PMEL

Pacific Marine Environmental Laboratory

Strategic Plan
2013–2017

NOAA OAR Special Report

Pacific Marine Environmental Laboratory (PMEL) Strategic Plan 2013–2017

July 2013

UNITED STATES DEPARTMENT OF COMMERCE

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Overview of PMEL's Strategy

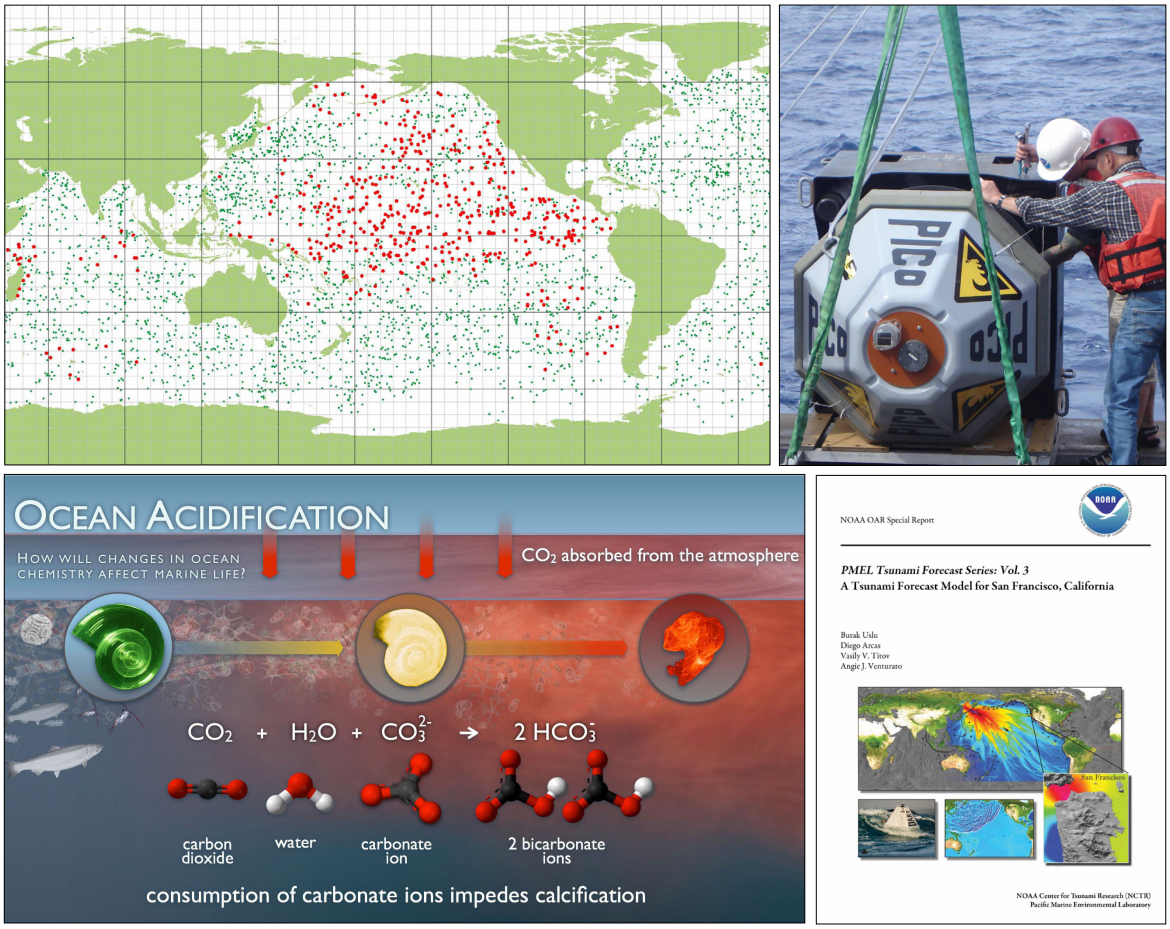
THE PACIFIC MARINE ENVIRONMENTAL LABORATORY (PMEL) is one of seven federal research laboratories within the Office of Oceanic and Atmospheric Research (OAR) of the National Oceanic and Atmospheric Administration (NOAA). Government laboratories have an important role in the Nation's scientific infrastructure as they are well-suited to develop and sustain observational networks over regional to global scales. Unlike the operational components of the government, the OAR laboratories continue to explore new and innovative ways of studying the Earth's environment, to identify emerging scientific issues, and to develop ways to improve the efficiency of the observational networks. PMEL research is made rapidly available to the agency, the scientific community, and the American public, to provide society with the knowledge it needs to make informed decisions.

PMEL's vision of the future:

An informed society that relies on PMEL's observations and the critical advancement of knowledge about the global ocean and its interactions with the earth, atmosphere, ecosystems, and climate

This vision of an informed society sits squarely within the visions of both OAR and NOAA. OAR's leadership role as NOAA's centralized research line office is critical to NOAA's ability to carry out its mission of science, stewardship, and service. Through research and development activities, PMEL, in collaboration with its many partners both inside and outside of NOAA, characterizes and predicts ocean processes critical for understanding the health and resilience of coupled natural and social systems.

As a NOAA laboratory, PMEL focuses its research efforts on the scientific challenges of critical importance to NOAA's mission and OAR's strategic goals and objectives.



Illustrating PMEL's mission, clockwise from top left: Observe—world map of Argo ocean profiling floats (red dots indicate floats maintained by PMEL); Innovate—deployment of a Platform and Instrumentation for Continuous Observations (PICO) buoy developed at PMEL; Inform—cover of PMEL Tsunami Forecast Series report;. Understand— illustration of ocean acifification process

PMEL's Mission:

Observe, Innovate, Understand, and Inform

- **Observe, analyze, and predict oceanic and atmospheric phenomena**
- **Lead the development and deployment of innovative technologies**
- **Identify and understand ocean-related issues of major consequence**
- **Inform society with well-documented, high-quality science**

PMEL's Core Values:

Integrity, Excellence, Leadership, Collaboration, and Communication

Since its creation in 1973, PMEL's core values of integrity, excellence, and leadership have helped the Laboratory to combine fundamental scientific research with strategic integration and societal relevance. More than a collection of individual scientists, PMEL provides an infrastructure that promotes interaction between researchers with related interests to achieve the NOAA, OAR, and PMEL missions. PMEL is a global leader in ocean observing systems, providing an observational backbone that supports a wide array of research and operational activities within NOAA, in other federal agencies, in academia, and in the international community. The Laboratory's administrative, computing, and engineering divisions support productive research and create opportunities to share developing technologies. The collegiality of the Laboratory's diverse workforce fosters innovation and helps to advance scientific knowledge.

PMEL Quick Facts:

The following information current as of July 2013:

PMEL is one of seven Oceanic and Atmospheric Research (OAR) laboratories within NOAA.

Website:
www.pmel.noaa.gov

Year established: 1973

Location:
PMEL is headquartered at NOAA's Western Regional Campus, located at Sand Point in Seattle, Washington. Additionally, PMEL's Ocean Environment Research Division is partially located at the Oregon State University Mark O. Hatfield Marine Science Center, located in Newport, Oregon.

Staff size: Approx. 200

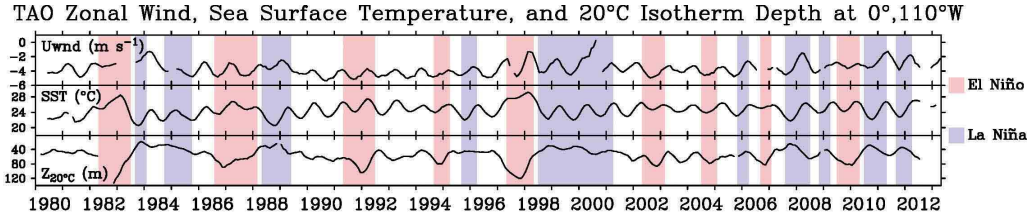
Staff composition:
44% Federal
47% Cooperative Institute
3% NOAA Corps
3% NRC post-doc
3% Contractor/other

Staff location:
90% Based in Seattle
10% Based in Newport

PMEL supports and promotes collaborations with researchers outside the Laboratory to extend the availability of its capabilities and opportunities. Whether it is working with academic colleagues to ensure a comprehensive interdisciplinary research project, or working with industry and international partners to extend observational capabilities, an environment of cooperation and collaboration is at the heart of PMEL's operations.

As a publicly funded laboratory, PMEL embraces the concepts of data sharing and an informed public. PMEL aspires to lead the scientific community in generating high-quality, well-documented observations that are openly available. Because PMEL's research will only be important to society if the public has access to the information the Laboratory produces, PMEL strives to bring its data and its scientific insights to a wide array of stakeholders through effective use of information technology and innovative online tools. To best use this information, stakeholders need to understand the implications of this research. Public outreach and education is becoming increasingly important as society addresses a growing range of environmental issues.

Historically, PMEL's core values helped establish the Laboratory's identity as a scientific leader and guide its long-term vision and mission. The next 20 years hold many opportunities to make meaningful contributions to society as PMEL builds on its 40 years of successful research. Strategic decisions concerning research directions, laboratory personnel, and infrastructure development will be based on the foregoing mission statements as PMEL aims to achieve its long-term vision. PMEL's core values carry through today as the Laboratory looks to the future.

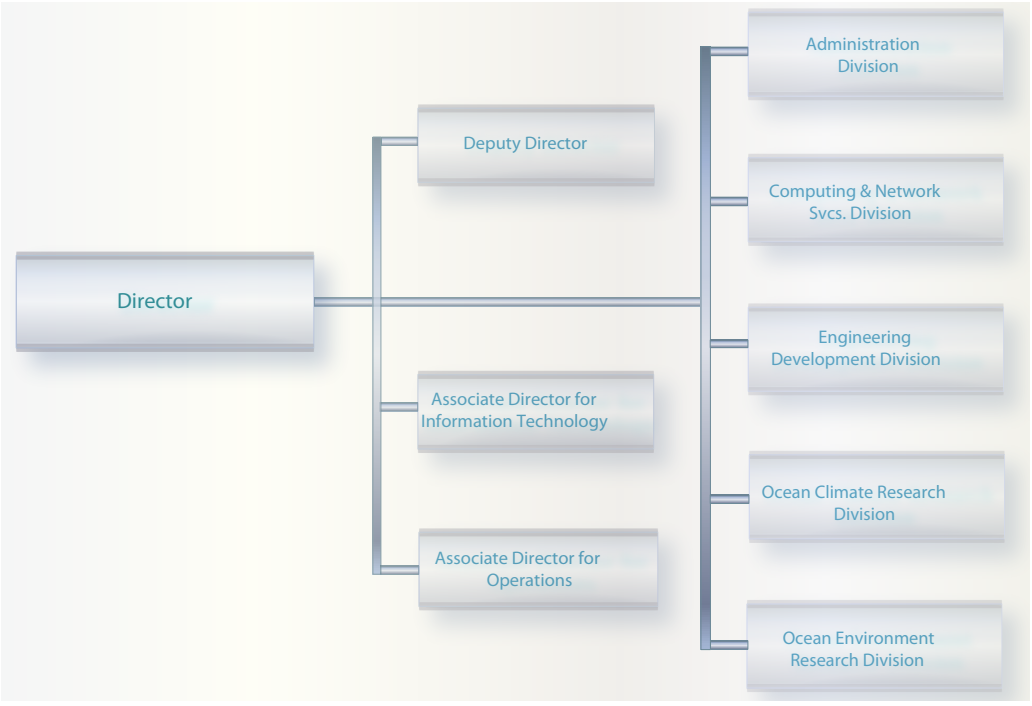


Observed buoy data from the TAO mooring site at 0°, 110°W showing the zonal component of wind, sea surface temperature, and depth of the 20°C isotherm (with monthly average data smoothed using a 5-month running mean)

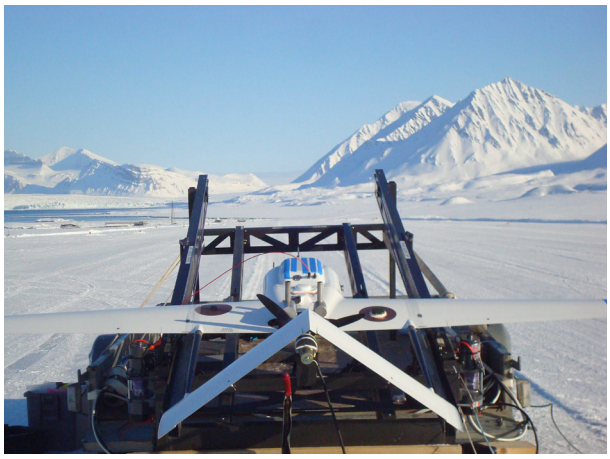
Laboratory Structure

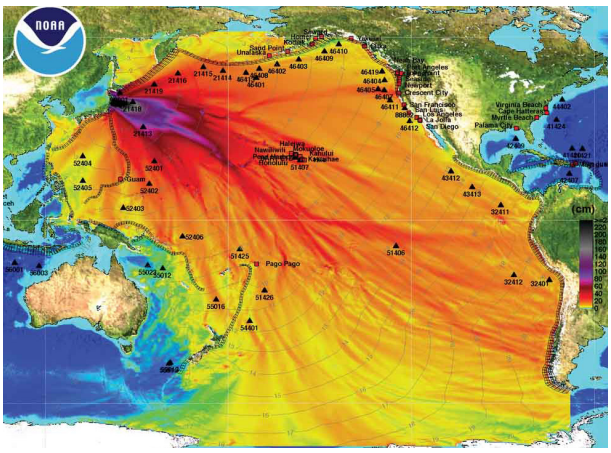
THE PACIFIC MARINE ENVIRONMENTAL LABORATORY is a team comprised of approximately 200 researchers, technicians, engineers, information technology (IT) professionals, and administrators working together from two locations: Seattle, Washington, and Newport, Oregon. Approximately half of the personnel have advanced science or engineering degrees.

