The Ocean Observatories Initiative: Establishing A Sustained And Adaptive Telepresence In The Ocean

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The significance of the ocean to our nation and world is evident and has been of increasing concern in recent years. In 2003 and 2004, the U.S. Commission on Ocean Policy and the Pew Oceans Commission issued major reports with sweeping sets of recommendations designed to improve society's use and stewardship of, and impact on, the coastal and global ocean. These recommendations highlight key areas that require continuous investigation to enable timely and sound decision-making and policy development. Global, regional, and local climate change and impacts, coastal hazards, ecosystem-based management and the relationship between the ocean and human health are amongst the critical issues noted in the Commissions' recommendations that point to the need for a sustained, research-driven, ocean observing capability. The ocean science community and society at large are now poised to embark on a novel and revolutionary approach for studying the ocean that calls for the establishment of an interactive, globally distributed and integrated network of sensors in the ocean. The Ocean Observatories Initiative (OOI) is part of a broader trend in the physical and natural sciences toward use of arrays of *in situ* sensors, real-time data, and multidisciplinary approaches to study complex natural systems [1].

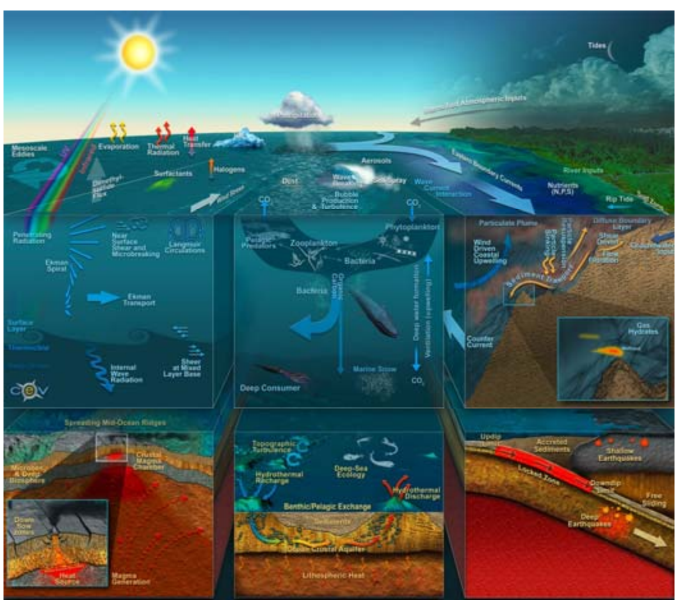

Figure 1. Graphical representation of ocean-earth processes (credit-Center for Environmental Visualization, University of Washington).

The OOI, with its geographically disperse observing assets (Global, Regional, Coastal) has the capability to address key high priority science drivers, generated and identified through numerous workshops, National Research Council reports, and influenced by societal priorities. These science drivers include the ocean carbon cycle and its response to global change, the impact of climate variability on ocean circulation, coastal ocean dynamics and ecosystem response, and the impact of tectonically driven fluid flow on deep ocean ecosystems, the carbon cycle and earthquakes (Figure 1).

For example, controls on the ocean carbon cycle include organic input near the coasts, preferential transfer of carbon dioxide (CO_2)) from the atmosphere to the oceans at high latitudes and methane (CH_4) seeping from the seafloor. Within the Regional Scale Nodes deployed on the Juan da Fuca plate, one node is sited at a convergent plate boundary where methane gas hydrates form on the seafloor, and will be used to understand the interplay of ocean temperature, seafloor bathymetry and plate tectonics on the formation and stability through time of gas hydrates. The Global Scale Nodes are deliberately sited at high latitudes, which are areas where CO_2 input to the oceans is largest, and are complementary to the existing sub-tropical times series data near Hawaii and Bermuda, produced by repeat ship visits over 20 years. With about 30% of anthropogenic CO_2 now in the oceans, high latitude regions are acidifying most rapidly and are both bellweather and test bed for understanding the impacts on the rest of the ocean. Ocean acidification has a strong and often deleterious impact on the ability of ocean plankton and larger animals to take up calcium and CO_2 in their shells. This in turn affects the viability of ocean food webs, including those in the Mid-Atlantic Bight and the Pacific Northwest that support fish stocks such as pollock and salmon. In addition to these ecosystem impacts, the Coastal Scale Nodes will investigate transfer of organic matter across the coastal shelf to the deeper ocean, and the impact of ocean acidification on coastal ecosystems. As an integrated network, the OOI provides a sustained presence in critical areas of the ocean, capable of capturing both short-term events and longer-term processes in their entirety.

