The Research Fleet

University-National Oceanographic Laboratory System

University-National Oceanographic Laboratory System

UNOLS

The University-National Oceanographic Laboratory System: an organization of academic oceanographic institutions established to coordinate the use of federally supported oceanographic facilities.

Table of Contents

This brochure was prepared under a grant from the National Science Foundation.

Editor: Laura Dippold and Mike Prince
Designer: Laura Dippold

Photo Credits

THIS PAGE: Top: Dolphins on the bow of the R/V *Atlantis* (Woods Hole Oceanographic Institution-WHOI). Photo by: Lance Wills. Bottom: Wave as seen through a port hole on the R/V *Cape Hatteras* (Duke University/ University of North Carolina). Photo courtesy of Duke University Marine Lab. Background: Sunset over the Atlantic. Photo by Sam DeBow.

FRONT COVER: Clockwise starting at the top left, R/V *Atlantic Explorer* (Bermuda Institute for Ocean Studies-BIOS) photo by: Jonathan Whitefield; R/V *Blue Heron* (University of Minnesota - Dulth) photo by: Brett Groehler. R/V *Melville* (Scripps Institution of Oceanography-SIO) photo by: Bruce Appelgate; R/V *Wecoma* (Oregon State University-OSU) off the Marianas Islands. Photo courtesy of OSU; Ordinary Seaman and swimmer, Ronny Whims, dives off submersible *Alvin* (WHOI) during its recovery. He will be picked up by the waiting Avon inflatable. Photo by: Lance Wills.

BACK COVER: Clockwise starting on the left, wave on the Pacific Ocean. Photo by Laura Dippold; R/V *Kilo Moana* leaving port (University of Hawai'i) photo by Bruce Appelgate; R/V *Point Sur* at sunset (Moss Landing Marine Laboratories-MLML) photo by: Laura Dippold; R/V *Pelican* (Louisiana Universities Marine Consortium-LUMCON) photo courtesy of LUMCON.

Special thanks to Lynn McMasters throughout this project and for redrawing the ship silhouettes.

10K-2009

Introduction 1

The ocean covers nearly three quarters of the Earth's surface and contains 97% of the water on the planet. The ocean is the major force for our weather and climate through the transfer of heat and water on a global scale. Most of the oxygen we breath is generated by organisms in the ocean. The ocean is a source of food and mineral resources, it supports the transportation for much of our commerce and more than half of the U.S. population lives in coastal counties. Beneath the depths of the ocean are secrets such as the sedimentary records of past planetary changes, the structure of major ridges and tectonic plates and communities of organisms that live without sunlight in the heat and nutrients of hydrothermal vents.

Lance Wills

Alvin *technician, Anthony Zafereo, throws the submersible* Alvin*'s tow line to a swimmer waiting in the Avon inflatable boat standing off stern of R/V* Atlantis *(WHOI).*

Our knowledge of the oceans and the life it supports has increased dramatically in the past few decades with advances in remote sensing from satellites giving us a much more global awareness of changes in ocean temperature, color, currents and other parameters at or near the surface. However, it is the observations and experimentation done from and with the aid of research vessels that gives us the opportunity to discover and understand what is going on beneath the surface. We use research vessels as the primary vehicle for increasing our knowledge of the oceans. Research vessels support direct measurements of the ocean waters with onboard sensors and sample collecting equipment, remote sensing using acoustic sensors and other systems, and the deployment of a wide variety of other devices that are capable of surveys, direct observations, data collection and sampling the ocean water and seafloor. Some of the other systems that are deployed and supported from research vessels include human occupied vehicles such as the *Alvin*, remotely operated and autonomous vehicles, drifters, gliders, moorings, remotely operated aircraft, and weather balloons. And as with many things, the more we understand, the more we discover there is much more to learn.

Lauren Decker

Scott Stachelhaus, Dave Hebert and fellow researcher, bringing in a rosette on the R/V Endeavor *(Univ. of Rhode Island-URI).*

For the U.S. academic ocean science community, much of their research work and educational opportunities are carried out aboard the U.S. academic research fleet, which is organized and operated in a cooperative way under the auspices of the University-National Oceanographic Laboratory System (UNOLS). The U.S. Academic Research Fleet is often referred to as the UNOLS fleet. The UNOLS organization is a partnership between the U.S. federal agencies that support research and education in the ocean sciences and the community of academic oceanographic institutions, that uses and operates those facilities. UNOLS

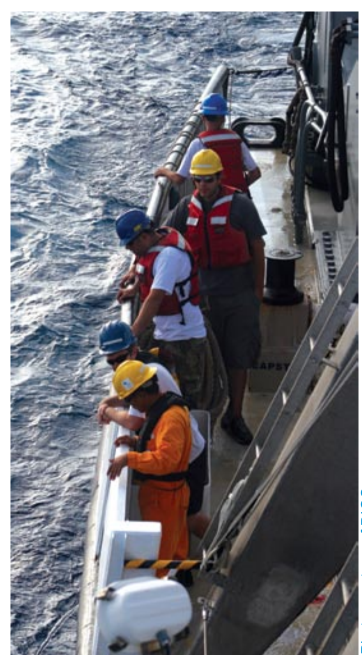


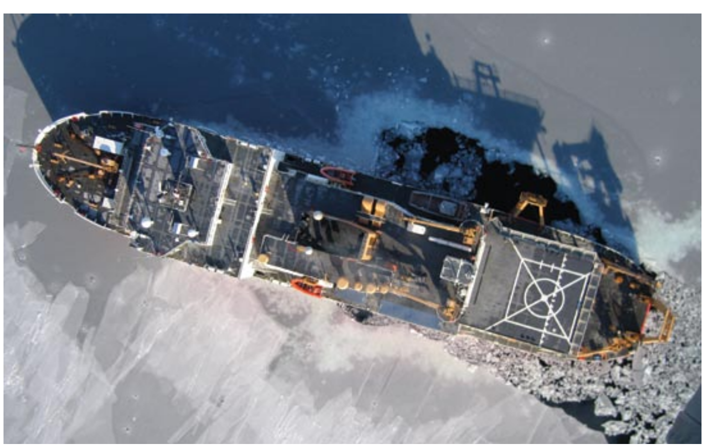
Photo courtesy of BIOS

Partnership for the Observation of the Global Ocean (POGO) scholars in shipboard training on the R/V Atlantic Explorer *(BIOS).*

Scientists on the R/V Robert Gordon Sproul *(Scripps Institution of Oceanography-SIO) participating in an emergency drill.*

was founded in 1971 with 17 ship-operating academic institutions. By 2009, UNOLS has grown to a union of 61 academic institutions and national laboratories involved in oceanographic research. The UNOLS fleet consists of 22 vessels, a deep submergence facility, a seismic research facility and one aircraft facility with 17 of the 61 members being operating institutions. These research vessels and facilities are operated as major shared-use assets available on an equal basis to all members of the academic community and the federal agencies.

The mission of the UNOLS organization is to provide a primary forum through which the ocean research and education community, research facility operators and the supporting Federal agencies work cooperatively to improve access, scheduling, operation, and capabilities of current and future academic oceanographic facilities. By doing this we support our vision of having healthy and vigorous U.S. Ocean Science research and education programs, thanks to broad access to the best possible mix of modern, capable, efficiently run, and well-operated research vessels, aircraft, submersibles and other major shared-use facilities.



USCGC Healy *breaking ice in the Bering Sea.*

UNOLS coordinates and reviews the access to and utilization of facilities (e.g. ships, planes, submersibles) for academic oceanographic research. UNOLS reviews the current match of facilities to the needs of academic oceanographic programs and makes appropriate recommendations for replacing, modifying, or improving the numbers and mix of facilities, especially research vessels. UNOLS fosters federal and other support for academic oceanography, thereby continuing and enhancing the excellence of this nation's oceanographic program.

The UNOLS Office, directed by an Executive Secretary, is located at one of the UNOLS member institutions on a rotating basis. Host institutions have included the Woods Hole Oceanographic Institution (1971 to 1982), the University of Washington (1982 to 1991), the University of Rhode Island (1991 to 2000), Moss Landing Marine Laboratories (2000 to 2009), and has now returned to the University of Rhode Island.

An elected Council made up of representatives from its member institutions governs UNOLS. The Council makes recommendations to funding agencies regarding the needs for specialized or new facilities, the balance between facilities and funded research programs and accepts charges for special studies and reviews. In addition to the Council, there are eight standing committees, which oversee major UNOLS activities and facilities. All Council and committee members are volunteers.

UNOLS Standing Committees:

- **Arctic Icebreaker Coordinating Committee (AICC)**
  The AICC provides oversight and advice to the U.S. Coast Guard for the purpose of enhancing facilities and science aboard their icebreaker fleet.

- **DEep Submergence Science Committee (DESSC)**
  The DESSC has oversight responsibilities for the use of the National Deep Submergence Facility (NDSF) assets and promotes new technological advances.

- **Fleet Improvement Committee (FIC)**
  The FIC reviews and recommends policies for fleet replacement, renewal, and planning.

- **Marcus Langseth Science Oversight Committee (MLSOC)**
  The MLSOC provides community input and oversees the scientific operation of the seismic survey ship R/V *Marcus G. Langseth* as a National Oceanographic Seismic Facility.

- **Research Vessel Operators' Committee (RVOC)**
  The RVOC is made up of marine superintendents from UNOLS and non-UNOLS research ship operators. They work to promote cooperation, fleet standards, marine safety, efficiency, and quality of service on board academic research vessels.

- **Research Vessel Technical Enhancement Committee (RVTEC)**
  The RVTEC fosters activities and improvements that enhance technical support for sea-going scientific programs and oceanographic facilities.

- **Scientific Committee for Oceanographic Aircraft Research (SCOAR)**
  The SCOAR provides advice and recommendations to aircraft facility managers and supporting federal agencies on aspects of operations, technology, aircraft fleet composition, utilization, and promotes collaborations and cooperation between facility stakeholders.

- **Ship Scheduling Committee (SSC)**
  The SSC develops and coordinates ship schedules to assure the most effective, efficient, and economic utilization of UNOLS ships and associated facilities. Committee members work closely together and with the federal agencies to keep ship tracks compact and cost-effective.


Tara Hicks Johnson

On the bridge of the R/V Kilo Moana *(U. Hawai'i).*

UNOLS is supported by six federal agencies. The National Science Foundation (NSF) provides approximately 60 percent of the funding for the U.S. academic fleet. An agency of the United States government, NSF was established in 1950 to advance the country's scientific progress. It fulfills its mission through support of scientific research and education, by acting as a clearinghouse and enabler for scientists and educators who


Tiffany Wardman

Marine Technician Jay Turnball aboard the R/V Atlantic Explorer *(BIOS) prepares for a Conductivity, Temperature and Depth (CTD) cast.*

submit proposals for the research programs they conduct at universities and other institutions. NSF allocates federal monies for oceanographic investigations and facilities at over one hundred institutions.

The U.S. Navy, through the Office of Naval Research (ONR), has played a leading role in building and providing the larger UNOLS ships, and also shares in fleet operations costs. Additional support of UNOLS comes from the National Oceanic and Atmospheric Administration, the U.S. Minerals Management Service, the U.S. Geological Survey, and the U.S. Coast Guard. Other agencies such as the Environmental Protection Agency, the National Atmospheric and Space Administration, and the Army Corps of Engineers have also funded UNOLS in the past.


Bruce Appelgate

R/V New Horizon *operated by SIO.*

Scott Taylor

R/V Cape Hatteras *(Duke/Univ. North Carolina) underway on the Atlantic Ocean.*

(Adopted from the *Two Years of Turbulence Leading to a Quarter Century of Cooperation: The Birth of UNOLS* by Captain Robertson P. Dinsmore and John V. Byrne written for the 50th anniversary of the National Science Foundation.)

The roots of UNOLS go back to the 1960's, often called the golden years of oceanography. There was an unprecedented growth in the marine sciences; existing labs were expanding; new labs were being established; and more and more research ships were putting to sea; and the sizes of the ships were increasing. The support of research ships and their operations was becoming big business. By 1970 there were 33 ships operated by 17 laboratories. Twelve of the ships were of a size invoking regulatory inspection (over 300 gross registered tons).

Courtesy of Harbor Branch Oceanographic Institution

The R/V Seward Johnson *operated by Harbor Branch Oceanographic Institution at Florida Atlantic University (HBOI), with the submersible* Johnson Sea Link.

