The Martha's Vineyard Coastal Observatory

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Abstract. Underwater observatories with real time data and virtually unlimited power transmission capabilities (when compared to traditional oceanographic moorings) are beginning to provide scientists with continuous access to the coastal and even open ocean. The Woods Hole Oceanographic Institution (WHOI) is committed to efforts that are providing this technology to scientists, students, and the general public. As part of these efforts, WHOI is constructing the Martha's Vineyard Coastal Observatory on the south shore of the island in the coastal waters of the Atlantic Ocean. This paper describes the new facility, and in particular its system architecture, as developed by WHOI with support from the National Science Foundation.

1. Introduction

Coastal processes are of crucial societal importance. Engineers and planners long have been concerned with coastal protection, particularly in heavily populated areas where wave attack, set-up, and shoreline erosion threaten coastal structures. Geologists have been struggling to understand how the astonishing variety of coastal geological features form and evolve in response to nearshore processes. Coastal meteorologists are only now beginning to investigate physical processes that are unique to the coastal environment, including the adjustment of the near surface flow to extreme changes in the surface roughness, differential heating, and extensive sea-spray production in the surf zone.

WHOI scientists and their colleagues have been involved in coastal and nearshore field studies ranging from an investigation of respiratory irritations caused by airborne sea-spray generated during outbreaks of red-tide (Woodcock, 1948) to more recent investigations of the flow structure measured in the atmospheric (Mahrt et al., 1998) and bottom boundary layers (Lentz and Trowbridge, 1991), waves in the shoaling (Elgar and Guza, 1985), surf (Chen et al., 1997), and swash (Raubenheimer et al., 1995) zones, and nearshore morphological changes at scales ranging from sand bars (Gallagher et al., 1998) to orbital ripples (Traykovski et al., 1999). To date, none of these studies have taken advantage of Cape Cod and the Islands' southward facing Atlantic coastline because Martha's Vineyard and the Elizabeth Islands protect the shoreline from ocean waves, and thus preclude investigation of wave-driven nearshore and surf zone processes. In contrast, using both coastal research vessels and ground transportation, researchers have easy access to the unprotected southward facing shore of Martha's Vineyard, allowing nearshore processes to be investigated locally.

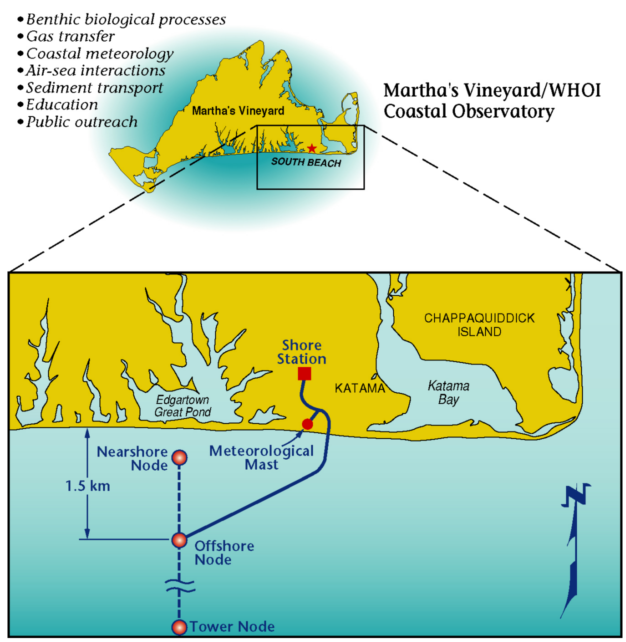

Figure 1. Cable routes for the MVCO. The solid line indicates the present cable. The dotted lines indicate the cable that will be deployed in the near future.

The approximately 25-km long southern shoreline of Martha's Vineyard is nearly straight with homogeneous alongshore bathymetry upwind of the predominantly southwesterly winds from the open ocean. Waves and currents cause sediment transport and beach erosion that results in an average of 2-3 m of shoreline retreat each year. The orientation of the shoreline allows the effects of winds, waves, and currents in mild and severe conditions to be observed, and thus provides a natural laboratory to study nearshore hydrodynamics, sediment transport, biological and benthic processes, gas transfer, aerosol physics, and coastal meteorology.

