Multiple Shallow-Water Systems Analysis to Improve the Assessment of Chesapeake Bay Water Clarity and Submerged Aquatic Vegetation Water Quality Standards

Modeling Quarterly Review

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Multiple Shallow-water Systems Analysis to Improve the Assessment of Chesapeake Water Quality Standards RFP:

The Chesapeake Bay's shallow-water conditions are difficult to simulate with the current suite of CBP models due to interactions between the shallow waters, open waters, and land (including shoreline erosion, waves, settling and re-suspension, biogenic solids production), fractal shorelines, shallow bathymetry, and watershed inputs. Variables and processes are currently not well understood.

But, there's an opportunity to refine the shallow water simulation for the 2017 Midpoint Assessment.

Multiple Shallow-water Systems Analysis to Improve the Assessment of Chesapeake Water Quality Standards RFP *(continued)*:

Therefore, the CBP is supporting the application of shallow-water models to improve Chesapeake Bay shallow-water simulations of ***dissolved oxygen, chlorophyll a, suspended solids, and water clarity*** in order to better understand the impacts of alternative management strategies on water quality and living resources in the tidal Chesapeake Bay.

Multiple Shallow-water Systems Analysis to Improve the Assessment of Chesapeake Water Quality Standards RFP *(continued)*:

Over the course of the two-year project, multiple modeling teams will be funded to apply different shallow-water models using common forcing conditions over a three– to five–year-base-case run at specified shallow-water sites.

The RFP will cover two years from an expected start date of March 24, 2014. EPA plans to award up to four cooperative agreements under this RFP. The total estimated funding for two years is approximately $300,000, with an estimated $150,000 available for the first and second years.

Multiple Shallow-water Systems Analysis to Improve the Assessment of Chesapeake Water Quality Standards RFP *(continued)*:

EPA will also fund an independent model evaluation team that will use state-of-the-art metrics to assess the relative skill of these shallow-water models based on available CBP water quality and submerged aquatic vegetation (SAV) monitoring data. The independent model evaluation team will also compare the results from a series of nutrient and sediment change scenarios and analyze causes and impacts of differences among the shallow-water models.

Shallow-water Model Applicants will:

• ***Present status reports of technical aspects of their work at the CBP Partnership Modeling Workgroup's Quarterly Reviews as requested by the Modeling Workgroup.***

• Recommend representative sites to which their model will be applied to simulate a number of bottom types, salinity ranges, and weather and tidal forcing parameters. ***The CBP Partnership's Modeling Workgroup will select the specific study sites for application of the set of estuarine shallow water models as outlined below under "Study Site Selection."***

• Apply existing models with the ability to simulate estuarine shallow-water hydrodynamics and water quality parameters and processes. The models should be capable of simulating SAV abundance indirectly by providing simulations of dissolved oxygen and water clarity, two parameters known to be crucial to the successful establishment and persistence of SAV beds.

• Possibly develop their own SAV model, though this is not a requirement. The CBP Partnership's Modeling Team will provide all teams with a standard empirical model.

• Use input data and provide output data as outlined below under "Shallow-water Models Input and Output Specification"

Study Site Selection

Applicants will apply their shallow-water models at study sites selected by the CBP Partnership's Modeling Workgroup, which will:

• Include the following contrasting types of areas:

- Shallow water habitats with present SAV abundance and known historical SAV abundance;
- Shallow water habitats without present SAV abundance but with known historical SAV abundance; and
- Shallow water habitats with no historical or present SAV abundance.

