Ocean Observatories: The U.S. Case

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U.S. National Science Foundation
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In-situ sensors allow us to hear the Earth

MARS
Monterey Accelerated Research System

Bermuda Atlantic Time-series Study (BATS)

Carbon Retention in a Colored Ocean Time Series (CARIACO)

Aloha Cabled Observatory Hawaii Ocean Time-series (HOT)
What is IOOS®?

- An Integrated and Sustained Ocean and Coastal Observing and Prediction System.
- A collaborative framework.
- A network of many different land-, water-, air-, and space-based facilities and technologies:
  - Platforms
  - Instruments and Sensors
  - Telecommunications Systems
  - Computer Systems
- Contributes to the Global Ocean Observing System (GOOS)
A National and Regional Collaboration

17 Federal Agencies

11 Regional Associations
U.S. Data Management & Communications

Other Third Party Users

IOOS/GEOSS

Data Providers

Federal States  Industry  Local  Tribes  Academia  NGOs

Data also returned to providers with processing.

End Users (YOU!)

National Observing Systems
Regional Observing Systems

Data Management  Modeling
All Observing Assets in GOM (Fed/Non-Fed)

Includes: Private, Academic, State, NOAA/NDBC, NOAA/CO-OPS, NOAA/IOOS*

* Includes IOOS Regional Associations
US IOOS®: Delivering New Observing Capability

• >100 Coastal High Frequency Systems
• Uses: SAR; Oil Spill; Harmful Algal Bloom; Ocean Circulation

96 hr: Without HFR
36,000 Km²

96 hr: With HFR
12,000 Km²
The Initial Global Ocean Observing System for Climate
Status against the GCOS Implementation Plan and JCOMM targets

- **Surface measurements** from volunteer ships (VOSclim)
  - 200 ships in pilot project
- **Global drifting surface buoy array**
  - 100% resolution array: 1250 floats
- **Tide gauge network** (GCOS subset of GLOSS core network)
  - 59% 170 real-time reporting gauges
- **XBT sub-surface temperature section network**
  - 81% 51 lines occupied
- **Profiling float network** (Argo)
  - 100% 3° resolution array: 3000 floats
- **Repeat hydrography and carbon inventory**
  - 62% Full ocean survey in 10 years

- **Total in situ networks**: 61%
- **continuous satellite measurements** of sea surface temperature, height, winds, and colour
- **Reference time series**: 48% (58 sites)
- **Global reference mooring network**: 34% (29 moorings planned)
- **Global tropical moored buoy network**: 73% (119 moorings planned)
IOOS®: Delivering the Benefits

Improve Safety

Enhance Our Economy

Protect Our Environment
Protecting Coastal Communities

- Hazard and ecosystem assessment
- Oil and hazardous materials spill response
- Support for coastal management
- Habitat loss management
- Environmental mapping
Safe and Efficient Navigation

- Coastal Data Information Program (CDIP) providing wave observations, nowcasts, and forecasts.
- SCCOOS providing HF Radar surface currents.
- NOAA Physical Oceanographic Real-Time System (PORTS)
Benefits Across Disciplines

Public Utilities

Ecological Management

Weather & Climate

…Water Supply, Agriculture, Commercial Fishing, Energy, Tourism and more…
US IOOS® support to: Energy Sector

**Pre-Construction**
- Avian Studies
- Geophysical/Geotechnical Investigations
- Met Tower Installation
- Wave Sensor Deployment
- Staging Port Development

**Construction**
- Foundation Installation
- Sub-sea Electrical Cable Installation
- Offshore Substation Installation
- Turbine Installation

**Post-Construction**
- O&M Activities; Decommissioning
Industry Participation

The Observing Subsystem
- Buoys, gliders, gauges.

DMAC Subsystem
- Boeing, SAIC, and ASA working with IOOS regions

Modeling and Analysis Subsystem
- Noblis, Inc. helping create inundation forecasting (CIPS)

Partnerships
- Shell and NOAA NDBC

Value-Added Companies
- Surfline; ROFFS; Weatherflow
US IOOS® and US National Water Quality Monitoring Network - example

- Serve observational data according to common OGC/WMO standards
- Feeds multidiscipline prediction models for eutrophication, beach health, invasive sp., etc.
- Integrate watershed “circulation” model with GLOS/IOOS into a Virtual Observatory
The Future of U.S. IOOS

Operational IOOS

– Network of Observations
  - biological
  - physical
  - chemical

– Fully developed Data Management and Communications (DMAC)

– Robust Partnership with Regional Coastal Component

– Models & decision tools at resolution to support coastal communities
What is the OOI?

A *system of systems* that will document, for 25-30 years,

air-sea, water column and seafloor processes, across full ocean depths, using the best technical solutions available.
The Science Context for the OOI

The ocean, which covers 70% of the earth’s surface, can hold 1,100 times more heat than the atmosphere, and does hold 96.5% of the freshwater, is critical to life on earth.