Three principal concerns began to emerge: (l) Investigators from non-operating labs were seeking a positive means of gaining access to ship time, even to the point of more labs acquiring more ships. Operators were willing to accommodate outside users but there was no orderly means of achieving it. (2) Federal supporting agencies, chiefly NSF and ONR, were concerned over the increasing costs of the vessels and the differing modes of operations and their funding. They also were acutely aware of (1) above. (3) The university ship operators saw a collision course between higher ship costs and increasing ship numbers on what was becoming a level funding field.

About this time, in 1969, the President's Commission on Marine Science and Engineering (Stratton Commission) in its classic report included a recommendation for National Oceanographic Laboratories intended to be a partnership between federal agencies and academic institutions in a full range of research and supporting facilities. To NSF, the report served as a possible means of bringing the academic research fleet together into a more coherent arrangement. First proposed as "NOLS" the plan contained provisions for coordinating and scheduling the fleet. University labs agreed with the goals of the arrangement but opposed the scheme as tilting toward excessive federal control. A joint group of federal and university administrators worked out a counter proposal for a University-NOLS which achieved the goals of community-wide ship access, cooperative ship scheduling, standardized operations, and uniform funding arrangements, but remaining within the university sphere and to be coordinated by an association of labs designated as UNOLS.

UNOLS was officially launched at its charter meeting in 1971 by seventeen ship operating labs. The initial thrust was development of ship scheduling and investigator placement procedures. This was followed by uniform cost accounting, cruise reporting, ship operations data, and information services. Key elements of UNOLS were that ship operations remained the responsibility of the individual lab operator, and that UNOLS was not a ship funding activity.

In order to make UNOLS more responsive to the entire community, non-ship operating labs were quickly brought in as associate members and later becoming full members.

Other efforts developed at the outset of UNOLS were standards for shipboard equipment and technical services, foreign research clearance procedures, mission requirements for new ship planning, and shipboard safety standards. In recognition of the uniqueness of specialized facilities, a category of National Oceanographic Facility was established each with its own oversight body and scheduling arrangement. These have included an expeditionary vessel, instrumented aircraft, deep submergence vehicles, and seismic ships.

Sean Whelan

Stern view of R/V Oceanus *(WHOI).*

Although not on the original agenda for the establishment of UNOLS, fleet replacement quickly became an important consideration. Over two thirds of the ships sailing in the early seventies were mission obsolete. Most were becoming platform obsolete as well. By the fall of 1972 working groups were established to develop mission requirements and concept designs for new ships in the coastal, intermediate, and global size categories as well as specialized vessels such as polar research, geophysical, and submersible handling. With its close ties to the overall community, UNOLS was uniquely suited to serve this function. As a result, almost every U.S. research vessel built in the past 35 years (as well as some foreign) bears the mark of these studies.

As UNOLS has evolved over the years to meet changes and challenges, its role remains the same as was first envisioned; to coordinate and serve the U.S. Academic Research Fleet.

Bruce Appelgate

The R/V Melville *operated by SIO.*

6 The Research Fleet

The 2009 fleet of 22 UNOLS vessels falls roughly into six size categories: There are six Global Class, one Ocean Class, five Intermediate Class, three Regional Class, four Regional/Coastal Class, and three Local Class vessels.

Global Class ships are the high endurance vessels. They are large general-purpose, multidisciplinary oceanographic research ships capable of worldwide cruising (except in close pack ice) and able to support both over-the-side and laboratory work in high sea states. The ships can accommodate large scientific parties of 30 to 38 people. The six Global ships are: R/V *Atlantis*, R/V *Knorr*, R/V *Marcus G. Langseth,* R/V *Melville*, R/V *Roger Revelle*, and the R/V *Thomas G. Thompson*.

Kathy Newell

The R/V Thomas G. Thompson, *operated by the University of Washington, is a Global Class vessel.*

Ocean Class ships are a new class of research vessel. These ships will fulfill a critical need in fleet modernization by replacing the aging "Intermediate" ships with vessels of increased endurance, technological capability, and number of science berths. The 2009 fleet includes one Ocean Class vessel, R/V *Kilo Moana* operated by the University of Hawai'i. The R/V *Kilo Moana* is a Small Waterplane Area Twin Hull (SWATH) ship. Making it a very stable platform with excellent bottom mapping capabilities.

Tara Hicks Johnson

The R/V Kilo Moana *(U. Hawai'i).*

Intermediate Class ships are medium endurance, general-purpose research vessels. They are ocean-going vessels, though not globally ranging. The vessels in this class typically accommodate 18 to 20 scientists, but some have increased berthing capacity. The Class includes: R/V *Endeavor*, R/V *New Horizon*, R/V *Oceanus*, R/V *Seward Johnson*, and R/V *Wecoma*.

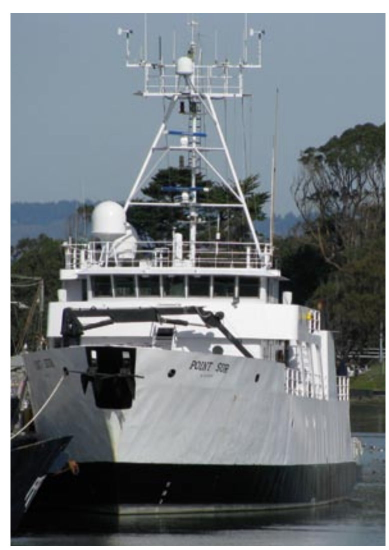
Sam DeBow

The R/V Endeavor *(URI).*

Regional Class ships work in and near the continental margins and coastal zone. They are general-purpose ships, designed to support integrated, interdisciplinary coastal oceanography in the broadest sense from shallow coastal bays and estuaries out to deep water beyond the shelf. The primary requirement is a maximum capability commensurate with ship size to support science, education, and engineering. The ships in this class are: R/V *Atlantic Explorer*, R/V *Cape Hatteras* and R/V *Point Sur*.

Regional/Coastal Class ships operate in a mode that is similar to the Regional ships; however, they are generally smaller in size and tend to have lower operating costs. Regional/Coastal ships include: R/V *F. G. Walton Smith*, R/V *Hugh R. Sharp*, R/V *Pelican* and R/V *Robert Gordon Sproul*.

Local Class ships fulfill near-shore needs that do not require larger or higher-endurance ships. They are fully capable of continuous 24-hour operations. Although these ships are designed for small size and cost effectiveness, they still have the multidisciplinary capabilities required by modern research. The ships in this class are: R/V *Blue Heron*, R/V *Clifford A. Barnes* and



Laura Dippold

The R/V Point Sur *(MLML) is a Regional Class vessel.*

R/V *Savannah*.

UNOLS vessels explore coastal waters, major oceans, polar seas, and the Great Lakes. They serve both educational programs and oceanographic research. On any given day, oceanographers aboard these ships may be studying deep-sea hydrothermal vents along the eastern boundary of the Pacific Plate, collecting plankton from the Gulf Stream, or setting an instrumented mooring to measure the earth's oceanic and atmospheric currents in the Atlantic or Pacific Oceans.

Jon Cox

The R/V Hugh R. Sharp *(U. Delaware) is the newest Regional/Coastal Class vessel.*

Many of the ships are also equipped with sophisticated navigation, dynamic positioning (a computerized system that helps the ship hold position), and satellite communications systems, which keep the ships in touch with laboratories and classrooms ashore and with each other. UNOLS vessels also have a variety of winches, cranes, and other over-the-side handling systems that allow launch and retrieval of instrumentation that are essential to oceanographic science.

Some research vessels also offer multibeam swath mapping systems and Acoustic Doppler Current Profilers or ADCP (systems that map the seafloor and measure ocean currents). Scientific instruments and equipment, both in the lab and on deck, often change completely between voyages. Workspace and benches in the labs may be used for microscopes on one cruise, and then used for sophisticated computer systems on the next. On deck, large nets may be deployed daily and then changed out for water sampling equipment for the next cruise. Ships also have the ability to provide running water for aquaria as well as accommodations for the delicate analytical instruments of modern chemistry.

Three of the UNOLS vessels are uniquely suited for specific types of research. R/V *Atlantis*, operated by Woods Hole Oceanographic Institution, is outfitted with hangars and handling systems for the human occupied submersible DSRV *Alvin*. Also, the R/V *Seward Johnson* operated by Harbor Branch is designed to handle the submersible *Johnson Sea Link*. The R/V *Marcus G. Langseth*, operated by the Lamont-Doherty Earth Observatory of Columbia University, is specially outfitted for geophysical work with state-of-the-art tools for studying the seafloor and the layers beneath it.

The overall size of the UNOLS fleet has fluctuated over the past decade. In 1995, the UNOLS fleet was comprised of 26 ships operated by 19 institutions or consortia. In 2009, the UNOLS fleet consisted of 22 ships with 17 operators. Vessels constructed or converted with federal funds are designated as federally owned. Academic institutions or consortia operate these vessels through cooperative agreements. Seven of the UNOLS ships were built or acquired under grants from NSF (one Global Class, three Intermediate Class, two Regional Class, and one Local Class vessel). Six ships, including five Global Class vessels and the Ocean Class ship, were built and are owned by the U.S. Navy. The remaining ten ships of the fleet are either state or privately owned.

Brett Groehler

Mike Sullivan

Left, the R/V Blue Heron *(Univ. of Minnesota - Duluth) and R/V* Savannah *(Skidaway Institute of Oceanography), right, are both examples of Local Class vessels.*

8 Oceanographic Science

Oceanographic research encompasses all the basic sciences as they apply to the marine world. Ocean scientists, or oceanographers, explore the physics, biology, geology, geophysics, and chemistry of the oceans and utilize complex ocean engineering instruments to retrieve data. The interdisciplinary nature of ocean research generally demands a breadth of knowledge across multiple disciplines and cooperation among scientists from several fields.

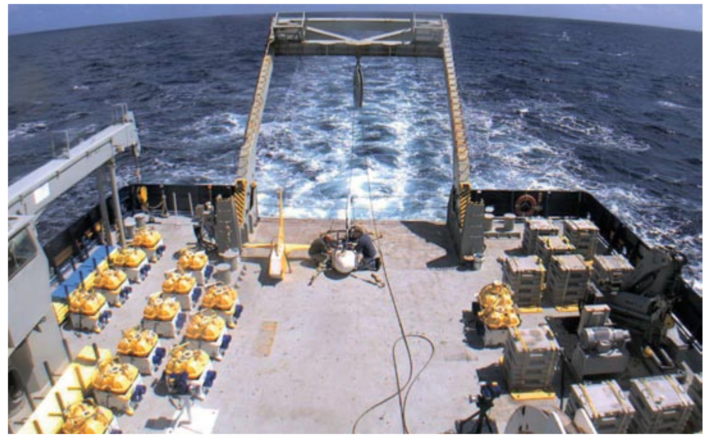
Oceanographic Research Vessels allow scientists to conduct research on processes and interactions that occur in the ocean, in the marine atmosphere, and on and beneath the seafloor. Scientists use research vessels to map, sample and monitor geologic activity in the ocean floor, and research extreme habitats. Research vessels allow us to deploy newly developed instruments and technology such as the seafloor sensors that allow scientists to warn coastal residents of tsunamis. They help us enhance ocean science education programs, support biomedical research, discover new means of renewable energy, as well as provide oceanographic information to aid our defense forces and homeland security. Research vessels help scientists understand and assess the status of our natural resources and provide information for policy decisions. They also help scientists to understand the Earth's changing climatic history, as well as discover, study, and protect archeological resources.

Uriel Zajaczkovski

Crew members and scientists working to secure equipment on the deck of the R/V Roger Revelle *(SIO).*

Physical Oceanography

Physical oceanography is the study of how water moves and mixes in the ocean. Some of the goals of physical oceanography include: understanding ocean circulation, quantifying the distribution and flux of heat, and determining how the ocean interacts with the atmosphere to maintain our climate. Physical oceanographers use



Bruce Appelgate

View of the main deck of the R/V Roger Revelle *(SIO).*

a variety of approaches, including observations from ships and remote platforms, satellite measurements, computer simulations, and theoretical models. They investigate major currents such as the Gulf Stream in the Atlantic and the Kuroshio Current in the Pacific as well as the deep boundary currents that flow beneath them. They study large circular eddies of water, wind generated surface waves, internal waves that transmit energy without disturbing the sea surface, and small scale water movements that can dissipate energy. They also aim to increase our understanding of the oceanic fluxes of heat and fresh water, as well as the air-sea exchanges of buoyancy and momentum.