To take advantage of this shoreline and its research opportunities, WHOI is building the Martha's Vineyard Coastal Observatory (MVCO) near South Beach in Edgartown (Edson et al., 2000). The MVCO is nearing completion and is expected to be operational by the summer

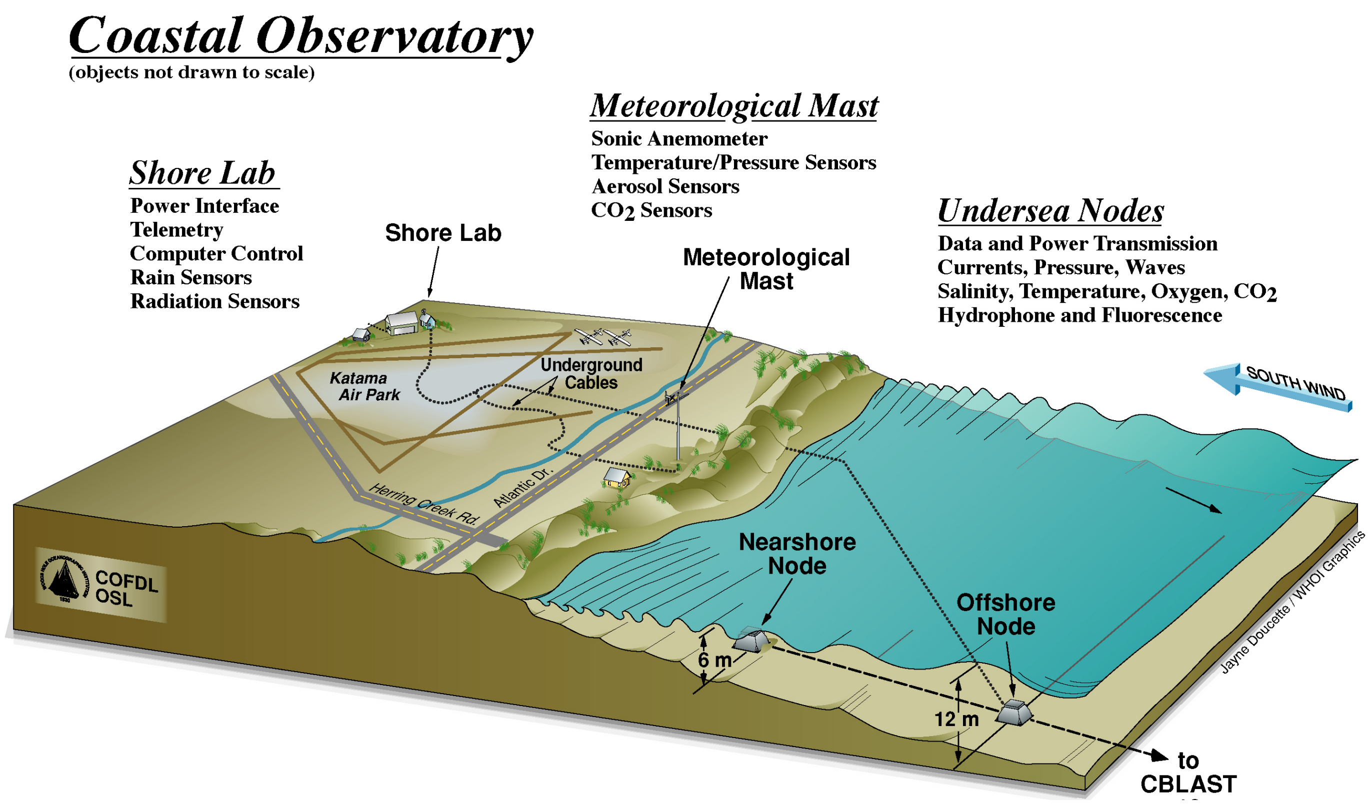

Figure 2. Schematic showing the various components of the MVCO. Instruments at the shore lab and on the meteorological mast are operational. The offshore node will be operational by the summer of 2001.

of 2001. The project was initiated by scientists in the Coastal and Ocean Fluid Dynamics Laboratory (COFDL) at WHOI, who will use the observatory to monitor coastal atmospheric and oceanic processes. Specifically, the observatory is expected to:

- Provide a local climatology for intensive, short duration field campaigns.
- Further facilitate regional studies of coastal processes by providing infrastructure that supports easy access to power and data.
- Provide a reliable system and rugged sensors that allow opportunistic sampling of extreme events.
- Provide continuous long term observations for climate studies.
- Provide a means for public outreach and educational programs.
- Provide a component of a larger network of observatories and platforms for real-time observations and initial conditions for ocean and atmospheric models.

