U.S. Coast Guard Research and Development Center
1082 Shennecossett Road, Groton, CT 06340-6048

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Examination of Chesapeake Bay Observing System for Local Environmental Data for Coast Guard Operations

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NOTICE

Marc B. Mandler, Ph.D.
Technical Director
United States Coast Guard
Research & Development Center
1082 Shennecossett Road
Groton, CT 06340-6048

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The R&D Center's technical point of contact is Kathleen Shea, 860-441-2770, email: kshea@rdc.uscg.mil.

16. Abstract

The effective conduct of many of the U.S. Coast Guard's (USCG) missions is strongly influenced by the availability of accurate information on local environmental conditions. As an example, in search and rescue (SAR) operations, pollutant/hazardous product spill response, as well as interdiction of Law Enforcement (LE) targets (migrants, contraband), planning and execution depend on knowledge of water current velocity at the location of the incident, and on forecasts over time-scales that may range from hours to days.

Through the National Oceanographic Partnership Program (NOPP), guidelines are being developed for the integration and linking of environmental data into a single, *integrated* and *sustained* ocean-observing system (IOOS) that will specify standardized data formats and data access protocols that will enable system-wide data to be obtained in a consistent manner. An example of a local contributor to IOOS is the emerging Virginia Institute of Marine Science (VIMS) Chesapeake Bay Observing System (CBOS), which is described in this report. This unified approach to coastal data access is well suited to USCG needs.

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EXECUTIVE SUMMARY

The National Oceanic and Atmospheric Administration (NOAA) conducts research and gathers data about the global oceans, and provides this knowledge to services, such as the U.S. Coast Guard (USCG). NOAA, a Commerce Department agency, provides these services through five major organizations: the National Weather Service, the National Ocean Service, the National Marine Fisheries Service, the National Environmental Satellite, Data and Information Service, and the Office of Oceanic and Atmospheric Research. The National Weather Service provides basic information on present conditions and short- and long-term forecasts through a well-established, national network of observation stations and predictive models. In USCG search and rescue (SAR) operations, pollutant/hazardous product spill response, as well as interdiction of Law Enforcement (LE) targets (migrants, contraband), planning and execution depend on knowledge of water current velocity at the location of the incident and on forecasts over time-scales that may range from hours to days. Local data on currents and waves are extremely limited, and some measurements are not accessible in a standardized manner.

RDC learned about work being done at the Virginia Institute of Marine Sciences (VIMS) that supports guidelines set up by the National Oceanographic Partnership Program (NOPP). NOPP has established a national program office, Ocean.US, to oversee and organize an *integrated* and *sustained* ocean observing system (IOOS). IOOS is building towards nationwide coverage of U.S. coastal waters, and is specifying standardized data formats for data providers and data access protocols that will enable data to be obtained in a consistent manner. This document describes an example of an observing system structure that is consistent with that of the overall IOOS program.

In 2004, VIMS completed development of a pilot observing system infrastructure. The system included wind and current, speed and direction, wave height, period and direction and air and water temperature. Telemetry capabilities allowed this data from the deployed instruments to be received by shore-based data acquisition computers in near real-time. The data is available at www.vims.edu/realtime/ under "Real-Time Data." The real-time wind and current data was incorporated in a current prediction model that was validated with NOAA tide tables at

Gloucester Point and Chesapeake Bay Bridge - Tunnel, in the Virginia area. NOAA National Oceanic Service is the recognized U.S. Government source for prediction of tides and tidal currents. Based on review of this work, RDC recommends that the USCG continue to expand interactions with existing and emerging local observing systems. Through such cooperative activities, the USCG can identify and help shape data and model products that are potentially useful to USCG operations. Likewise, USCG capabilities can assist in observing system developments. For example, the capability of numerical models to predict currents and particle trajectories needs to be assessed. But validation of models for current prediction is not as straightforward as calibration for tidal height, partly because of a lack of local current velocity data. During training exercises or actual cases, the USCG could work with local observing systems to coordinate deployments of self-locating data marker buoys (SLDMB) so as to generate data that could be shared for assessing and refining the particle tracking capability of the local numerical models.

RDC has identified key issues that must be addressed in order for local observing system information to be applied as a practical tool in USCG operations. In particular, we recommend:

- That local-user input drives development of regional ocean observing systems
- That once these systems are developed their information is available on a full-time basis
- That the USCG develop methodologies to process or analyze the local environmental data to be used in USCG decision-support applications
- That the USCG implement software compatible with the IOOS standardized data formats and access protocols

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INTRODUCTION

Effective mechanisms for delivering local environmental data products to the U.S. Coast Guard (USCG) must be developed and standardized. Recently, collections of instrumentation known as observing systems have been deployed in certain regions such as the Gulf of Maine and the Chesapeake Bay. Observing systems are intended to provide data on a long-term, sustained basis in contrast to special purpose buoy deployments of limited duration. In general, these observing systems include telemetry capabilities so that shore-based data acquisition computers receive data from deployed instruments in near real-time. This data is then made available through a secure web site interface.

The potential value of the collection of individual observing systems is enhanced when they are integrated and linked into a single coherent system. The efforts of NOPP and Ocean.US are producing an integrated and sustained ocean observing system (IOOS). In a hierarchical context, the national IOOS program falls between the global ocean observing system (GOOS) and a federation of regional observing systems in the United States. Martin (2003) provides background information and discusses the current status of IOOS in a special issue of *Oceanography* (Vol. 16, No. 4, 2003) devoted to observing systems.

An essential component of IOOS is data management and communication (DMAC). In order to facilitate integration of the growing number of local observatories into a coherent national system and to provide convenient and consistent access to data for users standardized data access approaches and data formats must be adopted. In 2004, the IOOS DMAC Steering Committee developed and specified such standards. Their considerations and recommendations are summarized in a recently released report, "Data Management and Communications Plan for Research and Operational Integrated Ocean Observing Systems: I. Interoperable Data Discovery, Access, and Archive, Ocean.US, Arlington, VA 292 pp. http://www.dmac.ocean.us/dacsc/imp_plan.jsp. This unified approach to coastal data access is well suited to USCG needs. Procedures should be developed to acquire relevant data and process it for the use in various USCG activities that can be implemented consistently and efficiently within different geographical areas of operation across the country.

Full realization of a sustained national integrated observing system will evolve over a period of years. An example of a local contributor to IOOS is the emerging Virginia Institute of Marine Science (VIMS) Chesapeake Bay Observing System (CBOS), which is described in this report.

Organizational Structure

CBOS is considered a Coastal Ocean Observing System (COOS) - a federation of regional observing systems. Following the IOOS principles, it is a system designed to produce and disseminate ocean observations and related products deemed necessary to the users, in a common manner and according to sound scientific practice. A COOS links users to measurements of the coastal oceans and the Great Lakes on a regional or sub-regional basis. Such a system requires a managed, interactive flow of data among three subsystems: 1) the observing subsystem, 2) the communications network and data management subsystem, and 3) the analysis and applications subsystem. A COOS consists of the infrastructure and expertise required for each of these subsystems. It also includes oversight, evaluation, and evolution mechanisms that ensure the continued and routine flow of data and information, and the evolution of a system that adapts to the needs of the user groups and to the development of new technologies and understanding.