A central challenge of seagoing physical oceanographic research is the range of space and time scales that must be encompassed by a successful effort to understand the ocean. Some of the current research trends and initiatives include cross-shelf transports, the study of how water moves between the land and the open ocean. Upper ocean process studies examine how the atmosphere interacts with the surface water through wind stress, precipitation/evaporation, and heating/cooling. Physical oceanographers are also trying to understand benthic boundary layers, how the water moves around features on the seafloor, and how that affects the circulation and distribution of nutrients and other materials from continental shelves. Mesoscale eddies tens of

Bruce Appelgate

A crew member secures a Go-Flow Bottle on the R/V Robert Gordon Sproul *(SIO).*

kilometers wide are also an important research topic, as are large-scale gyres that can encompass much of an ocean basin. Physical oceanographers are working to understand how these transient and permanent features affect the global transport of ocean water, and why they are important to the health of the Earth.

Courtesy of the Univ. of Delaware

Courtesy Univ. of Hawai'i

Left: Scallop dredge and catch from the 2008 NOOA/NMFS survey of scallop populations along the East Coast aboard the R/V Hugh R. Sharp *(U. Delaware). Right: Senior Marine Technician Daniel Fitzgerald showing his dedication to science by finding every last sample in the rock dredge on the R/V* Kilo Moana *(U. Hawai'i).*

UNOLS research vessels allow scientists to deploy a variety of sensors and equipment all over the world. Some equipment is stationary, like moorings, anchored to the seafloor, while other sensors are left adrift in the ocean currents or are towed behind the ship. Modern towed and autonomous vehicles offer the chance to explore the physics of the ocean on larger scales, which takes less time than when traditionally sampled by the stopping and starting of a ship. Yet, new technology is still needed to study the physical properties of the ocean without disturbing the area being sampled.

Biological Oceanography

Biological oceanography is the study of the abundance, distribution, and life cycles of marine organisms, and their interactions with one another and with their environment. The studies include all forms of life in the oceans, from microscopic bacteria, plants, and animals to squid, fish, and whales. Their habitats include the waters of the open ocean, coastal regions, and the Great Lakes, and the benthic regions extending from the continental shelf and slope into the deep sea. The high latitude regions of the Antarctic and Arctic Oceans are of increasing interest due to their warming and loss of ice, and the rapid changes taking place. Interest is in the dynamics of populations and food webs, the rates of organic matter production and its ultimate fate, and the biodiversity of the world's oceans.

Biological oceanographers gain access to the sea via research vessels and deep submergence vehicles (tethered and autonomous) equipped with samplers and instruments to help them study the diverse habitats. To study the organisms and their biological processes, biological oceanographers use techniques ranging from traditional sampling with water bottles and nets to gather living animals for experimental studies, to in situ acoustic and video sampling to view their spatial distribution and behavior. New analytical techniques are being developed or borrowed from other disciplines, including molecular genetic and genomic approaches, radioisotope and fluorometric labeling of molecules, among others.

Biological oceanography includes many different areas of research. Marine microbial ecology is the study of organisms the size of microns or less, including viruses, bacteria, and small multicellular organisms. Microbes are abundant and active in both the open and benthic realms of the ocean. Deep-sea biology and the discovery of hydrothermal vents and deep-water methane seeps – with organisms that live off the chemicals released by the seeps - revolutionized biological oceanography and stimulated the investigation of possible life forms both on and beyond Earth. Land-sea interactions and coastal oceanography are of increasing interest and importance to science and society. Coastal areas are the oceanic regions most impacted by human activity. Harmful algal blooms and 'dead zones' are consequences of coastal eutrophication where an excess of nutrients attributed to runoff causes increased plant growth and the eventual death of animals due to lack of oxygen. The sequestration of CO2 in the oceans is a major area of interest and large scale studies to understand how organisms mediate the process involve

Lance Wills

Two researchers study organisms collected from the DSRV Alvin *(WHOI) under microscopes.*

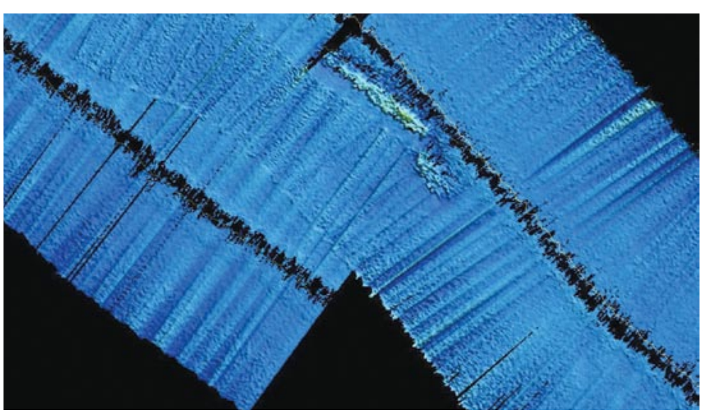
study of the mechanisms of primary production. Production in some ocean areas is limited by the availability of iron and open ocean enrichment experiments are being conducted to develop a mechanistic understanding of consequences of iron dispersal. The population dynamics of zooplankton species key to the development of fisheries resources are the subject of field, laboratory, and modeling studies. Continued studies in biodiversity and conservation are essential to provide a baseline for measuring changes likely to take place as global climate change takes hold. As biological oceanographers continue the search for new species, habitats, and ecosystems in the ocean, recent samplings of marine microbes has revealed unexpectedly high diversity from the ocean surface to the deep sea. New species of marine fish and invertebrates continue to be described at the same rate as over past decades. While some organisms are thriving, others are in trouble. Many marine mammals such as whales, dolphins, polar bears, and even marine birds are endangered.


Courtesy of LUMCON

Preparing to deploy a sediment corer off the R/V Pelican *(LUMCON).*

Marine Geology and Geophysics

Marine geologists and geophysicists study the earth beneath the oceans. Marine geophysical investigations extend from the planet's center out to the rock/water interface using sound waves, variations in Earth's gravity and magnetic fields, and other remote sensing techniques to delineate vertical and lateral variations in internal structure. Geologists examine the rocks and sediments of the seafloor to determine its history and what tectonic, volcanic, and other active processes have determined its shape and depth.


Courtesy of the URI

A sidescan sonar image of the seafloor from the R/V Endeavor *(URI).*

Modern marine geophysical techniques allow three-dimensional mapping of the seafloor as well as a means for determining the stratigraphy, composition, and structure of the sub-seafloor. This allows investigation of the processes that shape the seafloor and the formation and development of the sub-seafloor sediments and solid earth. Multibeam bathymetric tools provide a three-dimensional picture of the depth and surface roughness of a wide swath of the seafloor beneath the ship. Seismic techniques probe the seafloor with sound waves at scales that range from extremely high-resolution images of the stratigraphy of sediments to CAT scan-like images of slices of the entire crust. Measurement of variations of the Earth's gravity and magnetic fields at the sea surface are used to deduce changes in the thickness of the sediments and crust as well as variations in the composition of the rocks. Seafloor-spreading magnetic anomalies are used to determine the age and evolution of the seafloor.

Geologists use acoustic mapping to determine the topography and structure of the seafloor, and then sample important locations. They can sample from the ship using devices lowered on wire rope, or they use remotely operated vehicles (ROVs) and autonomous underwater vehicles (AUVs) to photograph the bottom and sample specific locations. Paleoceanographers use long sediment cores to interpret environmental history from the chemical composition and fossil remains in the sediments. Sedimentologists also use sediment traps, particle counters, camera systems, and current meters to understand the transport of solids from the surface ocean to the seafloor. Volcanologists sample undersea volcanoes and mid-ocean ridges with ROVs, submersibles, and dredges to understand how ocean crust is made and altered.

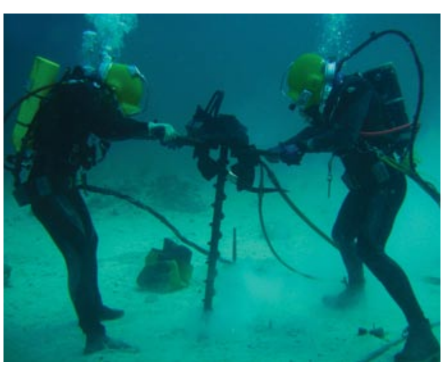
Marine geologists exploit the record in marine sediments and growth bands in corals to extract some of the longest, most uninterrupted, and most detailed records of variations in climate that give clues to environmental conditions up to 100 million years ago or more. Investigations of the sea-level rise during the last deglaciation provide constraints on the timing and mechanisms of global climate change. Since most of the world's population lives within a few meters of sea level, understanding the reason for distinct pulses of rapid sea-level rise in the past can help reduce uncertainty in inundation models for the near future.

Much geophysical research has focused on plate boundaries and continental margins in order to understand the processes that have shaped the oceans. Mid-ocean ridges are divergent plate boundaries where new crust is created. The presence of young volcanic rocks and hot magma below the surface leads to vigorous hydrothermal circulation near ridge axes. The resulting hot water vents provide the habitat for vigorous biological communities. Geophysical studies of the nature and evolution of hydrothermal cells provide valuable information to biologists studying the vent communities. Other studies investigate processes deeper in the earth that result in the delivery of hot magma to the mid-ocean ridges.

Very large destructive earthquakes are often associated with subduction zones, where one lithospheric plate is thrust below another. Major research programs focus on understanding the mechanics of theses interactions and the generation of large earthquakes These areas are also the source of most tsunamis and studies of the sediments and upper crust of subduction zones aim at understanding the generation of tsunamis.

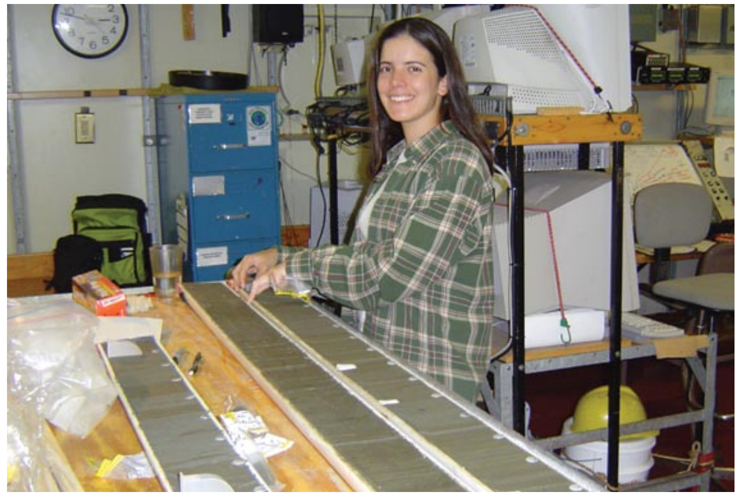
Passive continental margins are of scientific interest because they are areas with large accumulations of natural resources and because they record the rifting of continents to form new oceans. Gas hydrates are studied at continental margins because of their potential as an energy resource and their role in carbon sequestration.

Archeological oceanography is allied closely with geological oceanography as an application of marine geological tools and techniques to excavate and investigate the cultural significance of submerged sites (beyond the capability of a diver). Non-intrusive techniques, such as side-scan sonar and sub-bottom profiling, are useful for archeologists to map the distribution and state of preservation of ancient shipwrecks, habitation sites, and modern cultural artifacts.



Courtesy of the Univ. of Delaware

Installing mooring plates for the AUTEC Junction Box recovery in the cul-de-sac, Tongue of the Oceans, Bahamas.



Craig Nicholson

A researcher studies sediment cores aboard the R/V Melville *(SIO).*

In addition, tools such as suction samplers deployed from remotely operated vehicles, provide archeologists with the effective means to excavate sites in deep water.

Chemical Oceanography

Chemical oceanographers study the balance of chemicals with the oceans, estuaries and large lake systems, and the effects of human and natural disturbances. For much of the 19th and 20th centuries, chemical oceanographers focused on assessing the distributions of the elements and their key molecular forms throughout the oceans. In addition to this fundamental study, chemical oceanographers worked to understand the processes controlling material inputs to and removal from seawater. A major concern was and continues to be the fate of carbon dioxide released by burning fossil fuels into the atmosphere and then absorbed by the ocean. The origin and composition of the seafloor and its interaction with seawater was also found to be surprisingly important.

