to see the ingenuity of these people.

Since sea water and the sediments obviously interact, we also conducted some labs related to this topic. We ran a porosity and permeability test on four cores whose sediments were distinctly different. Most of us have students conduct this lab in class using spherical plastic beads and/or gravel and we can usually predict what the results will be. Our follow up discussion revealed some surprises. We came to the conclusion that there is not always a good relationship between porosity and permeability, especially when working with sediment cores.

Figure 2

The amount of moisture within a sample is also an important piece of information to scientists. To determine the moisture content of a material, a 5 cm slice of the core is removed, placed in an anvil capable of applying a pressure of 41,000 lbs/in^2, and the water is collected in syringe mounted to the side of the device. As you probably can guess, anytime you place such an instrument in sight of a group of Earth Science teachers ideas quickly surface. Have you ever seen an apple placed under 20,000 lbs/in^2 of pressure? I have! Since a steel ring isolates the samples, partly for safety reasons and so liquids don't escape, the apple took on a very interesting shape. *See Figure 2.*

In addition to all of this, the chief scientist on board, Dr. Andrew Fisher, had an objective to cover while we were out to sea. His goal was to visit the Juan de Fuca plate and cement some previously drilled holes, 1301A and B. Dr. Fisher is interested in how sea water flows through the ocean crust in areas near the ocean ridges. This is an important area of study as it is related to hydrothermal vents or black smokers and heat flow within the ocean crust. CORKS, (Circulation Obviation Retrofit Kit) are instruments inserted in drilled holes so that conditions within the sea floor can be monitored over long periods of time. Instruments within the CORK can be used to measure temperature, pressure, water flow, chemistry, etc. The above two holes did not seal properly when the CORKS were inserted about four years ago. Several unsuccessful attempts had been made to reseal the holes when the JOIDES Resolution was in the region in the past so now it was our turn. We reached the site about midnight of our fifth day on the ocean; the crew immediately went to work, as the ship runs 24 hours a day. The thrusters were lowered into the water to hold the ship steady and the drilling crew began stringing pipe together at 1:00 A.M. I cannot even begin to convey the excitement of watching 30 meter lengths of pipe loaded up into the derrick and then lowered through the floor of the ship. The workers and machinery were amazing! The drilling crew worked till early the next morning to lower drill pipe down to a depth of 2,660 meters. The dynamic positioning system held the ship perfectly still while one of the crew members (and all the teachers) watched the end of the drill pipe on monitors, *see Figure 3,* via an underwater camera. The goal? To get the drill pipe into a hole about a foot wide while working from the ocean surface! After several tense hours SUCCESS!! Everyone was glued to the monitors and when the drill punched down into the hole the level of excitement among us was compa-

Figure 3

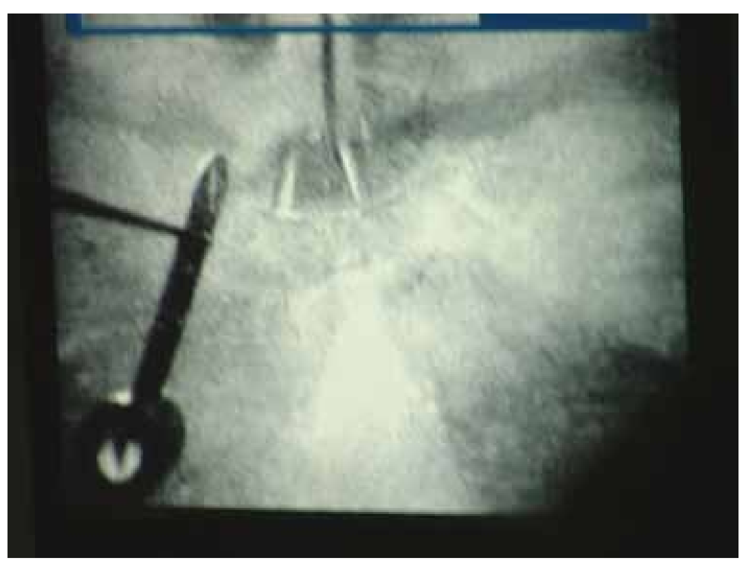


Figure 4

rable to NASA Mission Control after a successful space mission. Tons of cement were then pumped down the hole to seal the leaking CORK. Even this step was tricky since all of the cement couldn't be mixed in one large batch. A constant flow of cement had to be maintained at just the correct consistency to avoid its hardening in the pipe during the 30 minute trip down to the CORK. On the other hand, if the cement was too watery, it would simply flow all over the sea floor and be useless. The next hole was offset by about 30 meters so the crew moved the ship slowly, all the while dragging 2,660 meters of drill pipe. Again the tension built as an even smaller hole had to be penetrated this time. Once again it was unbelievable to see the pipe successfully inserted. Altogether about 40 tons of cement was pumped into the holes. We then watched as the crew then had to pull up that entire length of pipe – an all night process, *see Figure 4.* Was the mission a success? Hopefully, for Dr. Fisher won't actually know if the holes sealed properly until August 20 when he returns to the site to collect data from the instruments. He and many others are hopeful that conditions within the hole will have stabilized. I can now say that I am much more knowledgeable of how scientists use the JOIDES Resolution to carry out oceanographic research of the ocean floor.

During my 11 days, I have met some truly remarkable teachers. We exchanged stories and shared ideas. We had a great time and had some long days, shifts are 12 hours long, but it was definitely worth it. Other related oceanographic topics were also included but I do not have enough space here to cover everything. If you are interested in ocean floor sediments and are eager to have first-hand experience, I highly recommend that you apply for next year's School of Rock. This is the 5th year of the program and I have been fortunate enough to have been selected to participate twice. My first experience was at Texas A & M University in College Station, Texas. There we got experience working with cores stored in the Gulf Coast Repository but didn't get any ship experience, for at that time the *JOIDES Resolution* was in Singapore being refurbished. I can say that I have lived the best of both worlds and it has made me a much better teacher. I would like to extend my thanks to my teacher colleagues, a wonderful group of scientists/instructors who made this such a worthwhile experience and one that I will never forget: Leslie Peart, Sharon Cooper, Jennifer Collins, John Firth, Katie Inderbitzen, Phil Rumford, Leslie Sautter, Louise Anderson, Kusali Gamage, Andy Fisher, David Divins, and all of the ship's crew who were very accommodating to a group of wildly enthusiastic teachers.

Visit the web site for the School of Rock, which is part of the Deep Earth Academy. It has many classroom resources, such as activities, background information, and posters. Also check it to find out when next year's application process begins. The web site is www.oceanleadership.org.