The observing subsystem deals with measurements and the transmission of measurement data to central observing system facilities. This subsystem includes platforms (such as buoys and stationary mounting structures), sensors (including cameras) and associated instrumentation, and telemetry equipment (radios, antennas, etc.). The communications network and data management subsystem provides internal links between the data acquisition and the analysis and applications subsystems, as well as links via the Internet. The analysis and applications subsystem deals with assessing and predicting conditions in the relevant waters of the observing system.

IMPLEMENTATION OF VIMS COMPONENT SUBSYSTEMS

Observing Subsystem

Equipment summary

The principal components of the VIMS observing system are represented schematically in Figure 1. The technical details of the equipment are described in the Appendix, and summarized below:

Measurement platforms:

- Buoy
- Stationary mounting structure
- On-bottom instrument frame, with acoustic release

Sensors:

- Meteorological (*e.g.*, wind speed, air temperature)
- Basic hydrographic (*e.g.*, water temperature and salinity)
- Other water quality (*e.g.*, dissolved oxygen, pH, chlorophyll)
- Water current velocity, using acoustic Doppler current profiler (ADCP)
- Waves, also using ADCP
- Cameras, providing motion video and saved still images

Telemetry and interconnections:

- 900 MHz radios and antennas
- 2.4 GHz radios and antennas
- On-bottom cable
- Acoustic modem (not shown)

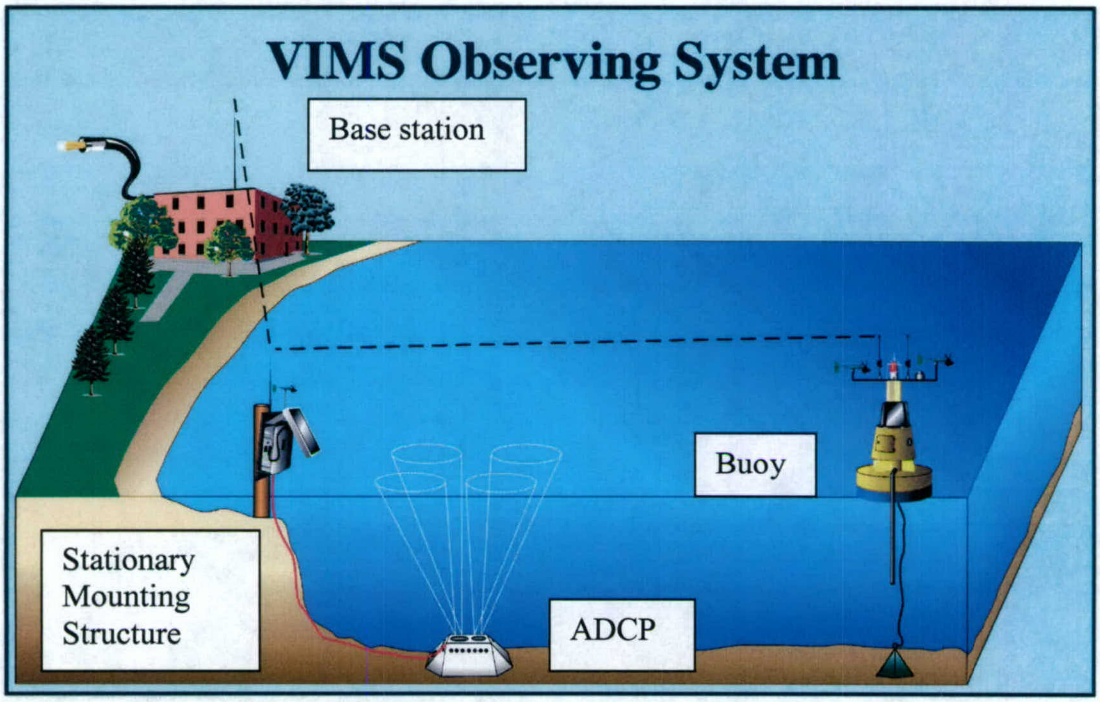

Figure 1. VIMS Observing System. Schematic representation of the primary components of the observing subsystem.

Also depicted in Figure 1 is the base station, physically located at the top of Byrd Hall on the VIMS campus. It includes the shore-based telemetry components and computers.

Configurations and deployments

Wherever possible, flexibility and modularity were built into the observing system design. In the summer of 2003, a fully stationary mounting structure was established, with solar- and wind-generated power, meteorological sensors, and telemetry systems. On 18 September 2003, the station and its platform were destroyed during Hurricane Isabel. A more compact, rugged, portable station without wind-generated power was then developed and deployed on an available tower structure on the Goodwin Islands, Virginia. More detail about the sequence of deployments is described in the Appendix.

Communications Network and Data Management Subsystem

Background

Development and implementation of the VIMS observing system is in alignment with the national IOOS program, where the role of data management and communications (DMAC) standards is given prominent and extensive attention. A central point of IOOS at the national level and GOOS at the international level is that local observing systems, while operating independently and each with its own unique features, make their data available via the Internet through standardized IOOS access approaches and data formats. DMAC also covers information management and networking *within* a local observing system. For example in the VIMS observing system, the DMAC module provides the real-time data to the VIMS models for assimilation, thereby improving accuracy of predictions and now-casts.

Overall, development and adoption of DMAC standards at the national level is a large-scale and long-term process. Recognizing this, and addressing the need to provide early guidance, the IOOS-DMAC Steering Committee has specified high-priority recommendations that data suppliers make their data available through the Open-source Project for a Network Data Access Protocol (OPeNDAP). OPeNDAP (http://opendap.org) is the newer, discipline-neutral name and organization for the older system known as the Distributed Oceanographic Data System (DODS http://www.unidata.ucar.edu/packages/dods/). In practice, the names are often used interchangeably or together i.e. OPeNDAP/DODS.

Standardized data access is directly relevant to USCG usage of observing system data. During review of the VIMS observing system, RDC, VIMS and USCG SAR controllers discussed the VIMS model capabilities, data and image output and current SAR planning procedures. Potential roles for observing systems data and model output in SAR operations were identified. A major point was that procedures must be generalized beyond one observing system and beyond one USCG Group's area of responsibility to be of real value to the USCG. Thus, effort toward standardized data access protocols such as OPeNDAP is needed.

As important as OPeNDAP access is, it should not be regarded as the only data delivery option. IOOS data providers and data users are both in the early stages of establishing OPeNDAP capabilities on the provider and the user side. OPeNDAP software tools are still evolving toward more user-friendly and stable releases. In the meantime, existing protocols (i.e. http and ftp) can still provide useful options for presenting and delivering data. Over time OPeNDAP will play a larger role. The GOOS is still identifying several different data access approaches including OPeNDAP, that will be best suited for different types of data and different user needs.

