The Martha's Vineyard Coastal Observatory: A Long Term Facility for Monitoring Air-Sea Processes

Thomas Austin, James Edson, Wade McGillis, Chris von Alt, Mike Purcell, Robert Petitt, Marguerite McElroy, Jonathan Ware, Roger Stokey

Woods Hole Oceanographic Institution
Department of Applied Ocean Physics and Engineering
Woods Hole, MA 02543
email: taustin@whoi.edu

Abstract- **The desire to gain a better understanding of coastal processes over the past decade has led to an increased focus on coastal research in the scientific community. As an estimated 50% of humanity lives within 100 miles of a coastline and as national defense initiatives shift towards littoral regions, this interest in coastal processes will continue to grow. The south shore of the island of Martha's Vineyard is an ideal location for the study of the near-shore environment, due to its uninterrupted, south-facing beach with open ocean exposure. This area is frequented by all types of weather systems, including winter storms, hurricanes, and calm summer conditions. The seasonal variations provide a wide range of biological activity as well. To support long-term research in these areas, the Woods Hole Oceanographic Institution (WHOI), supported by the National Science Foundation, is currently developing and installing a coastal observatory system on the south shore of the Vineyard in Edgartown, MA.**

The Martha's Vineyard Coastal Observatory includes two sub-sea sensor platforms connected to shore via a buried fiber-optic cable, a land based meteorological sensor mast located near the waters edge, and a shore laboratory. The observatory is connected to the WHOI network via a high-speed network communication link, thus allowing global access to the observatory via the Internet. The normally unmanned shore lab includes more meteorological sensors, as well as the power and telemetry components of the system. Buried cables route from the shore lab to the sensor mast on the beach, and to the seafloor nodes. The main seafloor node is on the seabed at 14 meters depth, approximately 2 km offshore. A satellite node is located very near the beach, in approximately 7 meters water depth. The system architecture is designed to allow simple integration of any sensor by the implementation of a standard guest port configuration. Each guest port provides a flexible DC power interface and a choice of data interfaces, including Ethernet, RS-232, and RS-422 communication options. 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.

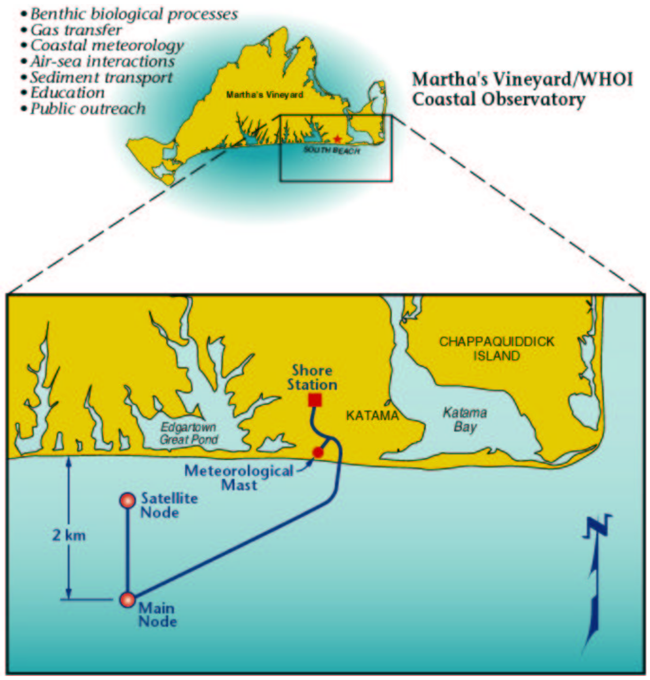

Figure 1: The Martha's Vineyard Coastal Observatory

INTRODUCTION

Ocean Observatories with real time data and power transmission capabilities provide scientists with reliable and continuous access to their instruments. While similar observatory systems are common over land, the difficulties and risks associated with long-term sub-sea operations have limited the numbers of underwater observatories to but a few. Recent developments in this field, combined with an increased interest in the shallow water environments, have begun to fuel a number of new installations. One of these, the Martha's Vineyard Coastal Observatory (MVCO), is currently being developed by the Woods Hole Oceanographic Institution (WHOI), with support from the National Science Foundation. Located about 2 kilometers off the south coast of Martha's Vineyard, this observatory will provide access to the shallow water environment near a south facing, open ocean beach. The project was initiated by the Air-Sea Interaction Group in the Coastal and Ocean Fluid Dynamics Laboratory (COFDL) at WHOI, who will use the observatory