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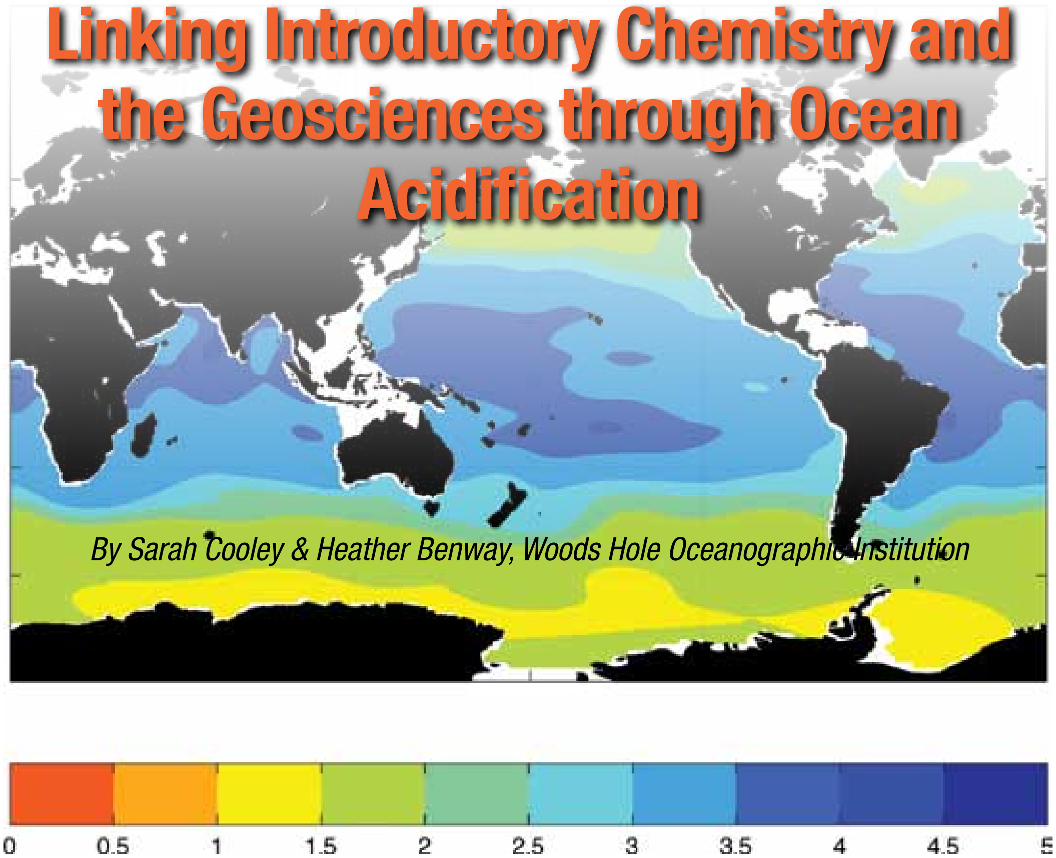
Linking Introductory Chemistry and the Geosciences through Ocean Acidification

By Sarah Cooley & Heather Benway, Woods Hole Oceanographic Institution



Present day surface ocean omega-aragonite value based on data from the Global Ocean Data Analysis (GLODAP). Omega-aragonite indicates the saturation state of the calcium carbonate mineral aragonite, which many marine organisms use to create hard skeletons and shells.

Abstract

Ocean acidification isn't just the next "issue of the day" in climate change studies: it is a wholesale change in ocean chemistry resulting from rising atmospheric CO2, and it could affect human communities by changing the mix of organisms found in the ocean ecosystems our societies depend on. Along with decreasing ocean pH, ocean acidification changes seawater chemistry and makes it more difficult for organisms like mollusks and corals to form their hard shells and skeletons. Possible future ecosystem-wide shifts towards noncalcified species could lead to changes in benefits to humans. Ocean acidification thus links introductory chemistry to the geosciences and social sciences and provides opportunities to engage students in interdisciplinary thinking. Several teaching tools and background materials are available to help science educators to present this multidimensional issue.

Ocean acidification (OA) research now makes news headlines somewhere in the world every week. But because OA results from rising atmospheric CO_2 concentrations, which are also associated with the highly politicized issue of climate change, some audiences are unsure of whether OA is "real." In fact, OA is a tangible demonstration of introductory chemistry concepts. OA's chemistry is certain and predictable, and each day its biological consequences are becoming clearer.

Approximately 25-30% of the CO_2 released by fossil fuel burning ends up in the ocean. This CO_2 dissolves in seawater and combines with water (H_2O) to create carbonic acid (H_2CO_3), a weak acid. Carbonic acid dissociates into hydrogen ions (H^+) and bicarbonate ions (HCO_3^-). Bicarbonate ions dissociate into more H^+ and carbonate ions (CO_3^{2-}).

$$CO_2(\text{gas}) + H_2O \Leftrightarrow H_2CO_3 \Leftrightarrow H^+ + HCO_3^- \Leftrightarrow 2H^+ + CO_3^{2-} . \quad (1)$$

This H^+ increase provides a one-two punch to ocean chemistry: it decreases the pH of seawater and drives the equilibrium of this "carbonate system" further towards HCO_3^-. Bicarbonate is the

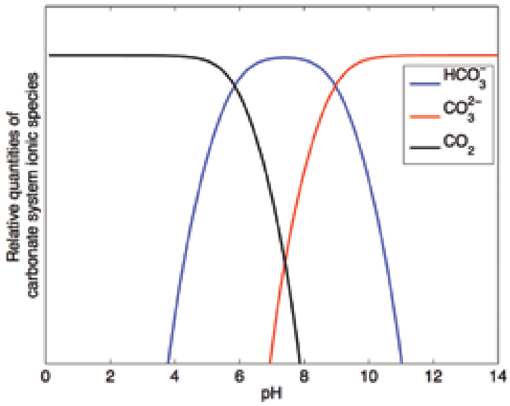


Figure 1. The relative quantities of carbonate system ions in seawater as a function of pH. Ocean pH is currently around 8.1, making bicarbonate the dominant ion in solution. Decreasing seawater pH will increase bicarbonate concentrations and decrease carbonate concentrations.

dominant ion in this system at seawater pH, which currently averages 8.1, and decreasing pH removes CO_3^{2-} from solution (Fig. 1).

It's important to note that even though seawater pH is around 8.1, placing it on the basic side of the pH scale, a decrease in pH, for any fluid — acid or base — is called "acidification." So even though future projections show that ocean pH will not become truly acidic (pH < 7) in any future CO_2 emissions scenarios (Fig. 2), geochemists still use "ocean acidification" to concisely refer to this process.

Many marine organisms, like mollusks, corals, urchins, and crustaceans, use carbonate and calcium ions from seawater to create hard calcium carbonate ($CaCO_3$) shells and skeletons. But as carbonate ion concentrations decrease, the saturation state of $CaCO_3$ minerals, or Ω, also decreases. In areas where Ω declines below 1, unprotected pieces of $CaCO_3$ dissolve. In most of the present-day surface ocean, Ω is well above this threshold (see lead image; Ω was calculated using GLODAP data as in Cooley et al. 2009), and ocean chemistry favors the construction of biological $CaCO_3$ structures like mollusk shells and coral skeletons.