VIMS implementation of OPeNDAP/DODS capability

An overview of the role of OPeNDAP/DODS in the DMAC subsystem of the VIMS observing system is shown schematically in Figure 2.

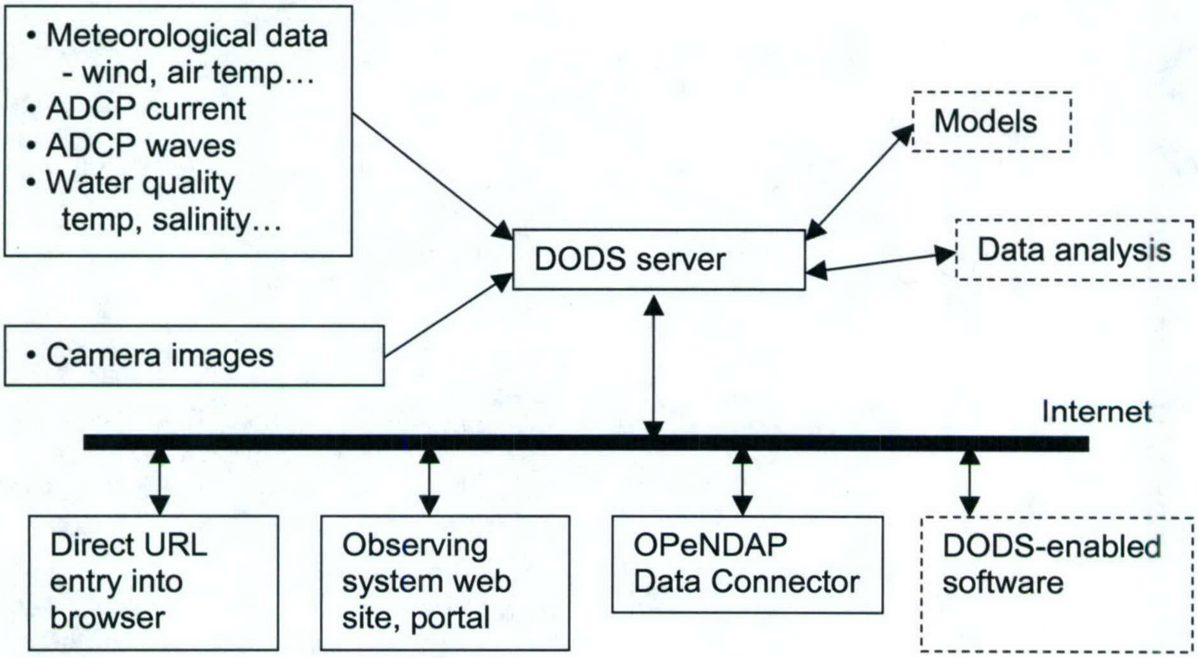

Figure 2. OPeNDAP/DODS Server. Schematic representation of linkages associated with the OPeNDAP/DODS server. Linkages indicated by dashed rectangles have not been implemented.

In the VIMS pilot observing system, only the ADCP and water quality data are converted to conform to the OPeNDAP format.

Several modes of access can be used to request and receive data from the DODS server via the Internet.

- Direct URL entry into the address field of a web browser. This approach assumes that the user knows the Uniform Resource Locator (URL) for the data of interest and knows the appropriate syntax to specify the desired variables and subsets of records. While useful in some cases, this is in general a tedious way to work with DODS.

- Web interface to DODS. Several observing systems feature a web home page that serves as a portal to various types and presentations of information, including a link to DODS-based data. This approach has been demonstrated at the VIMS web site (see SUMMARY section of this paper). The web page provides the context for finding data of interest via an intuitive and convenient interface.

- OPeNDAP Data Connector. This tool, available at http://opendap.org/ODC, facilitates access to DODS data by providing search modules and visualization capabilities for displaying data time series, images, etc.

- DODS-enabled software. Several software systems, such as Mathworks' MATLAB® and Research Systems Inc. (RSI) IDL, are used for performing mathematical calculations, analyzing and visualizing data, and cross-platform application development, and can be configured to function as DODS-enabled software. For MATLAB®, the interaction can be conducted at the operating system's command line or through a General User Interface (GUI). For users already familiar with MATLAB®, this is an appealing approach.

Analysis and Applications Subsystem

VIMS has been engaged in the development of a new generation three-dimensional (length, width and depth), numerical model utilizing the Unstructured Grid Tidal, Residual, and Intertidal Mudflat (UnTRIM) Model developed by Casulli (1999) and his colleagues. UnTRIM is a general-purpose model, which is an integration of a hydrodynamic model, a sediment transport model, and a water quality (eutrophication) model. The area of coverage (domain) of the model can vary from entire embayments (e.g., the Chesapeake Bay and all its tributaries) to individual river estuaries (e.g., the James, York and Rappahannock Rivers in Virginia). To implement the model, a grid work of cells must be constructed that accurately fits the outline of the water body and a depth for each cell must be added from bathymetric surveys. Large grids in large embayments use fewer cells, relatively large in size, to achieve low or moderate resolution. Small grids in small estuaries use many small cells to achieve a higher resolution.

Two kinds of models were developed by VIMS: a high-resolution, small-grid model for the rivers and tributaries, and a low-resolution, large-grid model for the Chesapeake Bay that includes a section of adjacent continental shelf. The river models can be used to predict tide and current distributions at a high resolution throughout the rivers, and the Chesapeake Bay model can be used to predict tide and current distributions at low resolution throughout Chesapeake Bay. The Chesapeake Bay model can also be used to investigate the transport of water-borne materials anywhere within the Chesapeake Bay. The Chesapeake Bay model is also used to generate boundary conditions for the river models.

In order to calibrate the accuracy of the VIMS models, the tide levels were compared to NOAA tide tables. NOAA National Ocean Service is the recognized U.S. Government source for prediction of tides and tidal currents. Figure 3 shows the large-grid Chesapeake Bay model with the location of the expanded small-grid river models. The large grids of the Chesapeake Bay model ranged from 80 to 5000 square meters. The small grids of the York River model ranged from 50 to 270 square meters. The comparison of the Chesapeake Bay Model to the NOAA tide tables proved satisfactory. But initially, the model for the York River did not simulate tide propagation properly. It was determined that the grid structures for the two tributaries, Mattaponi and Pamunkey Rivers which meet at the head of the York River, were not small enough. Once the York River grid was re-defined in the tributaries, it simulated NOAA tidal constituents satisfactorily. Figure 4 shows three different grid scales: the largest outside the Chesapeake Bay mouth, smaller in the main Chesapeake Bay, and smaller still in the Hampton Roads/James River area in the lower left of the Grid D enlargement (Figure 4).