The MVCO includes a small shore lab located 1.5 km inland, a 10-m meteorological mast 50-m from the shoreline, and a subsurface node mounted on the bottom in 12-m water depth, 1.5 km offshore as shown in Figure 1. The meteorological and subsea instrumentation is connected directly to the shore lab via an embedded electro-optic-power cable. The core set of instruments at the meteorological mast will measure wind speed and direction, temperature, humidity, precipitation, CO_2, solar and IR radiation, and momentum, heat, and moisture fluxes. The core oceanographic sensors at the offshore node will measure current profiles, waves, temperature, salinity, turbidity, fluorescence, CO_2, dissolved oxygen, and bottom stress.

Besides the core set of instruments, the offshore node and the meteorological mast will act as "extension cords" into the coastal environment because they will allow connection of a wide range of instruments for prolonged deployments. The node architecture is designed to allow simple integration of any sensor by the implementation of a standard guest port configuration. Each guest port will provide a flexible DC power interface and a choice of data interfaces, including Ethernet, RS-232, and RS-422 communication options. The observatory will be connected to the WHOI network via a high-speed network communications link. A web-based, graphical user interface provides the user with total control over his assigned port, allowing him to power on and off his sensor system at will, and continuously monitor its status from anywhere in the world.

The system is designed to be expandable, with spare power and fiber-optic connections provided for these future nodes. For example, two other offshore nodes are planned for the near future; a nearshore node just outside the surf zone at 6-7 meters depth and another located 5 km from shore at 20 meters depth as shown in Figures 1 and 2. The latter node will provide power and data access to instruments deployed on an air-sea interaction tower that will span the coupled boundary layers from the ocean bottom to a height of 10-m above the sea surface.

2. Overall Description

The MVCO is located along the southern coast of Martha's Vineyard. This coastline is characterized by a 25 km long, south-facing beach, which provides ideal exposure for the predominant winds from the southwest. It is also routinely exposed to severe coastal storms during the winter months that are of particular interest to the scientists involved in this project. Therefore, the MVCO will provide a unique setting on the East coast to investigate coastal processes that will complement the research being conducted at the existing observatories along the eastern seaboard shown in Figure 3.

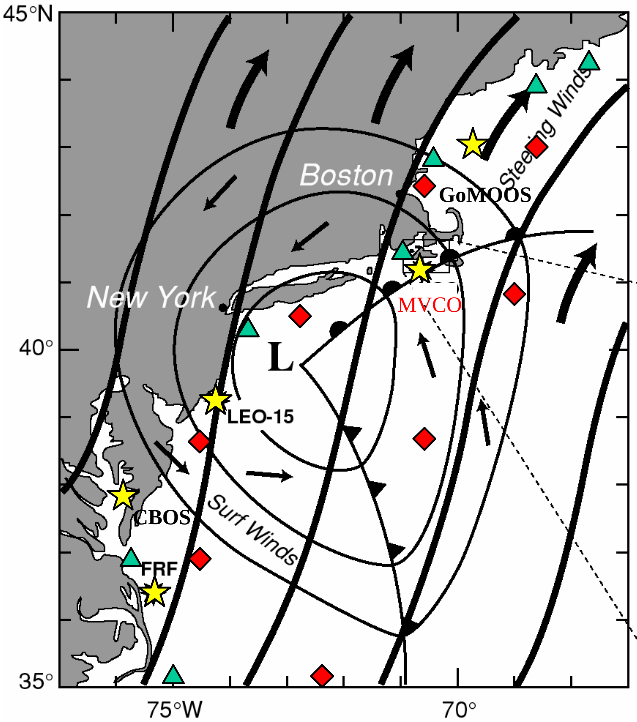

Figure 3. Some of the coastal observatories and observing systems along the northeastern seaboard (yellow stars). Also shown are the existing NDBC buoys (red diamonds) and CMAN stations (green triangles).