The potential societal impacts of further discovery in ocean science and of variability and change in the ocean are large.
OOI Science Themes

• Ocean-Atmosphere Exchange
• Climate Variability, Ocean Circulation, and Ecosystems
• Turbulent Mixing and Biophysical Interactions
• Coastal Ocean Dynamics and Ecosystems
• Fluid-Rock Interactions and the Sub-seafloor Biosphere
• Plate-scale, Ocean Geodynamics

Additional Science Foci

• Ocean ecosystem health
• Climate change
• Carbon cycling
• Ocean acidification
Baseline Design

- **4 Global** sites
- **3 Regional cabled** sites in the NE Pacific
- **2 Coastal** arrays: Mid-Atlantic Pioneer Array, PNW Endurance Array
- **Each scale** incorporates mobile assets
- **Cyberinfrastructure**: enables adaptive sampling, custom observatory view, collaborative analysis
- **Interfaces for education** users
Coastal and Global Scale

- Pioneer array
- Endurance array
- Global array
OOI assets off PNW coast are unique

Cable provides high power and bandwidth to:
- Instrumented nodes on Juan de Fuca plate
- Full water column moorings at Axial and Hydrate
- 2 moorings of Endurance Array connected to the cable
Cyberinfrastructure

- Creates an interactive ocean laboratory integrated by leading-edge, multi-scalar software tools. Broad access... science, education, and policy.
Scientific requirements underpin the infrastructure design and its capabilities

- Science Question
- Processes to be observed
- Spatial Scale
- Temporal Scale
- Measurements Required
- Sensors Required
- Sampling Requirements
- Site(s) Required for Science
- Experiment Description
# OOI Construction Schedule

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<th>OOI Installation Schedule</th>
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**Global Sites**
- Argentine Basin
- Irminger Sea
- Southern Ocean 55S
- Station Papa

**Coastal Arrays**
- Endurance
- Oregon
- Washington

**Regional Arrays**
- Primary Infrastructure
- Submarine Cable Installed
- Primary Nodes
- Sensors
- Moorings

**Legend**
- I: Installation
- D: Data Flow
- C: Commissioning
- G: Gliders Deployed
- A: AUVs Deployed
- RF: Integrated Observatory Network Release
MARS
Monterey Accelerated Research System

A test bed, cabled observatory
- 9 kW of power for science
- 8 science ports providing 100 Mbit/sec Ethernet and Precision time distribution ~5 uSec
- Deep water - 890 meters
- Accessible - 2 hrs from port
- A comprehensive workflow process – from proposal through development, test, and deployment
- Data routed to science users’ IP address
What is MARS?

MARS is a single "science node" 891 meters below the surface of Monterey Bay, California. The MARS science node has eight ports. Each of the eight ports is equipped with an underwater mateable connector. The science node is connected to the shore through 52-km of subsea telecom cable that carries data and power.
On November 10, 2008, the ROV Ventana connected the main MARS telecom cable’s power and fiber optic links to the MARS electronics node.
While over-fishing was the ocean crisis realized in the 20th century, ocean acidification will be the crisis of the 21st century.

What will be the ecology of the acidic ocean? How will the food chain be altered? What management practices will need to be changed?

FOCE
Free Ocean CO2 Experiment
Dr. Peter Brewer
http://www.mbari.org/mars/general/foce.html
Deployed Dec 9, 2008
Eye-in-the-Sea
Dr. Edith Widder

http://www.oceanrecon.org/research.htm
Deployed January 21, 2009

- Objective is to collect unobtrusive video observations of deep sea animal behavior using red lights, no thrusters
- Low light camera ($10^{-7}$ lux) and LED bioluminescence array
- Connected to significant education and outreach program
MOBB
Monterey Ocean Bottom Broadband

Deployed February 26, 2009

Seismic Observatory

- Only continuously recording subsea seismometer west of the San Andreas fault system
- Hookup to the MARS cable provides data in real time, avoiding use of lithium batteries
DEIMOS EK60
Deepwater Echo Integrating Marine Observatory System

- Upward looking EK60 Sonar 38 kHz; 7° beam
- Examine distributions and fluxes of pelagic animals over long periods
- John Horne, David Barbee, and Dick Kreisberg (Fisheries Acoustic Research /University of Washington).
Acoustic Communications for Deep-ocean Observatories

• Acoustic modem
• Prototype system for connecting remote instruments to a cabled observatory
• Reduce the need for ROV services.
• Deployed Feb 2010
• Lee Frietag, Keenan Ball, and Peter Koski (WHOI)
Station Aloha-Cable Reuse
Hawaii Ocean Time-series (HOT)

- Biogeochemical and physical measurements - temporal dynamics in the North Pacific subtropical gyre

- Spatial sampling:
  - Bottom instruments
  - Mooring with vertical profilers
  - Autonomous nodes
  - AUV with docking station (perhaps from subsurface float)
  - Navigation, communications, timing

![Diagram of Station Aloha-Cable Reuse](image)