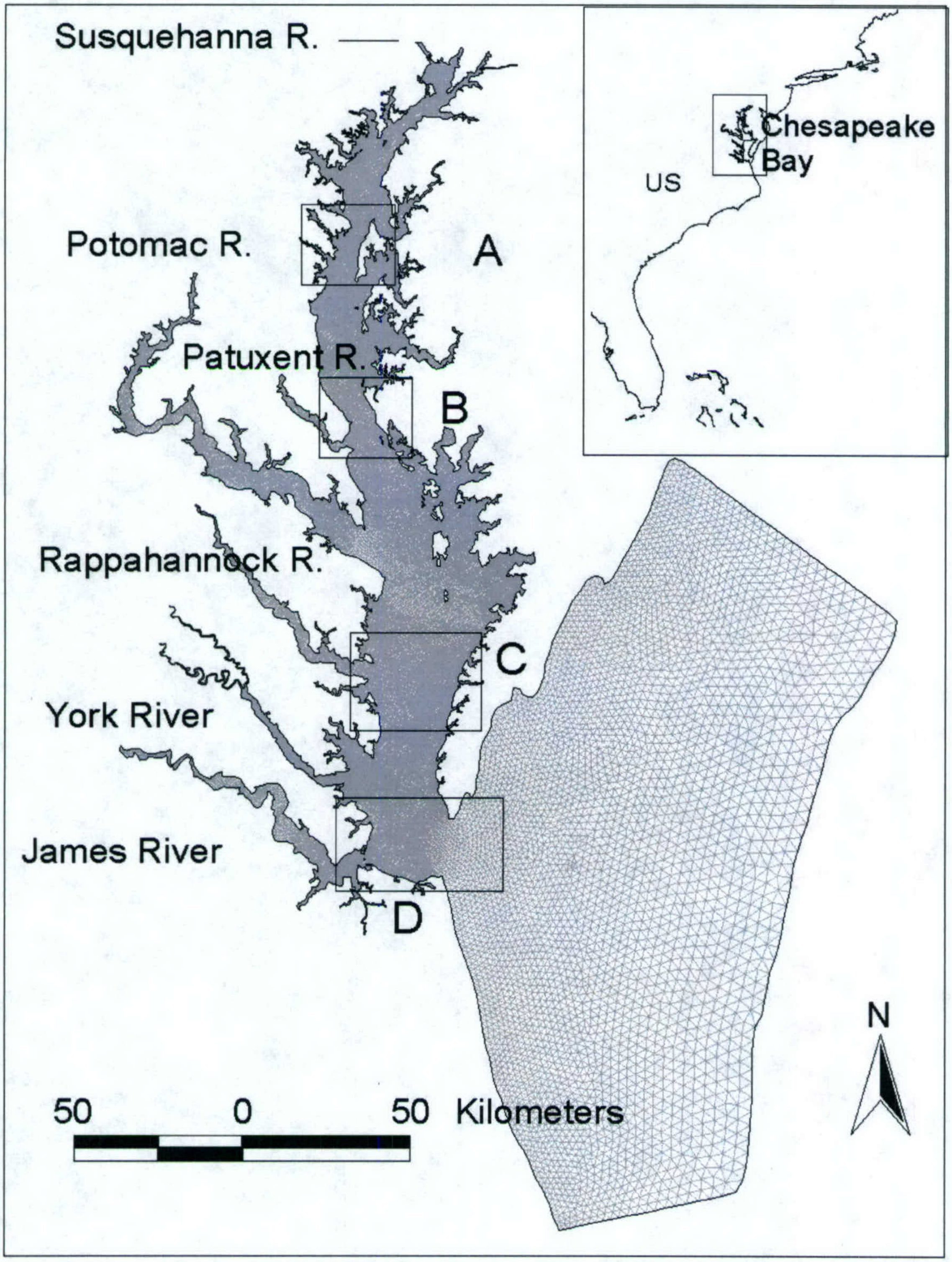

Figure 3. Chesapeake Bay Model Grid and Locations of Expanded River Grids.

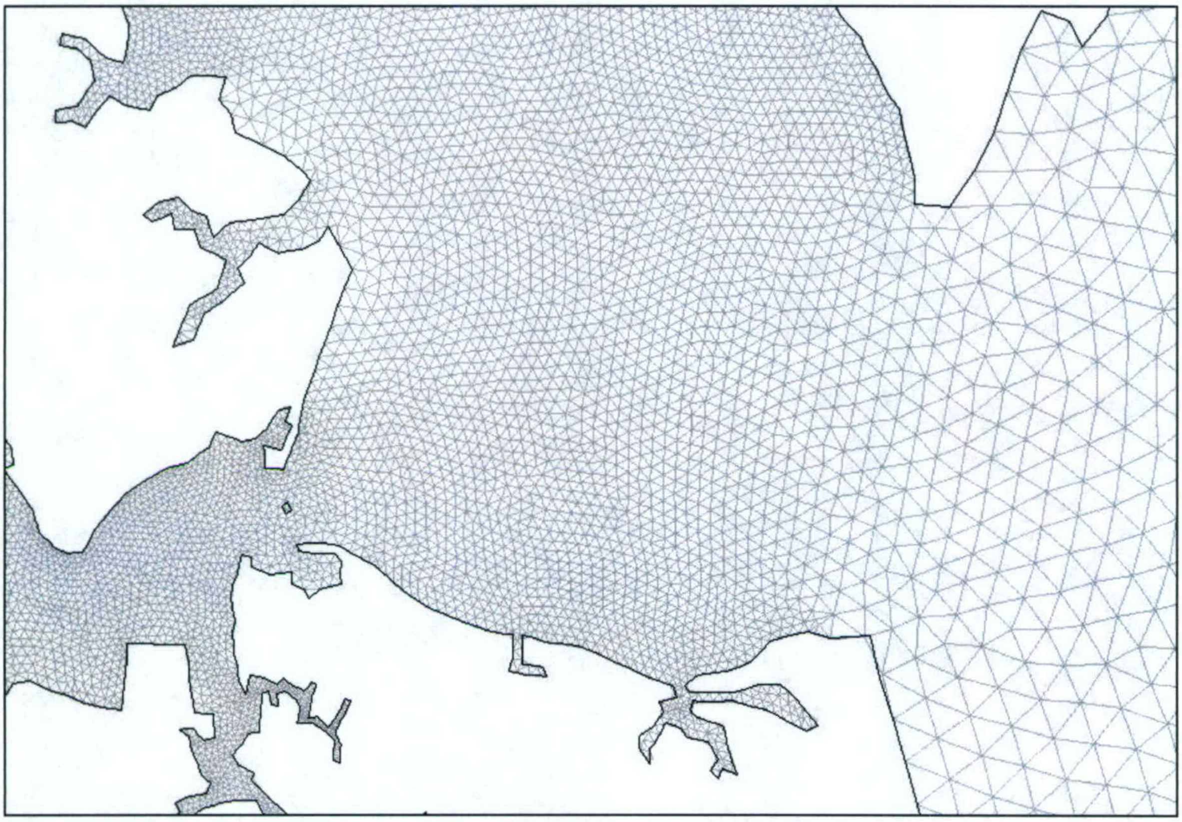

Figure 4. Grid D near the Hampton Roads/James River.