Site Selection will consider the following:

- Salinity – predominantly freshwater site vs. brackish site vs. high-salinity site
- Bottom type – sandy site vs. silt-covered or muddy site
- Wave influence – a site with moderate waves permitting SAV growth vs. a site dominated mainly by tides
- Input-forcing variables – a site influenced by locally forced conditions vs. a site influenced by mainly external factors
- Nutrient levels – a site with high levels of nutrients exhibiting eutrophic characteristics vs. a site with lower levels of nutrients exhibiting oligotrophic characteristics

• ***CBP Partnership's Modeling Workgroup will select sites that have at least three to five years of data, including temperature, salinity, light/turbidity, chlorophyll a, bathymetry, wave height, wave period, open boundary conditions, freshwater flows and loads, and, where appropriate, SAV acres.***

Work Underway:

- University of Maryland Center for Environmental Science - Jeremy Testa (UMCES), Damian Brady (U. Maine) and Ming Li (UMCES): $73,333 for Activity 1.
- Virginia Institute of Marine Science, Center for Coastal Resources - Joseph Zhang (VIMS) and Harry Wang (VIMS): $73,333 for Activity 1.
- Old Dominion University Research Foundation - Richard Zimmerman (ODU), Victoria Hill (ODU), John Klinck (ODU), Michael Dinniman (ODU), and Chuck Gallegos (SERC): $73,333 for Activity 1.
- Virginia Institute of Marine Science, Biological Sciences - Marjorie Friedrichs (VIMS) and Raleigh Hood (UMCES) :$80,000 for Activity 2

Application and Analysis of a Coupled Hydrodynamic-Biogeochemical Model (ROMS-RCA) in Shallow-Water Habitats of the Chesapeake Bay

Jeremy Testa (UMCES), Damian Brady (U. Maine), and Ming Li (UMCES)

- An application of ROMS (HM) and RCA (WQM)
- Includes consideration of benthic algae and sediment resuspension
- Builds on a currently operational model of shallow water in Delaware Bay

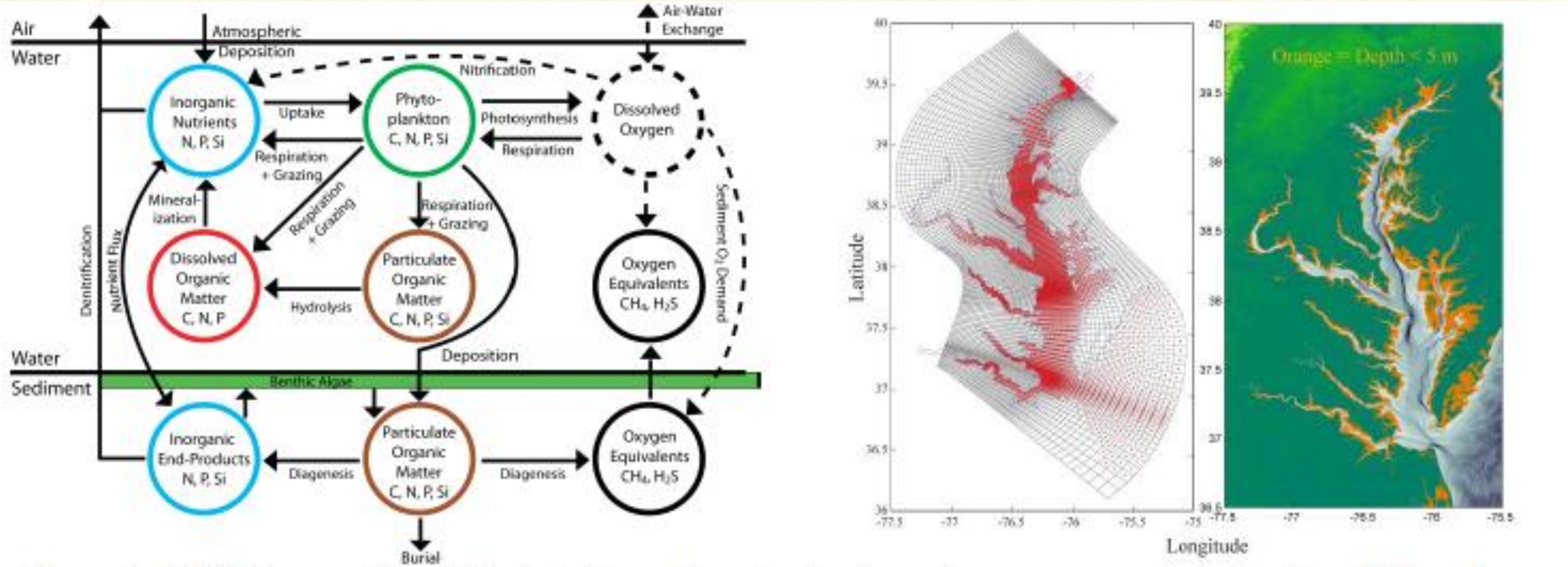

Figure 4: (left) Diagram of the RCA, including sediment and water-column processes, including the addition of a benthic algal layer at the sediment surface. In the middle is the ROMS-RCA model domain in Chesapeake Bay to the right is a map of Bay bathymetry with orange areas indicating the areas of habitat less than 5 meters in depth.