From an operational standpoint, PMEL is divided into five divisions that sit outside the Office of the Director (see figure below). Laboratory personnel can be divided into 13 science-focused groups (e.g., large-scale ocean physics, tsunami, carbon), four product-focused groups (e.g., engineering, science IT), and the administrative and computer services staff. However, the close interaction among the different groups and the interdisciplinary nature of the work conducted at PMEL results in flexible boundaries between these groups. The Laboratory's strategic goals are accomplished through the efforts of these groups as well as partnerships among them.



Schematic of Pacific Marine Environmental Laboratory's structure





Clockwise from top left: Deployment of carbon coral reef mooring; Aerial Unmanned Vehicle (AUV) before take off to measure aerosols above Norway; tsunami energy plot for March 2011 Japan tsunami event;. West Mata underwater volcano captured on camera during a 2009 expedition to the NE Lau Basin

PMEL Themes

When we try to pick out anything by itself, we find it hitched to everything else in the Universe.

–John Muir, *My First Summer in the Sierra*, 1911

JOHN MUIR'S POETIC QUOTE IS an intuitive perspective on the intertwined nature of the world. Interconnections between the physical world and biological organisms are complex. Further, rapidly changing environments and limited spatial and temporal data increase the difficulties in resolving linkages. PMEL's efforts to understand changes in our oceanic and atmospheric systems on local, regional, and global scales support NOAA's commitment to providing effective services and stewardship to the Nation. PMEL has developed and executed capabilities to support NOAA's goals through decades of world-class research, recognizing that the ability to monitor, understand, and predict key aspects of the environment is essential for protecting our oceans, advancing our economy, and preserving life and property.

PMEL activities are organized under five themes:

- **Climate Research**
- **Marine Ecosystem Research**
- **Oceans and Coastal Processes Research**
- **Research Innovation**
- **Foundational Services**

The work conducted in support of these themes is represented by the activities described in this chapter.

CLIMATE

Climate Research

Climate research at PMEL is undertaken to support NOAA's mission to understand and predict changes in climate, weather, and the oceans. Our society is affected by recurring patterns of climate variability, by more secular global trends in ocean temperature and carbon, by as-yet poorly understood aspects of the global ocean circulation, and by the connections between the open ocean and our coastal oceans. PMEL's climate efforts focus on observing and interpreting the physical and chemical variability of the ocean and marine atmosphere. Many different in situ observing technologies are used, and new techniques are always under development to improve the observing network and increase its efficiency. PMEL collaborates with scientists and institutions around the world in many international programs and partnerships, and training of the next generation of scientists takes place both formally through relationships with students and postdocs and through collegial interactions with the Laboratory's partners.

Description and motivation

Humankind is increasingly aware of its vulnerability to extremes of weather and climate. Storms and droughts have both short- and long-term consequences. Rising sea level and temperatures also pose rising risks to our coastal communities, national transportation infrastructure (e.g., ports), and ecosystems worldwide. We continue to learn more about the extent to which ocean-atmosphere-cryosphere interactions affect our ability to forecast such conditions. PMEL's climate research and observations contribute centrally to national and international efforts to improve climate science and deliver climate services to the Nation. PMEL is well-positioned to help address the societal need for understanding the climate system and the efficacy and consequences of possible mitigation strategies. The Laboratory has the expertise, partnerships, and infrastructure to design and build instruments, make sustained observations, analyze resulting data, and carry out the necessary theory and modeling to understand why the climate system works as it does. PMEL works closely with the operational components of NOAA and transitions technologies and observational systems from research to operations as appropriate.

There are eight activities within PMEL focusing on Climate Research:

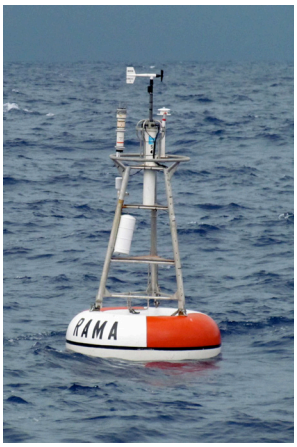
Tropical Moored Buoy Array
Ocean Climate Stations
Large-Scale Ocean Physics
TMAP Data Management
Arctic Climate Dynamics
Ocean Carbon
Pacific Western Boundary Currents
Atmospheric Chemistry

Recent significant climate research accomplishments (2008–present)

PMEL's record of accomplishments illustrates the integrated nature of a laboratory embracing collaborative efforts. Successes of forward looking programs have contributed significantly to our understanding of climate. One of PMEL's most successful climate programs is the development of the Tropical Atmosphere Ocean (TAO) buoy array across the equatorial Pacific, which has led to improved description, understanding, and prediction of El Niño and La Niña. Over 650 research papers have been published using data generated by TAO together with the companion TRITON array, maintained by the Japanese in the far western equatorial Pacific. NOAA's Climate Prediction Center now routinely makes ENSO (El Niño-Southern Oscillation) predictions based on the TAO-TRITON data. Operation of the TAO array is currently being transferred from PMEL to the National Weather Service.

The Argo profiling float array was initiated in 1999 as a multi-institutional and international collaboration to provide systematic observations of temperature and salinity in the upper two kilometers of the world's oceans to improve understanding of the dynamics of the upper levels of the ocean and to improve ocean and atmosphere computer models. PMEL's initial contribution to Argo involved calibration of salinity measurements, but in 2003 the Laboratory became active in the deployment of Argo floats. PMEL is now responsible for about 13% of the global Argo array of more than 3000 floats.

The NOAA/NSF Repeat Hydrography Program, a component of the international Global Ocean–Ship-based Hydrographic Investigations Program has enabled the production of the first accurate estimates of the decadal changes in temperature, salinity, tracers, dissolved oxygen, nutrients, and anthropogenic CO_2 in the global ocean. These data are crucial for understanding the role of the ocean in global climate change. The repeat hydrography cruises also provide information on changes in a number of key oceanic properties in the half of the ocean volume that currently lies beneath the reach of the Argo array. For instance, they have allowed the only global assessment of the contribution of deep ocean warming to the global climate system energy budget. The Repeat Hydrography Program completed its second global ocean decadal survey in 2011. Expansion of Argo into the ice covered zones and the deep ocean would improve our ability to assess the roles of ocean temperature and salinity changes in climate, including the interaction of changing ocean temperature and ice melt, as well as improve our estimates of climate sensitivity via the ability to perform truly global assessments of changes in ocean heat storage on an annual basis.



Top to bottom: Tropical moored buoy in the Indian Ocean; an Argo profiling float before deployment; a CTD rosette being lowered into the ocean

CLIMATE

Current and future climate research activities

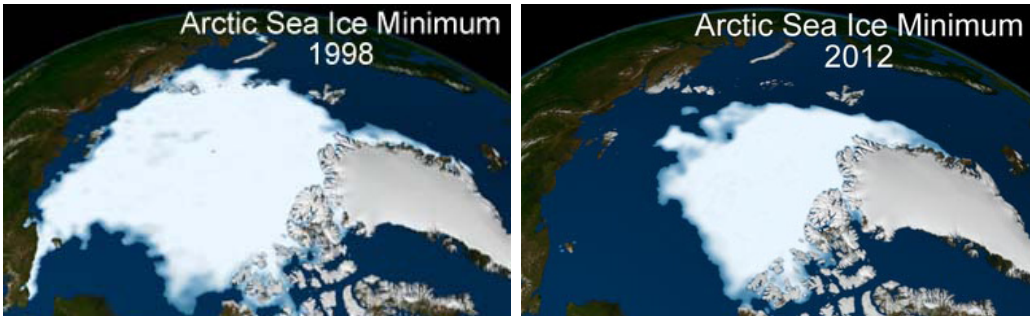
PMEL's climate research activities are centered on collecting high-quality climate observations, data sharing, and employing analysis tools to improve predictability and understanding of climate phenomena and their global impacts. PMEL climate research is conducted in all the major ocean basins of the world.

The **Tropical Moored Buoy Array** group is working with the National Weather Service (NWS) to finalize the transition of operational responsibility for the TAO array to NWS Operations. Using data from the array, PMEL researchers continue their research on ENSO events and assess their impacts on global weather patterns. The Tropical Moored Buoy Array group maintains the Prediction and Research Moored Array in the Tropical Atlantic (PIRATA) and is developing the Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction (RAMA) networks of moored buoys in the Atlantic and Indian oceans, respectively. The PIRATA array was initiated in 1997 and is a highly successful partnership between the U.S. (NOAA/PMEL), France, and Brazil. RAMA is under development in the Indian Ocean as a joint effort between the U.S., Japan, India, Indonesia, France, China, Australia, and a consortium of East African nations that support the Agulhas and Somali Current Large Marine Ecosystems (ASCLME) Project.

The **Ocean Climate Stations** group maintains two OceanSITES reference station moorings: the Kuroshio Extension Observatory (KEO) in the western North Pacific, initiated in 2004, and Station Papa in the eastern North Pacific, which was first deployed in 2007. OCS moorings contribute to the global network of OceanSITES reference stations and their data are used world-wide to assess numerical weather prediction and climate reanalyses and satellite products.

Successful climate research depends on PMEL's ability to maintain existing time series observations; therefore, improving the effectiveness and efficiency of the tropical moored buoy arrays and ocean climate stations is a high priority. Developing and deploying innovative technologies, instrumentation, and systems to increase the scientific return from moorings is an ongoing effort. The Tropical Moored Buoy Array and Ocean Climate Stations groups continue to cultivate new international partnerships to increase the cost-effectiveness of these arrays.

The **Large-Scale Ocean Physics** group has been an early advocate for expanding the depth range of the original Argo floats from one kilometer to two and is now a proponent of "Deep Argo," an expansion of Argo's



Summer sea ice minimum in 1998 (left); lowest sea ice extent in recorded history (right), in 2012

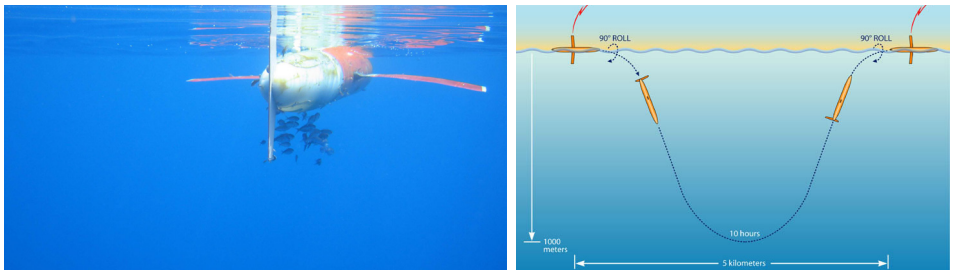
capabilities to depths of up to six kilometers. The group uses data from the global Argo floats collected over the last decade, as well as deep hydrographic profiles from sites occupied in the Repeat Hydrography Program and historical ocean temperature observations, to monitor and conduct research on ocean heat changes and their impacts, including sea level rise and climate sensitivity. PMEL scientists support additional capabilities for Argo floats, including developments to allow their use in ice-covered areas and the incorporation of additional sensors, such as for measuring oxygen and carbon dioxide (CO_2) into Argo.

The **TMAP Data Management** group's research focuses on how ocean and atmosphere interact to produce different patterns of climate variability (e.g., El Niño) around the globe. The group examines climate data and model output to determine how to best identify climate patterns in and over the sea in order to anticipate unusual weather in the months ahead.

The **Arctic Climate Dynamics** group conducts observations and evaluates models of Arctic sea ice to document and predict climate change impacts on Arctic marine ecosystems. The group is also documenting Bering Sea changes, where research suggests a shift from predominantly interannual variability to decadal variability.