Figures 5 and 6 show a comparison of the VIMS model predictions of tide against those predicted using the NOAA tidal constituents from 9/17/2003 to 9/18/2003. It can be seen that the VIMS model results agree with NOAA tidal predictions at the Chesapeake Bay Bridge - Tunnel (Figure 5) and in the York River at Gloucester Point (Figure 6).

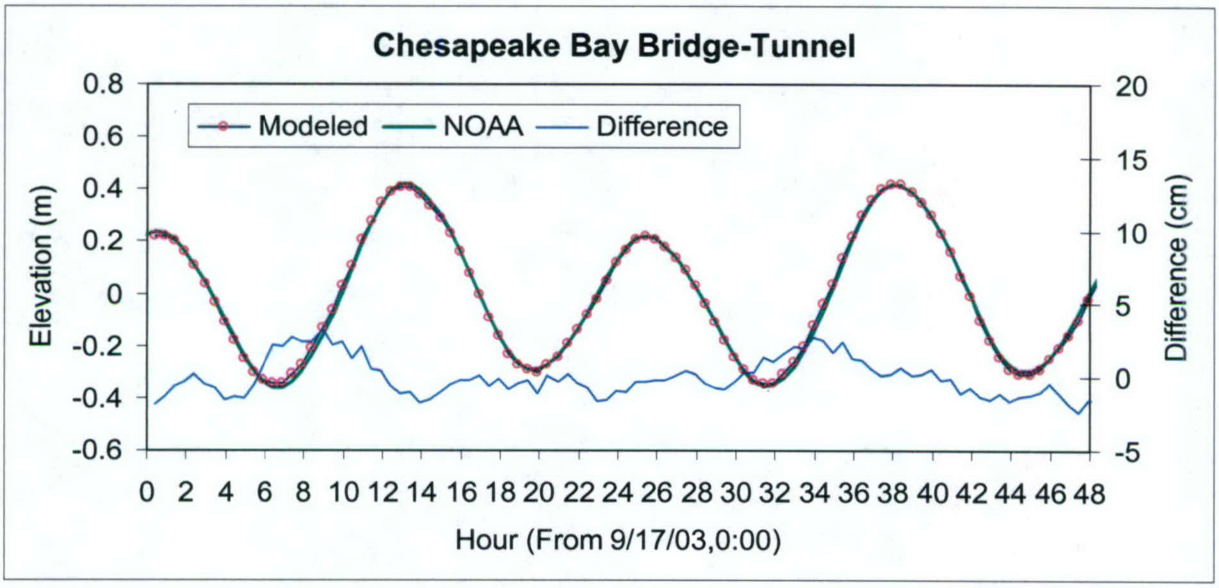

Figure 5. Comparison of the VIMS modeled tide predictions to NOAA tidal constituents at the Chesapeake Bay Bridge – Tunnel.

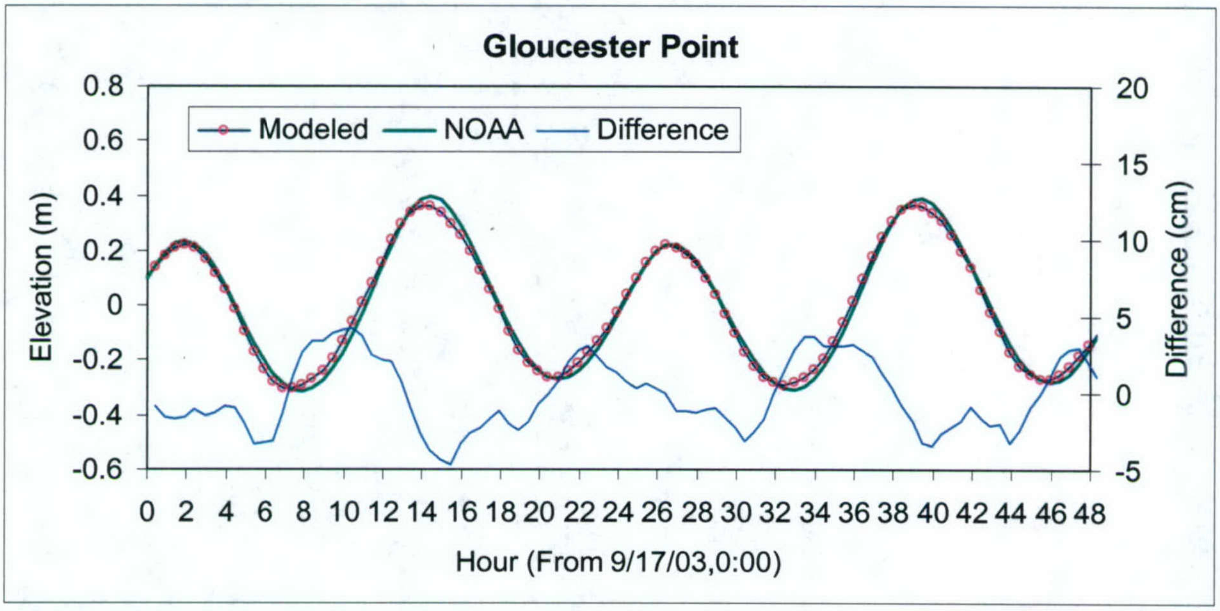

Figure 6. Comparison of the VIMS modeled tide predictions to NOAA tidal constituents at Gloucester Point.

SUMMARY

VIMS observing system is in the pilot phase of development. The main result at this stage is the implementation of a complete observing system infrastructure consisting of subsystems for: observing system data, communications network and data management, and analysis and applications. All major elements of the system have been demonstrated in operation. The infrastructure provides the deployment platforms, operating power, data sampling, transmission, management, and modeling capabilities for a variety of applications. In this pilot phase, the particular configuration of sensors and outputs available at a given time will vary as different modes of operation are tested, improvements introduced, and the system expanded. Generally the following types of data are being collected and available at VIMS.

Observing Subsystem Data

Currently, the primary location for measurements from the buoy is at 37° 14.7 and, 76° 30.0'W, in the York River off Gloucester Point, VA. Data sampled include:

- Wind speed (mph, knots, m/s)
- Wind direction (compass-heading)
- Air temperature (°C, °F)
- Water surface temperature (°C, °F)
- Water surface salinity (ppt, practical salinity)
- Water quality parameters (chlorophyll, oxygen, turbidity)
- ADCP Water velocity profile
- ADCP Wave spectra

Different unit options are shown for the display of the data, indicating that different units can be made available for different purposes or users. Real-time display of the non-ADCP data is available at www.vims.edu/realtime/ under "Real-Time Data." The ADCP is being deployed in a series of trials to test and evaluate alternative configurations for data transmission back to VIMS. In this situation, data availability will be sporadic, and full access is limited at this time to VIMS personnel.