Chemical oceanography requires very careful sampling techniques, as substances to be characterized may exist in extremely small

Mike Sullivan

Scientists collecting samples of the seafloor aboard the R/V Savannah *(Skidaway).*

quantities that can be measured only by sophisticated analytical instruments. Modern chemical oceanographers are concerned with establishing the validity of analytical measurements, accurately determining the amounts and distributions of critical substances in seawater (e.g., trace elements that are essential micro-nutrients for phytoplankton), and developing sensor networks to follow chemical properties in time and space. The result will be a fuller and more accurate appreciation of the dynamic cycling of many elements and substances that occur in seawater, and the dominant processes controlling their distributions throughout the oceans. At the root of these advances must be ocean access. Chemical oceanographers rely on access to all areas of the ocean including remote, relatively pristine open ocean environments in order to collect seawater and other materials.


Peter Guest

Scientists aboard the R/V Point Sur *(MLML) retrieve data from their scientific equipment after deployment.*

Chemical oceanography forms a number of essential interdisciplinary linkages between other fields of study. For example, continued improvement in global climate models and estimates of radiatively important trace gas fluxes between the atmosphere and oceans depends critically on enhanced capabilities for measuring both the concentrations of these gases (e.g., carbon dioxide and methane), and the properties of the sea surface microlayer that controls gas fluxes over a variety of scales of time, space, and sea state.

Material and chemical fluxes that occur between rivers and continental margin environments and beyond also link chemical oceanographers to terrestrial scientists. Chemical oceanographers use UNOLS vessels to survey the distributions of specific chemical substances in the coastal ocean and their transport in response to events such as major storms and floods. Understanding how the water is mixing and where entrained substances are going can help us to prevent pollution or harmful algal blooms from affecting coastal communities that rely on the ocean for food and sustenance.

Education and Public Outreach

The unique ability of research vessels to provide educational and outreach opportunities to children of all ages is extremely important. And through various programs aboard UNOLS ships children as well as the general public can explore the wonders of ocean sciences. This social responsibility will only continue to grow, and is one of the many unique experiences these ships can offer.

Current education and outreach programs, initiatives, and opportunities associated with the UNOLS fleet include:

- At sea programs for K-12 teachers
- At sea programs for college students and instructors
- Informal education activities
- Virtual programs
- Facility open house events

K-12 teachers are able to take part in expeditionary marine science and to share their experiences with the public, usually through journals posted on the Internet, live broadcasts, and/or follow-up classroom activities. These programs help teachers learn and convey the importance of observation and hands-on experiences in science learning, and they also promote teamwork and networking. As a result, the research is enriched and new scientific inquiry approaches are incorporated into teaching practices. Virtual research programs distributed on the Internet and with live video links have also provided additional links to resources such as information about educational funding opportunities, lesson plans, classroom activities, teacher-training opportunities, and library materials. For more information see the Research at Sea section on page 29.

Harpa Frimannsdottir

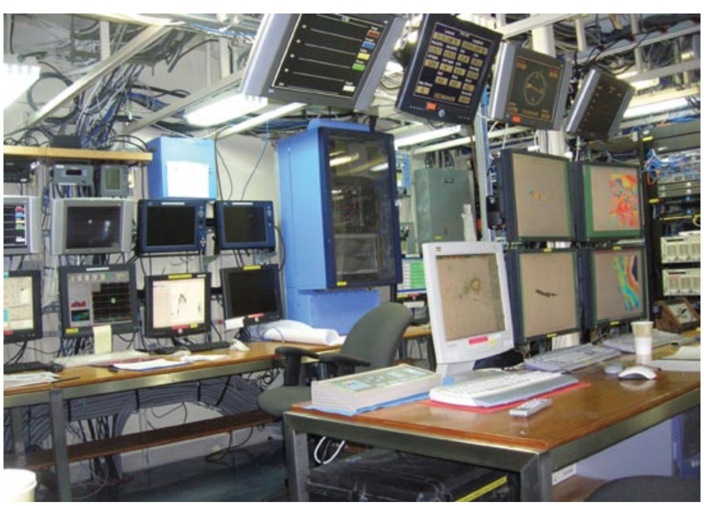
School children visiting the R/V Knorr *(WHOI) while making a port call in Iceland.*

Working on the ocean can be unpredictable and often difficult. Research instruments must be designed to operate in corrosive seawater and in deep, dark, high-pressure conditions. Instruments need to be of a size and weight that can be deployed by the ship in wet, rough, and windy conditions. Deployments of instruments must also be precise, and the instruments themselves need to be able to survive in these adverse conditions for extended periods of time. Deployed instruments also need to be able to transmit information and data collected via acoustic signals, cables or radio signals to ship and shore stations either directly or via satellite links. Many of the research instruments used today were designed for a very specific task and are one-of-a-kind.


Courtesy of Scott Hiller

Bongo nets being deployed off of the USCGC Healy.

Ocean engineering is on the forefront of research instrumentation design. Research scientists call upon various combinations of electrical, mechanical, civil, chemical, and marine engineering to accomplish increasingly difficult research tasks. One of the newest advances in ocean technology is autonomous underwater vehicles (AUVs), which can operate without human interaction to survey the ocean. Once programmed, these vehicles are typically deployed from a research vessel. The vessel can then continue to carryout research operations while waiting for the AUV to return to the surface once it has completed its mission.


Tara Hicks Johnson

The computer lab on the R/V Kilo Moana *(U. Hawai'i).*

Shipboard Laboratories

Research vessels offer a wide variety of research facilities but what they all have in common is a "main lab." The main lab is the center of all research on a ship, it is where the daily operational plans are laid out, samples are prepared and analyzed, and data are received and processed. The laboratory is active both day and night. The main lab is designed for flexibility so that ship operators and scientists can change its configuration from cruise to cruise with the appropriate sampling equipment, tools, computers, and other instruments required to carryout the research objectives. Many research vessels have other smaller labs that each have a specific purpose. Two examples are the electronics lab, which houses delicate instruments and computers that need to be secured in a dry location and the clean lab where experiments are conducted that need to be free of contaminants. Research vessels also have other important facilities like large specimen refrigerators and freezers, darkrooms, and storage areas for science gear. If there isn't enough laboratory space on a vessel more can be supplied with the installation of specialized laboratory vans, which are loaded in port and secured to the ship's deck.

Specimen Collection

There are many ways to collect specimens from the ocean. Researchers can collect specimens in a variety of nets and other devices. The smallest of the nets can be as short as a meter, and are usually towed for brief periods of time in the near-surface waters of the ocean for collecting plankton. Larger nets can be towed for many hours, and a metal frame usually supports the openings of these nets. Some of these frames can hold up to 20 nets at one time, and researchers aboard the ship have the ability to remotely open and close the nets with computerized cues. This allows researchers to sample


Courtesy of Scott Hiller

Worms collected from the seafloor by the USCGC Healy.

areas of the water column that have the desired parameters such as temperature, depth, salinity, and other physical, chemical, and biological characteristics of interest.

UNOLS vessels provide space for the researchers to view the organisms that are collected under microscopes. Many of the organisms are preserved for future examination in laboratories on shore. SCUBA divers also have the ability to collect some animals, such as gelatinous zooplankton, which do not survive intact in nets. These animals are maintained in aquaria in the ship's laboratory for studies at sea as they are difficult to preserve. Similar techniques are used on submersibles and remotely operated vehicles, which use suction samplers and other devices that have been specially adapted to sample delicate organisms at depths that exceed safe access by divers.

Seafloor Sampling & Bottom Landers

To sample the seafloor or benthic organisms, researchers use bottom trawls, dredges, coring devices, sediment plates and bottom landers. Bottom trawls and dredges are dragged along the seafloor picking up anything that they come across, from rocks to organisms. Hard rock samples can be recovered using human occupied submersibles or with remotely operated vehicles equipped with robotic arms and video systems to document the collection area.

Coring devices use a weighted tube to push into the seafloor sediment and return to the surface with the sediment intact much like a cork in a bottle. A multi-corer can capture up to eight short 20-inch (50-centimeter) long cores of seafloor sediment per deployment with virtually


Alexander Dorsk

R/V Knorr *(WHOI) at sea with the long corer loaded along side.*

WHOI Long Coring System

In 1999, a team of researchers and engineers at the Woods Hole Oceanographic Institution (WHOI) began working on a new long coring system to sample seafloor sediments. In the past, scientists have had difficulty retrieving long deep-sea cores because of various issues like vessel size, strength of the wire and winches, and the core itself. Finally in 2007 the WHOI team was able to create a long coring system that is capable of collecting a 150-foot (45-meter) long sediment core from the seafloor. These are some of the longest cores in the world. The corer is nearly twice the length and five times as heavy as any existing coring system used in the U.S. oceanographic fleet. It weighs 30,000 pounds when it is assembled and is so large that the R/V *Knorr* operated by WHOI had to be modified to accommodate the corer and its special handling system, which uses a specially made synthetic rope, instead of the traditional wire cable.

Sediment cores are important for climate research because of the fossils and chemicals they contain. Fossils can help us understand what types of animals lived in the past, and the chemicals allow us to see what the conditions on Earth were like when those organisms were alive. The long reach of this corer will allow researchers to look even farther back into Earth's history than ever before.


Alexander Dorsk

R/V Knorr *(WHOI) with long corer queued up, ready for deployment.*


JC Weber

Researchers prepare for the deployment of the Oceanic Flux Program (OFP) time-series sediment trap mooring off Bermuda on the R/V Atlantic Explorer *(BIOS).*

no disturbance to the top layers of sediment in the core. Large diameter gravity corers can extract 16 to 20-foot (5 to 6-meter) long samples. These corers can weigh up to 770 pounds (350 kilograms) and are often 5 inches (12 centimeters) in diameter. Jumbo piston corers are capable of recovering 100 to 132 foot (30 to 40 meter) long cores. These samples can hold up to several million years of sedimentary history. The corer weighs 8,800 pounds (4,000 kilograms), and has a hydraulic extrusion system that helps reduce sample disturbance. An even larger coring system has recently been developed by scientists at Woods Hole (see sidebar).

Another technique to measure the rate of colonization and distribution of benthic organisms, used in more delicate research areas, involves placing blocks of foam or trays of sterile sediment on the seafloor and then returning after a known amount of time to study the organisms and sediment that settled on them.

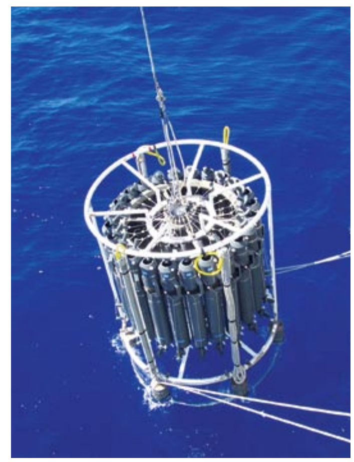
Bottom landers are "free vehicles" that descend to the seafloor with a miniature laboratory of experiments on board. After being released from the ship, the lander transmits data to the ship as it descends through the water column. Once it gets close to the seafloor the lander adjusts its buoyancy for a soft landing and to avoid disturbing the surface sediments. When it has reached the bottom, the lander secures its position and begins a series of experiments on the seawater and sediment surface boundary. Bottom landers are left on the ocean floor, to be recovered at a later time, when the experiments are complete.


Capt. Richard Vullo

The R/V Robert Gordon Sproul *operated by the SIO.*

Water Sampling

Water sampling devices can range from simply dropping a bucket over the side of the vessel to lowering a set of large water bottles thousands of meters towards the seafloor. The most commonly used water sampler is known as a CTD and Rosette. CTD stands for Conductivity, Temperature and Depth. It is a set of sensors that are lowered into the ocean to measure the salinity (measured by the water's conductivity) and temperature of the water according to depth as it descends from the surface. The rosette is made up of a framework of 12 to 36 sampling bottles (ranging from 1.2- to 30-liter capacity) affixed around a central cylinder. Researchers are able to signal the rosette to collect a water sample whenever they see properties from the CTD sensors that are of interest.