2.1 Shore Laboratory

WHOI has leased space at the publicly owned Katama Air Park, which is a grass strip airfield located in Edgartown, MA, and has constructed a small, unmanned shore laboratory at the site. The airfield provides a safe, secure location for the shore-based laboratory with proximity to power and telecommunication services. The shore laboratory is the termination point for the fiber-optic/power cable. It contains the computer systems and power supplies necessary for controlling the sensors and logging the data locally via these cables. A 10-meter mast extending above the laboratory holds sensors to measure solar and infrared radiation, rainfall rate, temperature, humidity, wind speed and direction. We currently plan to connect the shore laboratory to WHOI via a wireless 11 Mbps data link with a 56 Kbps leased-line as back-up. The laboratory includes an automatic backup power generator to continue operation of the entire system during power outages. All computer and equipment operation will be monitored remotely from WHOI.

2.2 Cable Description and Installation

The main cable design consists of six AWG13 copper power conductors, with high voltage insulation. Ten single-mode optical fibers are contained in a loose-tube assembly at the center of the cable. The core is jacketed with a polyurethane sheath, and is protected by two layers of cross-laid armor and a polyethylene outer jacket. The cable has a maximum working load of 1,573 Newtons, which is well above the anticipated loading experienced during the cable installation process.

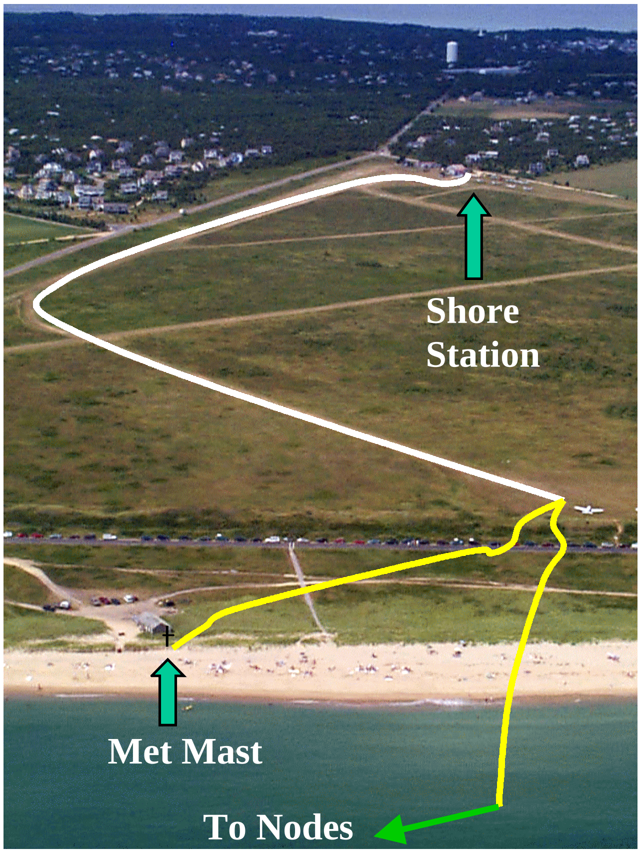

Figure 4. The various techniques used in cable burial: White – traditional trenching, Yellow- directional drilling, Green – jetted trench.

The cable was buried from the shore lab to the plane parking area using traditional techniques along the airfield runway. The route is indicated by the white line in Figure 4. WHOI then utilized directional drilling technology to cross the beach area with the least environmental impact. The drilling operation, accomplished in May, 2000, provided a sleeved hole, 626 meters in length, between the airfield and the seafloor (to approximately 300 meters off of the beach). A second hole (206 meters in length) was drilled to provide a cableway to the meteorological sensor mast, located on the beachfront. These pathways are given by the yellow lines in Figure 4.

The seafloor cable has been buried approximately 1 to 1.5 meter below the seabed, from the offshore end of the drilled section (i.e., the green arrow in Figure 4) to the location of the offshore node. The cable was buried using a technique that relied on high pressure water jets that created a trench for the cable to fall into as the operation moved along the cable route. As shown in Figure 1, the cable route was chosen to place the offshore node closer to the center of the island's coastline. This positions the sensors in simpler bathymetry at a location that is upwind of the meteorological sensors for southwesterly winds.