A subset of the incoming data can be accessed via the OPeNDAP protocol. Files currently available are listed and linked for access at www.vims.edu/realtime/ under "DODS Server." The value to the USCG is that observing systems like VIMS are using standard formats and data access protocols to provide access to their data. USCG would have to develop applications to accept this standard data format on input and use the standard data access protocols to get to the data. Once the application procedures have been developed, the USCG should be able to obtain accurate and available, local IOOS-compliant data for USCG operations.

Camera Images

Multiple observational cameras with different capabilities have been deployed as VIMS has evolved. Currently cameras are operating on the data buoy and on the roof of Byrd Hall on the VIMS campus. These could be used to capture the time and identity of passing vessels and used in USCG operations if a vessel is reported missing.

Communications Network and Data Management Subsystem

An OPeNDAP/DODS server has been implemented and several modes of access have been demonstrated. A directory structure has been established and populated with sample files for various kinds of observing system data. MATLAB® code was used to convert raw data files from instruments into appropriate format for the OPeNDAP server. Data can be accessed by:

- Direct URL entry into web browser.
- Navigating the website: www.vims.edu/realtime/
- The OPeNDAP Data Connector tool.
- OPeNDAP/DODS-enabled client, like MATLAB® or RSI's IDL. This has not been tested by VIMS.

Analysis and Applications Subsystem Models

High spatial resolution, three-dimensional numerical models of the York River and of the Chesapeake Bay and adjacent shelf has been implemented using the UnTRIM model. A tidal (water level) calibration was completed, with good agreement between the model and NOAA tide predictions. Results at each model cell include water level, as well as velocity at a series of depths. The model provides data for each of these locations as opposed to the NOAA tables, which only provide tidal data for the location indicated by the NOAA tide table. The velocity output provides the information necessary to simulate the trajectory of objects affected by the water current, and this "particle tracking" capability of the VIMS model was demonstrated to USCG SAR experts. Presently, the tracking is available in a mode that runs only on computers that have UnTRIM installed and requires an operator familiar with the UnTRIM software. USCG can call or e-mail VIMS to get the velocity information for a particular location in Chesapeake Bay, so they can manually input this into their SAR planning or oil-spill response programs.

CONCLUSIONS AND RECOMMENDATIONS

The developing national program for an integrated and sustained ocean observing system (IOOS) represents a valuable resource for the USCG in a variety of operations, including those associated with SAR and oil spill response. Key attributes of the IOOS that are attractive for USCG applications are that it is building toward nationwide coverage of U.S. coastal waters, and that it will specify standardized data formats and data access protocols that will enable system-wide data to be obtained in a consistent manner.

As a member agency of the NOPP, the USCG has already been involved in the leadership structure responsible for developing the concept of the IOOS. Beyond that administrative connection, we recommend that the USCG continue to expand interactions with existing and emerging observing systems like VIMS. Such relationships can facilitate the interactions between the USCG and the developers of the observing systems. Observing systems exist to serve users such as the USCG and the effectiveness of that service depends on user needs being clearly identified and specified in some detail.

RDC has identified key issues that must be addressed in order for local observing system information to be applied as a practical tool in USCG operations. In particular, we recommend that:

- The USCG implement software compatible with the IOOS standardized data formats and access protocols. This will enable acquisition of local observing system data and extraction of the desired subsets for USCG operations.
- Methodologies are developed to process or analyze the data to be used in USCG decision-support applications. Elements of this work are being investigated for implementing the USCG Search and Rescue Optimal Planning System (SAROPS).
- Information technology groups at local observing systems resolve concerns about network security so that convenient access to observing system outputs can be provided without opening up vulnerabilities to the local observing systems.
- Local and regional ocean observing systems develop methods and procedures to provide full-time ocean observing system operation and information availability.
- Local and regional ocean observing systems seek local-user input as they are developing observing systems.
- The USCG considers providing SLDMB data to local and regional ocean observing systems to calibrate their particle-tracking models.
- Review of this work be part of RDC efforts at investigating operational means to use high resolution and "new" types of environmental data for the SAR program.

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APPENDIX

The IOOS observing subsystem includes platforms (such as buoys and stationary mounting structures), sensors (including cameras) and associated instrumentation, and telemetry equipment (radios, antennas, etc.). In the VIMS pilot, there are two platforms with instrumentation and telemetry equipment: the buoy and a stationary mounting structure; and an ADCP, as well as the central observing system facility at Byrd Hall on the VIMS campus. Following are the details of the instrumentation:

Parameter	Accuracy	Resolution	Level*	Platform	Instrument system
Wind speed	±0.3 m/s	Variable	+3 m	Buoy	Campbell
Air temperature	±0.1 °C	Variable	+1.5 m	Buoy	Campbell
Image	N/A	Variable	+2 m	Buoy	Panasonic
Water temperature	±0.15 °C	0.01 °C	-1 m	Buoy	YSI
Conductivity	±0.5% ±0.001 mS/cm	Variable	-1 m	Buoy	YSI
Salinity	±1 % or 0.1 ppt	0.01 ppt	-1 m	Buoy	YSI
Dissolved Oxygen	For 0-20 mg/L: ±2 % or 0.2 mg/L For 20-50 mg/L: ±6 %	0.01 mg/L	-1 m	Buoy	YSI
pH	±0.2 units	0.01 units	-1 m	Buoy	YSI
Turbidity	±5 % or 2 NTU	0.1 NTU	-1 m	Buoy	YSI
Chlorophyll	No spec	0.1 µg/L 0.1 % FS	-1 m	Buoy	YSI
Water current	±0.25% ±0.25 cm/s	0.1 cm/s	Multi-level	Bottom mount	RDI ADCP
Wind speed	±0.3 m/s	Variable	+5 m	Pier node	Campbell
Wind direction	±3°	Variable	+5 m	Pier node	Campbell
Air temperature	±0.1 °C	Variable	+5 m	Pier node	Campbell
Solar radiation	< ±5 %	Variable	+5 m	Pier node	Campbell
Image	N/A	Variable	+3 m	Pier node	Panasonic

* Level denotes distance above (positive) or below (negative) water surface.

Locations

- Buoy and bottom-mounted ADCP: 37° 14.67' N, 76° 30.02' W
- Stationary mounting structure: 37° 14.75' N, 76° 30.00' W

Sampling intervals

- Data at buoy: 15 minutes
- Data at stationary mounting structure: 1 minute
- Cameras: 15 minutes

- ADCP currents: 10 minutes
- ADCP waves: 1 hour

Sensor manufacturers, models

- Wind speed and direction: R.M. Young, 05103 Wind Monitor
- Air temperature: Campbell Scientific, Inc., 107 Thermistor
- Cameras: Panasonic, KX-HCM270
- All sensors at -1 m at buoy: YSI Environmental, 6600 Sonde
- Solar radiation: Li-Cor, LI200X Silicon Pyranometer

Buoy

- Manufacturer: Mooring Systems Inc.
- Guardian G2000
- http://www.mooringsystems.com/

Bottom mount for ADCP current meter

- Manufacturer: Mooring Systems Inc.
- MTRBM (miniaturized trawl-resistant bottom mount)
- http://www.mooringsystems.com/
- includes Edgetech CART (coastal acoustic release transponder)

Wireless telemetry

- Apex SS200, 900 MHz
- Freewave FGR900, 900 MHz
- Netgear Wet11 bridge, 2.4 GHz

Stationary mounting structure

During the summer of 2003, development of the stationary mounting structure proceeded in the form of a shed-based station at the end of a ferry pier as shown in Figure A-1. This had solar- and wind-generated power, meteorological sensors, and telemetry systems. This station, along with most of the ferry pier, was destroyed during Hurricane Isabel on 18 September 2003.