The OOI facility incorporates marine infrastructure to observe the ocean over spatial and time scales relevant to a diverse and interconnected environment. The OOI is organized operationally by subsystems: the Global Scale Nodes; the Regional Scale Nodes; the Coastal Scale Nodes; the integrating Cyberinfrastructure; and the Education and Public Engagement Infrastructure [2]. The OOI marine infrastructure will provide the unique new observations that when taken together with existing observations integrate to form the observing capability needed for the high-level science questions facing the ocean science community and society at large. As currently planned, the OOI incorporates a combination of seafloor, water column and surface instruments and infrastructure, powered by seafloor cables or from surface moorings. The nodes of the OOI are designed with many common elements, including core sensors with standardized interfaces to the planned cyberinfrastructure (CI), common mooring designs, and consistent sampling methodologies.

– The Global Scale Nodes will support air-sea, water-column, and seafloor sensors operating in remote, but scientifically important locations. A suite of fixed and mobile assets outfitted with stationary and profiling sensor packages will provide mesoscale observations of processes at critical high-latitude sites for which little or no time series data exist.
– The Regional Scale Nodes will enable studies of water column, seafloor, and sub seafloor processes using the high-power, high-bandwidth capabilities of telecom cable to support robust instrument arrays and deliver data directly to shore.
– The Coastal Scale Nodes will support long-term and relocatable, high space-time resolution observations using profiling moorings and mobile assets (gliders and autonomous underwater vehicles [AUVs]) to understand the physics, chemistry, ecology, and climate science of key regions of the complex coastal ocean.

The OOI's broadly distributed, multi-scale network of observing assets are bound together by an interactive Cyberinfrastructure backbone that will link the physical infrastructure elements, sensors, and data into a coherent system of systems. Linkage through the Cyberinfrastructure would provide data sharing nationally and with

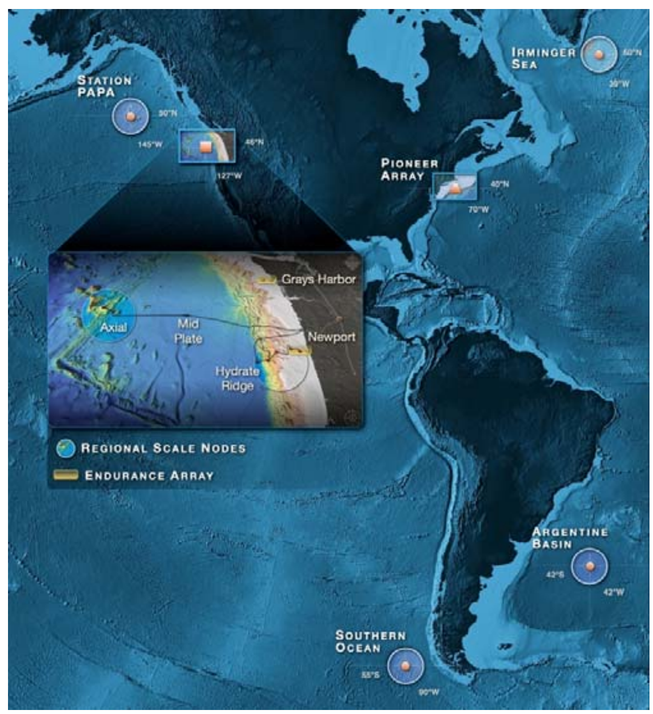

Figure 2. Geographic locations of the components of the OOI, including global moorings in mid and high latitude regions, coastal observatories on the West and East Coasts, and regional cabled nodes on a tectonic plate off the coast of the Pacific Northwest.

other developing systems internationally, and maximize the impact of ocean science for scientists, educators, students and citizens who will never go to sea in ships. The OOI Cyberinfrastructure will enable anyone—scientist, engineer, or educator—to have access to two-way interactivity, command and control, and resources (e.g., instruments, near-real-time data, historic data archives). The Cyberinfrastructure will permit mediation among different protocols, data streams, and derived data products. In accordance with the OOI data policy, calibrated and quality-controlled data will be made publicly available with minimal delay.