Climate change in the Arctic presents a need for expanded research in support of NOAA's climate program. The Arctic has evolved to a "new normal" that lies outside the bounds of recent natural variability. Opportunities for the Arctic Climate Dynamics group include: developing new capabilities for NOAA sea ice forecasting on weekly, seasonal, and decadal scales; providing baseline observations for the Beaufort and Chukchi seas; detecting and predicting changes in physical, chemical, and biological structure and dynamics in the U.S. Arctic marine environment; evaluating the potential for strengthened linkages between Arctic climate change and mid-latitude extreme weather events; and determining causes and estimating future impacts of changes in atmospheric composition and radiative fluxes.

CLIMATE



The Solomon Sea spray glider measuring the Pacific Western Boundary Currents (left), and its path of flight (right)

The **Ocean Carbon** group has focused its efforts on understanding the ocean's role in uptake and redistribution of natural and anthropogenic CO_2 from the atmosphere. The details of this uptake and storage as well as the mechanisms controlling them are still not fully understood. Continued monitoring and scientific analysis of the ocean carbon cycle is critical to understand how the ocean sink for anthropogenic CO_2 is functioning and how the carbon storage might change in the future. The group generates high-quality carbon data, quantifies global ocean carbon uptake and storage from repeat hydrography and VOS cruises, and acquires in situ measurements from moorings. They use multiple platforms to observe patterns and trends of carbon uptake and transport, as well as to provide critical model validation, and have used historical and newly compiled databases to develop data synthesis products. This work has led to a determination of seasonal to decadal trends in carbon fluxes and storage in the global oceans. Research publications based on these long-term data sets have led to a more comprehensive understanding of the ocean's role in climate. The group plans to continue global repeat hydrographic cruises, including coastal cruises for model validation; broaden the CO_2 mooring network to include physical, chemical, and biological sensors; expand the use of Argo floats, wave gliders, and Slocum gliders for CO_2, pH, O_2, and, ultimately, other inorganic carbon parameters; extend observations into new areas including the Arctic and subarctic seas; continue to advance technology for improved ocean carbon autonomous sensors and platforms; develop new syntheses, data products, and modeling efforts that provide critical information to other scientists, stakeholders, and the public; and publish papers on ocean carbon and acidification processes.

The **Pacific Western Boundary Currents** group began exploratory missions in the Solomon Sea with ocean gliders, crossing the New Guinea Coastal Undercurrent in late 2007. This project was motivated by the inability of the large-scale networks to observe fluctuations of the equatorward western boundary currents, and by the centrality of those currents in the meridional exchanges that contribute to ENSO. The ENSO

signal in this western boundary current is seen to be a first-order contribution to the equatorial mass and heat balance.

Using decades of PMEL aerosol measurements, the **Atmospheric Chemistry** group has shown that oceanic phytoplankton sulfur emissions are not the major source of cloud condensation nuclei to the marine atmosphere. This work has renewed the importance of understanding the direct emissions of sea spray to the atmosphere as a major source of sub-micrometer particles. The group plans to continue roughly biannual process studies to target regions where the current level of understanding of aerosol sources and atmospheric processing inhibits the ability to accurately model weather and climate change.

Potential climate research opportunities

With increasing demand for frequently repeated monitoring of climate signals in remote parts of the ocean, relatively inexpensive autonomous samplers will play a more important role in PMEL's repertoire. As ocean gliders mature—in particular with the capability to service and redeploy them in the field and to simplify their piloting—the Laboratory envisions larger fleets of gliders, corresponding to the development of tropical arrays evolving from single purpose-built deployments to an array that could be managed as a network.

Many new instruments that may be useful for climate research require further development. PMEL scientists and engineers have used Unmanned Aerial Systems (UAS) to make atmospheric aerosol measurements. UAS were obtained as a potential tool for making such measurements in the marine atmosphere, but have been mostly deployed from land rather than water. Currently, there is no effective way to land such aircraft on a research vessel. PMEL has developed new instrument packages that extract the power they need to profile the ocean from surface wave energy. Instrument packages should be developed to address a variety of questions, including distribution of marine-carbon parameters in the ocean, input of atmospheric dust to the oceans, and flux of CO_2 and methane (CH_4) from Arctic coastlines as they become exposed.

Another opportunity lies in the use of PMEL's climate expertise to evaluate Earth system models. As a primarily observational laboratory, PMEL can provide strong constraints for evaluating the quality of climate simulations. PMEL scientists hope to collaborate more closely with modelers at NOAA's Geophysical Fluid Dynamics Laboratory and Earth System Research Laboratory to evaluate and improve climate system projections.

Climate Research Evidence of Progress

PMEL's overarching Climate Research objectives will be to acquire data, store and distribute data for current and future use, analyze results, and develop products and services that facilitate the delivery of science, service, and stewardship to the Nation.

Four primary metrics of progress indicate PMEL's success:

- Number and quality of peer reviewed papers published
- Number of observing platforms deployed/ maintained
- Number of accessible datasets documented to the appropriate Federal Geographic Data Committee (FGDC) and/or ISO metadata standard
- Number of supporting scientific documents and presentations provided by PMEL researchers to policy makers

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Marine Ecosystem Research

Marine ecosystem research at PMEL is focused on measuring, understanding, and predicting impacts of natural physical, chemical, biological, geological, and anthropogenic processes on the oceanic web of life. Since ecosystem research involves capabilities beyond those which PMEL can provide, the laboratory partners extensively with the NOAA Fisheries Science Centers, academic colleagues, and other federal, state, and tribal entities. PMEL's primary contribution is to put the biological research into the context of the physical and geochemical settings. PMEL marine ecosystem research is focused primarily along the U.S. Pacific and Arctic ocean coastal zones, but efforts are global with respect to explorative research and fundamental processes. Researchers strive to meet NOAA's vision, as stated in the Next Generation Strategic Plan, of "healthy ecosystems, communities, and economies that are resilient in the face of change," using diverse skills to acquire, process, analyze, predict, disseminate, and archive data for the long-term benefit of the Nation.

Description and motivation

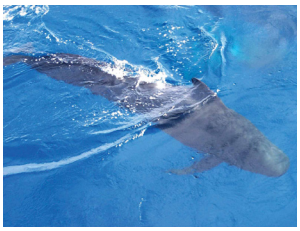
Marine ecosystem research at PMEL is based on the study of anthropogenic and natural processes that affect the composition of marine communities. This research clarifies relationships between living systems and the environment through a multidisciplinary approach. Examples include the impacts of climate change, fishing, ocean acidification, and tectonic and volcanic processes on the biological, physical, and chemical structure of ecosystems. Changes in one part of an ecosystem will feed back to influence other parts.

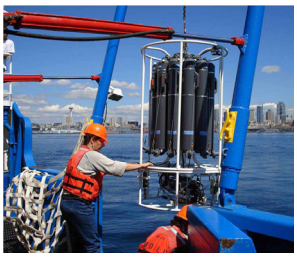
PMEL is well-positioned to contribute to NOAA's objective of achieving a holistic understanding of ecosystems through research and resource management. The Laboratory's personnel, partnerships, infrastructure, and culture form an effective matrix suited to untangling linkages within ecosystems. Scientific teams that are experts on ocean physics, ocean carbon, atmospheric chemistry, climate, marine nutrients, and hydrothermal vents partner to create results that are internationally recognized.

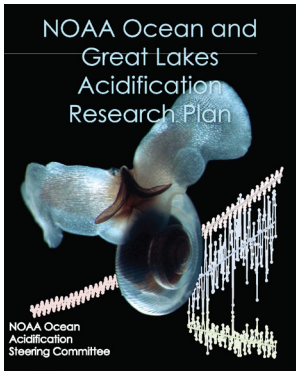
Within PMEL, four research groups are focused on Marine Ecosystems:

Ecosystems & Fisheries-Oceanography Coordinated Investigations (EcoFOCI)
Earth–Ocean Interactions
Acoustics
Ocean Carbon

Ecosystem research is conducted with the primary objective of providing the information needed to make scientifically informed decisions in support of a prosperous future that is both economically and environmentally sound. Given a changing climate and ever escalating anthropogenic pressures, marine ecosystem research is increasingly important in ensuring healthy oceans.







Top to bottom: Pilot whale; CTD rosette used to collect water samples in the Puget Sound; NOAA Ocean and Great Lakes Acidification Research Plan, released in April 2010

Recent significant marine ecosystem research accomplishments (2008–present)

PMEL's record of accomplishments illustrates the integrated nature of a lab embracing collaborative efforts. Successes of forward looking programs have contributed significantly to the national discussion on ecosystem-related issues.

The gradual process of ocean acidification—the uptake of excess carbon dioxide from the atmosphere by the oceans and the subsequent chemical reaction that makes the ocean waters more acidic—has long been recognized, but the ecological implications of such chemical changes have only recently been examined. It has become increasingly clear that changes in oceanic carbon dioxide (CO_2) and pH can affect the growth, behavior, and survival of a wide variety of marine organisms. One example of the benefits of the Ocean Acidification (OA) program is the work undertaken to understand the devastating die-offs of larval oysters in 2006–2009 along the Pacific Northwest coast due to upwelling of acidic waters. The corrosive water prevented oyster larvae from forming shells; West Coast oyster hatcheries that sold oyster seed were experiencing larval oyster mortality rates of 80%. Without seed, the entire industry was jeopardized. By creating a monitoring network at regular intervals along the coastline to measure ocean chemistry, the OA program was able to recommend strategies to oyster hatcheries to avoid the intake of acidic water and increase the recruitment of oyster larvae.

PMEL's acquisition of data, research, publications, public presentations, and congressional testimony has changed the national conversation on ocean acidification. By clearly articulating the consequences of decreasing ocean pH to the general public and decision makers, the research has contributed to two positive outcomes: the passing of the Federal Ocean Acidification Research and Monitoring Act of 2009, which mandates that NOAA has an active monitoring and research program to determine potential impacts of changing ocean chemistry; and the development of the NOAA Ocean and Great Lakes Acidification Research Plan. The goals are to understand and predict how ecosystems will respond to

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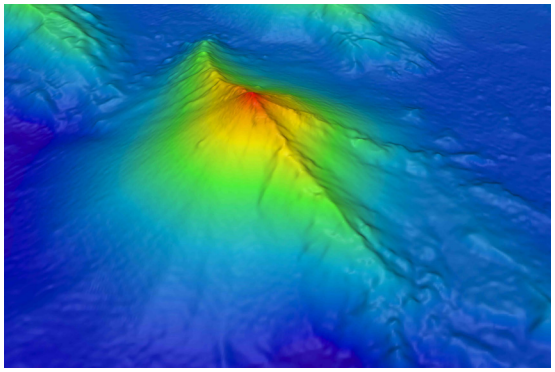
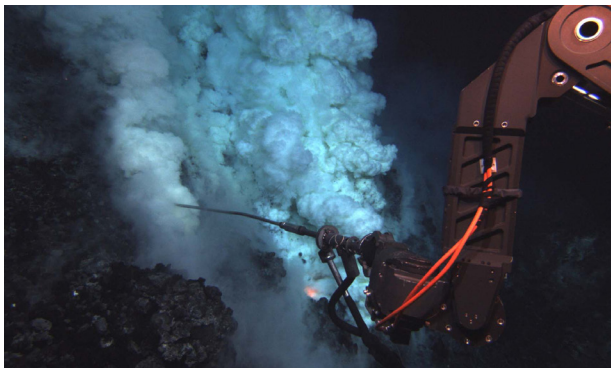
EcoFOCI personnel service the M2 mooring, which has (as of 2013) collected year-round temperature, salinity, nitrate, chlorophyll, current, and sea ice measurements in the Bering Sea for 19 consecutive years

acidification and to provide information that will aid resource managers in choosing approaches to mitigate the effects of acidification.

PMEL's large-scale, comprehensive research in the Gulf of Alaska and Bering Sea has resulted in a wealth of data and an unprecedented opportunity to assess how marine ecosystems respond to multi-year and long-term climate variability and other stressors (e.g., fishing). From these data, a vertically integrated ecosystem model of the Bering Sea was created that is actively being used to evaluate fisheries management strategies, and will eventually result in a model capable of providing reliable forecasts of ecological changes in the context of a dynamic climate. The goal is to use the model to inform long-term management strategies of fisheries in the Bering Sea and North Pacific.

For more than a decade, PMEL scientists have continuously maintained the New Millenium seafloor Observatory (NeMO), located at Axial Seamount in the northeast Pacific, making it the longest observational record of an active hydrothermal system in history. The range of scientific interests at this site includes geophysical monitoring, hydrothermal vent geochemistry, macro-biological colonization and succession, and the diversity and evolution of subsurface microbiological communities. Exciting research results from NeMO over the years has led to the selection of this site by the National Science Foundation as a key





Clockwise from top: Dr. Richard Feely provides testimony addressing climate change in November 2010 before the House Science and Technology Subcommittee on Energy and Environment (image courtesy of House Science and Technology Subcommittee on Energy and Environment); a fluid sampler reaches into the very active West Mata volcano during a 2009 expedition to collect volcanic fluids for analysis; 3-d image of West Mata submarine volcano located in the Northeast Lau basin

MARINE ECOSYSTEM

site on the Ocean Observatories Initiative's (OOI) Regional Scale Nodes (RSN) cabled observatory network. PMEL scientists have also discovered numerous significant volcanic and hydrothermal phenomena that affect local chemosynthetic ecosystems and the global ocean.