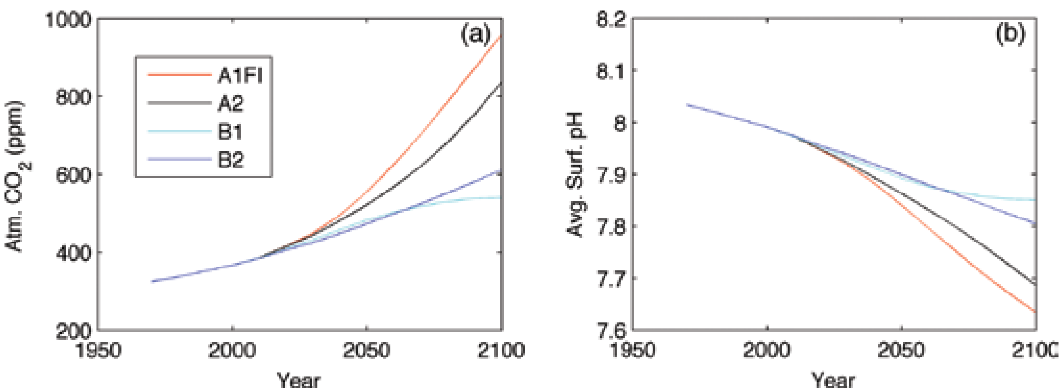


Figure 2. (left) Atmospheric CO2 concentrations associated with different industrial-development scenarios from the Intergovernmental Panel on Climate Change (IPCC). (right) Average surface ocean pH associated with each of these scenarios. Adapted from Cooley & Doney 2009.

Biologists have discovered that marine organisms respond differently to changes in ocean pH and Ω associated with rising CO_2. Many groups, including calcifying plankton, mollusks, echinoderms, and corals, show decreased calcification with increasing seawater CO_2 (Doney et al., 2009). Recent research shows that crustaceans may actually increase calcification when Ω decreases (Ries et al., 2009). Other studies have shown that photosynthesis in calcifying plankton increases in a high-CO_2 ocean, whereas mollusks and echinoderms have been shown to decrease reproduction under those conditions (reviewed in Doney et al. 2009). Still other studies suggest that larval mollusks may form shells later, and their shells may be increasingly deformed, in high-CO_2, low-Ω conditions (A. Cohen, WHOI, personal communication).

Most studies of OA's effects on marine biota have been carried out in laboratory conditions. The limited number of ecosystem-wide studies that have been performed to date suggest that OA pressures ecosystem shifts from calcifying organisms to noncalcifying organisms. For example, an 8-year decrease in pH in a coastal lagoon environment was associated with a shift from mussels and coralline algae to macroalgae (Wootton et al., 2008). In another study, seafloor organisms transitioned from calcifying organisms like sea urchins and barnacles far from a natural volcanic CO_2 vent to noncalcifying organisms like seagrass and algae near the vent. Furthermore, the few adult calcifiers found near the vent, where pH was lowest, had damaged shells, and no juvenile calcifiers were found there (Hall Spencer et al., 2008).

Calcifying organisms like pteropods (tiny free-swimming shelled organisms) and larval mollusks provide prey for many finfish, while calcifiers like urchins are important predators in many ecosystems. At the same time, corals provide habitat for a number of noncalcifying species. If OA alters populations or locations of calcifiers, ocean predators and reef-dependent species could face food shortages or lack of protection. Competition among predators could increase, and some noncalcifying species could thus be forced out.

Species shifts in marine ecosystems will also likely change marine harvests and alter other benefits to humans. In just the United States, calcifying organisms provide nearly half ($2 billion) of the primary commercial fishing revenues ($4 billion) each year, while wholesale, processing, and retail of seafood products added another $34 billion to the gross national product in 2007 (Cooley and Doney, 2009). In addition to providing revenue through fishing, calcifying species provide other benefits, including tourist attractions, coastal protection, and nutrient recycling. The estimated values of these services vary, depending on the analysis method, but most countries derive benefits in the millions or billions of dollars from these services (Cooley et al. 2009). Changes in these benefits resulting from OA could have trickle-down economic effects through regional communities or industries.

Ocean acidification's linkages to geochemistry, marine biology, economics, and sociology provide a number of ways for teachers to connect this current event with classroom curricula. The teaching tools currently available usually focus on the chemistry and biology of OA, because the ecosystem-level effects and socioeconomic dimensions are still being assessed.

The existing teaching and outreach modules begin with introductions to pH, usually using familiar household materials, and visual demonstrations of the effect of increasing atmospheric CO2 levels on seawater pH, using pH indicator solutions or pH meters. Each module also demonstrates OA's biological impacts by showing how it damages the carbonate shells and skeletons of different larval and adult marine calcifiers.

Teaching materials include:

C-MORE Ocean Acidification Teaching Module (http://cmore.soest.hawaii.edu/education/teachers/science_kits/ocean_acid_kit.htm)

OCB Ocean Acidification Lab Kit (http://www.us-ocb.org/publications/OCB-OA_labkit102609.pdf)

Acid Ocean Virtual Lab (http://i2i.stanford.edu/carbonlab/co2lab.swf)

Videos about OA are also available. Some of these are available on YouTube and Google Video, and some are available on DVD from their creators.

Acid Test (http://www.acidtestmovie.com/)

The Other CO2 Problem (http://www.youtube.com/watch?v=55D8TGRsl4k)

Hermie the Hermit Crab (http://www.youtube.com/watch?v=RnqJMInH5yM)

A Sea Change (http://www.aseachange.net/)

Ocean Acidification (http://www.eur-oceans.eu/training_and_outreach/wp10/Documents/Videos/high/acidification_english.wmv or http://video.google.com/videoplay?docid=-

88165186643350049 98&ei=HNsGS-r9KpOorQLqjYC9DQ&q=Eurocean+Ocean+Acidification &hl=en#)

Overview documents about OA provide more detailed overviews of the state of scientific knowledge. Some include:

The Dangers of Ocean Acidification, Scott Doney, Scientific American, 2006. (http://www.scientificamerican.com/article.cfm?id=the-dangers-of-ocean-acid)

Current: The Journal of Marine Education special issue: Ocean Acidification--- from Ecological Impacts to Policy Opportunities. 2009. (http://www.mcbi.org/what/what_pdfs/MCBI_Current.pdf)

Ocean acidification--- the facts. 2009. European Project on Ocean Acidification. (http://www.epoca-project.eu/index.php/Ocean-Acidification-the-facts.html)

NOAA Ocean Acidification fact sheet. 2008. (http://www.pmel.noaa.gov/co2/OA/Ocean_Acidification%20FINAL.pdf)

EUR-Oceans Ocean Acidification fact sheet. 2007. (http://iodeweb3.vliz.be/oanet/OAdocs/FS7_oceanacidification.pdf)

Monaco Declaration. 2008. (http://ioc3.unesco.org/oanet/Symposium2008/MonacoDeclaration.pdf)

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Hall-Spencer, J.M., R. Rodolfo-Metalpa, S. Martin, E. Ransome, M. Fine, S.M. Turner, S.J. Rowley, D. Tedesco, and M.-C. Buia. 2008. Volcanic carbon dioxide vents show ecosystem effects of ocean acidification. Nature 454:96–99.

Ries, J.B., A.L. Cohen, D.C. McCorkle. 2009. Marine calcifiers exhibit mixed responses to CO2-induced ocean acidification. *Geology* 37 (12): 1131-1134

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Breaking Ice, Building Knowledge

The Benefits of Ship-Based Teacher Research Experiences

By Dolores (Lollie) Garay, Redd School; Janet Warburton, PolarTREC PI; Kristin Timm, Arctic Research Consortium of the U.S.