Mike Lomas

R/V Atlantic Explorer *(BIOS) Conductivity, Temperature and Depth cast (CTD) deployment.*

There are other instruments that can be attached to the CTD and rosette or used in tandem with other research instruments. Some of the commonly used instruments include a transmissometer that measures the number of particles in the water, a fluorometer that measures fluorescence as an indicator of plant life, a PAR sensor that measures global solar radiation from 400 to 700 nm, which approximates the spectral band active in photosynthesis and oxygen sensors that measure dissolved oxygen in the seawater.

An Inside Look at a Modern Research Vessel

This illustration is based on the planned Alaska Region Research Vessel to be operated by the University of Alaska, Fairbanks. It shows a cross-section of the starboard side of the ship.

Located at the very top of the vessel are the mast, RADARS, warning lights, and meteorology sensors. The large round dome on top of the bridge contains the satellite communication equipment. Next is the 04 Level with the bridge containing fore and aft ship control stations, which give the crew great visibility of operations.

The 03 Level contains the Captain and Chief Engineer's quarters along with a small lab and electronics equipment. The 02 Level has a large bow crane and staterooms for the rest of the crew. Also there is a winch control station near the center of the ship as well as work and rescue boats.

The 01 Level holds the berthing spaces for the science party along with other common spaces on the port side of the ship such as a small gym, galley, mess/lounge,

library, and spa. The after-most stateroom on this level will be wheelchair accessible. Just aft of this stateroom is a second winch operator station for controlling the CTD as it is launched through a side door from the Baltic room below it.

The Main Deck is where most of the research activity will take place on this vessel. There are storerooms, a workshop, a large main laboratory and then the wet lab and Baltic room. On deck there is a large van for more science space, cranes, and an A-frame. A mooring and the floats for the anchor line are on deck waiting to be deployed. On the port side and hidden from view the main deck includes more labs and storage spaces.

Below the main deck are the anchor chain locker, storerooms, food freezers, and the electrician's workshop. Next is the winch room for the CTD and Hydro winches, another storeroom for science gear, the aft winch room, and the thruster engines. Below that is the bow thruster room, the main and auxiliary machinery rooms and most of the tanks for fuel, water and oils.

Remotely Operated Vehicles & Autonomous Underwater Vehicles

Remotely Operated Vehicles (ROVs) have become an important asset to oceanographic research. They are sophisticated robotic systems that can be controlled from a ship on the ocean surface. Video cameras send back images through an umbilical cord that allows researchers and pilots to see where the ROV is and what it is doing. ROVs can be "flown" over research sites for surveys, and remain neutrally buoyant in the water column or land on the seafloor to perform experiments. ROVs can also be used to install and maintain sampling equipment deployed on the seafloor.

Courtesy of U. Hawai'i

R/V Kilo Moana *(U. Hawai'i) watches over the Li'l KM2, a small radio controlled water sampling device.*

An emerging technology is the Autonomous Underwater Vehicle (AUV). AUVs do not require an umbilical. Once deployed, AUVs use a computer program to run surveys and experiments. AUVs can be home-based on the seafloor or can be launched from a ship. Once in the water, AUVs start their programmed survey and then return to their docking station on the seafloor or back to the ship from which it was launched. AUVs can be actively surveying while the ship goes to another location to perform other research.

Peter Guest

This water profiler is "flown" through the water to acquire 3-dimensional profiles of the water column.

Profilers

Profilers are devices that descend through the water column making continuous measurements of ocean water properties. While the CTD is one kind of profiler, another is the eXpendable BathyThermograph (XBT). An XBT is released from the deck of a research vessel or from an aircraft, tethered by a thin copper wire, which it uses to return temperature and depth information back to shipboard computers. Once launched the probe never returns. XBTs can reach depths up to 6,500 feet (2,000 meters). Data from over 10,000 XBTs launched every year by U.S. oceanographers are a major source for physical oceanographic information.

Peter Guest

A researcher deploys an eXpendable BathyThermograph (XBT) from the back deck of the R/V Point Sur *(MLML).*

Researchers also use profilers that are retrievable. Some of these profilers measure sound velocity and micro-turbulence. Deployed from a vessel, the profiler free falls to the seafloor, where it adjusts its buoyancy and returns back to the surface, recording data as it ascends. Other retrievable profilers are used to obtain a three-dimensional image of the physical, chemical, and biological properties of the ocean. These profilers are towed behind research vessels, usually in an undulating pattern, where the researchers can control their depth in the water column much like piloting an aircraft. Some profilers are able to sample water or contain incubation experiments. They can be deployed on a wire or are free drifting in the ocean or on the surface. They measure the nutrient uptake of phytoplankton and plants, the incorporation of dissolved organics into marine bacteria, or planktonic feeding rates. Samples are enclosed in special water bottles where experiments can be performed.

Floats and Drifters

Floats and drifter instruments follow sea surface or mid-water currents. Floats stay along the surface of the ocean, but drifters are specially weighted to be neutrally buoyant at a certain depth. These instruments collect data on the ocean's currents, temperature, salinity, and marine life for months or even years. Some instruments


John Simenson

Researchers deploying the Large Lakes Observatory's meteorological buoy in western Lake Superior off of the R/V Blue Heron *(U. Minnesota - Duluth).*

are equipped with communications equipment that allows them to transmit their location and data to shore via satellite. Other instruments send data through sound waves that are received by moorings. Floats and drifters allow researchers to get a long-term look at ocean currents. Trajectories of groups of floats show how eddies mix ocean waters. This information is used to understand global ocean circulation, and how the ocean transports nutrients and pollutants.

Moorings

Moorings are anchored to a specific location on the seafloor and can be supported in the water column with subsurface flotation or with surface buoys. They can be deployed for a short period of time during a cruise or for months or years to collect samples and data. The anchor system and the line between the anchor and the surface buoy can support a variety of instruments that record temperature, salinity, current speed and direction, and other characteristics of the water column. The mooring on the surface can also act as a platform to collect ocean and atmospheric data. On some moorings, data is relayed from the instruments along the anchor line to the buoy on the surface, which is then sent to shore via satellite. An example of moorings being used today are the arrays of data buoys along the Equator that are used to research the El Nino phenomenon, and also the group of buoys along our coasts used to predict tsunamis.


Peter Guest

Researchers release a weather balloon from the deck of the R/V Point Sur *(MLML), which will acquire weather data as it rises.*

Paul Mauricio

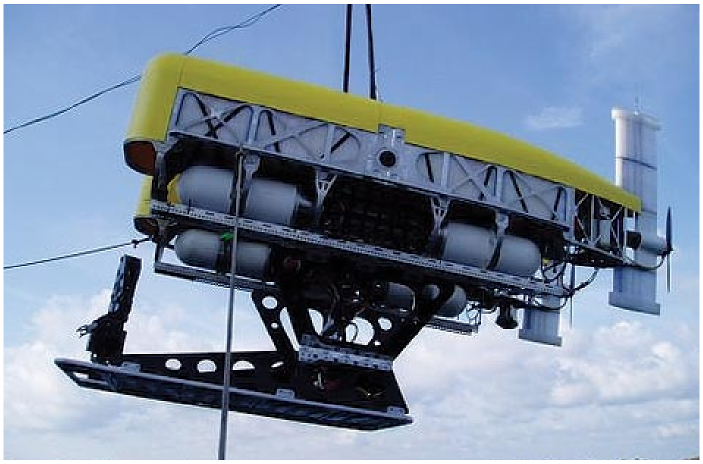
Loading the SIO blimp aboard R/V Revelle *(SIO).*

Meteorological Sensors

Meteorological sensors are used for collecting atmospheric/weather data. They can be installed on a ship or buoy. They measure exchanges of heat and water across the air-sea interface, wind direction and speed, air temperature, barometric pressure, humidity, precipitation, and the amount of sunlight reaching the ocean's surface. These are all important factors in understanding global climate change, El Nino, and even predicting tomorrow's weather. Meteorological measurements are also important for improving the accuracy of global air-sea flux estimates. Some sensor packages can send their data via satellite to a central data facility.

Sound

Sound is used extensively for ocean research because it can travel and be measured over great distances in water. Researchers use sound in many different ways to analyze ocean currents, temperature, density, map the ocean floor and to look into the seafloor sediments and the earth's structure below. This is possible because different densities of water and sediment change the speed of sound. For example sound waves travel faster in warm water than they do in cold water, which allows scientists to estimate ocean temperatures. Sound can also be used to record earthquakes and the movements of marine mammals.



The Hybrid ROV Nereus *(WHOI), an underwater vehicle that can function autonomously as well as tethered to a research vessel.*

Christopher Griner

Acoustic Doppler Current Profilers use the shift in sound frequency to measure currents beneath the ship while it is underway. Sound waves are sent from the ship and are bounced back to the ship's receivers from particles and plankton in the water column. These waves are then translated into a profile of water movement. Similar instruments can be mounted on moorings for the same purpose. Some scientists are able to use the information sent back to the receivers to estimate plankton biomass, since they reflect a small amount of sound energy back.

Four air gun streamers being towed behind the R/V Marcus G. Langseth *(LDEO).*

John Diebold

Geologists also use sound for geophysical exploration. Side-scan sonar instruments use sound to make profiles of rock outcroppings and sediment surfaces. This data can even be used to distinguish rocks from other smaller sediment types. A more powerful type of sonar uses airguns that are deployed by ships to create multi-channel seismic profiles of the seafloor. Sound from the airguns is received by hydrophones towed behind the ship. The data is then processed into a map of the different layers of soil, because the density, elasticity, and other properties of the materials they pass through alter the speed and direction of the sound waves. Another type of mapping system used by geologists, called a multibeam bathymetric mapping system, uses sound to create an accurate map of seafloor depths, features and surface sediment types.

The R/V Roger Revelle *operated by SIO.*

Uriel Zajaczkovski

Satellites

Even though satellites are in space, they are very important to ocean research. Satellites are used to relay data from instruments at sea back to laboratories and data centers on shore. This allows scientists to control and monitor their equipment in the field, and send a ship to repair their equipment if necessary. Satellite remote sensing data allows researchers to direct or revise underway experiments while at sea to make their use of ship time more efficient.

Satellite instruments can be useful to researchers studying global ocean circulation and sea level rise. These instruments include altimeters which measure variations in sea level height and infrared sensors which measure sea surface temperature to reveal currents, eddies, and other features of ocean circulation. Researchers can also use ocean color scanners to find areas that are high in chlorophyll, which is indicative of phytoplankton growth and an increase in primary production. Satellite images also help researchers studying sea ice coverage in polar regions or to choose a path of least resistance for vessels working in the ice.

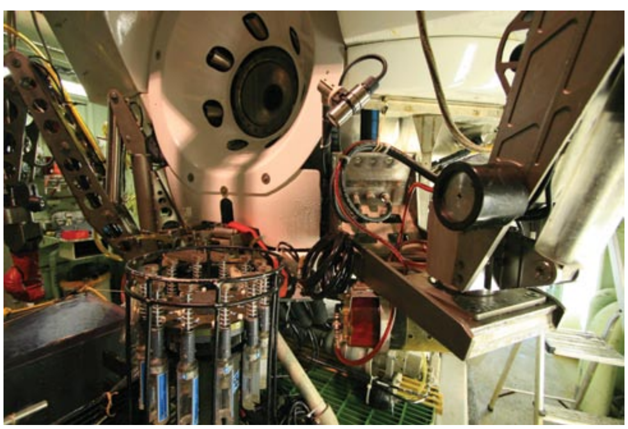
The R/V Clifford A. Barnes *operated by the University of Washington.*

Kathy Newell

National Deep Submergence Facility (NDSF):

In 1974, NSF, ONR, and the National Oceanic and Atmospheric Administration (NOAA) recognized the significance of maintaining a deep submergence operational team, and established the National Deep Submergence Facility (NDSF). The UNOLS Standing Committee, DESSC, provides advice on the operation and upgrade of the NDSF. At the start of 2009, the NDSF consists of an integrated suite of vehicles; a human occupied vehicle, *Alvin*; ROV *Jason*, and AUV *ABE*.