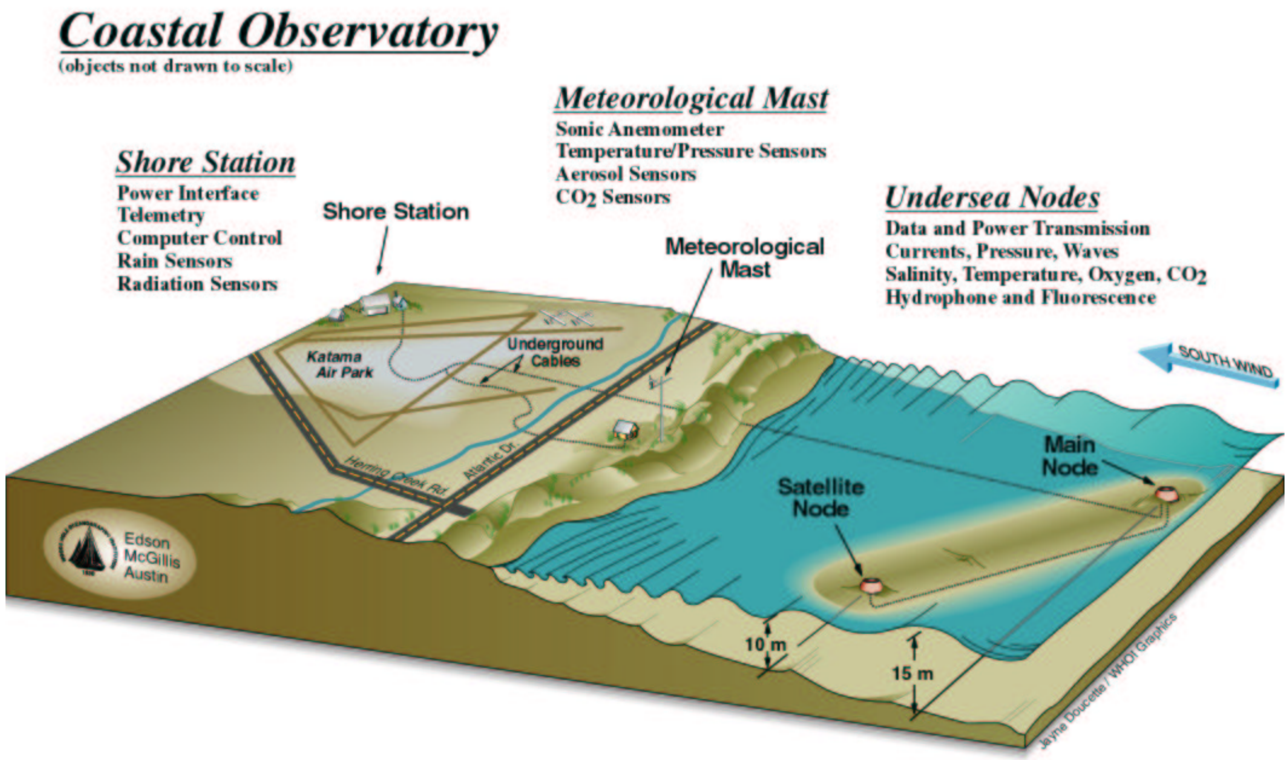

Figure 2: MVCO Overview

to monitor coastal atmospheric and oceanic interaction. Other scientists in COFDL will use the observatory to study beach erosion, sediment transport, and coastal biological processes [1]. In addition, the observatory provides simple, generic power and data interfaces which will be made available to any scientist interested in connecting instruments for long or short term experiment. Once connected, the scientist will have direct access to his or her instrument from anywhere in the world via the Internet.

In 1997, WHOI developed and installed a similar observatory (LEO-15) for the Rutgers University Institute of Marine and Coastal Studies. The MVCO design integrates a great deal of the concepts, technology and experience gained by the successful LEO-15 installation [2].

SYSTEM DESCRIPTION

This observatory will consist of a sub-sea "main-node" located approximately 2 km offshore in 14.5 meters water depth. It will be connected to a shore-based laboratory by a buried cable. The node will serve as a connection point for numerous scientific instruments used for long term environmental monitoring of the coastal ecosystem. A second "satellite node" will be installed very close to the beach in approximately 7 meters of water depth. In addition to the seafloor nodes, there will be a shore-based mast containing a suite of meteorological sensors to monitor the atmospheric conditions at the site. Scientists are most interested in the correlation of the sub-sea data with the local atmospheric data, to gain a better understanding of air-sea and sea-bottom interaction processes. Figure 1 shows the overall plan for the cable route.