Photo by Simone Welch (PolarTREC 2009) Courtesy of ARCUS.

The ship rocks while hurricane force winds and tall seas batter anything not tied down. Katabatic winds bite bitterly as ambient temperatures hover near single digits. Gear is swaying back and forth as the waves rush over the ship's deck. Not to be deterred, people are still working out on the deck and in the onboard labs. They are thousands of miles away from civilization with little contact to the 'outside' world. As the ship presses through the extreme conditions into one of the most remote regions of the world, cutting edge science is taking place and teachers are working alongside scientists to investigate our changing oceans.

As part of the International Polar Year (IPY) (2007-2009), teachers from across the United States left the warmth and comfort of their homes and schools behind for weeks at a time to join scientists on ship-based expeditions to polar regions. It is here among the winds, waves, and breaking ice that they've push themselves to new areas of discovery and taken on the role of student to experience oceanographic science first-hand through a Teacher Research Experience (TRE). TRE's are powerful professional development opportunities, taking teachers out of the classroom and putting them into field experiences and collaborative relationships with scientists towards the shared goal of increasing the understanding of our polar oceans. Participating teachers' often return from their expeditions empowered with new purpose and conviction for their teaching, oodles of classroom material, and a newfound network of scientific content experts. Sharing their discoveries, the teachers' experiences have engaged students in active and meaningful learning and inspired the next generation of scientists and citizens.

Figure 1. Researchers, Will Ostrom, Jim Dunn, and PolarTREC teacher, Gerty Ward start to drill the hole for the ice tethered profiler.

Photo: Rick Krishfield. Courtesy of ARCUS

Over the past three years, seventeen teachers have participated in ship-based TRE's in the Bering and

Figure 2. The USCGC Healy busts through early spring sea ice on the Bering Sea. This ice isn't dirty; it is colonized by ice algae that are the primary producers of the Bering Sea ecosystem.

Photo by Maggie Prevenas (PolarTREC 2007). Courtesy of ARCUS

Beaufort Seas and Arctic and Southern Oceans on expeditions like the *Bering Sea Ecosystem Studies*, *Beaufort Gyre Observing System*, and the *Central Scotia Seafloor and the Drake Passage Deep Ocean Current Gateway*. The Arctic Research Consortium of the U.S. (ARCUS) supports TRE's through a program called PolarTREC (Teachers and Researchers Exploring and Collaborating), which is funded by the National Science Foundation, with some additional support from the NOAA Teacher at Sea program and the North Pacific Research Board. PolarTREC has matched teachers and researchers for hands-on polar research experiences on land, ice, and sea across the planet's polar regions. Using current technology and online tools such as journals, short videos, images, and real-time live events teachers shared their adventures before, during, and after the field experience with classrooms, families, and the public. Diverse audiences utilized these tools, learning about places and things that stimulate curiosity and bring about new dimensions of discovery and understanding. Additionally, seeing their own teachers take risks out of their comfort zones has inspired students' ambitions and learning. TRE's are not new and additional programs such as ARMADA and the Teachers Experiencing the Arctic and Antarctica program have supported the immersion of teachers in polar and oceanic field research for over 15 years.

While onboard, teachers were more than mere observers of the science; they described themselves as active participants who felt like members of the research teams. PolarTREC teacher Jeff Peneston (New York) spent three weeks on the Swedish Icebreaker Oden as it travelled to McMurdo Station, Antarctica in the austral summer of 2008-2009. He describes the research activities he conducted while onboard, "I learned to drill and measure ice cores up to two meters thick...I spent time with the physical oceanographers and was able to use my underwater video camera to document how the CTD collects data from the water column. I also spent time with the atmospheric and oceanographic chemists. Perhaps my most memorable experiences came from helping the seal research team capture Crabeater and Weddell seals on the sea ice." Peneston added that, "these experiences will be woven into the stories I tell my students for the rest of my career."

Figure 3. Working with Swedish and American researchers, PolarTREC teacher Jeff Peneston displays an ice core sample that was drilled from this ice floe in the Southern Ocean. This part of the core is white because it did not contain the algae rich layer that the team was working to collect.

Photo: Jeff Peneston (PolarTREC 2008). Courtesy of ARCUS

Unique to ship-based expeditions, teachers were often able to rotate among research projects learning about multiple scientific disciplines.

The researchers who work closely with the teachers and mentor them in the field described them as working very hard and performing many of the same tasks as graduate students or technicians. Teachers participated in science meetings onboard, asked numerous questions, and even made contributions to the scientific missions. In the spring of 2007, Maggie Prevenas (Hawaii) spent three weeks on the U.S. Coast Guard Cutter *Healy* participating in the Bering Ecosystem Study as a PolarTREC and NOAA Teacher at Sea. She describes her place in the research expedition,

It was after my training of ice observations that my place on the mission was made clear to me... I remember looking down at the ice in the front of the ship, and seeing, rusty almost red like streaks in the water and on the broken ice. After breakfast, I scurried to the back of the ship and noticed the color of the ice was not as rusty, more of a brown color, and not as vivid as from the front... I gallop up to the bridge, look at the breaking ice. Yes, definitely red. Is it the reflection of the ship on the ice? Carlton, was the walrus expert on board and veteran ice watcher... I swallowed nervously and said, 'Hey Carlton, the color of the ice at the back of the ship is different than the ice at the front.' 'Hmm,' he said. Later I learned he had

> spoke with Dr. Ray Sambrotto, and my observations added to other observations of the ship's effect on the photosynthesis of the ice algae. This was to be the start of a beautiful relationship we had—the ice and me... I think back to the day when my observations of the ice made a difference in an important research mission on global climate change effects in the Bering Sea Ecosystem.

Lollie Garay (Texas) spent seven weeks as a PolarTREC teacher on the Icebreaker Oden in 2007. Like others, she spent her time onboard engaged in numerous science activities.

> As the sole teacher onboard that cruise, I was initially overwhelmed with the magnitude of the expedition and my own expectations of how I was going to translate this experience back into the classroom. However, within a few days at sea and with the encouragement and support from the science team, I began to feel like a contributing member of the expedition. Over the course of the next seven weeks in the Antarctic Seas, I was actually DOING science: observing sea ice conditions, ice coring, assisting in CTD casts, plankton tows, and processing samples...By the end of the cruise I had learned more than I could have ever imagined about the physical ocean, marine sciences, and the incredible Antarctic seas environment. I realized immediately that this was not the end of an experience, but only the beginning of a longer life study.

Figure 4. The nasal swab is quickly sealed into a sterile tube with a preservative. Once the team gets back to Sweden, the bacteria and viruses can be identified. Within minutes the procedures were complete and the seal was released.