2.3 Seafloor Node

The MVCO will initially include one seafloor node, with two more planned for the near future. The seafloor node will be constructed on a pedestal base that is permanently jetted into the seabed at the offshore site. The pedestal will support the instrument frame at a distance of approximately 0.5 meters above the bottom, in order to allow sand to flow through without accumulating within the frame. The node will contain twenty "guest ports" which will be available to the users via a simple, 8 pin underwater matable connector. Each port provides electrical connections for two isolated DC power supplies (12V and 24V) and a remotely programmable data interface allowing Ethernet, RS-232, or RS-422 connections. The seafloor nodes will be equipped with a core set of sensors including an Acoustic Doppler Current Profiler, Acoustic Doppler Velocimeters, an altimeter, and oceanographic sensors to monitor a wide range of water properties including temperature, salinity, turbidity, and dissolved gases.

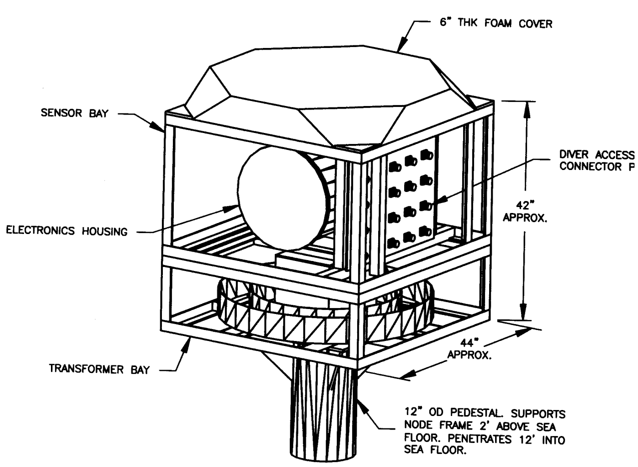

Figure 5. MVCO seafloor node.

Figure 5 shows the layout of the offshore seafloor node. The electronics housing contains all the power and telemetry circuits. The guest port connectors will be easily accessible by divers. The neutrally buoyant instrument frame, which will be the upper section of the node, will be easily recovered for routine maintenance and upgrades. The lower frame houses an oil-filled transformer box. The transformer box contains three step-down transformers. Diver matable fiber-optic connectors mounted on the transformer box provide access to the main cable's optical fibers. When the upper instrument frame is recovered, divers detach the fiber-optic and power connectors, leaving the transformer box on the pedestal.

2.4 Meteorological Sensor Mast

A meteorological sensor mast (10 meters tall) is located near the beachfront, just behind the present location of the dunes. The mast rises approximately 8 meters above the dunes and 13 meters above mean sea level. This height places the sensors above most of the flow distortion induced by the changing bathymetry (Jensen and Peterson, 1978). Investigations will be conducted to quantify and remove the remaining effects of flow distortion that are present at the sensor locations atop the mast.

The mast has a core set of fast response sensors that include a 3-axis ultra-sonic anemometer, which also provides fast-response temperature measurements derived from its sound speed measurements, and an infrared hygrometer/CO_2 sensor. Additional sensors will measure the mean wind speed and direction, relative humidity, temperature, pressure, and CO_2 levels in the atmosphere. The fast response sensors will measure the exchange of momentum, heat, and mass between the atmosphere and ocean when winds are onshore. The mast also includes a number of extra guest ports that will be available for general use.

3. Power System

There are six AWG13 power conductors in the seafloor cable, with insulation ratings of 2500V. These six conductors provide for three independent power circuits offshore. Initially, only one of the three circuits will be utilized for power to the seafloor node. The other two circuits will be reserved for the future offshore nodes. Each circuit will be capable of providing 4 kW of power to a distance of up to 5 km from shore. Power will be transmitted from shore at 1,500 Vrms, using single phase 60Hz AC.

Power is derived from the local utility, with generator backup and a Uninterruptible Power Source (UPS) to maintain seamless power transfer during local outages. The automatic generator/UPS combination will maintain data collection capability even during severe storm events. At the seafloor node, the high-voltage AC will be stepped down to 240VAC using a transformer. This 240VAC supply will be fed into the main electronics bottle where it will be converted to regulated DC power at each guest port interface using internal AC/DC converters. These converters supply isolated 12VDC and 24VDC power at up to 100 watts at each of the guest ports.