Current and future marine ecosystem research activities

The **Ecosystem and Fisheries Oceanography Coordinated Investigations (EcoFOCI)** group uses biophysical moorings, satellite-tracked drifters, remote sensing, hydrographic and atmospheric measurements, and numerical models to examine the changing ecosystems of the Chukchi Sea, Bering Sea, Gulf of Alaska, Aleutian Islands, and the Arctic. The program is built upon multidisciplinary collaborations that explore ecosystem components ranging from climate to biological predators. EcoFOCI researchers work with scientists at the National Marine Fisheries Service (NMFS) and academic partners to improve understanding of how marine physical (including climate change) and chemical environments impact the biological realm. Several major research programs are currently in progress. In the Gulf of Alaska, science and stewardship are inherent in understanding the physical transport mechanisms and nutrient availability that influence lower trophic levels and, subsequently, the survival and recruitment of economically important fish species. Baseline studies of existing ecosystems (physics, plankton, and marine mammals) and sea ice thickness are being conducted in the Arctic. Currently, PMEL maintains four biophysical moorings in the Bering Sea and, in conjunction with the Bureau of Ocean Energy Management (BOEM), maintains additional biophysical moorings at three locations in the Chukchi Sea. These moorings, together with other long-term monitoring efforts and process studies, allow for a better understanding of mechanisms important to the marine ecosystem of the continental shelves of the Bering and Chukchi seas.

Seasonal forecasts of ocean conditions are presently being developed and evaluated for the coastal waters from central California to Vancouver Island in support of NOAA's Integrated Ecosystem Assessment program. The work is being conducted in collaboration with NOAA's Northwest Fisheries Science Center. This project aims to provide 6- to 9-month forecasts of upper ocean properties, based on input from NOAA's Climate Forecast System (CFS) and dynamical downscaling with the ROMS regional mesoscale ocean model. Forecasts of specific oceanic properties crucial to the nearshore and coastal marine ecosystem, such as upwelling, pH, mixed layer depth, and oxygen concentration, are anticipated with updates on a monthly basis. The projections of circulation and plankton

distributions may also prove valuable for use in individual-based models of commercially significant fish populations. Interest has been expressed to expand this effort to provide similar information for other regions, such as the Gulf of Alaska and Bering Sea.

The Arctic Ocean has changed markedly in the last decade, and changes are predicted to continue for the foreseeable future. The EcoFOCI group, in partnership with other federal agencies, plans to expand its investigations of the Arctic. Within the next few years, EcoFOCI scientists will co-lead and participate in a major synthesis of Arctic Ocean ecosystem research, continue and expand investigations on the Chukchi Sea, and participate in baseline fisheries studies in the northern Bering and Chukchi seas. The program will provide critical data for model evaluations.

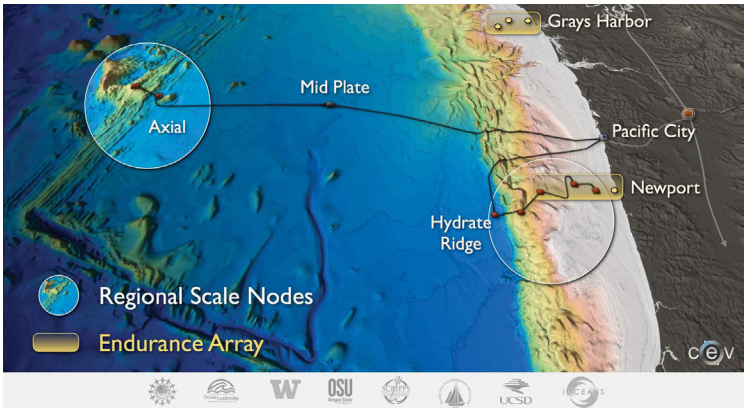
Work in the Arctic will be greatly enhanced by the development of new instrumentation. For example, working in partnership with its designer, EcoFOCI has helped improve an acoustic instrument (TAPS-8) that measures zooplankton abundance. This is important, because the patchy nature of the zooplankton populations makes them difficult to characterize, but these populations are critical to fish and are likely to change with Arctic climate changes.

A long-held goal of NMFS is to expand from single-species management of fisheries to a more holistic, ecosystem-based management. A synthesis of ecosystem indicators enables an ecosystem-based approach to fisheries management in the Alaska region. This process is still in its infancy and is being implemented through the North Pacific Fisheries Management Council (which establishes fishing quotas) through the NMFS Science and Statistical Committee. EcoFOCI will continue to propose, evaluate, and modify indices of biophysical processes in an effort to improve prediction and reduce uncertainty in ecosystem forecasts. In addition, EcoFOCI will expand its contribution of the individual assessment chapters (Plan Team reports) to discuss how and what climate indices to incorporate directly into the single stock assessments. Through these predictions, EcoFOCI passes the results of scientific research directly on to operational use, to benefit the national economy.

The **Earth–Ocean Interactions** group is renowned for interdisciplinary seafloor and water column processes work at numerous volcanic and hydrothermal sites around the globe. The group discovers unique chemosynthetic ecosystems and studies biogeochemical processes of global importance that address the NOAA goals of healthy oceans, technology development, and ocean stewardship. The Earth–Ocean Interactions group researchers are developing and deploying new

Top to bottom: A bongo net used to sample phytoplankton preparing for deployment; NOAA Ship *Miller Freeman* in the Gulf of Alaska; sampling an ice core on the Bering Sea

MARINE ECOSYSTEM



Location of Axial Volcano, on the Juan de Fuca Ridge off the U.S. West Coast

technology on undersea cabled observatories on the Juan de Fuca ridge at Axial Seamount. Their research is providing a deeper understanding of the complex links between volcanic activity, hydrothermal chemistry, and microbial ecology. This group has also pioneered exploration and research in the U.S. Exclusive Economic Zone (EEZ) of the western Pacific, where their discoveries of new hydrothermal vent ecosystems directly inspired the establishment of the Marianas Trench Marine National Monument.

The **Acoustics** Program is an ocean sound research group that develops and provides acoustic tools, technologies, and services to address a wide variety of NOAA missions. Using autonomous stationary hydrophones, mobile platforms such as ocean gliders and floats equipped with acoustic sensors, and cabled observatories the Acoustics group studies both natural and anthropogenic sounds in the marine environment.

The vision of the program is to a) quantify ambient sound levels from man-made sources, such as commerce and energy production; b) monitor processes and potential hazards related to marine volcano-seismic activity; and c) assess potential changes in the abundance and distribution of endangered marine mammal populations due to anthropogenic noise and climate-related changes in the environment.

This group of interdisciplinary researchers has deployed and operated acoustic monitoring systems in every major ocean basin on Earth and is currently developing novel systems to efficiently monitor large ocean areas and their living marine resources for extended time periods. The Acoustics group develops open-source and user-friendly ocean sound analysis software tools, which are used by several NOAA/NMFS laboratories in support of their research. The Acoustics Program, in close collaboration with the Earth-Ocean Interactions and EcoFOCI programs,

studies the links between volcanic and hydrothermal processes at seamounts around the globe as well as the underwater soundscape in the Arctic.

In the open and coastal oceans, the **Ocean Carbon** group is currently making high-quality measurements of ocean acidification parameters (dissolved inorganic carbon, total alkalinity, CO_2 partial pressure, and pH), as well as ancillary properties, such as dissolved oxygen and nutrients that are related to ecosystem research. In order to understand spatial and temporal changes occurring in the world's oceans, the OA program uses automated analytical systems on moorings and underway platforms. The program is in the process of adding pH, oxygen, chlorophyll, and turbidity sensors to these systems to more accurately and precisely study the changes associated with OA. The Ocean Carbon group plans, as described in the Climate Research section, to expand the CO_2/pH mooring network; extend observations into new areas; further develop the use of wave gliders. Slocum gliders, and Argo floats; advance new technology and data products; and disseminate critical information to other scientists, stakeholders, and the public.

The Ocean Carbon group is partnering with EcoFOCI to increase the number of ocean acidification moorings in the high latitudes. In 2013, two EcoFOCI moorings (one in the Gulf of Alaska and the other in the Bering Sea) will be equipped with pCO_2 sensors. In addition, the two programs will collaborate (ship time, equipment, and expertise) to introduce a third mooring in the Gulf of Alaska.

Potential marine ecosystem research opportunities

Significant changes have occurred in the Arctic during the last decade. Observations of the unprecedented reduction in Arctic sea ice coverage in 2012, combined with projected decreases in extent over the next several decades, indicate the Arctic ecosystem is in rapid flux. Ocean acidification is expected to develop more rapidly in the Arctic than anywhere else in the global ocean. Changes in ice extent and water temperature will certainly modify the timing and strength of phytoplankton blooms, zooplankton concentrations, the ocean heat content, and thus, very likely, the north-south gradients in the atmosphere. There are many opportunities for the PMEL Marine Ecosystems research programs to make significant contributions to understanding Arctic changes over the next decade or more.

Marine Ecosystem Research Evidence of Progress

PMEL's overarching Marine Ecosystem Research objectives will be to acquire, distribute, and store data for current and future use, analyze results, and develop products and services that facilitate science, service, and stewardship to the Nation.

Four primary metrics of progress indicate PMEL's success:

- Number and quality of peer reviewed papers published
- Number of observing platforms deployed/ maintained
- Number of accessible datasets documented to the appropriate Federal Geographic Data Committee (FGDC) and/or ISO metadata standard
- Number of supporting scientific documents and presentations provided by PMEL researchers to policy makers

OCEANS AND COASTAL PROCESSES

Oceans and Coastal Processes Research

Oceans and Coastal Processes Research captures those elements of PMEL's integrated research agenda that do not easily fall into the broad categories of climate or ecosystems, but still comprise important contributions to NOAA's mission. Elements captured in this goal include an understanding of ocean physics and interactions between the ocean and both the seafloor and atmosphere.

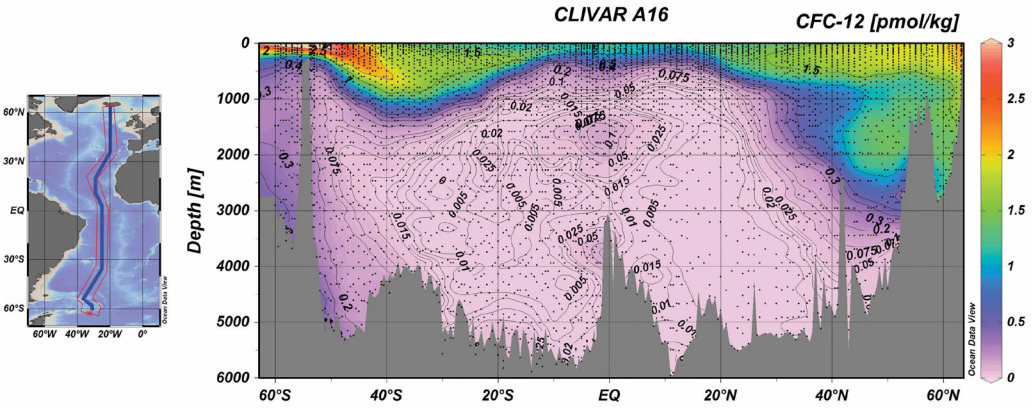
There are three areas of Ocean and Coastal Process Research within PMEL: ocean tracers, tsunami inundation forecasting, and characterization of seafloor environments. Ocean tracers help improve understanding of the rates of exchange of gases between the atmosphere and the ocean, and of the rates and pathways of circulation in the interior of the ocean. The tracer data collected are critical for testing global ocean models and for improving estimates of the rate at which the ocean can absorb carbon dioxide and other important gases on long time scales. Tsunami research continues to develop cutting-edge ocean observation technology and directly supports NOAA's ability, through research-directed model enhancements, to help save lives and property by providing accurate and timely forecasts of tsunami inundation. Seafloor environment research is focused on the biogeochemical interactions between the deep ocean and the solid earth and the resulting impacts in areas of tectonic activity.

Description and motivation

Three PMEL research groups are focused on Oceans and Coastal Processes:

NOAA Center for Tsunami Research (NCTR)
Ocean Tracer
Earth–Ocean Interactions

Tsunamis have been recognized as potential hazards to U.S. coastal communities since the mid-twentieth century, when multiple destructive tsunamis caused damage to the states of Hawaii, Alaska, California, Oregon, and Washington. In response to the scale of destruction and unprecedented loss of life following the December 2004 Sumatra tsunami, the U.S. refocused efforts to reduce the tsunami vulnerability of coastal communities. PMEL is at the forefront of NOAA's tsunami research program and contributes to the national and international effort by conducting research in support of tsunami measurement technologies. PMEL also develops improved models and methods to both increase the timeliness and accuracy of operational forecasts and



Chlorofluorocarbon-12 (CFC-12) concentrations, used as ocean tracers of circulation and mixing processes, measured along the meridional section A16 in the Atlantic Ocean basin

warnings and predict tsunami impacts on the population and infrastructure of coastal communities. The improved tsunami hazard assessment tools and warning products developed at PMEL are transitioned to the two operational NOAA Tsunami Warning Centers.