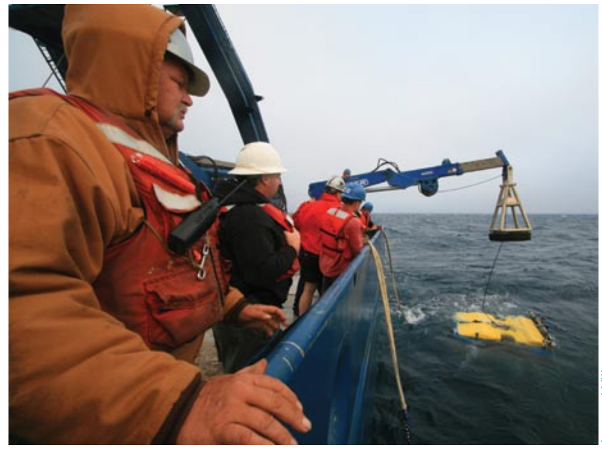
DSRV *Alvin* is a U.S. Navy-owned Deep Submergence Research Vehicle (DSRV) that can carry two scientists and a pilot. Its maximum depth is 14,764 feet (4,500 meters). Three 12-inch diameter viewports allow direct human observation and four video cameras are mounted on *Alvin*'s exterior for recording events and experiments. *Alvin* also has two hydraulic, robotic arms, which may be used to manipulate sampling gear. A basket mounted on the front of the submersible can also carry a variety of instruments down to the seafloor and samples back to the surface. *Alvin* began operations in 1964 and has made more than 4,000 dives and taken more than 2,500 scientists to the seafloor. Although the vehicle is over 40 years old, it is completely over-hauled about every three years, inspected and recertified. R/V *Atlantis* is the support ship for *Alvin*. Efforts are currently underway to upgrade Alvin with enhanced capabilities and a replacement sphere that can provide a deeper depth rating.



Lance Wills

A close-up view of the DSRV Alvin *(WHOI) showing one of the viewing portholes and sampling equipment.*

ROV *Jason* - *Jason/Medea* is a two-body ROV system with *Medea* serving in a tether management role that allows *Jason* to be free from surface water motion. Together they offer wide area survey capabilities with



Lance Wills

Bosun's mate, Wayne Bailey, monitors launch of ROV Jason *from R/V* Atlantis *(WHOI).*

Jason as a precision multi-sensory imaging and sampling platform. Both *Medea* and *Jason* are designed to operate to a maximum depth of 21,385 feet (6,500 meters), are transportable, and can be operated from a variety of vessels.

AUV *ABE/Sentry* - The AUV *Autonomous Benthic Explorer* (*ABE*) operates to depths of 14,764 feet (4,500 meters) and is used to produce bathymetric and magnetic maps of the seafloor. It has also been used for near-seabed oceanographic investigations, to quantify hydrothermal vent fluxes. *ABE* has taken digital bottom photographs in a variety of deep-sea terrains, including the first autonomous surveys of an active hydrothermal vent site. In 2009, *ABE* is expected to be replaced with a new *AUV* named *Sentry*. *Sentry* is faster, has greater depth capability, and is capable of longer deployments than *ABE*. *ABE* and *Sentry* are transportable and can be operated from a variety of vessels.

National Oceanographic Aircraft Facility (NOAF):

In February 2003, UNOLS designated the Center for Interdisciplinary Remotely-Piloted Aircraft Studies (CIRPAS), operated by the Naval Postgraduate School in Monterey, California as its first NOAF.

UNOLS appointed the SCOAR committee to advise CIRPAS on how to increase availability and outreach to the oceanographic science community. CIRPAS operates several piloted aircraft and many remotely piloted or autonomous aerial vehicles. The workhorse for university oceanographic research projects is the UV-18A Twin Otter, a medium-size twin turboprop aircraft.


Courtesy of CIRPAS/NPS

CIRPAS' UV-18A Twin Otter aircraft used for a variety of scientific sampling.

Aircraft are valuable assets for oceanographic research because they are capable of greater speed, and therefore greater range and spatial coverage during a short time period when compared to surface and subsurface ocean research platforms. Such speed and range attributes lead to better synoptic coverage of oceanic and atmospheric variability. Aircraft-mounted sensors provide data with much of the appeal of the aerial view provided by satellites, but with much greater specificity, spatial and temporal resolution, and scheduling flexibility, and they can provide resolution adaptable to phenomena of interest. Aircraft are ideal for both fast event-response investigations and routine, long-term measurements, and they naturally combine atmospheric measurements with oceanographic measurements on similar temporal and spatial scales. Aircraft surveys reach across a wide range of environmental and geographic conditions. Aircraft have a particular advantage for coastal observing that comes from the combination of speed and range they make available for remote measurements and expendable instrument deployment. Airborne remote and expendable measurements of sea surface temperature, subsurface salinity and temperature, surface waves and currents, ocean color, coastal morphology, coastal bathymetry, and important atmospheric and terrestrial variables can significantly enhance data collected by fixed and mobile oceanographic platforms in coastal regions. The combination of satellite, aircraft, ship, and moored measurements has proven to be especially effective in both coastal and open-ocean regions.

National Oceanographic Seismic Facility (NOSF):

The R/V *Marcus G. Langseth* is a 235-foot (71 meter) research vessel that is owned by the NSF and operated by Lamont-Doherty Earth Observatory (LDEO) of Columbia University. It entered the UNOLS fleet in 2008. Originally constructed as a commercial seismic vessel in 1991, the *Langseth* was acquired in 2004 and has been modified and outfitted to provide general-purpose research support in addition to its seismic capabilities. After completion of the conversion period and required inspections, the ship was designated as a UNOLS NOSF and the standing committee, Marcus Langseth Science Oversight Committee (MLSOC), was formed to serve as an advisory body for this facility.

The ship provides the U.S. academic community with the resources to acquire state-of-the-art, two-dimensional (2-D) and three-dimensional (3-D) marine seismic-reflection data. Particularly unique to the academic research fleet, are the *Langseth*'s extensive geophysical capabilities that include a seismic recording system with four 6 km solid-state hydrophone streamer cables and a 2000 psi, pneumatic sound source array towed in four "strings" that can be configured either as a single, 2-D source or dual, alternating 3-D source arrays. No other ship in the UNOLS fleet approaches the seismic acquisition capabilities of this vessel, and consequently the *Langseth* represents a unique national resource.

Doug Brusa

The R/V Marcus G. Langseth *operated by Lamont-Doherty Earth Observatory of Columbia University.*

Special Platforms – Non-UNOLS:

In addition to UNOLS Facilities, there are other oceanographic facilities that are used by academic researchers and in some cases coordinated by UNOLS Committees. These facilities often provide unique access by either their ability to operate in more remote regions or by their specialized hull configurations. A few of these facilities are described below.

Semi-submersible Platforms and Spar Buoys

FLoating Instrument Platform (FLIP) is towed to station floating horizontally on the sea surface by a research vessel or tug. When flooded at the stern, it "flips" to a vertical attitude. In the vertical mode, FLIP is highly stable, heaving vertically less than 10% of the ambient wave height and pitching less than 5 degrees. The structure is designed to minimally perturb surrounding water and airflow. It serves as a platform for a variety of booms and winches, from which numerous sensors can be deployed. Living quarters and laboratories are located above the water-line.

FLIP has been in operation for over 45 years and there is renewed interest in its capabilities in the context of the Ocean Observatories Initiative (OOI). Specifically, there is a need for remote stable platforms, such as spar buoys, that can be moored in the deep sea to provide electrical power to scientific sensors and broadband communications between sensors and satellites.

Courtesy of Scripps Institution of Oceanography

FLoating Instrument Platform (FLIP) operated by the SIO.

Polar Icebreakers

The U.S. polar icebreakers supporting ocean scientists are operated by the U.S. Coast Guard (USCG) and by contractors on behalf of the NSF Antarctic program.

The USCG operates three polar icebreakers. USCGC *Healy*, the United States' newest polar capable icebreaker, was commissioned as a U. S. Coast Guard Cutter (USCGC) in 2000. *Healy*'s primary mission is to function as a high latitude research platform with emphasis on Arctic science. Most deployments are multidisciplinary, in support of a wide range of science and engineering

David Forcucci

USCGC Healy *taking leave from breaking ice in the Bering Sea.*

projects including, but not limited to: marine geology, physical, chemical and biological oceanography, and meteorology. This 420-foot (128 meter) ship is capable of icebreaking operations during any season in the Arctic and Antarctic with an endurance of 65-day missions. The vessel can accommodate science parties of 35 people with expansion to 50 (three to a stateroom). The ship's systems have been designed with sufficient redundancy and robustness to meet national contingencies in the polar regions, including intentional wintering over.

The other two Coast Guard icebreakers are the USCGC *Polar Star* and USCGC *Polar Sea*. These two icebreakers have traditionally been used to support the breakout of the channel to McMurdo station necessary for the annual re-supply of U.S. Antarctic facilities but can also be used for science projects and Coast Guard missions in the Arctic. Along with the USCG icebreakers other ships such as the *Nathaniel B. Palmer* and the *Laurence M. Gould* have been used for work in the Antarctic. All of these icebreakers can be requested for research projects in the Arctic through the UNOLS ship time request system.

Courtesy USCG

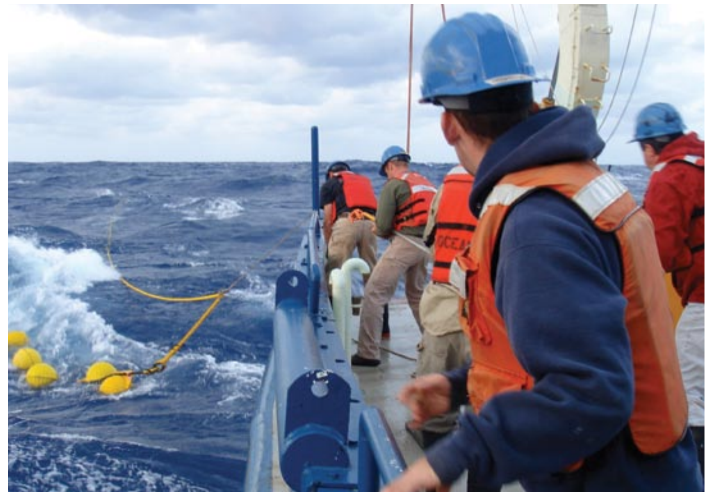
USCGC Polar Star *(foreground) and USCGC* Polar Sea *in port.*

Oceanographic research spans the globe. As researchers encounter the need for data from across an entire ocean basin in order to understand broad scale processes they band together to mount large programs that combine the efforts of many research institutions and laboratories. Research programs inspire the sharing of information, ship time, scientific instruments, facilities, and data. UNOLS ships have a long history of supporting global initiatives such as WOCE and JGOFS. As we move forward, the global initiatives of the future will integrate all aspects of oceanography on both a global scale as well as the near coastal environment. UNOLS ships of all classes will be there to provide the platforms for these programs, from setting moorings along the circumpolar fronts to monitoring water quality in urban bays and sounds. This section will review a few of these "global initiatives" in ocean science.

CLIVAR: Climate Variability and Predictability

CLIVAR is an international research program that is investigating climate variability and predictability on time-scales from months to decades and the response of the global climate system to the impacts of man. Created in 1995, CLIVAR is one of the major components of the World Climate Research Programme. Research for this program is conducted through observation and the development and application of models of climate systems. CLIVAR is also intended to extend records of climate variability, and extend the range of accuracy of seasonal and interannual climate prediction through the development of predictive models. By doing this, the CLIVAR program will help understand and predict the response of the climate system to increases in man-made aerosols, gases, and other modifications to the natural

The R/V Roger Revelle *(SIO) working near the Antarctic circle.*



Researchers aboard the R/V Oceanus *(WHOI) recovering a CLIvar MOde water Dynamics Experiment (CLIMODE) mooring.*

climate cycle.

There are three different divisions of research in the CLIVAR program. The first of the three divisions is looking at seasonal-to-interannual climate variability and predictability of the global ocean-atmosphere-land system. Research includes continuing observations to understand and help improve predictions of threatening global weather phenomena such as the El Nino Southern Oscillation, Asian-Australian and Pan American monsoon seasons, and changes in African climate. The second division is a study of decadal-to centennial climate variability and predictability. This section is interested in improving the understanding of ocean-atmosphere variability in the North and Tropical Atlantic, Pacific and Indian Oceans, and the Southern Ocean around Antarctica. The last division of CLIVAR is interested in modeling and detection of anthropogenic, human-caused, climate change. Research in this section is primarily focused on climate change prediction and detection. For more information on the CLIVAR program go to: <http://www.clivar.org/>.