Power supply isolation will be maintained between ports, allowing for independent ground fault sensing of each port. Each guest port will be monitored and controlled by a local Motorola 68HC11 microcontroller. This controller can connect or disconnect the AC input for that port, and can power on or off the two DC outputs as well. In addition, it monitors voltage, current and ground fault status for both the 12 VDC and the 24 VDC power supply outputs. The port will be configured to automatically shut down power to a guest port in the event that a fault is detected, and thus prevent further damage.

4. Networked Data Telemetry

The seafloor node electronics and the met mast data telemetry electronics are essentially identical. Each site will be connected to the shore laboratory by a 1 Gigabit/sec Ethernet fiber-optic trunk line with AC power. A Cisco Systems Ethernet switch provides 24 10/100 BaseT Network connections at the nodes. The same Ethernet switch will be used at the shore laboratory. Each switch contains a single-mode fiber-optic networking module as well as the 24 RJ-45 twisted pair connectors. The buried fiber-optic cables will be connected directly to the Cisco Ethernet switch to transmit the networked data at 1 Gbps to and from the shore laboratory.

Because all of the sensor nodes will be network connections, all nodes will be connected together on a common Ethernet network inside the shore laboratory at the Katama Airpark. This network will be connected to the global Internet in two ways. To provide the highest possible bandwidth to users working locally at WHOI, a direct connection to the WHOI campus network is desired. Currently, an 11 Mbps spread spectrum radio link is planned as the primary communication link between the shore laboratory and WHOI. A 56 Kbps leased line has been installed for use as a preliminary communication link, and will serve as the back-up to the radio link, when it is installed.

We expect that many of the scientific instruments connected to the guest port will initially utilize asynchronous serial communication interfaces such as RS-232 to control the instruments and collect data. Therefore, a method was needed to integrate multiple serial ports into the Ethernet data system. This function will be provided by a Cisco Systems serial communications server, which supplies 16 serial ports for distribution among the various user ports. The communications server has an Ethernet interface that connects to one of the network ports on the Ethernet switch. It allows direct IP, telnet, or COM-port redirection access to any of its serial ports, thus allowing users to access their underwater instrument from anywhere on the Internet.

5. Guest Port Interface

At each node there will be a number of identical guest ports. The main seafloor node will support 20 ports, and 10 ports will be provided at the met-mast. Each port is assigned an 8-pin underwater matable connector as shown in Table 1.

The data lines will be remotely programmable for one of three interfaces: 10/100BaseT Ethernet, RS-232, or RS-422. Baud rates up to 115 kbps will be supported on the serial interfaces. The data common (RS-232 and RS-422 only) is connected to the 12V Common pin. The Ethernet interface is connected to the Ethernet switch, which in turn routes all data traffic over the fiber optic cable to the shore lab, where it will be routed to WHOI and the World Wide Web.

If the user elects to use RS-232 or RS-422, these serial ports will be accessible via the Ethernet using TELNET, custom software (direct IP), or commercial COM-Port redirection software, the latter of which WHOI will provide to the users. The COM-Port redirection software allows users to run existing applications that normally connect to a local COM-Port. The software automatically redirects the transmitted and received messages to and from the remote port, over the Ethernet. For low-speed serial ports this will even work across the Internet. However, we expect that most users will store data locally and access this data remotely.

Table 1. Pin Assignments for the Guest Ports

Pin 1	12V + (100 Watts max)
Pin 2	12V Common (Data Common)
Pin 3	24V + (100 Watts max)
Pin 4	24V Common
Pin 5	Data TX+
Pin 6	Data TX-
Pin 7	Data RX+
Pin 8	Data RX-

6. Conclusions

The Martha's Vineyard Coastal Observatory is currently being installed off of the south coast of the island to monitor coastal atmospheric and sub-sea conditions. This observatory will provide scientists with direct access to the coastal environment and allow continuous measurements of environmental parameters under all conditions, including the severe storms of the North Atlantic. The observatory has been designed to be in operation for a minimum of 25 years, with minimal maintenance. Generic user guest ports provide simple connection of all types of instrumentation using conventional power and data interfaces. Spare power conductors and optical fibers in the main cable provide for significant expansion capability for future offshore nodes, AUV docking stations, and special experiments.

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