Knowledge of the mixing and circulation patterns of the world ocean is crucial for understanding how CO_2 and other pollutants will be mixed into and distributed throughout the ocean basins. Studies of chlorofluorocarbon (CFC) transfers from the atmosphere into the surface ocean, and the subsequent transport of these compounds into the ocean interior, provide a unique description of time-integrated circulation of the ocean on decadal time scales. These tracer data can be used to estimate the rates and pathways of ocean circulation and mixing processes, and as a means of testing and evaluating numerical models of ocean circulation. The development and testing of such models is critical to understand the present state of the ocean-atmosphere system, and to quantify the role of the oceans in the uptake of climatically important trace gases such as CO_2.

In the deep ocean, the conservative tracer helium-3 (^{3}He) has been extremely useful for delineating the patterns of mixing and circulation. ^{3}He is enriched in the Earth's mantle, and is therefore also enriched in volcanic gases and in submarine hydrothermal fluids, which are derived from the Earth's interior. Hydrothermal venting on the seafloor thus produces ^{3}He-rich plumes that can be traced for thousands of kilometers away from the source of injection. Since the source of these ^{3}He plumes is well constrained, the resulting plume distribution is useful for defining the deep ocean flow.

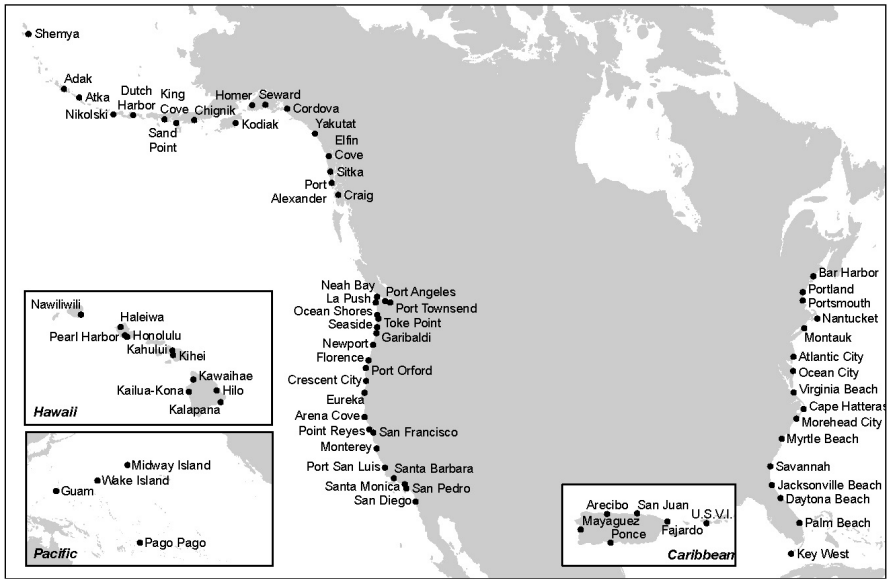
Humankind's accelerating desire for new resources is leading to commercial plans for harvesting mineral resources from hydrothermal deposits in the deep sea. The environmental consequences, both local and regional, are unknown.

OCEANS AND COASTAL PROCESSES

PMEL houses the sole NOAA expertise for discovering, characterizing, and studying the processes of chemical and physical interactions between the seafloor and deep sea. NOAA's ocean stewardship implicitly includes consideration of sustainable usage of resources available within the deep ocean. This stewardship is embodied in the Healthy Oceans goal of the NOAA Next Generation Strategic Plan.

Recent significant oceans and coastal processes research accomplishments (2008–present)

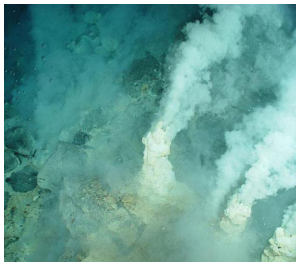
In 2012, PMEL completed an eight year process to develop and transition 75 tsunami flooding forecast models to NOAA's Tsunami Warning Centers. The models are a key component of the U.S. tsunami forecast system. Completion of these community-specific models is recognized as a major milestone for establishing upgraded forecast capabilities as part of the NOAA tsunami program-implemented enhancements, which were deemed vital in response to the 2004 Sumatra tsunami. These models, coupled with tsunami detection buoys (DART®), comprise the Short-term Inundation Forecasting of Tsunamis (SIFT) forecast system developed at PMEL to produce flooding forecasts for U.S. coastal communities.



Locations of 75 tsunami flooding forecasts developed by the NOAA Center for Tsunami Research.

PMEL was an active participant in the tracer component of the international GO-Ship Repeat Hydrography Program, which recently completed its second global ocean decadal survey. PMEL scientists helped pioneer efficient methods for measuring human-derived gases such as CFC and sulfur hexafluoride (SF_6) in seawater.

Since 2008, PMEL has participated in the discovery of dozens of new sites of living and non-living resources at hydrothermal vent sites in every ocean basin, including extensive exploration in western Pacific areas (including the U.S. Exclusive Economic Zone, encompassing the National Mariana Trench Marine Monument) where such sites are undergoing active exploration by commercial interests.



Top to bottom: A DART® tsunami detection buoy being deployed; NW Eifuku submarine volcano emitting carbon dioxide; instrument used to measure the concentration of helium-3 found in hydrothermal plumes

Current and future oceans and coastal processes research activities

NOAA Center for Tsunami Research (NCTR) is developing and testing new and improved modeling capabilities for both real-time tsunami forecasts, for use during tsunami warning operations, and community-based tsunami hazard assessment efforts. New generation tsunami models will provide estimates of currents resulting from tsunamis in ports and harbors, and incorporate the stage of the tide into predictions to increase timeliness and accuracy of tsunami forecasts.

Deep ocean tsunami observations from NOAA's DART® moored buoy array provide unique data sets for real-time tsunami hazard assessment and for model testing and verification. NCTR and PMEL engineers are working with industry to develop a next generation DART® system that returns higher frequency observations. The 2011 Tohoku tsunami vividly demonstrated the devastating effect of tsunamis to coastlines in close proximity to the tsunami source. Developing forecast and warning capabilities that can address the local tsunami problem and provide an accurate flooding forecast within minutes of an earthquake will present additional capabilities to emergency managers for warnings (and their expirations), real-time assessment, potential search and rescue operations, event planning, and other emergency management tasks. This suite of capabilities is of particular benefit to the U.S. West Coast communities most at risk from near-field tsunamis.

NCTR is performing modeling studies to determine the optimal distribution of the DART® array, with the goal of maximizing tsunami warning system efficiency while reducing the operational cost to maintain the array. The program is also collaborating with local and state emergency

OCEANS AND COASTAL PROCESSES

management communities in tsunami hazard mitigation activities, including production of tsunami inundation maps and tsunami hazard assessment studies.

In addition, NCTR will continue to collaborate with NOAA's Tsunami Warning Centers to develop enhanced capabilities for automated and accurate tsunami flooding forecasts. Specifically, NCTR will develop and test new tsunami current forecasts for ports and harbors. Tsunami-induced currents can produce damage to port facilities far from a tsunami source, as was dramatically demonstrated during the 2004 Sumatra/ Indian Ocean and the 2011 Japan tsunamis. NCTR is committed to ensuring that forecast products are clearly understood, and will develop new graphical tsunami forecast products to be used with new forecast distribution methods. Tsunami forecast delivery methods via web, cloud, and mobile platforms will be developed in partnership with NWS to provide NOAA clients with faster access to needed forecast information.

The **Ocean Tracer** group makes CFC and SF_6 measurements on Repeat Hydrography and other ocean research cruises to detect changes in water mass formation rates and to improve estimates of the uptake and storage of anthropogenic CO_2 in the ocean on a global scale. Tracer studies can also improve estimates of the rates of important biogeochemical processes in the ocean, including oxygen utilization rates (OUR) and the production and consumption of trace gases in the ocean.

The Ocean Tracer group plans to extend tracer studies to include other important greenhouse gases (e.g., methane and nitrous oxide) that are not currently measured, and to use these data to help estimate the importance of the ocean in the global budget of these gases. The group also plans to increase interaction with modeling groups and to utilize these tracers to help evaluate global-scale ocean models. The group will collaborate with other nutrient-focused groups to look at the relationships between changes in CFCs and SF_6 with changes in nutrients and dissolved oxygen in the ocean.

The **Earth–Ocean Interactions** group operates a helium isotope laboratory that has analyzed several thousand deep ocean samples for helium isotopes, many of them as part of the World Ocean Circulation Experiment (WOCE) tracer project. One result of WOCE is the most comprehensive description of helium isotope distributions in all the ocean basins. The helium isotope laboratory continues to analyze deep ocean samples to augment this existing tracer database. This data set provides

strong constraints on any model that includes a description of ocean circulation. The group also engages in collaborative ocean exploration and research with NOAA's Ocean Exploration and Research Program office. Currently, their joint expeditions also involve initial collaborations with private sector ocean mining interests for the purpose of understanding and evaluating both environmental and economic drivers for ocean floor mining activity. The group will continue to develop new technologies on undersea cabled observatories on the Juan de Fuca ridge at Axial Seamount to better understand the temporal evolution of this hydrothermal system.

The Earth–Ocean Interactions group will expand its global exploration and research reach by continuing successful partnerships with U.S. and international investigators, and planning initiatives for exploration and research in the Arctic and Antarctic. The group will focus efforts, in partnerships and with the support of other agencies, on the development of a range of both stationary and mobile autonomous technologies that will expand both the geographic and time domain reach of observations while decreasing the program's dependence on ships. Autonomous technology innovation will include development of sensor suites deployed on easily movable portable seafloor ecosystem observatories. Called Mobile Adaptive Seafloor Telemetry (MAST) systems, they will also have the ability to periodically communicate their data and receive instructions via a satellite connection.

Potential oceans and coastal processes research opportunities

Improving technology offers the potential for the development of full coastline inundation (flooding) forecasts within 30 minutes of an earthquake. This will be particularly important for the U.S. West Coast. PMEL is also hoping to conduct engineering projects to take advantage of available bandwidth on commercial telecommunications cables as they become available, to greatly reduce maintenance cost of the observation network and explore technologically driven regional cost reduction opportunities in tsunami detection.

PMEL has identified an emerging need for research to establish and monitor physical, chemical, and biological ocean environmental data in anticipation of increasing ocean mining activity.

Oceans and Coastal Processes Research Evidence of Progress

There are five primary metrics of progress indicating PMEL's success in this area:

- Number and quality of peer reviewed papers published
- Number of repeat hydrography cruises in which PMEL participates
- Number of regions for which PMEL has forecast capability for local tsunamis, including measurement and modeling components
- Number of tested tsunami current forecasts for ports and harbors
- Number of marine resource managers using PMEL environmental data to make decisions on the potential effects of seafloor exploitation

RESEARCH INNOVATION

Research Innovation

NOAA's success is predicated upon cutting-edge research, as well as the development and the delivery of products, tools, and information services to meet the needs of the nation. The first three PMEL goals are focused on developing a research agenda for the oceans. However, accomplishments across NOAA's mission goals are also dependent upon the continued innovative development and use of observing platforms, systems, and information technology to improve data quality and delivery, and lower operating costs. Ongoing investments are necessary to ensure continuity and timeliness of long-term data collection from key regions across the world. Such data are critical to improve understanding and prediction of complex phenomena. Innovative solutions provide modern tools that make valuable information accessible to the science community and the public at large. Further development of software tools and emerging technologies will greatly enhance the public understanding of the Earth system.

One of PMEL's strengths lies in the laboratory's focus on innovation. Beyond PMEL's research groups, there are three groups that focus on innovative development: The Engineering Development Division, Research IT Group, and Integrated Science Data Management Group. These groups work closely with all of the research groups and other NOAA partners to implement new and improved ways of conducting and communicating our science.

Description and motivation

Today, the need to collect more data at a lower cost and to share that scientific information has become the norm across many scientific disciplines. Even "one-off" observations may provide baseline understanding that proves essential for future observing system elements. High-quality observations are irreplaceable for the simple reason that they are unique in time and space and, therefore, can never be measured again. As a mission-driven agency, NOAA is well situated to make sustained large-scale observations. OAR's ocean observation programs increasingly recognize three goals: 1) to support the publication of new scientific results in peer-reviewed journals, 2) to contribute high-quality data to the emerging global ocean/climate observing system, and 3) to transition mature observing systems to operations.