The location for this observing system is directly offshore of a long, straight south-facing beach providing ideal exposure to severe coastal storm events that are of most interest to many scientists. WHOI has leased space at the publicly owned Katama Airfield (which is a grass strip airfield for small planes) 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.

Shore Laboratory: This structure will contain the computer systems and power supplies necessary for controlling the sensors and logging data locally. A short mast extending above the laboratory will hold sensors to measure solar and infrared radiation (a measure of cloudiness), rainfall rate, temperature, humidity, wind speed, and wind direction. Normally the laboratory is unmanned, with control and data signals transmitted between WHOI and the observatory via a network-based radio link with leased-line back-up. The laboratory will include 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.

Figure 3. Shore Laboratory

Cable Description: The main cable design consists of six AWG 13 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 armor wire, with an overall polyethylene outer jacket. The cable has a maximum working load of 7,000 lbf (1,573 Newtons) which is well above the anticipated loading expected during the cable installation process.

The satellite cable is a slightly different design, incorporating two twisted-shielded pairs that support serial data rates to the satellite node up to 19,200 bits/sec. Two AWG 12 power conductors can be used for AC or DC power transmission, and four single mode optical fibers are included for the planned future upgrade full network capability. It also includes steel armoring and an outer polyethylene jacket.

Figure 4: Directional Drilling of Cableway

Cable Installation: In order to cross the beach area with the least environmental impact, WHOI utilized directional drilling technology (See Figure 3). The drilling operation provided a sleeved hole, 615 meters in length, between the airfield and the seafloor (to approximately 300 meters off of the beach). In addition a second, shorter hole (225 meters in length) was drilled to provide a cableway to the meteorological sensor mast (met-mast), located on the beachfront. The seafloor cable will be buried 2 meters below the seabed, from the offshore end of the drilled section to the location of the seafloor node (a distance of approximately 4.5 km).

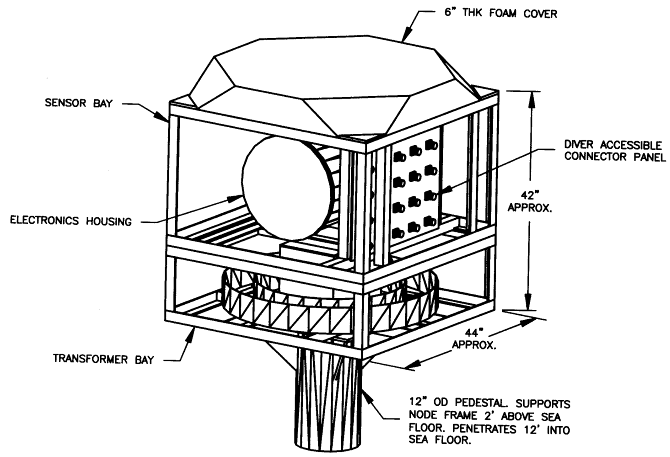

Figure 5: MVCO Seafloor Node

Seafloor Nodes: The MVCO will initially include two seafloor nodes. Both nodes are constructed on pedestal bases, permanently jetted into the seabed. The pedestal supports 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 main node, at the deeper location of 14.5 meters, will contain twenty "guest ports". Each guest port is made available to the user via a simple, 8 pin underwater-matable connector which provides connections for two isolated DC power supplies 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 (RD Instruments Workhorse ADCP), Acoustic Doppler Velocimeters (SonTek ADV), and an oceanographic sonde (YSI 6600) which monitors a wide range of water properties. Figure 4 shows the construction of the main seafloor node. The electronics housing contains all the power and telemetry circuits. The guest port connectors are easily accessibly by divers. The instrument frame, which is the upper section of the node, is easily recovered for routine maintenance and upgrades. The lower frame (see Figure 4) contains 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.

Meteorological Sensor Mast: A meteorological sensor mast (8 meters tall) is located on the beachfront, in order to accurately measure marine atmospheric variables that have been transported over the water to shore. The met-mast has a core set of sensors that include a 3-axis ultra-sonic anemometer/thermometer (Solent R3) and an infrared hygrometer/CO_2 sensor (LI-COR 7500), as well as mean wind speed, wind direction, relative humidity, temperature, pressure, and CO_2 sensors. The met-mast also includes a number of extra "guest ports" which are available for general use.