Photo: Jeff Peneston (PolarTREC 2008). Courtesy of ARCUS

Once described affectionately as 'summer camp for teachers,' PolarTREC teachers have described the program as providing profound personal, professional, lasting, and life-changing impacts. Being engrossed in the field experience, and all that it embodies—unique logistics, harsh conditions, beautiful scenery, cutting edge science and technology—has led to a greater overall understanding of science as a process. This understanding has been transferred in numerous ways to the teachers' classrooms, enriching student learning in earth system science and developing connections between the polar regions and their local environment.

Garay explains, "This experience impacted me deeply. It not only changed me but also my students in how we think and what we think about science. Being there made a profound impact on my ability to generate interest and develop inquiry in my science programs...that expedition was the catalyst for change in my classrooms."

Subsequent to his expedition, Peneston planned a weekend field camp experience for his own 9th grade students. The students will simulate their own research project, drilling cores and exploring life through the frozen surface of a local lake in upstate New York. They will use some of the same lines of inquiry that were used during his expedition in the Amundsen Sea. Students choosing to study polar topics as part of their honors level symposium projects are using peer-reviewed journal articles written by expedition scientists as part of the literature review to support their projects. Peneston's continued partnership with the researchers he met onboard provides not only expertise, but offers realistic examples of how scientists work and allows students to see them as "real people"—important for removing misconceptions about what scientists do.

Although the actual field research experience is central to the PolarTREC model and often the trip of a lifetime, many participants cite the ongoing collaboration and the relationship they

Figure 5. During a beautiful day in the high arctic, PolarTREC teacher Gerty Ward takes a reading of the solar radiation intensity with a Microtops photometer. Sunlight in the Arctic has an important contribution to the Earth's energy budget, and NASA will use the data collected by the photometer to verify satellite data.

Photo by Gerty Ward (PolarTREC 2008). Courtesy of ARCUS

built with their teacher/researcher as one of the best outcomes of the program. Relationships with researchers not only gave teachers a network of professionals to contact for content advice, provided students access to meaningful discussions with scientists to answer questions and discuss careers opportunities. Teachers have used online "Polar Profiles", interviews from the field, live events, pen pals, virtual and in person visits, and other methods to connect students and scientists. Ute Kaden (Texas) participated in a mission on the Icebreaker Oden in 2006. Her students in Brownsville, Texas had the opportunity to interview Emily Miller, a 23-year old graduate students with degrees in physics and applied mathematics. Onboard, she worked as a data technician where she oversaw real time data collection of plankton and monitored environmental conditions in seawater. The interview, *Diving, Physics, Math & Engineering—A Girl's Way*, not only highlighted an interesting science career but also demonstrated that girls can be successful in science and engineering.

As educational liaisons between the scientists and the public, it is the teacher's job to turn what they have learned onboard into meaningful opportunities to explain the science to students and the general public, and scientists have reported that the outreach activities related to the PolarTREC teacher have positively impacted their projects. Topics such as climate change often take new meaning when seen from the perspective of the teacher's first-hand experiences. Researcher satisfaction was also reflected in the interest to repeat the experience, and many researchers have applied to host additional PolarTREC teachers and/or continue to work closely with the teachers who join them in the field long after the expedition is complete.

Garay describes her ongoing relationship with researcher Dr. Patricia (Tish) Yager of the University of Georgia at Athens. When faced jointly with the challenge that natural oceanic cycles and their relationship to the carbon cycle are not well studied and therefore not well covered in the middle school science curriculum, Yager and Garay tackled this problem and together. They wrote a middle school level activity based on the role of the biological pump in moving carbon. They introduced the activity at a national conference, and as a result of that successful work, they have continued a dialogue for merging Dr. Yager's research with the teacher's interest in developing a cohesive unit of study on marine ecosystems and climate sensitive carbon sequestration. The educational outreach conducted jointly by teachers and researchers provides forums for disseminating valuable information for developing ocean and polar literacy and bringing attention to current research and important global issues.

Figure 6. The view of broken Antarctic sea ice as seen from the deck of the Icebreaker Oden.

Photo: Lollie Garay. (PolarTREC 2007). Courtesy of ARCUS

In the International Council for Science/World

Meteorological Organization Joint Committee report, *The State of Polar Research*, they stated that the, "IPY took place during a time when our planet was changing faster than ever in recorded human history, especially in the polar regions" (ICSU/WMO Joint Committee for IPY, 2009). The impacts of climatic change on the world's oceans, and their impacts on us, will be one of the greatest challenges of the next generation. An understanding of the changes in sea ice, circulation, sea level, and the marine carbon cycle—complex and interrelated subjects—will be essential as tomorrow's scientists, engineers, technicians, leaders, and citizens face the challenges associated with climate change.

PolarTREC teacher, Gerty Ward (North Carolina) participated in a 2008 oceanographic mission in Beaufort Sea, and explains, "I want to bring the excitement of the whole experience—from drilling holes in the ice, to the crunch of the icebreaker, to the quiet of a land of ice, to my tiny room on the ship—into the classroom, the living room, wherever. I want my students to understand the important role that science will take in their lives as we begin to adapt to our changing planet. I want students to appreciate the environment as something we are a part of every day, not just something 'to save.' I want my students to understand the relationship between cause and effect: ocean temperatures, daily climate change, and school-day wardrobe choice. Students learn in an exceptionally meaningful and permanent way when they can develop a personal connection to the material."

Figure 7. Lollie raises the plankton net.

Photo: Lollie Garay. Courtesy of ARCUS

Through ship-based expeditions, PolarTREC has developed an effective model for collaboration among educators and researchers interested in discussing, creating, sharing, and contributing their valuable knowledge, experience, and skills to learners of all ages across the globe. Engaging teachers in TRE's, sparks knowledge, inquiry, and often a renewed interest in learning at a time when education is faced with the challenge of recruiting and preparing students to meet the science, technology, engineering and math demands of our future workforce. A recent article about TRE's in the magazine *Science* agrees, "...that experience in the practice of science improves the quality and authenticity of science teaching and thereby increases student interest and achievement in science." Moreover, it "enhances teachers' skills in communicating science to students" and has "encouraged them to continue teaching" (Silverstein, *et al*, 2009).

The authors would like to thank all the contributors to this article, Maggie Prevenas, Jeff Peneston, Gerty Ward, and Ute Kaden. Without you, we wouldn't have had a story to share!

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Figure 8. PolarTREC teacher, Lollie Garay stands on the ice with the massive Icebreaker Oden in the background.

Photo: Lollie Garay (PolarTREC 2007). Courtesy of ARCUS

Links

PolarTREC – http://www.polartrec.com

NOAA Teacher at Sea Program – http://teacheratsea.noaa.gov

ARMADA Project – http://www.armadaproject.org

References

International Council for Science (ICSU)/World Meteorological Organization (WMO) Joint Committee for the International Polar Year (IPY). 2009. *The State of Polar Research.*

http://www.ipy.org/index.php?/ipy/detail/state_of_polar_research/.

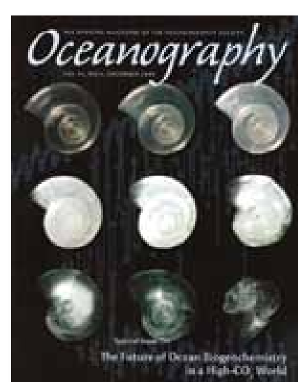
Silverstein, Samuel C. *et al.* 2009. Teachers' Participation in Research Programs Improves Their Students' Achievement in Science. *Science* 326, 440 (2009).