Engineering innovations at PMEL are multidisciplinary in nature and are driven by the formation of teams that integrate research and engineering to solve difficult ocean and atmospheric observing challenges. PMEL Engineering's objective is twofold: 1) to support PMEL field systems with engineering services, and 2) to foster technological innovation by pushing the limits of ocean and atmospheric observing platforms and sensors that advance NOAA research and operations.

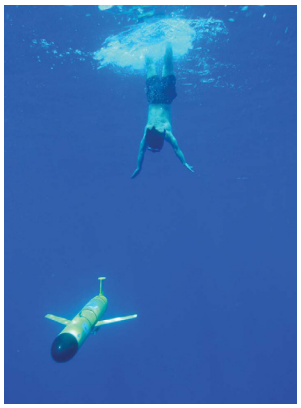
Innovative technologies provide essential support for the science process, from collection of data in the field to analysis, computer modeling, and graphical visualization that leads to scientific understanding, results, and publications.

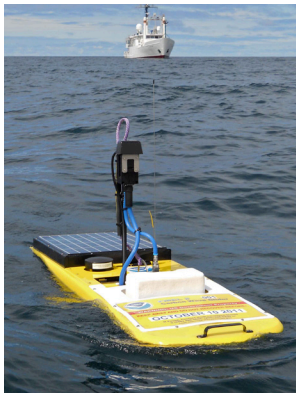
PMEL also foresees the trend of data sharing continuing and growing in the coming decade. Ever-increasing requirements are being placed upon NOAA observation programs to manage and share data more systematically. NOAA leadership is mandating data management plans to ensure the scientific value of data will be preserved over time and made available to users through community agreed-upon standards.

PMEL's plan for the evolution of its data collection and management as a strategic goal will gain significant advantages. Implemented properly, such changes will: 1) enhance scientific productivity by freeing scientists and staff to focus on science challenges, 2) increase the level of professional recognition that scientists receive, 3) secure the scientific value of the data over the long term, and 4) assure scientific results are readily accessible to all stakeholders. Implementing these changes through strategic, evolutionary planning will minimize costs and inconvenience to research projects.

PMEL research data resources are available online at

pmel.noaa.gov/datalinks.html



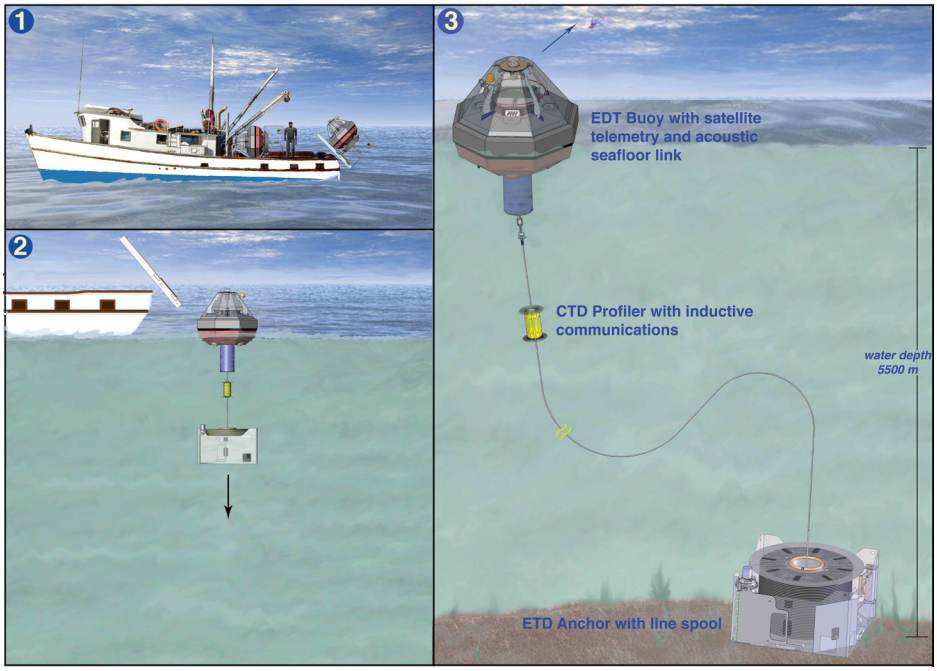


Top to bottom: Slocum glider; Easy-To-Deploy (ETD) buoy; carbon wave glider

Recent significant research innovation accomplishments (2008–present)

PMEL has made significant accomplishments in moored and autonomous observing systems throughout its 30 year history, including the development of the Tropical Moored Buoy Array, the DART® Array, the NeMO seafloor observatory, and the evolving ocean carbon observation network. For example, PICO (Platform and Instrumentation for Continuous Observations) is a product developed at PMEL to improve on conventional oceanographic mooring systems. One version of the PICO is the DART®-ETD (Deep Ocean Assessment and Reporting of Tsunamis, Easy-to-Deploy) mooring. The ETD is an all-in-one buoy, mooring line, and anchor that self-deploys when it is launched into the

RESEARCH INNOVATION



Schematic showing Easy-To-Deploy buoy with self deploying anchor and Profiler device

ocean. The "factory built" design dramatically reduces cost of ownership by reducing the vessel requirements and training of personnel, and by improving safety at sea for moored system deployments. The Prawler (Profiler + Crawler) is a wave-powered subsea instrument that was developed as part of the PICO concept. The Prawler eliminates the need for multiple sensors on the mooring line because the instrument moves up and down the mooring line, collecting real-time profiles of oceanographic properties.

PMEL has been developing unmanned mobile platforms, including vehicles that operate from 3000 m above to 1000 m below sea level. Two Manta Unmanned Aerial Systems (UASs) were adapted to fit a novel marine aerosol sensing package and flown near Svalbard, Norway, to study the effects of black soot on climate. The development included advancing GPS receivers for auto take-off and landing and advances in real-time telemetry via Radio Frequency (RF) and Iridium modems. PMEL has outfitted two off-the-shelf wave gliders (wave-powered autonomous surface vehicles) with pH, CO_2, temperature (T), salinity (S), and dissolved oxygen (DO) sensors. PMEL's so-called Carbon Wave Gliders (CWG) have been used off the Pacific Northwest coast and Hawaii in

Clockwise from top left: Slocum glider; Engineering Development division leader Christian Meinig shows Acting NOAA Administrator Dr. Kathryn Sullivan the electronics of PMEL's Unmanned Aerial Vehicle (UAV), with PMEL Director, Dr. Christopher Sabine in the background; DART® Easy-To-Deploy (ETD) buoy; Arctic Wave Glider; NOAA Ship *Okeanos Explorer*

support of the ocean acidification project. Wave gliders have also been used to further PMEL's Arctic observations in the Beaufort Sea. PMEL has adapted two Slocum underwater gliders with T, S, and DO sensors that have been used in conjunction with the CWG and research ship missions off the U.S. West Coast. A unique internally recording hydrophone package has also been integrated into a Slocum glider and used for missions, studying beaked whales off Hawaii and volcanic activity near the West Mata volcano in the South Pacific.

PMEL has also been proactive in transferring developed technologies to operations and to industry. For example, the TAO and DART® arrays are now operated by the NWS, and several mooring systems and the PMEL $MAPCO_2$ system have been transferred to commercial vendors. These transfers free up valuable PMEL resources for next-generation developments, while making these instruments more widely available to other researchers, generating more observations.

Innovative information technology has enabled PMEL research projects to develop robust processes for data acquisition from varied types of sensors, sophisticated data analyses, and effective communication of scientific understanding utilizing the internet and YouTube.

PMEL has produced important data handling tools, such as the Scientific Graphics Toolkit, Ferret, and the Live Access Server, which are extensively used by the ocean research community. For example, PMEL has used the Live Access Server to help bring the ocean CO_2 observations community together to produce a global collection of surface carbon data, called the Surface Ocean CO_2 Atlas (SOCAT). PMEL has also been a contributor in community-wide efforts to define standards and protocols for scientific data sharing, through leadership in the Climate and Forecast (CF) data conventions and the NOAA-wide Unified Access Framework (UAF) for sharing scientific data, among others.

RESEARCH INNOVATION

Current and future research innovation activities

PMEL's innovation enterprise largely enhances the capabilities of its research groups; in that sense, those science programs serve as the major drivers for the work of the Research Innovation groups. PMEL's well-known successes in innovation have led to successful collaborations with users and developers external to PMEL as well.

PMEL's Engineering Development Division (EDD) takes advantage of the close working relationship between researchers, engineers, and support staff to determine requirements and evaluate the effectiveness of innovative technologies. EDD provides end-to-end engineering services for NOAA Research from design to model studies, prototypes, production, deployment, and piloting. The current emphasis is to sustain, improve, and develop ocean and marine atmosphere observing systems. These systems include moorings, mooring crawlers (a.k.a. Prawlers), unmanned vehicles, gliders, and ship-based systems, along with the sensors and supporting electronics and software necessary for each mission. The primary engineering operational work is focused on high-quality production, cost-reduction measures, and improvement to the features and reliability of mature systems while supporting field projects with EDD field personnel. EDD manages a laboratory-wide scientific equipment pool consisting of $3.5M of commonly used field equipment, such as CTDs, acoustic releases, and autonomous marine vehicles. EDD also maintains a 38´ research vessel, R/V *Hayes*, to support local development and testing operations. Current programs mirror PMEL's scientific research efforts and include approximately 30 major projects.

EDD maintains an agile workforce, crucial to responding successfully to new opportunities. By keeping up with innovations in ocean engineering from related and diverse sectors, EDD can assimilate the best new ideas into potential solutions for emerging PMEL and NOAA research requirements. The group will support and nurture diverse teams of engineers and researchers by building communication feedback loops and encouraging a "learning culture" by supporting advanced training and education. Some research themes exceed EDD expertise and capacity. Choosing appropriate partnerships with organizations that have our shared vision is critical to creating and disseminating ocean innovations.

PMEL's Research IT group was created to provide innovation in the development of advanced, robust information technology. This group explores and exploits appropriate new information technologies to support the wide-reaching mission-driven requirements for observing system data

collection and the further development of innovative techniques for data analysis, visualization, presentation, and dissemination. Research IT promotes dialog and information exchange among PMEL research groups and with its operational Computer and Network Services Division (CNSD).

PMEL research projects and the Research IT group will actively explore ways to build on existing software and expertise in the laboratory, to find cost efficiencies in consolidated pooling or increased sharing of science IT staff and web programmers, consistent branding of PMEL project web pages, a content management system for consistent web pages, and establishing a secure "sandbox" for testing and/or developing innovative technologies. The group will also proactively participate in pilot projects to explore the use of innovative enterprise IT solutions, to support and communicate mission-driven science.

Potential research innovation directions

EDD will maintain and support PMEL operational systems with a flexible and diverse set of instruments, machines, and tools that are creatively integrated into the research mission. Innovation and application to ocean research require looking beyond a five year timeframe. Together with scientists, EDD will identify emerging technologies that may have a major impact on future NOAA research.

Looking forward, the Research IT group seeks to develop and pursue a strategy for consistent management and/or presentation of PMEL data with open and interoperable data access standards.

PMEL's Integrated Science Data Management infrastructure will make PMEL's data available through a uniform set of machine-usable services. With these changes, it becomes possible for the lab to seize a number of significant opportunities: 1) As new observation streams mature at PMEL, the effort required to share the data in real time will be greatly reduced; 2) If NOAA, the Department of Commerce, or Congress demands integrated data services, PMEL may be well positioned to lead other institutions by sharing its technical achievements; 3) With data services that can fuse data from multiple PMEL projects, as well as from outside sources, PMEL science projects have the opportunity to develop science-based web pages of extraordinary richness, featuring PMEL data in a manner that highlights its contributions to the in situ observing system, satellite calibration, and earth system modeling, as well as to scientific publications.

Research Innovation Evidence of Progress

PMEL's progress in meeting its mission, vision, and objectives through Research Innovation can be measured by the following criteria::

- PMEL engineering innovations are aligned with NOAA's overarching goals and are in demand by internal and external partners.
- PMEL technology is effectively communicated in science publications, media, and technology outlets.
- PMEL publishes (and safely archives) a large number of datasets each year.
- A high percentage of PMEL projects serve data through integration infrastructure.

FOUNDATIONAL SERVICES

Foundational Services

The success of PMEL's world-class research and science programs is dependent, in large measure, on the strengths of its foundational support systems operating behind the scenes. These supporting structures provide the essential tools that allow PMEL science programs to prosper. Foundational support at PMEL generates support at OAR, NOAA, Department of Commerce, and Congressional levels; manages budgets in an atmosphere of ever-changing policies and procedures; provides a robust information technology infrastructure to support administrative, scientific, and multimedia requirements; implements and manages human capital requirements, procurements, grants, and financial transactions; prepares and manages interagency agreements with scientific partners; and serves in a plethora of other roles, from securing ship time and ensuring everyone has a desk at which to work to educating the public on the value of PMEL's scientific and engineering accomplishments.