GLOBEC: Global Ocean Ecosystem Dynamics Program

GLOBEC is part of the International Geosphere-Biosphere Programme. The main objective is to advance our understanding of the structure and function of the global ocean system, major subsystems, and response to physical forcing so that a capability can be developed to forecast the response of the marine ecosystem to global change. GLOBEC considers how global climate change and short-term changes from human sources such as pollution, over fishing, and population growth in coastal areas will affect marine ecosystems. The major research objectives of GLOBEC include: a better understanding of how multi-scale physical and environmental processes force large-scale changes; to determine the relationships between structure and dynamics in a variety of ocean systems; to determine the impacts of global change on stock dynamics; and to determine how changing marine ecosystems will affect the global earth system. At the time of this publication, GLOBEC was entering its final year of operations, and preparing to transition into a new program – Integrated Marine Biogeochemistry and Ecosystem Research (IMBER).

IMBER originally started as a program known as OCean Ecosystems ANalysiS (OCEANS) and is building on the research of the completed Joint Global Ocean Flux Study and GLOBEC. Its main focus is to identify the most important science issues related to biological and chemical aspects of the ocean's role in global change and the effects of global change on the ocean. Four research themes will dominate this new program. The first will study the interactions between biogeochemical cycles and marine food webs. The second will be on the sensitivity of the marine ecosystems to global change. The third is a study of feedbacks to the Earth's systems. Finally, the fourth theme is the response of ocean systems to society. IMBER will employ the use of molecular techniques, and remotely sensed observations. This program is calling on many different researchers spanning multiple disciples from around the globe to help answer key questions about the impacts and feedbacks between the marine and human systems. For more information on GLOBEC and IMBER go to: <http://www.globec.org/> and <http://www.imber.info/>.


James Wood

The R/V Atlantic Explorer *(BIOS).*

Long Term Time-Series Programs:

BATS: Bermuda Atlantic Time-Series

As part of the Joint Global Ocean Flux Study two major time-series research programs were created. The first is BATS, a program that is studying the biogeochemical cycles in the Sargasso Sea near Bermuda. One of the major research stations of BATS, Hydrostation "S," was the first deep-ocean time series station implemented in 1954. The main driver behind setting up long-term time series investigations was to acquire a more diverse and detailed data set. Measurements are made monthly, studying hydrographic, biological and chemical parameters throughout the water column. Studies have highlighted the importance of biological diversity in understanding biological and chemical cycles. Other research focuses on carbon exchange between the ocean and atmosphere. Collaborative research projects between multiple institutions have measured sediment transport to the deep sea, and have developed testbed moorings hosting a collection of the high-technology instruments.


Bob Chin

The R/V Kilo Moana *(U. Hawai'i).*

HOT: Hawai'i Ocean Time-series

Like BATS the HOT program stations are located in deep water off of Hawai'i. Scientists have been making monthly observations of the hydrography, chemistry, and biology of the water column since October 1988. Objectives of the HOT stations are to provide a comprehensive description of the ocean at a site representative of the North Pacific subtropical gyre. The main deep-water station, A Long-Term Oligotrophic Habitat Assessment (ALOHA) for the HOT program is 100 km north of Oahu, Hawai'i. At this station, scientists measure the thermohaline structure (water temperature and salinity), water column chemistry, currents, optical properties, primary production, plankton community structure, and rates of particle export.

For more information on BATS and HOT go to: <http://bats.bios.edu/index.html> and <http://hahana.soest.hawaii.edu/hot/hot_jgofs.html>.

The MARGINS Program

The MARGINS Program studies continental margins, where the Earth produces hydrocarbon and metal resources, earthquakes, landslides, volcanic and climatic hazards and where the greatest human population density resides. The mechanical, fluid, chemical, and biological processes that shape these regions are poorly understood. These processes occur over large areas and over long

Researchers aboard the R/V Thomas G. Thompson *(U. Washington) preparing to deploy the ROPOS remotely operated vehicle in Maug caldera, Commonwealth of the Northern Mariana Islands.*

periods of time, which makes them difficult to study. The MARGINS Program coordinates an interdisciplinary investigation of four fundamental initiatives of research: the Seismogenic Zone Experiment, the Subduction Factory, Rupturing Continental Lithosphere, and Sediment Dynamics and Strata Formation (Source-to-Sink). Each initiative has two research locations selected by the community to address the complete range of studies over spatial and temporal scales.

The Seismogenic Zone Experiment initiative explores where most of the world's great earthquakes occur, subduction zones. Although plate tectonics is the main underlying force in seismographic activity, only a small portion of the plate contact generates earthquakes. Major research focus areas are in Costa Rica-Nicaragua Subduction zones and Nankai Trough in Japan.

The Subduction Factory initiative is focused on the subduction of oceanic plates and the causes of earthquakes, tsunamis, and explosive volcanism. Subduction also yields beneficial products to human society like ore deposits, geothermal energy, and the very surface of the Earth that we live on. Research locations for this initiative are in Costa Rica-Nicaragua subduction zones and the Izu-Bonin-Mariana Arc.

Researchers recovering a seafloor sensor from the Gulf of Mexico on the R/V Pelican *(LUMCON).*

The Rupturing Continental Lithosphere initiative addresses the kinematics of continental lithosphere deformation. The lithosphere, Earth's crust and upper mantle, is deformed when it is pulled apart, or stretched, as in seafloor spreading centers like the Gulf of California and the Red Sea/Gulf of Suez. Little is known about the physics during this deformation, nor is the manner in which strain is partitioned, either spatially or temporally, and the timing, composition, spatial distribution and melting depth of rift-related magmas.

The Strata Formation, or Source-to-Sink, Initiative studies how the Earth's surface is shaped above and below sea level. Geologic events leave a record of their impacts in the sediment that accumulate on continental margins. The main goal of this initiative is to develop a quantitative understanding of margin sediment dispersal systems and associated stratigraphy. Examples of these systems are geochemical cycling, ecosystem change tied to global warming and sea-level rise, and resource management. Main study sites for this initiative are in New Zealand and Papua New Guinea. For more information on the MARGINS Program go to: <http://www.nsf-margins.org/>.

OOI: Ocean Observatory Initiative

In recent years the promotion of ocean observatories has increased in significance. Ocean observatories are a network of science-driven sensor systems to measure physical, chemical, geological, and biological variables in the ocean and seafloor. Long-term time-series observations on the seafloor or within the water column are rapidly becoming a prominent component of the global marine science effort. Observatories allow time-series measurements at a location to determine temporal change in measured parameters and to detect and characterize episodic events. The main research goals for ocean observatories are: climate variability, food webs, biogeochemical cycles, coastal ocean dynamics and ecosystems, global and plate-scale geodynamics, turbulent mixing and biophysical interactions, and deep biosphere interactions with the oceans.

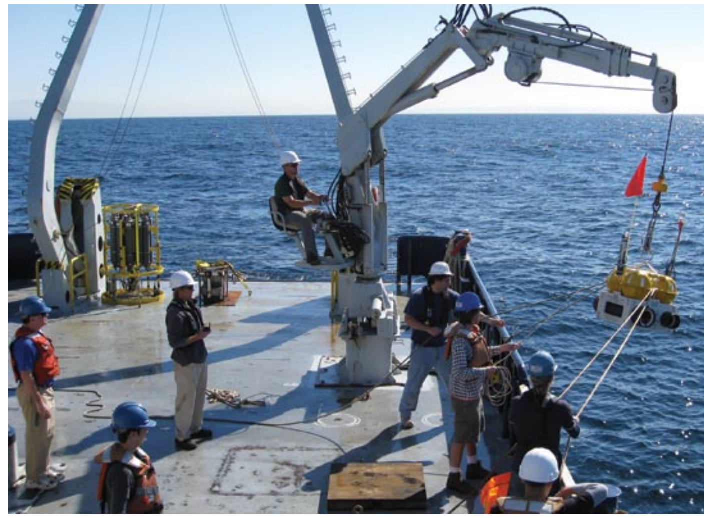
Current time-series programs have generated a wealth of information on variability in ocean properties over time scales of days to decades, and have especially contributed to understanding how the El Niño-Southern Oscillation

John Simenson

Gravity coring off the back deck of the R/V Blue Heron *(U. Minn.).*

(ENSO) and the North Atlantic Oscillation (NAO) affect the ocean's biogeochemistry and ecosystems. For example, the HOT data have shown clear linkages between ENSO and biogeochemical parameters and also long-term ocean trends, such as the switch from nitrogen to phosphorus limitation of primary production that occurred in the mid 1990s. The time-series have also clearly documented the importance of short-lived, episodic surface phenomena (e.g. the passage of mesoscale circulation features, hurricanes, and atmospheric dust deposition) in structuring ecosystems and biogeochemical cycles over longer time-scales. These phenomena, and their effects on ocean ecosystems and biogeochemical fluxes, can only be captured by sustained, ongoing observations. One of the longest ocean observatory research projects is the California Cooperative Oceanic Fisheries Investigations (CalCOFI) time-series, which has successfully documented decadal-scale variability in the California current ecosystems and linkages with the Pacific Decadal Oscillation. As regional and local human pressures on the coastal ocean increase, coastal time-series data are becoming increasingly valuable to assess human impacts on biogeochemical cycles and the marine food webs and for coastal resource management.

There are three main types of observatories planned for the OOI. The first are Global Scale Nodes. The Global Observatory component will consist of paired surface and profiler moorings that would cover the full water column. Each site will support a range of interdisciplinary measurements from the air-sea



Bruce Appelgate

Researchers deploying sea floor instruments on the R/V Robert Gordon Sproul *(SIO).*

interface to the deep seafloor. Satellite communication from each site is planned. Data collected are expected to include meteorological, air-sea flux, ocean properties, acoustic thermometry, seismic geodetic, and tsunami.

The second type of ocean observatory is Regional-Scale Nodes. The Regional-Scale Nodes Observatory is a cabled plate-scale observatory. Scientific research themes that regional observatories could address include: observations of the dynamics of oceanic lithosphere along active plate boundaries, temporal sampling of fluids and microbial life forms circulating in the hydrothermal oceanic crust and seafloor, and turbulent mixing and biophysical interactions in the water column.

The final type of ocean observatory is Coastal Observatories. Two types of coastal arrays are planned; one at the Atlantic shelf-break (Pioneer Array) and the other at the NE Pacific continental margin (Endurance Array). The infrastructure will allow users to remotely

Courtesy of Harbor Branch Oceanographic Institution

R/V Seward Johnson *(HBOI) conducting research at the Arctic Circle.*

John Calderwood

R/V Robert Gordon Sproul *(SIO) at dock.*

Courtesy of Oregon State University

R/V Wecoma *(OSU) making a port call in Honolulu, HI.*

control their instruments and perform in situ experiments. It will allow access to data in near-real time from almost anywhere in the world's oceans. Suites of tools including tethered and autonomous vehicles will play a key role in data collection and site telemetry. For more information on the Ocean Observatories Initiative go to: <http://www.joiscience.org/ocean_observing/initiative>.

RIDGE 2000: Ridge Interdisciplinary Global Experiments

The RIDGE 2000 program is working towards a comprehensive, integrated understanding of the relationships among the geological and geophysical processes of planetary renewal on oceanic spreading centers, the seafloor, and the subseafloor ecosystems that they support. While similar to the original RIDGE program (1989-1999), RIDGE 2000 studies encompass a whole-system approach. RIDGE 2000 uses a wide array of research disciplines while focusing on hydrothermal ecosystems to understand these systems within the context of geologic activity in a scientifically defined geographic area.

RIDGE 2000 uses two main themes for research activities. The integrated studies theme uses multidisciplinary studies focused within a small number of pre-selected areas and are designed to characterize integrated volcanic, hydrothermal, tectonic, and biological systems of the global ridge system. This theme is geared towards answering questions about relationships among mantle and ridge flow and formation, how melt transport is organized, how hydrothermal circulation affects characteristics of geologic zones, how biological activity affect vent chemistry and circulation, what determines the structure and extent of the hydrothermal community, what is the nature and extent of the community, and how does hydrothermal flux influence physical, chemical and biological characteristics of the ocean above. The second theme is time-critical studies, which is a program to enhance detection of volcanic and other transient events on oceanic spreading centers and to facilitate rapid-response missions to observe, record, and sample critical transient phenomena as they happen. Time-critical studies are focused on answering questions about how and where events begin and what happens after they start, what are the size and frequency of the events, how are event plumes formed and how do you sample them, and how are event-related thermal and chemical perturbations manifested. For more information on RIDGE 2000 go to: <http://www.ridge2000.org/science/info/science_plan.php>.