The OOI will also enable the effective translation of its capabilities and results into forms more readily usable by students, educators, workforce participants, and decision-makers via an Education and Public Engagement infrastructure. The Education and Public Engagement infrastructure will focus on tools such as web-based interfaces, interactive visualization of data streams, simulations from simplified ocean models, merging with non-OOI databases, virtual participation in OOI science activities, a comprehensive database of education-relevant products with interfaces that are appropriate for cultural diversity, and social networking to enable collaborative workspaces.

The OOI will be constructed and initially operated by an OOI Project Team consisted of a project lead and system integrator, Consortium for Ocean Leadership, and four implementing organizations (IOs): University of Washington for the Regional Scale Nodes, the University of California San Diego for the Cyberinfrastructure, and the Woods Hole Oceanographic Institution with two consortium partners, Scripps Institution of Oceanography and Oregon State University, for the Coastal and Global Scale Nodes. The fourth IO for Education and Public Engagement will awarded in the first year of construction. The OOI is anticipated to be constructed over a period of ~5.5 years, with phased operations beginning during the construction period as individual OOI components are deployed. First open access data streams from elements of the coastal and global moorings are expected within three years of construction start. A fully operational network is anticipated in 2015, with an expected network lifetime of at least 25 years.

A suite of national and international efforts exist that will complement and, in effect, expand the capabilities of the integrated OOI. For example, the OOI will directly contribute to U.S. Integrated Ocean Observing System (IOOS), which will be oriented towards applications and a component of the US contribution to the Global

Earth Observing System of Systems. OOI contributions will include development of new instrumentation and sensors, and novel observational, data assimilation, and data management techniques, as well as advancement of current understanding of ocean phenomena upon which accurate predictions and forecasts. The IOOS network will provide additional context to the OOI network, whose footprint and sensor deployment are determined by research priorities. The cyberinfrastructure underpinning OOI and IOOS will converge over time, enhancing interoperability of these two national systems. The U.S. Monterey Accelerated Research System is helping to reduce risk for the OOI by serving as a testbed, developing and testing new technologies, such as the medium voltage converter and cabled mooring capabilities.

The science drivers motivating the OOI represent not only national ocean research questions, but questions that have global interest and impact. The ability to address science oriented around geodynamics engendered the interest of our Canadian neighbors, such that they are leading the way in instrumenting the northern portion of the Juan de Fuca plate (Neptune Canada). A suite of international seafloor observatories is being planned and implemented in Europe (ESONET), Japan (ARENA), and other areas. European ocean time-series sampling (EuroSITES) shares an interest in the Irminger Sea, and a coordinated effort could link OOI's Global-Scale Nodes to this emerging network. The selection of the OOI global mooring locations represent the cumulative and coordinated interest of U.S. scientists and those from two dozen nations involved in OceanSITEs, an effort dedicated to providing long-term measurements to address questions involving climate change, ecosystem dynamics, carbon cycling, and tsunamis. OceanSITES, the Principal Investigator-led international time-series consortium, provides a framework for building global partnerships focused on open-ocean time-series observatories.

The paradigm shift in ocean research enabled by the OOI and other planned or implemented ocean observing efforts, will open entirely new avenues of research and discovery in the oceans, foster the development and application of advanced technology to ocean science problems, provide exciting new opportunities for conveying the importance of the oceans to students and the general public, and acquire critical information for decision-makers in developing ocean policy [1].

[1] ORION Executive Steering Committee. 2005. Ocean Observatories Initiative Science Plan. Washington, DC, 102 pp.

[2] T. Cowles, et al., *Ocean Observatories Initiative Project Execution Plan*, Consortium for Ocean Leadership, Washington, DC, 2009