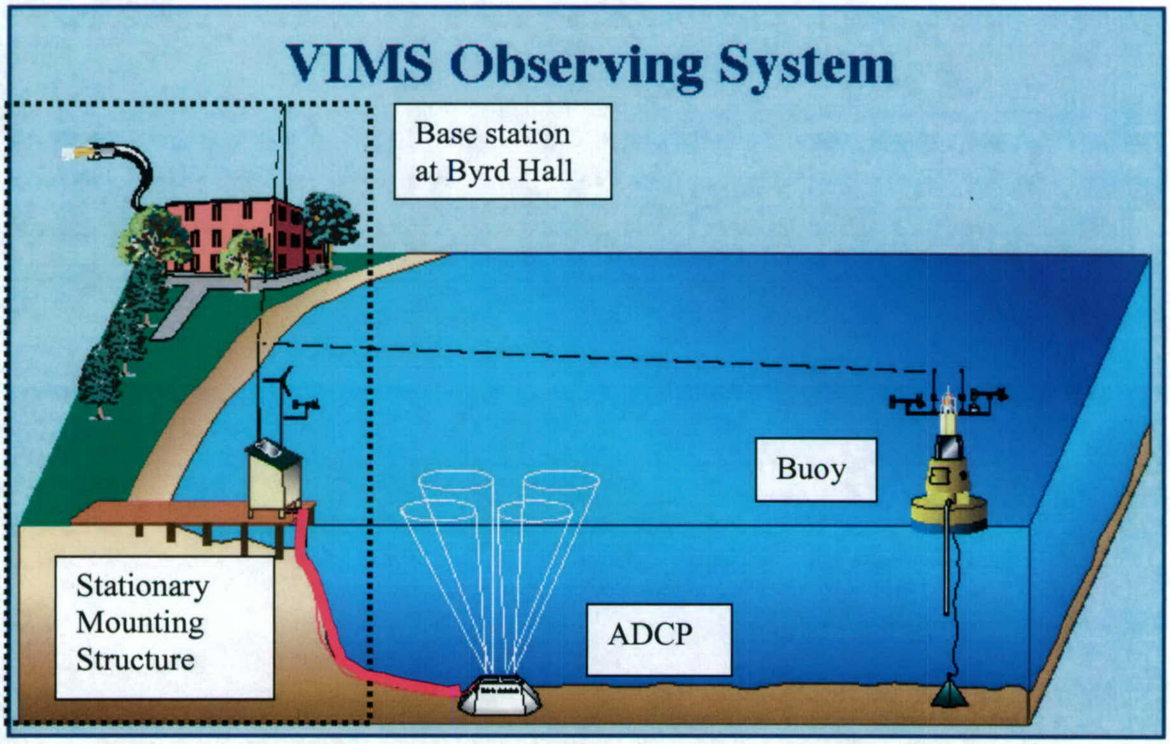

Figure A-1. Initial deployment configuration with shed station on ferry pier within the dotted rectangle, deployed in summer 2003.

A next-generation stationary mounting structure was designed retaining essentially the same functionality as the shed station, but without wind-generated power. The stationary mounting structure was much more compact, rugged, portable, and suitable for mounting on a variety of structures of opportunity. By November, the first unit had been fabricated and was ready for deployment. Heavy equipment engaged in hurricane-cleanup operations near the ferry pier rendered that area unusable for observing system activities. In order to maintain progress and accomplish the required field-testing without delay, the portable structure was deployed on an available tower structure at the Goodwin Islands site where other VIMS projects were underway (see Figure A-2).

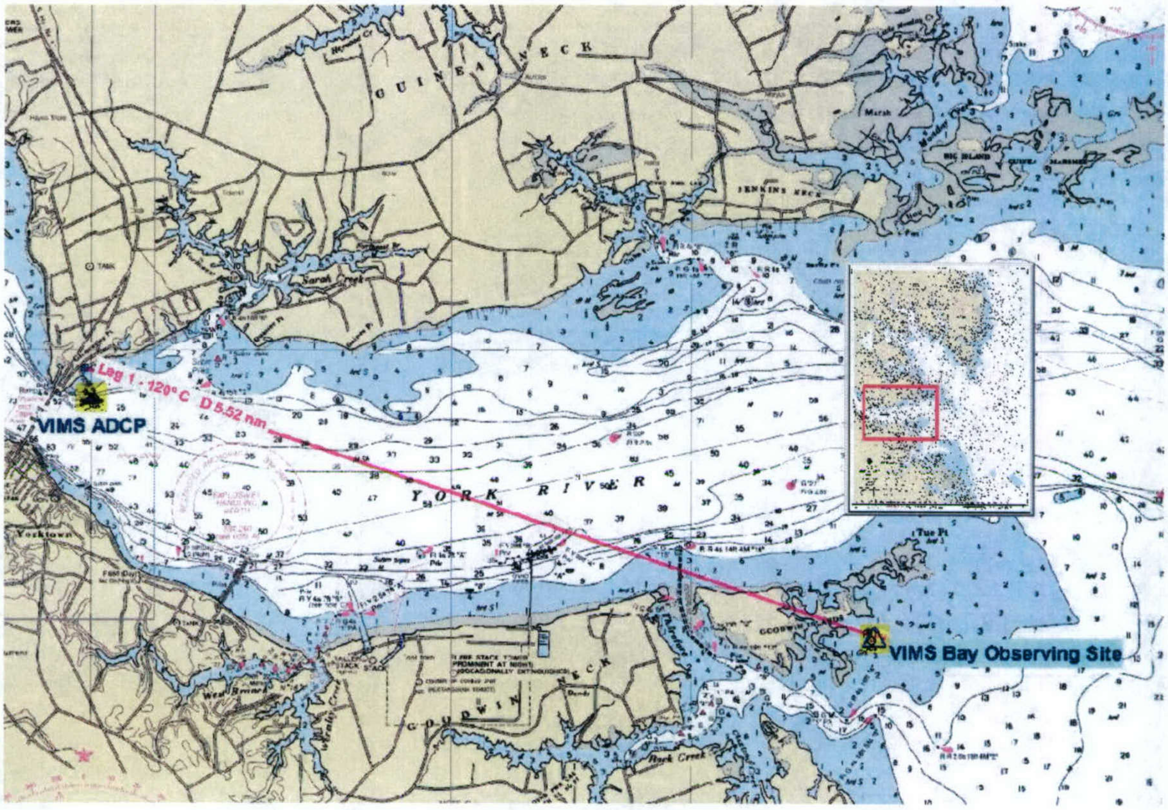

Figure A-2. Location of Observing subsystem site at Goodwin Islands relative to VIMS.

