# The Stevens Integrated Maritime Surveillance and Forecast System: Expansion and Enhancement

Michael S. Bruno and Alan F. Blumberg
Center for Maritime Systems
Stevens Institute of Technology
Castle Point on Hudson
Hoboken, New Jersey, 07030
phone: 201-216-5338 fax: 201-216-8214 email: mbruno@stevens.edu

ONR Grant No. N00014-03-1-0633

## LONG-TERM GOALS

The long-term goal of the project is to develop an advanced, integrated system of oceanographic, meteorological, and vessel surveillance sensors and littoral ocean forecasting models to allow for the **real-time** assessment of ocean, weather, environmental, and vessel traffic conditions throughout the New York Harbor region, and forecast of conditions in the near and long-term and under specific **threat scenarios**. In the long-term, the system will be enhanced by modern data assimilation techniques and model-controlled ocean observing sensors.

## OBJECTIVES

In littoral regions like New York Harbor, the properties of the water column are spatially and temporally dynamic. Any realistic picture of this environment must take into account this variability. During the year under report, the objective was to enhance and expand an existing observing and forecasting system of New York Harbor that is used to support both safe navigation and port security. The system is structured to enable real-time and ongoing changes to the sampling scheme of the observation system, based on model forecasts and/or user intervention.

## APPROACH

The range of potential threats to commercial and USN vessels and waterfront infrastructure requires comprehensive knowledge of the maritime environment. This "situation awareness", includes information regarding water and atmospheric conditions as well as vessel traffic. The challenge of providing this information is particularly difficult in shallow coastal areas and estuaries, where oceanographic and atmospheric conditions exhibit high spatial and temporal variability due to the influences of e.g., freshwater inflow, tides, micro-climate, and bottom and land topography. The design and installation of observing systems in these environments is further complicated by the presence of high turbidity, strong stratification, strong tidal and wind-driven flows, fog, and (in urban harbor areas) vessel traffic and limited shoreline access.

As a result of sustained accurate and efficient oceanographic field measurements in the past, computer forecasts are now feasible because of modern instrumentation and advanced three dimensional circulation models in which considerable confidence has been established. A carefully constructed observing and predicting system can produce nowcasts, forecasts and data-driven simulations by

# Report Documentation Page

| Report Documentation Page | *Form Approved* *OMB No. 0704-0188* |
|---|---|



| 1. REPORT DATE | 2. REPORT TYPE | 3. DATES COVERED |
|---|---|---|
| **30 SEP 2004** | | **00-00-2004 to 00-00-2004** |

| | |
|---|---|
| 4. TITLE AND SUBTITLE<br>**The Stevens Integrated Maritime Surveillance and Forecast System: Expansion and Enhancement** | 5a. CONTRACT NUMBER |
| | 5b. GRANT NUMBER |
| | 5c. PROGRAM ELEMENT NUMBER |
| 6. AUTHOR(S) | 5d. PROJECT NUMBER |
| | 5e. TASK NUMBER |
| | 5f. WORK UNIT NUMBER |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)<br>**Center for Maritime Systems,,Stevens Institute of Technology,Castle Point on Hudson,,Hoboken,,NJ,07030** | 8. PERFORMING ORGANIZATION REPORT NUMBER |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) | 10. SPONSOR/MONITOR'S ACRONYM(S) |
| | 11. SPONSOR/MONITOR'S REPORT NUMBER(S) |

12. DISTRIBUTION/AVAILABILITY STATEMENT
**Approved for public release; distribution unlimited**

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

| 16. SECURITY CLASSIFICATION OF: | | | 17. LIMITATION OF ABSTRACT | 18. NUMBER OF PAGES | 19a. NAME OF RESPONSIBLE PERSON |
|---|---|---|---|---|---|
| a. REPORT<br>**unclassified** | b. ABSTRACT<br>**unclassified** | c. THIS PAGE<br>**unclassified** | **Same as Report (SAR)** | **9** | |

**Standard Form 298 (Rev. 8-98)**
Prescribed by ANSI Std Z39-18

melding dynamics and observations via the assimilation of measurements into numerical models. The prediction systems provide mechanisms for important feedbacks including adaptive sampling for the observational component and improved dynamics for the model component. Such a system is The New York Harbor Observing and Prediction System (NYHOPS) - an Urban Ocean Observatory (Bruno and Blumberg, 2004). It is an example of what can be developed using today's technology. NYHOPS is an open-access network of distributed sensors and linked estuarine and coastal ocean forecasting models. NYHOPS is built around three main components: observations, numerical modeling, and information distribution, and has been operational since January 2004.