Additional Resources

Twentieth-century Marine Science: Decade by Decade and ***Earth Science: Decade by Decade***

These two recent publications from Christina Reed are available on Amazon. http://www.amazon.com/Christina-Reed/e/B001JS6CJK/ref=ntt_dp_epwbk_0

The December 2009 issue of ***Oceanography***, a publication of The Oceanography Society is dedicated to the future of ocean biogeochemistry in a high CO_2 world and features on its cover changes seen in foraminifera, organisms mentioned in the School of Rock article in this issue. (See TOS.org)



A Fiber-Optic Telescope to the Deep Sea

By Nancy Penrose,
Communications Coordinator,
Regional Scale Nodes Program

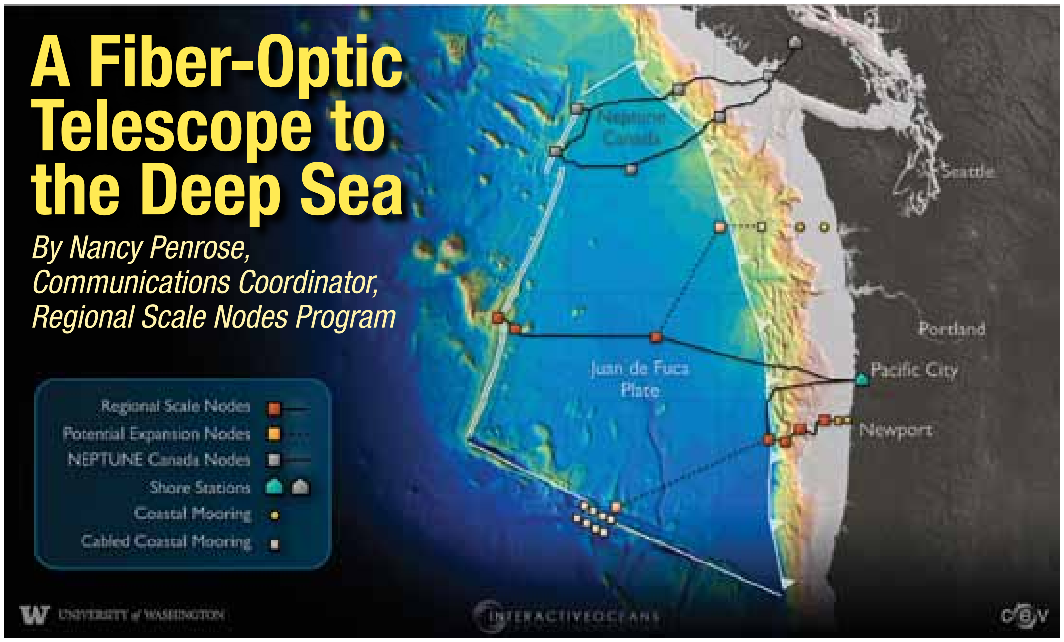


Figure 1. Regional Scale Nodes cable system map; RSN website: www.interactiveoceans.washington.edu; OOI website: www.oceanobservatories.org].

Image credit: RSN and Center for Environmental Visualization, University of Washington

Abstract

Real-time science and education in the North East Pacific Ocean using the Regional Scale Nodes cabled ocean observatory component of the NSF Ocean Observatories Initiative will soon be here. This innovative infrastructure, made up of 500 miles of fiber-optic/power cable and thousands of instruments, is now under construction and is scheduled to begin operations in 2014. By enabling continuous *in situ* studies of ocean phenomena 24/7/365 for decades, cabled ocean observatories are opening a new era of oceanography not only for scientists but also for educators and students.

A mysterious and fascinating deep-sea world hidden under thousands of meters of water is coming to computers in classrooms, laboratories, libraries, and homes around the world. Students, educators, scientists, anyone with an Internet connection will be able to explore the ocean from their desktops, dive to the seafloor without going near the water, chart the activity of an underwater volcano, or track the migration of a blue whale. The idea that the ocean is only what can be seen from the edge of the shore will begin to be replaced with the recognition that the deep ocean is a vitally important part of our planet to explore and understand.

Real-time science and education in the Northeast Pacific using the Regional Scale Nodes (RSN) cabled ocean observatory component of the NSF Ocean Observatories Initiative (OOI) will soon be here.

The OOI, which also includes coastal and global components, will construct a network of instruments, undersea cables, and moorings that will span the Western Hemisphere. A common computer architecture – cyberinfrastructure – will integrate the observatories' thousands of instruments, tens of thousands of users, and terabytes of data.

The OOI, one of the largest-ever ocean science programs, is managed and coordinated by the Consortium for Ocean Leadership. Institutions involved in construction of the infrastructure include the University of Washington, Woods Hole Oceanographic Institution, Scripps Institution of Oceanography, Oregon State University, and the University of California, San Diego. The OOI system will be open for use by a wide variety of science and education communities. Construction is expected to take five years, and the observatories are designed to operate for 25 years.

Development and construction of the RSN are led by the University of Washington (UW). Operations are scheduled to begin in 2014. Nearly 500 miles of fiber-optic/power cable will reach from the subduction zone off the coast of Oregon, where the Juan de Fuca tectonic plate is being pulled beneath the North American plate, all the way to the active underwater volcanoes and hydrothermal fields of the Juan de Ridge spreading center. The cable will provide unprecedented levels of power and two-way high bandwidth communications to instruments and moorings that will cover the ocean from below the seafloor to the tops of the waves. Data types will include stunning imagery from the particularly power and bandwidth hungry high-definition underwater video cameras.

Historically, oceanographers have gone to sea in ships to study the oceans. Limitations of this expeditionary approach include studies within very short time frames and little geographic coverage; battery-powered instruments with limited lifetimes and low-bandwidth communication capabilities; short periods of favorable weather when scientists can use ships to productively conduct research in the North Pacific; brief dives using research submarines and robotic undersea vehicles; and surface-only studies using satellites.

Despite the constraints, many exciting and beneficial discoveries have been made using these traditional methods: new life forms at hydrothermal undersea vents; changes in ocean temperatures that lead to El Niño climate patterns; the propagation of earthquakes across a tectonic plate, the motions of tsunamis across an ocean basin.

Each new discovery has triggered thousands of other questions, many of which cannot be answered without using new approaches. By enabling continuous *in situ* studies of ocean phenomena 24/7/365 for decades, cabled ocean observatories are opening a new era of oceanography, not only for scientists in many disciplines, but also for educators and students. Within the OOI, education-user needs are being integrated into all components of network design so that science educators will have the tools to derive products and programs from OOI data and other resources.

As part of the OOI effort, the UW brings many years of experience in conducting seagoing science-education programs. The UW has taken a phased approach to addressing the challenges of moving into the era of cabled observatories: 1) learning how to transmit high-bandwidth data live from sea; 2) distributing these data in real time to audiences around the globe; and 3) including students and educators in seagoing operations and observatory planning.