Figure 6: Meteorological Mast

Power and Telemetry: Power to the seafloor nodes is transmitted from shore at 1,500 Volts, using single phase 60Hz AC, providing 4 kW of available power offshore. 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 is stepped down to 240 VAC using a transformer. Each guest port contains internal AC/DC converters, which make isolated 12 Volt and 24 Volt DC power supplies from the unregulated AC source. These power supply outputs are provided at the guest port connectors. Power supply isolation is maintained between ports as well, allowing for independent ground fault sensing of each port. Power problems on one port do not affect any other ports. It is interesting to note that only two of the six available conductors in the main cable are currently being used, leaving two spare single phase AC power circuits from shore (4 kW each), which are available for special projects or future expansion.

The seafloor node electronics and the met mast electronics are essentially identical. Each is connected back to the shore laboratory by a 1 Gigabit/sec Ethernet Fiber-optic trunk line, with AC power. At each node there are a number of identical guest ports. The main seafloor node will support 20 ports, and 10 ports will be provided at the met-mast. Initially, the inshore satellite node is essentially an extension of one port from the main node. Eventually, WHOI plans to upgrade the satellite node to full capability, similar to the main node. Each port is assigned an 8-pin connector (Impulse IE8F underwater-matable at the node). The pins are arranged as follows:

24V + (100 Watts max)
24V Common
12V + (100 Watts max)
12V Common (Data Common)

Data RX+
Data RX-
Data TX+
Data TX-

The power supplies are electrically isolated from each other and from all other ports. The data lines are remotely programmable for one of three interfaces: 10/100BaseT Ethernet, RS-232, or RS-422 (RS-232 and RS-422 baud rates are supported up to 115 kbps). The data common (RS-232 and RS-422 only) is connected to the 12V Common pin. The Ethernet interface is connected directly to the WHOI network, and from there to the World Wide Web. If the user elects to use RS-232 or RS-422, these serial ports are accessible via the Ethernet using TELNET, custom software, 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 Windows® applications that normally connect to a local COM-Port. The software automatically redirects the transmit and receive messages to and from the remote port, over the Ethernet. For low speed serial ports this will even work across the Internet.

The data telemetry link between WHOI and the shore lab will be via an 11 Megabit/sec spread spectrum radio link with a 56K leased line as back-up. In addition to the existing network connections and serial ports available, there are multiple unclaimed single mode optical fibers between the shore lab and all sensor nodes, which are available for users with special data requirements.

The users will be provided with a password protected web page for control of their assigned port. This web page will include on/off controls for each power supply, as well as voltage and current gauges, ground fault gauges, and a check box table to select the interface type [3].

All ports will be automatically monitored for fault conditions, including over-current, ground faults, and data type violations (such as: RS-232 levels detected while RS-422 interface was selected). If a fault is detected, the port will be automatically shut down, with no effect on any other ports, and an email message will be sent to the user. The user may elect to override the fault condition at his discretion, by selecting the "fault override" control on that port's web interface.

WHOI is not providing any data-logging or archiving services to general users, however access is provided to the shore lab, or the MVCO lab at WHOI, if a user would like to set up a local computer system. The overall architecture is based on the relatively simple concept of an "extension cord", thus providing the users with direct connections to their instruments from anywhere on the Internet.

CONCLUSION

The Martha's Vineyard Coastal Observatory is currently being installed off of the south coast of the island of Martha's Vineyard to monitor coastal atmospheric and sub-sea conditions. This observatory will provide scientists with directly connected access to the coastal environment, allowing for continuous measurements of environmental parameters under extreme conditions, including the many severe storms of the North Atlantic. This 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.

ACKNOWLEDGMENTS

The authors would like to thank the Town of Edgartown, MA for their support throughout the permitting and installation phases of this project. In particular, we thank Robert Stone (Chairman, Edgartown Airport Commission), Roy Nutting (Manager, Katama Air Park), and Jane Varkonda (Conservation Commissioner, Town of Edgartown) for their support and efforts on this project. This work has been supported by NSF grant OCE-9871120 with cost-sharing from WHOI.

REFERENCES

[1] Edson, J. B., McGillis, W. R., and Austin, T. C., "A New Coastal Observatory is Born", Oceanus, 42, 31-33.

[2] Forrester, N. C., Stokey, R. P., von Alt, C. J., Allen, B. G., Goldsborough, R. G., Purcell, M. J., and Austin, T. C., "The LEO-15 Long Term Ecosystem Observatory: Design and Installation", Proceedings Oceans '97, Halifax, Canada.

[3] Stokey, R. P., "Web-centric Instrumentation: Controlling and Monitoring a Vertical Profiler using a WWW Browser", Proceedings Oceans 2000, Providence, RI.