By December 2003, hurricane-cleanup operations at the ferry pier had been completed and a stationary mounting structure was deployed on a piling at the end of the pier. In the same time frame, the ADCP was deployed (details below) so that the subsystem consisting of the elements within the dotted rectangle in Figure A-3 were all functional for a successful trial during December 2003 and January 2004.

During late winter 2003 and all of spring 2004, the ferry pier area was again unusable for the observing system project. Heavy equipment was being set up to rebuild the pier and associated structures. The stationary mounting structure was removed from the piling near the pier and installed temporarily on the roof of Byrd Hall on the VIMS campus, where it continues its role as a relay station (now linking to the buoy, deployed in April). The roof location is not well suited for environmental data measurement, but it does facilitate testing and refinement of telemetry systems. The reconstruction of the ferry pier was completed by the end of summer 2004, and VIMS again placed a stationary mounting structure near the pier for some of the observing system operations.

ADCP deployments

In summer 2003, the ADCP was deployed just off the ferry pier. Functionally, the configuration was as depicted in Figure A-3, with communication between ADCP and stationary mounting structure via an on-bottom cable, and between the stationary mounting structure and the base station via radio-telepathy. The cable also supplied shore-based power to the ADCP. This early deployment was primarily for the purpose of systems testing (power, communications, control).

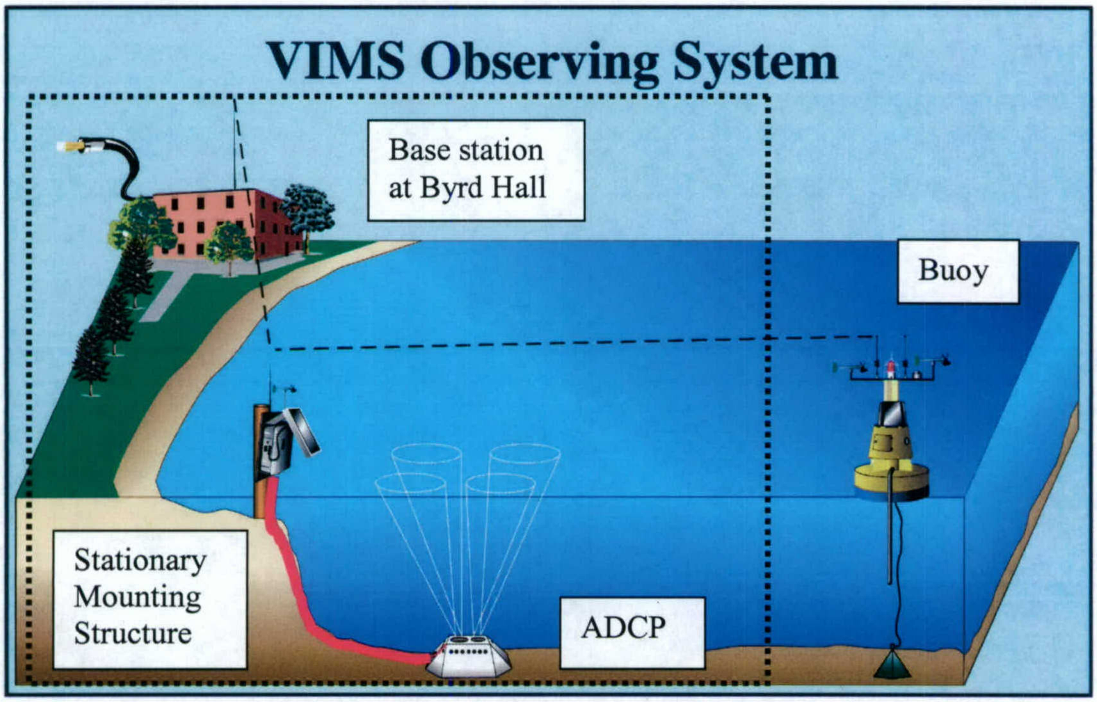

Figure A-3. Representation of the subsystem, within the dotted rectangle, deployed in December 2003, with a piling-mounted structure replacing the shed station shown in Figure A-1.

As Hurricane Isabel approached in September 2003, the ADCP was deployed in relatively open water at the channel edge, but this time it was configured to operate in a protected weather-resistant and self-contained mode. The ADCP used internal batteries for power and recorded data in internal memory. This deployment proved successful in withstanding the hurricane conditions and provided extraordinarily useful data. The tradeoff was that the data were not available in real-time, but were instead downloaded after the instrument was recovered, after the hurricane.

In December 2003, the ADCP was again deployed at the channel edge in relatively open water. Basically in the same site it occupied during the hurricane. But now it was directly linked to the stationary mounting structure by a cable on the channel bottom. Through part of December and January, the ADCP and cable link served as part of the integrated subsystem outlined by the dotted rectangle in Figure A-3. This deployment proved to be a successful trial enabling coordinated operations and testing simultaneously of several key observing system components. During this time, however, significant biofouling became a progressively worsening problem for the on-bottom cable. Massive hydroid aggregations attached to the cable, leading to a highly amplified drag force at times of strong tidal currents. The cable strain was deemed unacceptable and the ADCP and cable were removed.

While direct cabling of the ADCP to a near-shore stationary structure has some obvious advantages, it is not practical for more remote locations where ADCPs will be deployed as the observing system expands. One alternative is to use acoustic modems to communicate between the ADCP and the buoy, which would in turn transmit the ADCP data via radio telemetry back to base operations. In a test deployment, the acoustic modems achieved a base level of communication with the ADCP, but reliability was not robust at the higher data rates needed when the ADCP is sampling in a mode that provides information on surface wave conditions. Currently, design of a different approach is underway wherein a short length of cable, integrated with a buoy mooring, is used for the communication between ADCP and radio-telemetry on the buoy.

Buoy deployment

Considerable time and effort were devoted to preparation of the buoy. This involved:

- Tasks associated with the buoy itself, such as evaluation and application of appropriate anti-fouling paint, and design and construction of instrument wells and mounting structures.
- Mooring-related tasks, such as design and fabrication of an anchor assembly based on railroad wheels and outfitting the buoy with approved lighting.
- Development of power generation and control systems.
- Installation and testing of multiple radio telemetry systems.
- Mounting and testing of suites of sensors, cameras and associated instrumentation.
- Integration of the various subsystems, implementation of programmable sampling, temporary on-buoy data storage, and coordinated transmission of data to onshore base station.

On 9 April 2004, the buoy was launched in its initial deployment at the channel-edge site occupied by the ADCP during its December-January deployment. Mooring performance was monitored for about a week, after which instrumentation and communication systems were placed in service. This trial has been highly successful, with real-time data and camera images transmitted regularly back to the stationary mounting structure (currently on the Byrd Hall roof) and available on the VIMS Intranet.