Real-time oceanographic information within the Harbor is obtained using various sensors placed at strategic locations (see Figure 1 for station locations) to monitor the current state of the estuarine environment. The sensor design and network configuration were patterned after an existing Stevens system on the New Jersey coast (Bruno, et. al. 2001). The network sensors, all of which serve their data in real-time, include:

- 6 shore-based salinity, temperature, turbidity, and pressure sensors
- 2 moored platforms containing salinity, temperature, turbidity, and pressure sensors
- 2 Acoustic Doppler Current Profilers (ADCPs)
- Commuter ferry-based conductivity and temperature sensors
- 3 weather stations (nearshore and moored) providing continuous observations of local meteorological conditions,

The modeling component is centered on the use of a high resolution application of the Princeton Ocean Model (Blumberg and Mellor, 1987). Water surface elevation and three-dimensional fields of currents, temperature, salinity, and water turbulence are calculated in response to meteorological conditions, freshwater inflows, tides, and temperature and salinity at the open boundaries. The model has a long history of successful U.S. Navy use and confidence in its capabilities has been established. The modeling system provides accurate and comprehensive simulations of meteorological and oceanographic conditions in the past (hindcasts), present (nowcasts) and future (forecasts). The simulations are performed and archived on the Stevens Hydrodynamic Computational Laboratory's high-performance computer cluster resident in the Davidson Laboratory.

## WORK COMPLETED

The expansion and enhancement of NYHOPS is well underway. The work completed includes:

*Observing System* -

1. A CODAR system located on the southeast shore of Staten Island (see Figure 1) will provide the coverage necessary to enable surface current and wave measurements across much of the lower Harbor. When combined with the planned Rutgers CODAR systems at Sandy Hook and Rockaway, the Stevens CODAR systems will enable very fine resolution of currents, and waves.

2. An offshore instrument mooring near the entrance to New York Harbor, providing surface wave height and direction, meteorological information, near-surface current speed and direction, and near-surface and near-bottom temperature and salinity. This instrument mooring will enable the

measurement of critical oceanographic parameters at the outflow of the Hudson-Raritan Estuary to the Atlantic Ocean. This information is essential to enhancing our understanding of the flows into and out of the estuary, and to the accurate simulation and forecasting of the regional ocean dynamics, including circulation and wave transformation. These surface current measurements will also allow for ongoing, high-resolution validation of the CODAR surface current measurements, thereby benefiting many other researchers.

3. Meteorological stations on the two instrument moorings that were deployed as part of the original NYHOS project. These instrument platforms will provide wind speed and direction, air temperature, atmospheric temperature, and relative humidity. All observations will adhere to NOAA National Weather Service standards in terms of e.g., vertical location, averaging, etc.

4. Expansion of the ferry-based temperature and salinity measurement system that was initiated under the original NYHOS project. This highly-successful trial program will be expanded in order to include ferry vessels traveling throughout the Harbor, including a route from Manhattan south to the lower Harbor shoreline just east of Sandy Hook.

5. Newly expanded wireless data transmission capabilities. Initial tests suggest that much if not all information from the shoreline and moored instrument platforms can be wirelessly transmitted to the Stevens campus. We have continued to build on this initial success, and are endeavoring to build a 100% wireless system in the Harbor (with the exception of the CODAR systems). Issues such as wireless security and integrity have been addressed to ensure that the data continues to flow in a very busy urban environment.

*Prediction System* -

The prediction system is scheduled to simulate 72 hours, 24 hours in the past, the hindcast mode and then 48 hours into the future, the forecast mode. The nowcast is obtained at the conclusion of the hindcast part of the cycle and a file is written out which forms the basis for the next cycle. The forecast simulations are performed using forecasted forcing functions except for the river flows, which are based on daily persistence. The modeling system saves the proper hydrodynamic information for a restart. A smooth and seamless execution occurs to start the next cycle, which is scheduled to start 24 hours later. Three-dimensional fields of salinity, temperature, and currents and two dimensional fields of water level, significant wave height, period and direction are archived every 30 minutes.

## RESULTS

The best realization of present conditions, the nowcast, occurs at midnight each day. For the following 48 hours, the best estimate is the forecast. The forecast estimate of present conditions is improved by using the observations, which are continually available in real-time throughout the forecast period. Every 30 minutes a map of "Present Conditions" is prepared by assimilating all the available data for that 30 minute period with the appropriate forecast.

An objective optimal interpolation technique is used to create the assimilated distribution. These distributions are saved for use with the next cycle of the prediction system. Figure 2 illustrates "Present Conditions" of surface salinity in the NY/NJ Estuary for 09 October, 2004, 23:00 EDT.

In order to firmly establish the credibility and robustness of the modeling system, the assessment of model skill must be an ongoing task. As the forecasts proceed, comparisons between model results and observations are being made. Figure 3 taken from a typical web site display provides an assessment in real-time of how well the system is simulating water level. In addition, NYHOPS has already been used to support the Rutgers/CalPoly NSF LaTTE Hudson River Plume experiment. LaTTE is a coordinated program of field experiments to examine processes that control the fate and transport of nutrients and chemical contaminants in the Hudson River plume. Shipboard marine scientists released a nontoxic red dye into the Atlantic Ocean off New Jersey during the first week of July 2004. The forecasts from NYHOPS were used aboard ship to determine the sampling protocol for each day. It was quickly apparent that the forecasts were quite dependable. A formal validation of the forecasts using SST and CODAR maps has just begun.

## IMPACT/APPLICATIONS

The work presented here provides a major step forward to coupling real-time observations with a modeling system. NYHOPS provides a wealth of real-time data about tides, waves, winds, currents, temperatures and salinities in the waters of New York and New Jersey. This information is now available to serve the maritime user community in the same way atmospheric weather forecasting has delivered for on-land populations. All of the data is available over the Internet 24 hours a day by means of weather forecast-like maps that can be used effectively by sailors, power boaters, swimmers, and fishermen as well as port security officials, and emergency management personnel. NYHOPS can be located on the Web at: http://www.stevens.edu/maritimeforecast/.

The observational network and modeling system are parts of the integrated, sustained ocean observing system envisioned by the National Oceanographic Partnership Program (NOPP), under the OCEAN.US office, and the NOAA/ONR Coastal-IOOS (Integrated Ocean Observing System).

## RELATED PROJECTS

None

## REFERENCES

Blumberg, A. F., and G. L. Mellor, 1987: A description of a three-dimensional coastal ocean circulation model. *Three Dimensional Coastal Models*, Coastal and Estuarine Sciences, 4, N. S. Heaps (ed.), Amer. Geophys. Union Geophysical Monograph Board, 1-16.

Bruno, M.S., O. G. Nwogu, K.L. Rankin, and T. O. Herrington, 2001. "Real-Time Coastal Monitoring and Forecasting System : Preliminary Results", International Conference on Coastal Engineering, Vol 1, 283-291, ASCE.

Bruno, M. S. and A. F. Blumberg, 2004: An Urban Ocean Observatory – Real-time Assessments and Forecasts of The New York Harbor Marine Environment, *Sea Technology*, 45, 27-32.

## PUBLICATIONS

1. "An Urban Ocean Observatory – Real-time Assessments and Forecasts of The New York Harbor Marine Environment", M. S. Bruno, A. F. Blumberg, Sea Technology, 45, 27-32, 2004.

2. “Mixing in the Hudson Estuary: The Role of Estuarine Circulation and Tidal Trapping,” F. L. Hellweger, A. F. Blumberg, P. Schlosser, and D. T. Ho. Estuaries, 27, 527-538, 2004.

3. “A Particle-Tracking Model for Predicting Entrainment at Power Plants on the Hudson River,” A.F. Blumberg, D. J. Dunning, H. Li, R.C. Geyer , and D. Heimbuch. Estuaries, 27, 515-526, 2004.

4. “Wave Breaking and Ocean Surface Layer Thermal Response,” G. L. Mellor and A. F. Blumberg. J. Phys. Oceanogr., 34, 693-698, 2004.

5. “Geomorphological and Meteorological Control of Estuarine Processes – Modeling Analyses using a High Resolution 3D Hydrodynamic Model”, A.K.M.Q. Ahsan and A.F. Blumberg, A. J. Thuman, and T. W. Gallagher. J. Hydraulic Engineering, (accepted), 2004.

6. “Hydrodynamics of the Hudson River Estuary”, A. F. Blumberg and F. L. Hellweger. Hudson River Environmental Society, (submitted), 2004.

7. “The Influence of Centrifugal and Coriolis Forces on the Circulation in a Curving Estuary”, N. Georgas and A. F. Blumberg. Estuarine and Coastal Modeling, (in press), 2004.

**HONORS/AWARDS/PRIZES**

None.


***Figure 1. Location of sensors in the NYHOPS sensor network. The "partner" sensors are owned and maintained by NOAA/NOS, Rutgers University and The River Project. Supplementing this network are observations made from a battery of ferries which travel throughout these waters on a routine basis.***