Description and motivation

PMEL maintains an efficient and effective support system that impacts all PMEL programs in significant ways. The objective of the Foundational Services team is to encourage, enable, and facilitate the best science possible for meeting NOAA's mission within federal, departmental, and agency guidelines and directives. PMEL's Foundational Services group is able to adapt to changes in the agency business and regulatory environment while continuing to meet the needs of PMEL scientists and engineers by building and maintaining a technically strong work force.

Foundational Services consists of the following three components: Administrative and Technical Services, Computer and Network Services, and the Office of the Director.

First and foremost, PMEL scientists are our primary customers and, while it is necessary to respond to "taskers" from OAR, Program Offices, and others, our first responsibility is to support the projects' financial, logistical, safety, personnel, and computing needs.

Recent significant foundational services accomplishments (2008-present)

PMEL Foundational Services continues to provide outstanding administrative and IT services to PMEL scientific programs within an ever-expanding array of security and business rules. PMEL recently secured $150K procurement authority in-house to improve effectiveness of procurements, began transitioning responsibility for Western Regional Center campus networking from PMEL to Office of the Chief Information Officer, and consistently closes out annual budgets to within 0.1%.

Annually, a suitable number of sea days on NOAA ships and other vessels is acquired to carry out PMEL's scientific data collection activities, and the Laboratory's scientific productivity is supported by providing functional information technology, publications, multimedia, and web-based services and outreach communication.

About the Director

Dr. Christopher Sabine has been with PMEL since 1999, previously working as Supervisory Oceanographer in PMEL's Ocean Carbon Group before becoming Director of PMEL in November 2011. He has received numerous awards including the Department of Commerce Gold Medal, NASA Group Achievement Award, and the NOAA Technology Transfer Award. He received special recognition from the Intergovernmental Panel on Climate Change (IPCC) for his role in helping the IPCC win the 2007 Nobel Peace Prize, and he is a Coordinating Lead Author on the IPCC Working Group I Fifth Assessment Report.

He obtained his B.S. in Marine Science at Texas A&M University-Galveston before receiving his Ph.D. in Oceanography from University of Hawaii at Manoa in Hawaii in 1992. Prior to joining PMEL, Dr. Sabine was a Research Associate at Princeton University where he was actively involved in the World Ocean Circulation Experiment (WOCE) and the Joint Global Ocean Flux Study (JGOFS) programs, making state of the art ocean carbon measurements.

Current foundational services activities

A table listing many of the activities of the Foundational Services group follows.

Budget Management	Appropriated funding: budget operating plans, allowance advices, funds management and oversight, response to agency "taskers," Continuing Resolutions, quarterly allotments
	Reimbursable funding: MOUs/MOAs, reimbursable project setup, billing oversight, establishment of allotments, carryover, budget formulation, proposal oversight, budget operating plans, budget reports, project lists
Financial Services	Account management
	Detail level transfers
	Invoice payments
Purchasing	Purchase order awards up to $150K
	Regulatory oversight
	Acquisition management guidance
Grants/Contracts	Process all grant activity through Grants OnLine
	Process and fulfill COTR responsibilities for all PMEL contracts
Personnel Management Support	Training
	Recruits, promotions, and awards
Travel	Foreign and domestic, invitational and group travel for sponsored meetings
	Process travel orders and prepare travel vouchers through Travel Manager
Bankcards	Reconcile monthly statements, statement oversight
	Enter reconciled data into CBS
	Audit response
Publications	Provide typesetting/publishing services, edit/proofread manuscripts, maintain digital and print archives
	Manage publications databases and web content, develop online forms

Telecommunications	Maintain phones, voice mail, cell phones, etc.
	Manage Ditco, Stratos, CLS America (Argos) service
GSA Vehicles	Maintain vehicle fleet suitable to PMEL's needs
Graphics	Scan figures, manipulate image files for high resolution publication use; create images, coordinate waterproof printing with GPO
	Design and print posters and images on vinyl for use on equipment and vans; provide handouts and optimized files; troubleshoot file and printing issues
	Prepare items for exhibits and displays
Shipping	Advise, plan, coordinate, and/or execute freight shipments, foreign and domestic—all transportation modes, dockside logistics, Hazmat, customs
Property Management	Maintain PMEL property database; update data in NOAA Sunflower
	Tag and excess property, conduct annual inventory, etc.
	Interact with NOAA Property Office to address problems, issues, regulatory requirements
Security	Oversee and manage PMEL security clearance/ID program for non-feds
	Provide physical security interface with Western Region security staff (site security, visitor procedures, foreign national vetting through NOAA and DoC)
	Provide Common Access Card/ID management
Legal, regulatory oversight	Coordinate/manage FOIA responses
Local IT support	Provide support for process and procedures required for certification and accreditation of all PMEL network and computing resources (enables authorization to operate all PMEL systems)
	Automatically scan all networked systems for security vulnerabilities and patch installation (available for field systems upon request); provide encryption and system imaging services for laptop systems
	Provide central management and deployment of virus protection for Windows desktop systems (similar service available for Mac and Linux systems)
	Implement PMEL IT security policies

Multimedia and Communications	Development of an Iridium RUDICS communication infrastructure to ingest data from field instruments and serve that data to the appropriate PMEL projects
	Provide multimedia support for presentations, meetings, and display; provide a full range of photographic and video services; support and operate PMEL's multimedia facility; maintain video teleconference (VTC) equipment; assist with VTC scheduling, configuration, and facilities
	Disseminate information on the operation of PMEL computing and network resources.
Fleet Services	Conduct strategic and tactical planning with providers (NOAA, UNOLS, contract, and international vessels), identify appropriate vessels, negotiate schedules, prioritizing projects, etc.
Safety	Manage safety, inside and outside of PMEL facilities
Outreach and Education	Post hot items, locally manage press releases
	Respond to queries from public and NOAA headquarters
	Manage/oversee special events on campus and elsewhere, open houses, tour requests, congressional visits, outreach events, etc.
Strategic Planning	Produce annual budget narrative, SEE implementation plans, annual operating plans; track milestones and performance measures on quarterly basis
NEPA (National Environmental Policy Act) Management	
Communicate PMEL science to Congress, DoC, NOAA, and other state/federal agencies	
Provide information on potential funding opportunities to PMEL PIs	
Respond/manage response to OAR, NOAA, DoC, and other requests	

PMEL scientists demonstrate oceanographic measurement tools to middle school kids at NOAA Science Camp (left); Dr. Richard Feely shows data to former Washington State Congressman Brian Baird (right)

Future foundational services directions

As regulations and the business environment change, PMEL's Foundational Services will strive to respond in a way that minimizes impacts on scientific programs. By carefully planning recruitments, encouraging training, and enhancing functional competencies, PMEL Foundational Services will continue to evolve and remain relevant in terms of its ability to meet the needs of the scientific and technical staff. PMEL management will continue networking to gain insights into new opportunities for research, and pursue opportunities to increase funding for the laboratory's research activities.

Longer-term foundational services opportunities

PMEL will position itself to maintain the long-term stability of the laboratory. This means adjusting areas of research focus and personnel based on indications of the relevant future NOAA and OAR goals.

Foundational Services Evidence of Progress

PMEL's Foundational Services progress in meeting its mission, vision, and objectives can be measured by the following criteria:

- IT resources are secured to an acceptable level of risk to allow researchers and staff to carry out the mission of the laboratory
- Public network services are provided for dissemination of PMEL data and information products
- Available technologies that may meet PMEL's IT needs are researched, and appropriate solutions are evaluated and tested for potential deployment within PMEL
- Internal and external deadlines pertaining to data calls and expectations of timeliness of budget activities are met
- Adequate management strategies are applied to plan and expend resources in a manner that contributes to PMEL's strategic goals and objectives
- All funding is managed, distributed, and tracked to optimize use of fiscal resources within Program and Fund Codes.

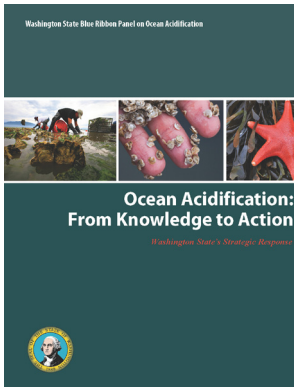
Carbon dioxide buoy before leaving PMEL to be deployed on the waterfront at San Francisco's Exploratorium science museum. Pictured in front: PMEL Director Christopher Sabine; in back (from left to right): Hendrick Miller, John Shanley, Andrew Meyer, Michael Craig, Steve Smith, Lauren Koellermeier, Robert Trask, and Dennis Holzer.

Partnerships

PARTNERSHIPS ARE ABSOLUTELY ESSENTIAL to the success of the Pacific Marine Environmental Laboratory. The laboratory would not be able to function without numerous partnerships at many different levels. Partners act as providers of resources and expertise, and range from those within OAR to the partnerships the lab maintains with the international community. By sharing PMEL's expertise and resources with partners, we increase the productivity of our collaborators on mutually beneficial projects.

OAR Partnerships

OAR primarily conducts research using two mechanisms: laboratories and programs. The laboratories are provided annual base funding to maintain infrastructure and trained staff, and with that funding, conduct a minimal amount of mission research. Over the last few decades, this funding has not increased substantially, particularly as inflation has continued to increase the costs of maintaining the infrastructure components of the laboratory and a core group of scientists dedicated to helping NOAA meet its mission. At the same time, NOAA's mission and responsibilities have continued to increase, with much of the funding for the additional OAR responsibilities going to OAR program offices. The OAR programs typically do not employ field scientists directly, but provide funding for scientists within the OAR laboratories and outside of NOAA to complete the research goals of that particular program. Thus, there is a close relationship between the OAR laboratories, which maintain the scientific expertise to conduct critical research, and the OAR programs, which provide much of the funding to conduct that research. Both partners have important roles to play, and PMEL scientists are dedicated to fostering a good relationship with their OAR program managers. The OAR program offices that PMEL works particularly closely with are the Climate Program Office, the Office of Ocean Exploration and Research, and the Ocean Acidification Program.



Top to bottom: In partnership with Seattle's Space Needle, PMEL placed a CO_2 sensor at the structure's top; report authored by Washington State Department of Ecology, PMEL, and other representatives of the Governor's panel to address ocean acidification in Washington; Indonesian partners and PMEL sign a Memoradum of Understanding

PMEL also works very closely with scientific personnel at most of the other OAR laboratories. Each of the laboratories has a different collection of scientific expertise, but all of the scientists are generally working toward the same set of NOAA and OAR goals. In many cases, productive long-term collaborations are formed within and across the OAR laboratories that enhance the productivity of the scientists.

NOAA Partners

The primary mission of the OAR labs is to conduct research to support the operational line offices of NOAA. In some cases, these line offices (e.g., National Weather Service, National Marine Fisheries Service) provide funding support for specific research products that benefit that particular line office. In other cases, the collaborations are among scientific personnel with mutual interests in a topic of study. For example, PMEL scientists receive funding and work alongside scientists from the National Marine Fisheries Service (NMFS) to conduct research on the impact of climate variability on marine ecosystems in the Bering Sea. This work benefits NMFS by providing valuable information on the controls of fish stocks relevant to their requirements to set fishing limits. At the same time, the collaboration between PMEL's physical and biogeochemical scientists and the large number of fisheries biologists within NMFS helps our scientists to conduct critical research for meeting OAR's Oceans and Coasts goal.

National and International Partners

PMEL works very closely with major partners outside NOAA. The strongest connection is with U.S. universities through the national network of Cooperative Institutes (CIs). Approximately one-half of the PMEL workforce is made up of CI employees. While PMEL interacts with four CIs on a regular basis, our main partner is the Joint Institute for the Study of the Atmosphere and Ocean (JISAO) at the University of Washington in Seattle, with about 80 scientists and technical staff, including 12 PIs who manage their own research

programs as well as collaborate with NOAA researchers. PMEL's Newport facility works very closely with the Oregon State University Cooperative Institute for Marine Resources Studies (CIMRS). PMEL also has staff from the University of Hawaii Joint Institute for Marine and Atmospheric Research (JIMAR) and the University of Alaska at Fairbanks Cooperative Institute for Alaska Research (CIFAR).

As PMEL is currently structured, the CIs are absolutely essential to the productivity and success of the laboratory's research programs. They foster important collaborations with university scientists, as well as provide NOAA with access to a broad range of university facilities and resources that would otherwise be unavailable.

PMEL also relies heavily on partnerships with academic institutions, other government agencies, private industry, non-governmental organizations, the states, and international organizations and governments to increase its scientific productivity. In some cases, these partners are providing funding to PMEL scientists. In other cases, there may be a pooling of resources, such as having a partner provide ship time to deploy PMEL instrumentation in exchange for immediate access to the data and co-authorship on journal articles based on the resulting observations. In many cases, scientific collaborations are established to round out needed scientific disciplines required for interdisciplinary research projects. These scientific partnerships allow PMEL to work with the world's best scientists to complement its in-house scientific expertise. PMEL also works with partners to exploit opportunities to develop paradigm-changing observational platforms. Industry partners may work with PMEL scientists to field test new scientific instrumentation or benefit from technology transfers, which allow production of needed equipment at quantities that are too large for PMEL to produce efficiently.