In 2005, the VISIONS '05 expedition, led by RSN Program Director and UW Professor of Oceanography, John Delaney, and UW Professor of Oceanography Deborah Kelley, broadcast live

Figure 2. Deborah Kelley, on the far left, Professor of Oceanography at the University of Washington and Project Scientist with the Regional Scale Nodes Program, inside the control van for the Jason II tethered robotic vehicle, onboard the research vessel Thomas G. Thompson, during the VISIONS '05 expedition in September 2005. Also shown are Jason operators. Jason II carried the high-definition underwater video camera that was used to broadcast live high-definition video imagery from the seafloor for the first time.

Image credit: University of Washington.

high-definition video imagery from the seafloor for the first time. Three educational programs were produced from sea. (Figure 2) Two-way dialogues between researchers and teachers at sea onboard the UW Research Vessel *Thomas G. Thompson* and K-12 science educators and students in a UW studio in Seattle were commingled with the seafloor video. The broadcasts were streamed over Internet2 via The ResearchChannel, which reaches 20 million households around the world. The broadcasts are available on the ResearchChannel website (http://www.researchchannel.org/prog/displayseries.aspx?fID=1704).

Delaney has a long history of engaging students and teachers in the ocean sciences. He is co-founder of the Research and Education, Volcanoes, Exploration, and Life (REVEL) program, which took more than 80 teachers to sea on expeditions studying the underwater volcanoes of the Juan de Fuca Ridge. REVEL involved science teachers from around the country in authentic, oceanographic research experiences as part of their professional development, and helped develop an extensive and collaborative community of lifelong learners, passionate about understanding the Earth system. (Figure 3)

Many other countries have recognized the value of putting high levels of power and bandwidth into the oceans, and several have begun planning and/or implementing cabled observatories. One such observatory is complementary to the RSN and has already been launched: NEPTUNE (NorthEast Pacific Time-Series Undersea Networked Experiments) Canada, installed on the northern third of the Juan de Fuca tectonic plate and run by the University of Victoria, began operations in December 2009. Data streams from instruments are available at www.neptunecanada.ca. Two other scientific cabled systems have been installed in shallow water: one in Monterey Bay (the Monterey Bay Accelerated Research System, MARS, www.mbari.org/mars) and one off Vancouver Island, Canada (the Victoria Experimental Network Under the Sea, VENUS, www.venus.ca). The University of Victoria, manager of the NEPTUNE Canada and VENUS systems, has partnered with the Shaw Ocean Discovery Center in Victoria (http://www.oceandiscovery.ca/) in outreach and education efforts. In conjunction with the MARS operations, the Monterey Bay Aquarium Institute (MBARI) has developed a program called Education and Research: Testing Hypotheses (EARTH), which uses near-real-time data from ocean observatories to design and test outreach with the Internet as an interface to scientists, teachers, students, and the public (http://www.mbari.org/earth/). EARTH workshops for educators are held each summer.

This image is a conceptual representation of a future seafloor laboratory on the Regional Scale Nodes of the Ocean Observatories Initiative network in the Northeast Pacific ocean.

Robotic systems will be the next-generation extensions of a human telepresence in the oceans as the ocean sciences benefit from a host of powerful emergent technologies driven by numerous disciplines that are entirely external to the world of ocean research. These technologies include, but are not limited to, nanotechnology, biotechnology, information and imaging technologies, and robotics.

Converging with the ability to place high levels of power and bandwidth into the oceans are enabling and adaptive capabilities that will allow sophisticated remote marine operations to be conducted on the seafloor and throughout the water column in ways never before imagined. Future laboratories on the seafloor could use robotic technologies to conduct adaptive sampling exercises from shore, in situ DNA analyses of microbes emerging from hydrothermal vents, and chemical probing of gas hydrates to understand their response to seismic events. High-definition video and other data will be transmitted via fiber-optic cable in real and near-real time to land-based laboratories, classrooms, and science centers. Because these images and data will be available via the Internet, learners of all ages will be able to participate in this journey of exploration and discovery.

Source/Credit: Regional Scale Nodes Program and Center for Environmental Visualization at the University of Washington

About the Author

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National Earth Science Teachers Association

Events at Philadelphia NSTA 2010

All NESTA events will be held in the Sheraton Philadelphia City Center Hotel Liberty A/B except as indicated.

NATIONAL EARTH SCIENCE TEACHERS ASSOCIATION

Friday March 19

9:30 NESTA Geology Share-a-Thon

11:00 NESTA Oceans and Atmospheres Share-a-Thon

12:30 NESTA Space Science Share-a-Thon

2:00 Don't miss the American Geophysical Union Lecture!

Predicting Earthquakes and Volcanic Eruptions: What Can and Can Not Now Be Done?
Dr. Stephen Malone
2010 IRIS/SSA Distinguished Lecturer, University of Washington
Location: Room 201C of the Philadelphia Convention Center

6:30-8:00 NESTA Friends of Earth Science Reception
Location: Sheraton Horizons Rooftop Ballroom

AGU CAROLINA WINDOWS TO THE UNIVERSE

These events are cosponsored by the American Geophysical Union, Carolina Biological Supply, UCAR, and Windows to the Universe.

http://www.nestanet.org

Saturday March 20

NESTA Earth and Space Science Resource Day: Earth System Science and the Environment

7:00-8:30 NESTA Resource Day Breakfast
Location: Sheraton Logans I Room
(Advance purchase tickets required)

Building meaningful Earth system science education partnerships across the K-20 community
Professors Tanya Furman *(The Pennsylvania State University)* and Laura Guertin *(Pennsylvania State Brandywine)*

9:30 NESTA Earth System Science and the Environment Share-a-Thon

11:00 ***Meteorology drives everything: the sensitivity of pollution episodes to atmospheric conditions in the mid-Atlantic region***
Professor Richard Clark, Millersville University of Pennsylvania

12:30 ***Changing Seas, Changing Life: Paleontological Research with Student Participation***
Dr. Robert Ross, Paleontological Research Institution

2:00 ***Environmental Earth System Science for Education in Urban Areas***
Professor Alexander Gates, Rutgers University

3:30-5:00 NESTA Rock and Mineral Raffle

5:00-6:30 NESTA Membership Meeting

The Earth Scientist (TES)
MANUSCRIPT GUIDELINES

NESTA encourages articles that provide exemplary state-of-the-art tested classroom activities and background science content relevant to K-12 classroom Earth and Space Science teachers.

- Original material only; references must be properly cited according to APA style manual
- Clean and concise writing style, spell checked and grammar checked
- Demonstrates clear classroom relevance

Format Specifications

- Manuscripts should be submitted electronically – Microsoft Word (PC or Mac), Appleworks, size 10 point, single-spaced
- Length of manuscript should not exceed 2000 words.
- All submissions must include a summary/abstract.
- Photos and graphs: should be submitted as separate files, of excellent quality and in PDF, EPS, TIFF or JPEG format. 300 dpi minimum resolution. Color or black and white are both accepted.
  - Photos/charts should not be embedded in the Word file. References to photo/chart placement may be made in the body of the article identified with some marker: <Figure 1 here> or [Figure 1 in this area].
- Figures should be numbered and include captions (Figure 1. XYZ.).
  - Captions may be included with photo/chart reference or at the end of the article.
- If using pictures of students under 18, a signed model release will be required of EACH student pictured
- Each article must include: author(s) names, the school/organizations, mailing address, home and work phone numbers (which will not be published), and e-mail addresses.

