Oceanography is evolving from a ship-based expeditionary science to a distributed, observatory-based approach in which scientists continuously interact with instruments in the field. These new capabilities will facilitate the collection of long-term time series while also providing an interactive capability to conduct experiments using data collected in real time.

The U.S. National Science Foundation has funded the Ocean Observatories Initiative (OOI), which over the next 5 years will deploy infrastructure to expand scientists’ ability to remotely study the ocean. The OOI is deploying infrastructure that spans global, regional, and coastal scales. This component will address planar-scale processes using a new network of moored buoys linked to shore via satellite telecommunications. A regional cabled observatory will “wet” a single region in the north-eastern Pacific Ocean with a high-speed optical and power grid. The coastal component will expand existing coastal observing assets in order to study the importance of high-frequency forcing on the coastal environments.

These components will be linked by a robust cyberinfrastructure (CI) that will integrate marine observatories into a coherent system-of-systems. This CI infrastructure will also provide a Web-based social network enabling real-time visualization and access to numerical model information, to provide the foundation for adaptive sampling science. Thus, oceanographers will have access to automated machine-to-machine sensor networks that can be scaled to increase in size and incorporate new technology for decades to come. A case study of this CI in action shows how a community of ocean scientists and engineers located throughout the United States at 12 different institutions used the automated ocean observatory to address daily adaptive science priorities in real time.

Connectivity Between Observations and Models

During its 5-year construction period, the OOI is committed to engaging the ocean sciences community. To fulfill this goal, researchers are developing a useful CI by using a “spiral design” strategy so that the oceanography community can provide input throughout the construction phase. An example of this strategy was conducted in fall 2009 when the OOI CI development team undertook a 3-night observing campaign using existing ocean-observing network in the Mid-Atlantic Bight waters (MAR, spanning offshore regions from Massachusetts to North Carolina) to test OOI CI software. The objectives of this CI test were to aggregate data from ships, autonomous underwater vehicles (AUVs), shore-based radars, and satellites and then make the aggregated information available in real time to five different data-assimilating ocean forecast models. Scientists use these multimodel forecast systems to forecast future underwater glider missions so that they can study quickly developing and fast changing characteristics of marine environments. Scientific interests spanned from the formation of the winter phytoplankton bloom to the role of storms that induce sediment resuspension from the seafloor. The test demonstrated the feasibility of two-way interactivity between the sensor web and predictive models.

Specifically, this effort tested the CI planing and prosecution software, which enables operators to monitor and control individual components within an ocean-observing network. The CI software coordinates and prioritizes the shared resources, allows for the semiautomated reconfiguration of asset tasking, and thus facilitates an autonomous execution of observation plans for both fixed and mobile observation platforms. For this effort, numerical model forecast ensembles, made interoperable by standard Web services, allowed scientists to simulate potential robot trajectories. This was used to guide scientists’ decisions about whether desired target areas could be reached by autonomous vehicles.

For example, the software allows a scientist to determine if any available underwater glider could be redirected to map a surf zone, a region of water that had been identified in an ocean color image within a 24-hour period. The software then could determine the optimal path to map the turbid plume. Such efforts were coordinated through a Web portal that provided an access point for the observational data and model forecasts. Researchers could use the CI software in tandem with the Web data portal to assess the performance of individual scientific missions, through real-time comparisons with satellite, shore-based radar, and in situ robotic measurements.

Testing CI Outputs

To try out the CI’s capabilities, scientists investigated the program’s ability to remotely coordinate the mission of an array of AUVs that were autonomous vehicles on shore in New Jersey used satellite data that were acoustically networked. Scientists coordinate the mission of an array of AUVs so that they can study quickly developing and fast changing characteristics of marine environments. Scientific interests spanned from the formation of the winter phytoplankton bloom to the role of storms that induce sediment resuspension from the seafloor. The test demonstrated the feasibility of two-way interactivity between the sensor web and predictive models.

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Ocean Sciences

Ice Core Drilling

described in the Long Range Drilling Technol-
ogy Plan spans the use of the midwater
Deep Ice Sheet Coring (DISC) drill for deep
drilling projects such as the West Antarctic
Ice Sheet Divide, to shallow drilling endeav-
ors using hand augers, and beyond, to iden-
tification of new drilling tools not yet in
existence. IDDO is aided by the advice of
technical experts in drilling on the Techni-
cal Advisory Board (TAB). At least one member
of the SAB attends the TAB meet-
ings, and vice versa. Both the Long Range
Science Plan and the Long Range Drill-
ing Technology Plan are living documents;

major updates with broad community input
are typically made yearly in the spring.

Communication and Information Exchange

IDPO/IDDO members attend science meetings to
exchange information with the research community. The http://icccdr.org
Web site serves as a resource for the sci-
ence community and the public and as a
gateway for all information on U.S. ice cu-
rring and drilling science projects and to
other resources. IceCdr.Net is an elec-
tronic mailing list for IDPO/IDDO activi-
ties important to the Web pages of the individual cor-
porate centers, and vice versa. Both the Long Range
Science Plan and the Long Range Drill-
ing Technology Plan are living documents;

A Cooperative Approach

The actions of NSF to establish the new polar
networks embodied in IDPO/IDDO for sci-
cific coordination and integrated science/
innovation are a testament to both the productivi-
ty of the interdisciplinary science community and
the importance of ice sheets and glaciers in
pursuing questions on the forefront of sci-
cenes. Updates on the polar networks are writ-
ned yearly in the spring. Information on insti-
tutional reforms” in the 7 September
1990 issue of Science, “Prepare and inspire: K-12 educa-
ion in science, technology, engineering, and
math (STEM) for America’s future.”

Noting that the U.S. lags
behind other nations in STEM education at the elementary and
secondary level, the report, prepared by the President’s Council on
Advancement and Science, also recommends
improving federal coordination and leadership
on STEM education and supporting a
steadily growing movement for shared
misunderstanding of science. The report
also indicates research efforts to improve

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