The sum of all these partnerships allows PMEL to bring in over three dollars of outside funding for every dollar of PMEL base funding, and conduct research that extends many times beyond the levels possible with the PMEL scientific personnel alone. The hundreds of partnerships routinely maintained at PMEL represent a fundamental construct of how the laboratory functions and is a hallmark of the success of this laboratory.

Top to bottom: PMEL's four cooperative institutes: University of Washington's Joint Institute for the Study of Oceans and Atmosphere, University of Hawaii's Joint Institute for Marine and Atmospheric Research, University of Alaska Fairbanks Cooperative Institute for Alaska Research, and Oregon State University's Cooperative Institute for Marine Resources Studies

PMEL's strategic planning process

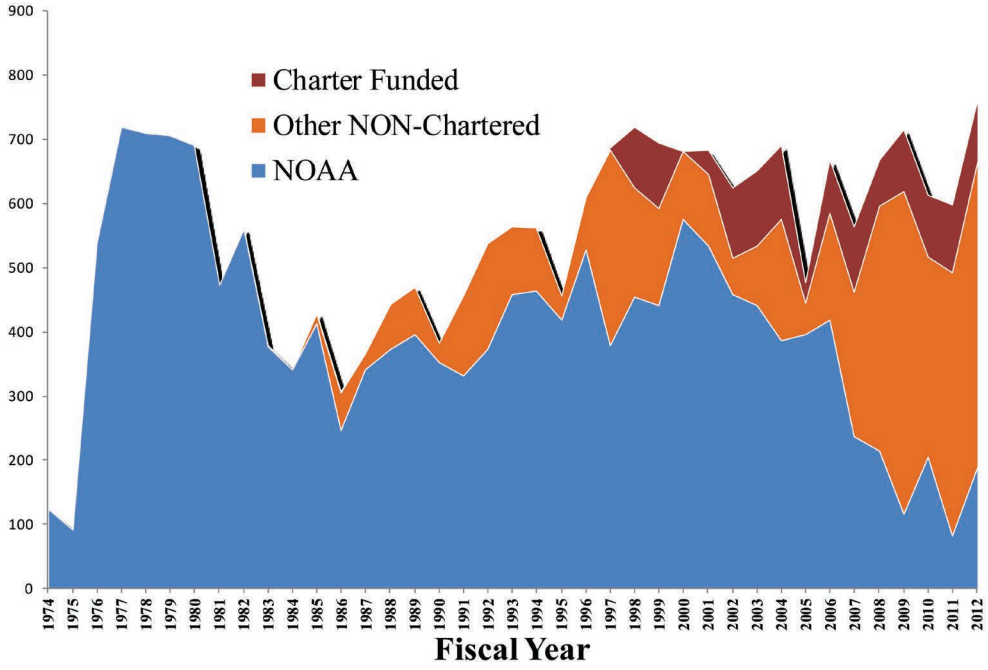
Challenges

PMEL IS A THRIVING, productive laboratory recognized throughout the earth science community as a preeminent research institution. However, there are many challenges that the laboratory must face to maintain that preeminence. The challenges can be summarized into three basic categories: infrastructure, workforce management, and regulatory controls.

Infrastructure

PMEL is primarily a sea-going laboratory. The research conducted by the laboratory has averaged around 600 sea days per year for the last decade. The ability to maintain moored arrays and other at-sea systems currently requires large vessels to cover great distances. Historic ship time on NOAA and UNOLS ships is not as available as it once was due to shrinking fleets and growing operational costs. As government fleets decrease in size, there is more competition for the sea time available after accommodating mandated projects. Ship time challenges within the NOAA Fleet are even more complex than just cost and lack of scheduled time. The NOAA Fleet is evolving, and the Pacific Coast is currently without a NOAA multi-purpose oceanographic vessel. If PMEL research is to maintain at-sea systems on NOAA vessels, projects are going to have to show flexibility not required in the past. In the longer term, OAR and NOAA Leadership must address the challenges that research faces and make informed decisions on the future composition of the NOAA Fleet.

Outside of the NOAA Fleet, the cost of a day at sea is doubling every 10 years, which far exceeds any budgetary ability of the lab to keep pace. PMEL must find partnerships and innovative ways to maintain the observations that have sustained its research through the years. Leveraging expertise for ship time, deploying autonomous vehicles and instruments, and becoming more efficient with the ship time PMEL already has are all part of the solution. There are barely tapped resources available, such as other U.S. government fleets (Military Sealift Command, Coast Guard, NATO), trans-oceanic cable systems, and working more effectively with in-house NOAA partners (NOS, NMFS, NWS) that can also be part of the future, but these will take time to develop and nurture.



PMEL shiptime organized by type of vessel used

PMEL's limited office and laboratory space is another significant infrastructure challenge. PMEL has been very successful over the years at leveraging its base funding to bring in external research dollars. To conduct this research, the Laboratory has had to expand its workforce and laboratory space requirements. These expansions have now exceeded the available space in current facilities. A major priority for PMEL as we move into the future is finding additional office, laboratory, and staging space to conduct research. This will include taking a close look at the current use of space to find opportunities to consolidate and maximize the utility of the currently assigned laboratory space. It also means working with OAR and NOAA leadership to locate or build additional facilities on the Western Regional Center campus to meet the Laboratory's needs.

Other infrastructure challenges include the growing difficulty of maintaining an effective and secure information technology (IT) infrastructure in an increasingly complex world, a growing need for infrastructure support to develop autonomous instrumentation and manage the volume of data these systems will generate in an environment of level or decreasing funding, and the Laboratory's ability to maintain all aspects of its infrastructure as costs increase and budgets decrease.

Workforce Management

PMEL is approaching its fortieth anniversary. Much of its growth in personnel occurred in the last 20 to 30 years. Once they arrived, the vast majority of scientists stay throughout their career. As a result, the mean age of the laboratory scientific personnel has been steadily increasing for the last decade or more. A significant challenge for the Laboratory is the smooth transition of programs as senior scientists retire. It is becoming increasingly important for group leaders to think strategically about the future of their groups and the succession of leadership.

An ongoing challenge in the Laboratory is maintaining a healthy balance of federal and cooperative institute scientists on staff. Both types of personnel have advantages and disadvantages for the laboratory and research groups. Research groups will need to work closely with PMEL leadership to develop a hiring strategy that maintains the long-term stability of the group, particularly in view of the succession of leadership issues previously discussed. PMEL will also continue to work with OAR Headquarters to minimize management decisions that highlight the differences between federal and CI personnel, because highlighting these differences introduces a chasm that detracts from the seamless interaction that the laboratory promotes.

An important aspect of PMEL's workforce management challenges is the difficulty of hiring and promoting personnel within the federal system. Significant challenges exist in the time and level of effort required to recruit and reward good federal scientists. Although hiring is more straightforward with the cooperative institutes, providing salary increases and performance rewards that are comparable to those in the federal system is exceedingly difficult. PMEL will continue to work with NOAA and CI leadership as appropriate to try and address these issues.

One way to address some of PMEL's workforce management challenges is to develop and promote a more vigorous post-doctoral program. Having a steady stream of post-docs that come through the lab exposes young scientists to how the government laboratories function and introduces fresh ideas to the research groups. The Laboratory's close association with several universities can also provide a good source of young scientists as PMEL establishes close partnerships with these institutions. This

exposure can also be a source of new highly talented scientists who could be brought into the federal workforce after they have proven their value to the research groups. Although some groups routinely have post-docs as part of their programs, PMEL leadership will promote an expansion of post-doc opportunities within the lab to the extent possible.

Regulatory Controls

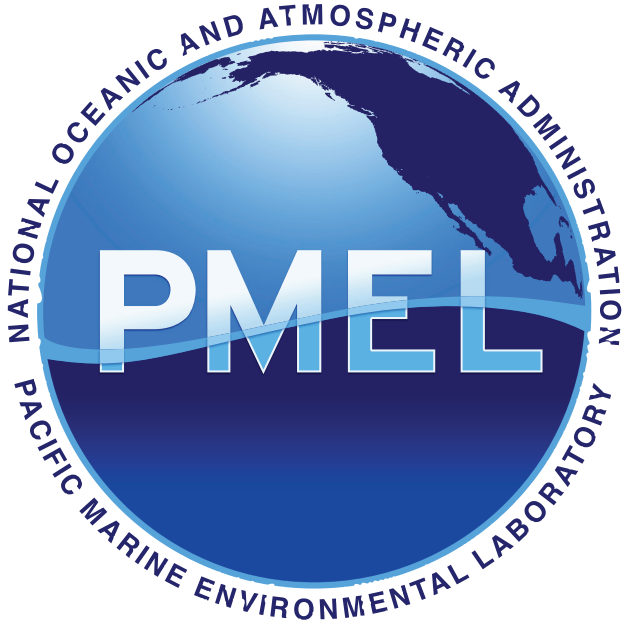
As scientific research becomes more reliant on information technology, and the world in general becomes more connected, cyber security and controls on information flow become increasingly important. Over the last few years, PMEL has seen a significant increase in the number of IT controls passed down from Headquarters. These controls take time and resources to implement, and, more often than not, limit the flexibility of scientists to conduct their research.

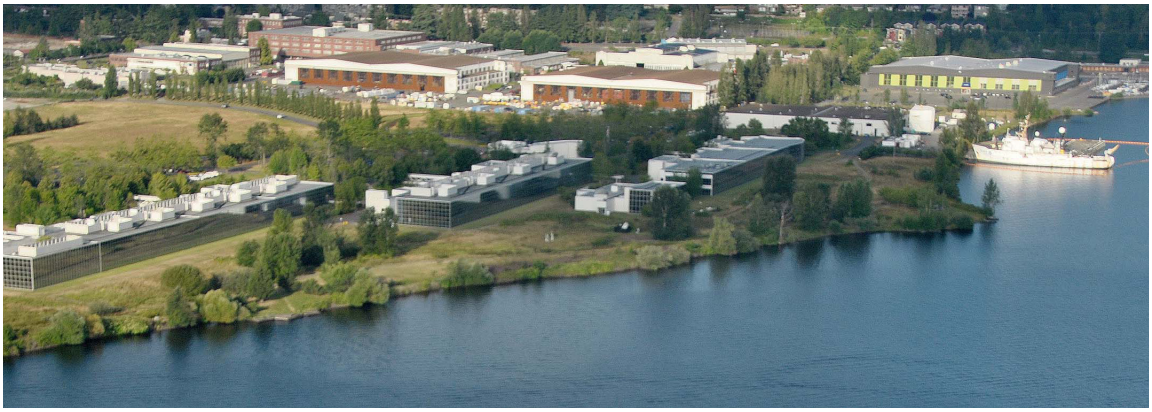
As budgets become tighter, we are experiencing similar challenges with increasing restrictions on how funds are allocated and used. Controls on travel and blanket efficiency initiatives often have unintended consequences for PMEL's ability to conduct its research.

Recent years have also seen a dramatic increase in the number of "taskers," or data calls, from Headquarters that require time and resources to complete, often without any indication as to how the requested information is being used. The same information is often asked by different groups at Headquarters with a requirement that it be packaged differently for each group. These increased regulatory controls never come with funding to meet the additional time and resource requirements, further eroding the operational base of the Laboratory.

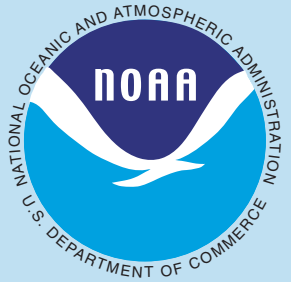
Summary

THE PACIFIC MARINE ENVIRONMENTAL LABORATORY'S core values of integrity, excellence, and leadership have helped us to combine scientific independence with strategic integration and societal relevance. The laboratory is more than a collection of individual scientists; it provides an infrastructure that promotes interaction between researchers with related interests to achieve the NOAA, OAR, and PMEL missions. This document outlines PMEL's 20 year vision and mission statements, as well as a set of 5 year strategic goals to achieve that long-term vision. Much of the laboratory's success is based on its ability to establish and maintain critical partnerships that allow PMEL scientists to leverage its base resources for the benefit of NOAA and the larger scientific community. Although the Laboratory faces many challenges in both the short and long term, PMEL is dedicated to the NOAA mission and optimistic about its ability to continue its preeminent research in the future.





Top to bottom: Aerial view of PMEL headquarters at NOAA's Western Regional Center campus in Seattle, Washington; aerial view of Hatfield Marine Science Center, located in Newport, Oregon; PMEL staff photograph


NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE