SUMMARY: RESPONSE TO REVIEW OF THE ROMS HYDRODYNAMIC MODEL APPLICATION TO NARRAGANSETT BAY
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In September 2007, Applied Technology and Management (ATM) reviewed the University of Rhode Island June 2007 report, "Development and Calibration of a Model for Tracking Dispersion of Waters from Narragansett Bay Commission Facilities within the Providence River & Narragansett Bay, Final Report to the Narragansett Bay Commission," prepared by Deanna Bergondo and Dr. Chris Kincaid. This review presented some concerns with the model regarding the grid resolution, incorporation of field data into the model, and model calibration and validation. Suggestions were made to increase data collection, adjust the grid resolution and model domain, and to conduct rigorous calibration and validation to improve the predictive capabilities of the model. ATM's main concerns regarding grid resolution, data, and data-model comparisons and subsequent URI model improvements in response to ATM's review are detailed below.

ATM was concerned about the use of multiple model domains to model processes in Narragansett Bay and the lower boundary of the model being located too close to the study region of interest.

D. Bergondo developed an Upper Narragansett Bay model that extended from the northern tip of Prudence Island northward to the Seekonk River. The horizontal grid spacing (i.e., east west and north-south distances for each grid cell) in this model was approximately 100-150 m in the Providence River (Fig. 1). To better simulate processes within the narrow and shallow regions of the Seekonk River, Justin Rogers improved the model grid resolution to 35 m x 35 m in the Providence and Seekonk Rivers (Fig. 2). J. Rogers also developed a version of the model encompassing all of Narragansett Bay, which had a lower boundary located in Rhode Island Sound. ATM was concerned about the use of three separate domains to model processes in Narragansett Bay and suggested a single larger domain be used to better evaluate full-bay transport of materials. The 2009 ROMS data report resolves the issue of multiple domains with development of the Full Narragansett Bay ROMS model, which is based on a curvilinear nested grid structure (finer resolution of 30 m in the north in the Providence River, expanding to a resolution of 200 m in lower Narragansett Bay). This model is similar to the Narragansett Bay-Rhode Island Sound domain, however, the open ocean boundary in this model is located at the mouth of Narragansett Bay (Fig. 3), rather than Rhode Island Sound (RIS model) or Prudence Island (Upper Bay model), which eliminates potential issues of the lower boundary being too close to the study area.

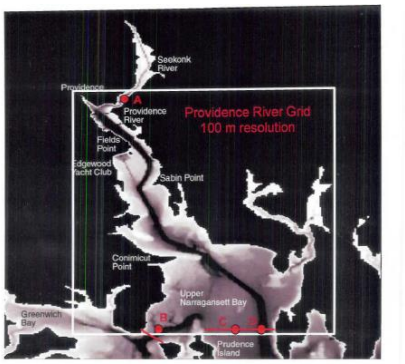

Figure 1: Upper Narragansett Bay/Providence River ROMS model. Red circles represent locations of bottom current profilers, red lines are current boat transects.

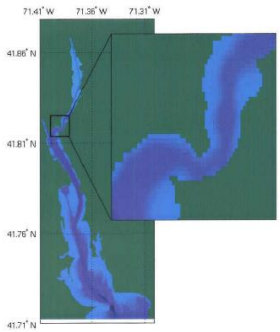

Figure 2: Seekonk River ROMS model, with higher resolution (35 m by 35 m) grid.

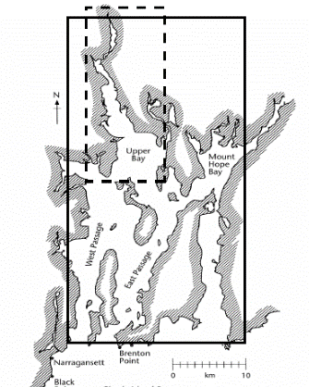

Figure 3: The new full Bay ROMS model domain (solid line) and Upper Bay ROMS model (dashed line).

ATM was broadly interested in understanding how data was collected and used in the model to improve data collection and integration efforts.

Starting in 2001, C. Kincaid et al. conducted detailed hydrographic surveys within the Providence River and the East and West Passages of Narragansett Bay, which included deployment of bottom mounted Acoustic Doppler Current Profilers (ADCPs) to measure water column currents. ADCPs were also mounted to boats, and transects were sampled to measure velocity through a vertical slice of river (see Figs. 1 and 4 for locations). A SeaBird water column profiler was also deployed to verify salinity, temperature, and dissolved oxygen while the boat was underway. In 2010, the NBC began to supplement ADCP data by deploying Tilt Current Meters

(TCMs), to generate time series data at multiple distributed sites for long periods of time. Calibrating the ROMS model with data from these TCMs improved the usefulness of the model in mapping relationships between flow, flushing, and transport. The new Full Narragansett Bay ROMS allowed for incorporation of additional data obtained throughout Narragansett Bay into the model. Continuous (15-minute) temperature and salinity data were obtained from Narragansett Bay Fixed-Site Water Quality Network buoys. Surface elevation data was obtained through the National Oceanic and Atmospheric Administration (NOAA) tide gauges. Stream flow data was obtained from United States Geological Survey (USGS) gages. A comprehensive series of data model comparisons have been conducted since the 2007 report.

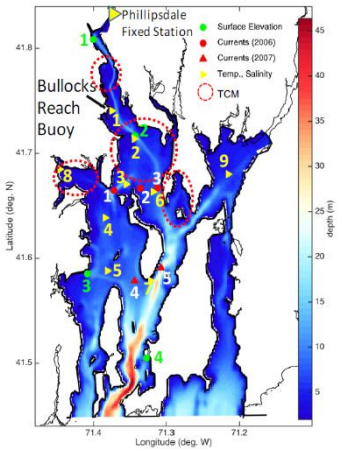

Figure 4. Locations of Acoustic Doppler Current Profilers (ADCPs; red circles and triangles), tilt current meters (circled areas), temperature- salinity measurements (yellow triangles), and surface elevation gages (green circles).

ATM suggested conducting comprehensive quantitative data-model comparisons for hydrographic parameters, including surface elevation, current speed and direction, salinity, and temperature.

The subsequent 2009 Report includes a section, *Protocols for Quantitative Data-Model Comparisons,* and associated appendices which contain computer codes for statistics used to assess the new Full Narragansett Bay ROMS model. Model output was compared to ADCP and hydrographic data using a variety of summary statistics. Dr. Dave Ullman, of URI-GSO, also worked to conduct comprehensive model-data comparisons of currents and hydrography, to assess how well the model simulates surface water elevation, currents, temperature, salinity, and vertical density stratification. Based on a Wilmott Skill assessment, which is a commonly-used metric to assess model performance, the model performs quite well. Many of these model skill assessments were discussed in the 2015 presentation (posted on NBC's *Snapshot of Upper Narragansett Bay* website), "Narragansett Bay ROMS: Model-Data Comparisons of Currents and Hydrography," given at the Narragansett Bay Commission's 2015 Workshop "Just Another Day on the Upper-Upper Bay: Update on NBC's Environmental Monitoring, Modeling, Construction Initiatives, and Water Quality Results." Co-authors of this presentation included C. Kincaid, Christelle Balt, D. Bergondo, and J. Rogers. These data-model comparisons are also described in subsequent data reports from 2009 and 2018, posted on the *Snapshot of Upper Narragansett Bay* website. Additionally, reports generated in 2018 describe the importance and use of comprehensive synoptic ADCP-sonde co-located data sets in ROMS model development and verification.

An important response to the ATM review is the deployment, analysis, and data-model comparison that occurred for the sub-tidal flows on Edgewood Shoals. Tilt current meters were deployed there in 2010 and the comparison of these de-tided records to ROMS output represents the most complete spatial-temporal data-model check on currents ever conducted in the Bay. The model's ability to recreate the nature of the recirculation on Edgewood Shoals, both qualitatively and quantitatively, is a significant advancement in modeling. Moreover, the model was shown to be able to match key aspects of the subtidal observed currents before, during, and after the Great RI Flood of 2010.

Additionally, upon inclusion of nutrient and algal parameters in the model, a sensitivity test was performed of many biological parameters, wherein many simulations were run for a short time period to most accurately model ecosystem processes and identify underlying processes responsible for phytoplankton blooms and algal transport throughout the Bay. Ongoing work is being conducted to increase the model grid resolution, assess data-model comparisons, and improve the predictive capability of the model in terms of nutrient transport and algal dynamics. Please see our *Snapshot of Upper Narragansett Bay* website for future reports, presentations, and updates!