Review

Manuscripts are reviewed by the Editor for content and language. The Editor is responsible for final decisions on the publication of each manuscript. Manuscripts may be accepted as is, returned for minor or major revisions, or declined, based on the decision of the Editor. The Editor reserves the right to edit the manuscript for typographical or language usage errors.

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by Bruce Hall, Membership Coordinator

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Informed Decisions Require an Integrated Approach

In the coming decades, scientists expect climate change to have an increasing impact on human and natural systems. In a warmer world, accessibility to food, water, raw materials, and energy are likely to change. Human health, biodiversity, economic stability, and national security are also expected to be affected by climate change. Climate model projections suggest that negative effects of climate change will significantly outweigh positive ones. The nation's ability to prepare for and adapt to new conditions may be exceeded as the rate of climate change increases.

Increasing our preparedness for these impacts depends not only upon our ability to understand climate and ocean sciences and the implications of climate change or ocean acidification, but also upon our ability to integrate and use that knowledge effectively. Changes in our economy and infrastructure as well as individual attitudes, societal values, and government policies will be required to alter the current trajectory of climate's impact on human lives. The resolve of individuals, communities, and countries to identify and implement effective management strategies for critical institutional and natural resources will be necessary to ensure the stability of both human and natural systems as temperatures rise.

Together, the Ocean and Climate literacy documents will promote informed decision-making and effective systems-level responses to global changes that reflect a fundamental understanding of ocean and climate sciences. It is imperative that these responses to climate change embrace the following guiding principle:

> Guiding Principle for informed climate decision: Humans can take actions to reduce climate change and its impacts.

Ocean Literacy: The Essential Principles of Ocean Sciences (2005)

1. The Earth has one big ocean with many features.
2. The ocean and life in the ocean shape the features of the Earth.
3. The ocean is a major influence on weather and climate.
4. The ocean makes Earth habitable.
5. The ocean supports a great diversity of life and ecosystems.
6. The ocean and humans are inextricably interconnected.
7. The ocean is largely unexplored.

Climate Literacy: The Essential Principles of Climate Sciences (2009)

1. The Sun is the primary source of energy for Earth's climate system
2. Climate is regulated by complex interactions among components of the Earth system
3. Life on Earth depends on, is shaped by, and affects climate.
4. Climate varies over space and time through both natural and man-made processes
5. Our understanding of the climate system is improved through observations, theoretical studies, and modeling.
6. Human activities are impacting the climate system
7. Climate change will have consequences for the Earth system and human lives

Source: *NASA Goddard Space Flight Center Image by Reto Stöckli (land surface, shallow water, clouds)*

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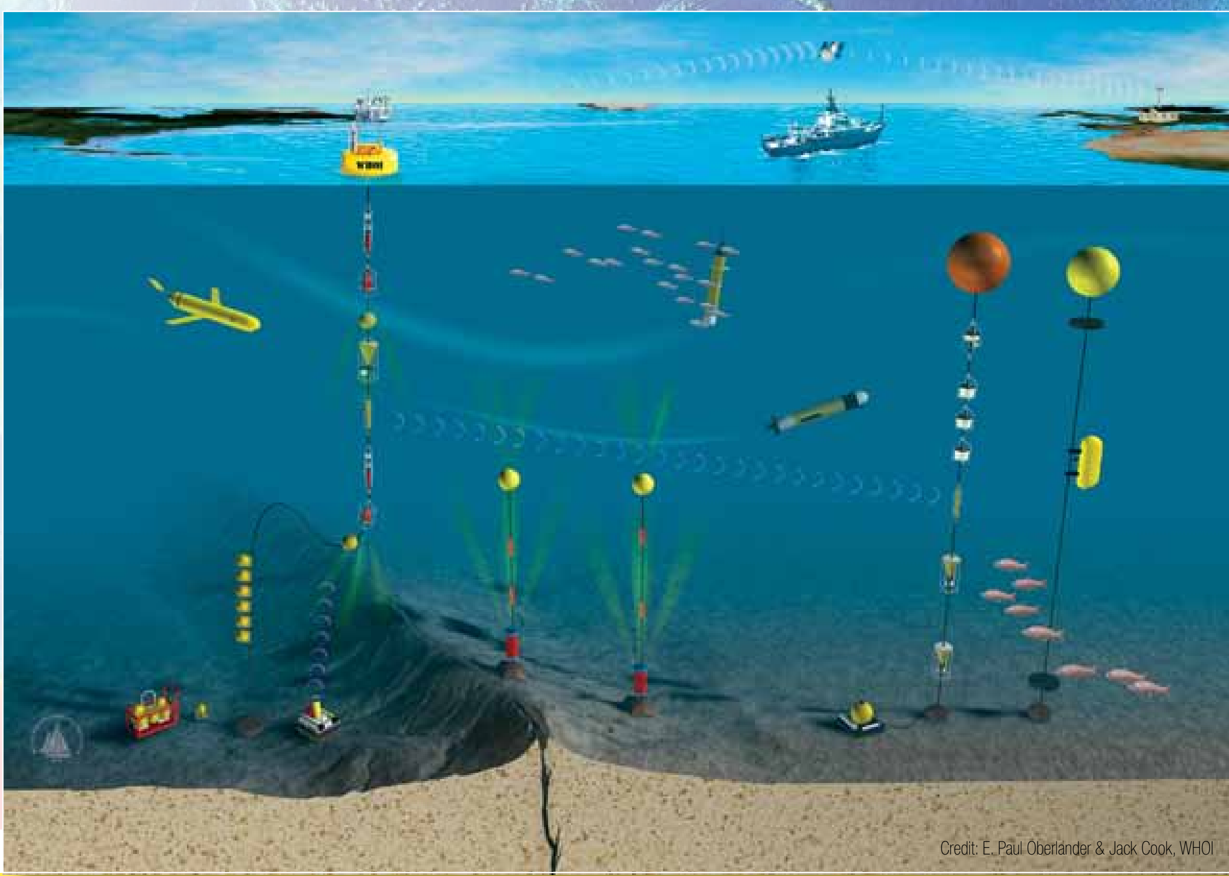

Credit: E. Paul Oberlander & Jack Cook, WHOI

Cover map: This map was created at NOAA's National Geophysical Data Center (NGDC) from digital databases of seafloor and land elevations on a 2-minute latitude/longitude grid (1 minute of latitude = 1 nautical mile, or 1.852 km). For more information see: www.ngdc.noaa.gov/mgg/image/globalimages.html

Back cover image insert: Ocean observing buoys can stay fixed in place for up to a year or more between maintenance visits. Under the waves, the buoy mooring lines carry more instruments. Wiring embedded in the lines carries data back to the surface and out to satellites. Scientists choose from sensors like the ones drawn here and use surface or subsurface buoys, research ships, gliders, floats and/or robotic vehicles based on their specific research goals.