Paul Mauricio

R/V Roger Revelle *(SIO) performing a CTD cast.*

Giving Educators Unique Access to Science at Sea

Gaining access to the deep ocean or polar regions is not easy for an every day elementary school or high school teacher. Finding new and exciting ways to convey science research to young students can be just as difficult. But scientists and educators have found a great way to overcome these obstacles by taking schoolteachers on research cruises. Today there are programs that have opportunities for K-12 teachers to participate and learn first hand about today's oceanographic research at sea. A few examples of these programs are described below.

Bruce Appelgate

Scientists practicing donning cold water exposure "gumby" suits on the R/V Robert Gordon Sproul *(SIO).*

William Sager

Researchers removing samples collected in a dredge on the R/V Melville *(SIO).*

PolarTREC is a program created by the Arctic Research Consortium of the United States and is funded by the NSF where K-12 teachers participate in polar research both in the Arctic and in Antarctica. Teachers are taken into the field on a research excursion for two to six weeks. They work closely with selected scientists on research projects that represent the leading edge of scientific inquiry. While in the field, teachers and researchers are able to connect with classrooms on shore through the use of the Internet. The teachers and researchers use online journals, message boards, photo albums, and podcasts to reach their students on land. Once the field research expedition is complete, teachers are encouraged to continue working with researchers to share their experiences through presentations, conferences, workshops, and journal articles. Teachers also create instructional activities based on the research done in the field for their classes at home. PolarTREC provides professional development opportunities for teachers who participate in the field and those who are connected through the Internet. The PolarTREC program also reaches beyond field research to support a sustained community of teachers, scientists, students, and general public though online seminars, email lists, and peer groups. For more information on PolarTREC go to: <http://www.polartrec.com/>.

Another educational program is the ARMADA Project, which in 2009 is in its fifth and final year. Funded by the NSF, K-12 teachers participate in ocean, polar, and environmental science research and peer mentoring. The teachers are partnered with research teams aboard research vessels including UNOLS ships. The teachers assist in science operations and develop ways to bring their research experiences and technology into their classrooms

Lance Wills

The R/V Atlantis *operated by WHOI.*

Mike Sullivan

Students aboard the R/V Savannah *(Skidaway) learn about proper sampling techniques for marine science research. Left: Students are looking at the samples caught in a bottom trawl including horseshoe crabs. Right: Students are collecting the water acquired in a Niskin Bottles during a CTD cast.*

back at home. They also instruct and mentor other teachers in their school districts to bring modern research into other classrooms. Students benefit from this program because their teachers gain knowledge of modern scientific research; the teachers also have an inspired and invested interest in what they are teaching; and students have the opportunity to work with real scientific data. For more information on the ARMADA Project see: <http://www.armadaproject.org/>.

NOAA also has a program, similar to those described above, called Teacher at Sea (TAS). The TAS program was created in 1990 and has brought more than 500 kindergarten through college-level educators on research cruises aboard NOAA vessels to help them gain a greater understanding of our planet, ocean research, and environmental literacy. Research cruises are focused on fisheries research, oceanographic and coastal research and hydrographic surveys. Cruise durations are usually 12-14 days and are usually during the summer months. For more information on TAS see: <http://teacheratsea.noaa.gov/>.

Courtesy of the Univ. of Delaware

Courtesy of the Univ. of Delaware

Left: Researchers are conducting a marine mammal survey aboard the R/V Hugh R. Sharp *(U. Delaware) for the State of New Jersey, pre-wind farm baseline study of Marine mammals and birds off the New Jersey coast.*
Right: Two Right Whales spotted during the survey.

The Future of the UNOLS Fleet

What does the future hold for the UNOLS fleet? The members on the Fleet Improvement Committee (FIC) try to answer that question. As many of the older UNOLS research vessels approach the end of their projected service life, they consider fleet renewal options.

Courtesy of the Univ. of Alaksa, Fairbanks

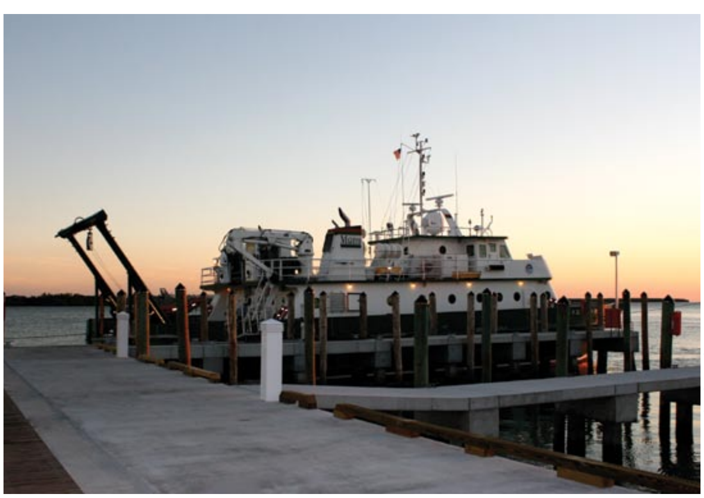
The proposed Alaska Region Research Vessel to be operated by the University of Alaska, Fairbanks.

The R/V *Alpha Helix*, operated by the University of Alaska, Fairbanks, was retired in 2006 with plans to replace the *Alpha Helix* with the new Alaska Region Research Vessel (ARRV). This vessel, funded by the National Science Foundation, will be approximately 240-250 feet (73-76 meters) long and ice-strengthened for light ice breaking. It will support high-latitude research along the Alaskan coastline and region. The ARRV will have the ability to support ROV operations and will be equipped with a state-of-the-art handling system that will allow deployment and recovery of a broad spectrum of scientific equipment. The ship will also be able to transmit real-time information directly to shore and classrooms all over the world. It will have 26 science berths, including accommodations for individuals with disabilities. The ARRV is expected to enter service in 2014.

There are plans for up to three Regional Class vessels to be built with funding through from NSF. The objective is to replace the older and less capable ships with more technologically advanced and highly efficient regional vessels. The FIC, along with help from ocean-going scientists, have created Science Mission Requirements for this class of vessel based on future science initiatives. Design efforts are currently underway taking those requirements into consideration, with plans for the first vessel to enter the fleet in the near future.

The U.S. Navy has plans to build two new Ocean Class vessels. The ships are envisioned to be more technologically advanced and capable than the Intermediate Class ships that they will replace. If all goes as planned, these ships will enter the fleet in 2014 and 2015. These vessels will have better maneuverability and station-keeping capabilities and will have improved equipment-handling systems. They will be designed to be quiet thereby enhancing the operations of acoustic systems.

For more information on the need for continued access to a state-of-the-art fleet, check the UNOLS and FIC web pages for updates.



Courtesy of RSMAS/U. Miami

Courtesy of the University of Miami

Left: The R/V F. G. Walton Smith *is a catamaran operated by the University of Miami, Rosenstiel School of Marine & Atmospheric Sciences. Right: Researchers on the R/V* F. G. Walton Smith *are removing the collection containers from the ends of sampling nets.*

UNOLS Research Vessels

		Operating Institution	Owner	Built/Refit/ Converted	Length	Berths
	GLOBAL					
	*Knorr*	Woods Hole Oceanographic Institution	Navy	1970 / 1989	279 ft / 85 m	34
	*Melville*	Scripps Institution of Oceanography	Navy	1969 / 1991	279 ft / 85 m	38
	*Atlantis*	Woods Hole Oceanographic Institution	Navy	1997	274 ft / 84 m	37
	*Roger Revelle*	Scripps Institution of Oceanography	Navy	1996	274 ft / 84 m	37
	*Thomas G. Thompson*	University of Washington	Navy	1991	274 ft / 84 m	36
	*Marcus G. Langseth*	Lamont-Doherty Earth Observatory	NSF	1991 / 2007	235 ft / 72 m	35
	OCEAN					
	*Kilo Moana*	University of Hawaii	Navy	2002	186 ft / 57 m	29
	INTERMEDIATE					
	*Seward Johnson*	Harbor Branch Oceanographic Institution	HBOI	1985 / 1994	204 ft / 62 m	29
	*Endeavor*	University of Rhode Island	NSF	1977 /1993	185 ft / 56 m	18
	*Wecoma*	Oregon State University	NSF	1976 / 1994	185 ft / 56 m	18
	*Oceanus*	Woods Hole Oceanographic Institution	NSF	1976 / 1994	177 ft / 54 m	19
	*New Horizon*	Scripps Institution of Oceanography	SIO	1978 / 1996	170 ft / 52 m	19
	REGIONAL					
	*Atlantic Explorer*	Bermuda Institute for Ocean Sciences	BIOS	1982/2006	168 ft / 51 m	20
	*Cape Hatteras*	Duke University/UNC	NSF	1981 / 2004	135 ft / 41 m	14
	*Point Sur*	Moss Landing Marine Laboratories	NSF	1981	135 ft / 41 m	12

	Operating Institution	Owner	Built/Refit/Converted	Length	Berths
REGIONAL/COASTAL					
Hugh R. Sharp	University of Delaware	U. Del.	2005	146 ft / 45 m	14
Robert Gordon Sproul	Scripps Institution of Oceanography	SIO	1981 / 1985	125 ft / 38 m	12
Pelican	Louisiana Universities Marine Consortium	LUMCON	1985 / 2003	116 ft / 35 m	14
F.G. Walton Smith	University of Miami	U. Miami	2000	96 ft / 29 m	16
LOCAL					
Savannah	University System of Georgia	Skidaway	2001	92 ft / 28 m	19
Blue Heron	University of Minnesota - Duluth	U. Minn.	1985 / 1999	86 ft / 26 m	6
Clifford A. Barnes	University of Washington	NSF	1966 / 1984	66 ft / 20 m	6

UNOLS Members

- Alabama Marine Environmental Sciences Consortium
- University of Alaska Fairbanks
- **Bermuda Institute of Ocean Sciences**
- Bigelow Laboratory for Ocean Sciences
- **University of California, San Diego, Scripps Institution of Oceanography**
- University of California, Santa Barbara
- University of California, Santa Cruz
- Cape Fear Community College
- Caribbean Marine Research Center (Perry Institute for Marine Science)
- **Columbia University, Lamont-Doherty Earth Observatory**
- University of Connecticut
- **University of Delaware**
- **Duke University/University of North Carolina**
- Florida Institute of Oceanography
- Florida Institute of Technology
- Florida State University
- **Harbor Branch at Florida Atlantic University**
- Harvard University
- **University of Hawai'i**
- Hobart & William Smith Colleges
- Humboldt State University Marine Laboratory
- The Johns Hopkins University
- School of the Coast and Environment - Louisiana State University
- **Louisiana Universities Marine Consortium**
- University of Maine
- The Marine Science Consortium
- University of Maryland
- Massachusetts Institute of Technology
- **University of Miami, Rosenstiel School of Marine & Atmospheric Sciences**
- University of Michigan
- **University of Minnesota, Duluth**
- Monterey Bay Aquarium Research Institute
- **Moss Landing Marine Laboratories**
- **Naval Postgraduate School ***
- University of New Hampshire
- State University of New York at Stony Brook
- University of North Carolina at Wilmington
- Nova University
- Old Dominion University
- **Oregon State University**
- University of Puerto Rico
- **University of Rhode Island**
- Romberg Tiburon Center for Environmental Studies - San Francisco State University
- Rutgers University
- San Diego State University
- Sea Education Association
- **University System of Georgia, Skidaway Institute of Oceanography**
- Smithsonian Tropical Research Institute
- University of South Carolina
- University of South Florida
- University of Southern California
- Southern California Marine Institute
- University of Southern Mississippi
- University of Texas
- Texas A&M University
- Virginia Institute of Marine Science
- **University of Washington**
- University of Wisconsin at Madison
- University of Wisconsin at Milwaukee - Great Lakes WATER Institute
- University of Wisconsin at Superior
- **Woods Hole Oceanographic Institution**

** National Oceanographic Aircraft Facility.*

Map Key: Red dots are Operator Insitutions (show in bold lettering). Non-operator institutions are shown in yellow.




UNOLS Office
Graduate School of Oceanography/URI - Box 32
Ocean Science and Exploration Center
215 South Ferry Road
Narragansett, RI 02882
www.unols.org

The National Science Foundation
Division of Ocean Sciences
4201 Wilson Boulevard
Arlington, VA 22230
www.nsf.gov/