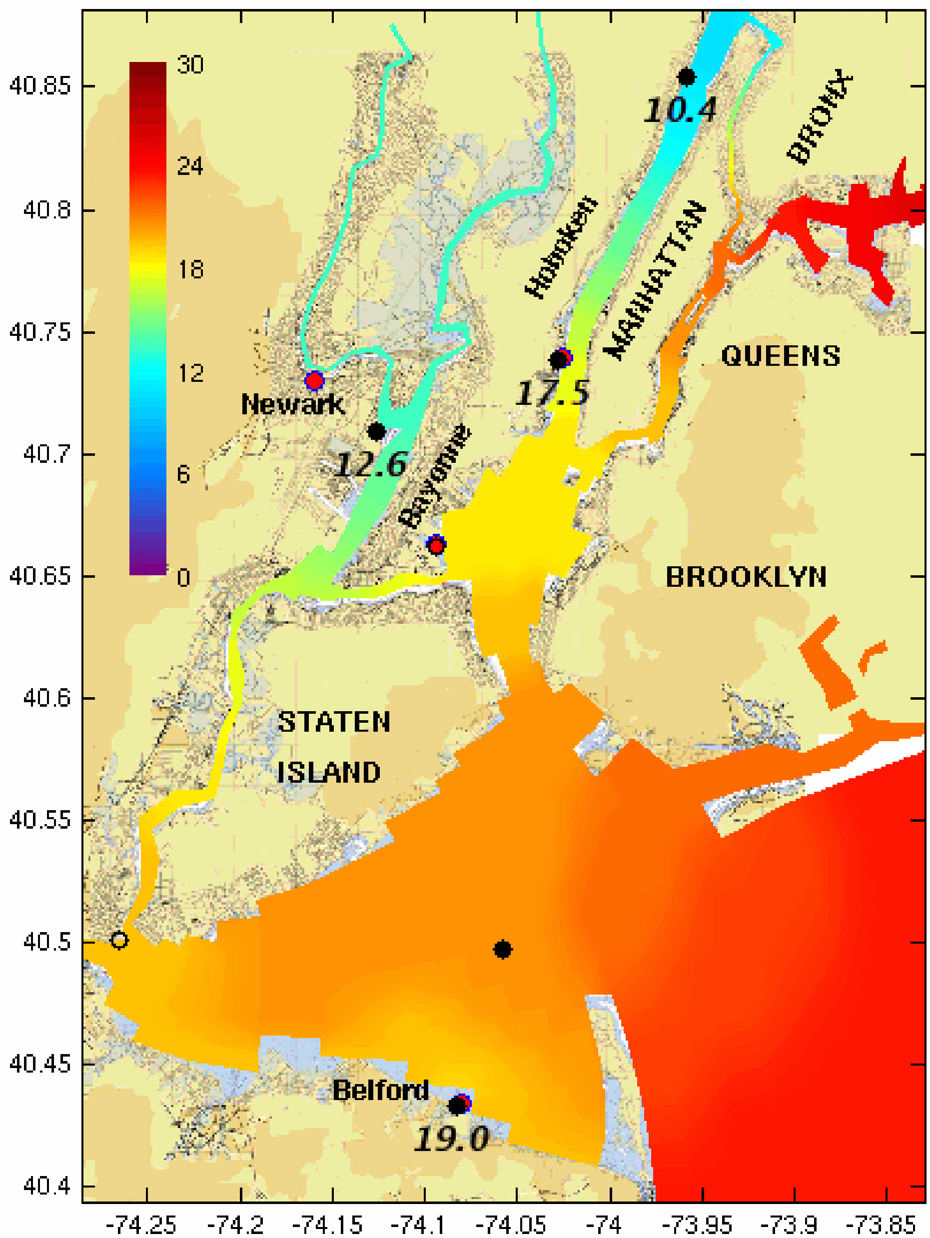


***Figure 2. The present surface salinity in the NY/NJ Estuary subdomain. The spatial distribution is created using data from the sensor network available in real-time, the forecasted field available every 30 minutes and an objective interpolation technique. The dots represent the locations of the sensors.***

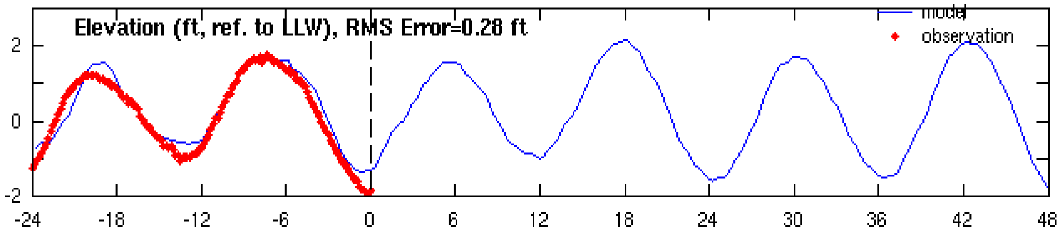


***Figure 3. This NYHOPS web site graphic provides a time history over 72 hours of water levels at Castle Point, NJ one of 15 stations available to the user. The forecast time is denoted by the vertical dashed line at 0 hours. Times from the previous day are in negative hours (-24 to 0) and the forecast times into the future are in positive hours (0 to 48 hours).***