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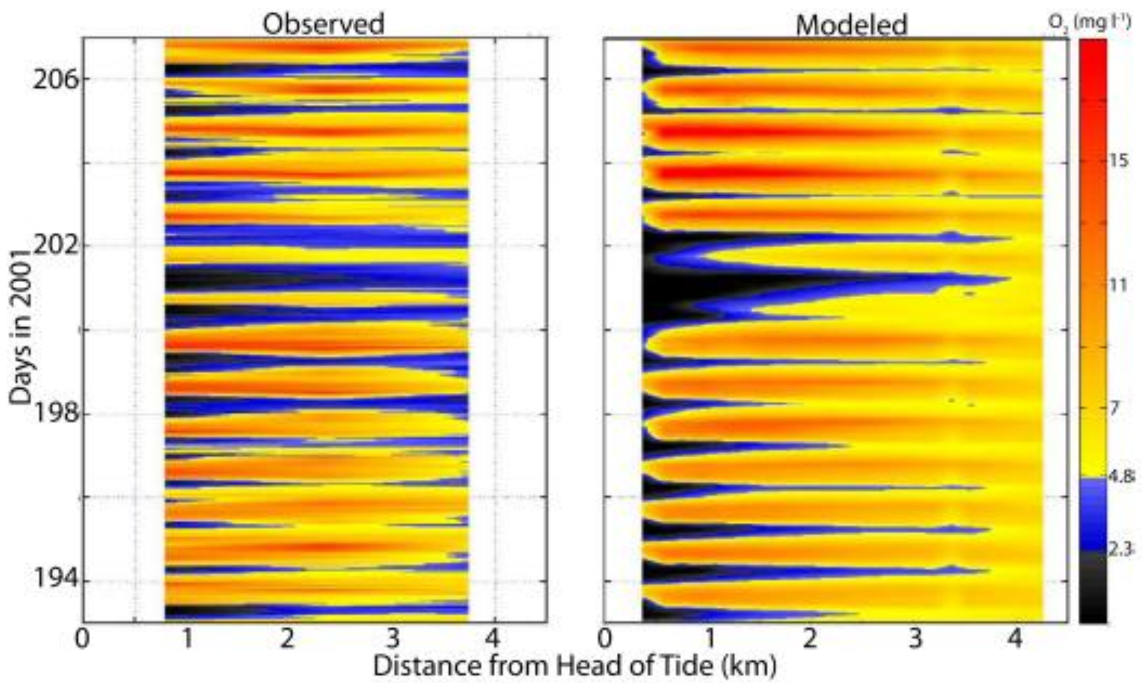

Figure 6: Validation of diel O_2 cycles in the Delaware's Coastal Bays over a two-week period in July 2001. The left panel includes observations (Tyler, et al. 2009), while the right panel is a simulation made with ROMS-RCA.

Simulation of diel O_2 concentrations in shallow water will be challenging for all shallow water teams.

Simulating Shallow Water Hydrodynamics Coupled with ICM Water Quality Model Using Finite Volume Method on Unstructured Grids

Joseph Zhang (VIMS) and Harry Wang (VIMS)

- An application of SELFE (HM) and ICM (WQM)

- A two-pillar approach. The first is to increase the model resolution in spatial and temporal resolution. The second is to improve the representation of sediment resuspension dynamics including direct coupling with a wind-wave model rather than the present fetch-limited wave formulation.

- Based on unstructured grids suited for complex geometry and bathymetry due to flexibility for local refinement to achieve high spatial resolution of features that bear implications for various physical and biological processes.

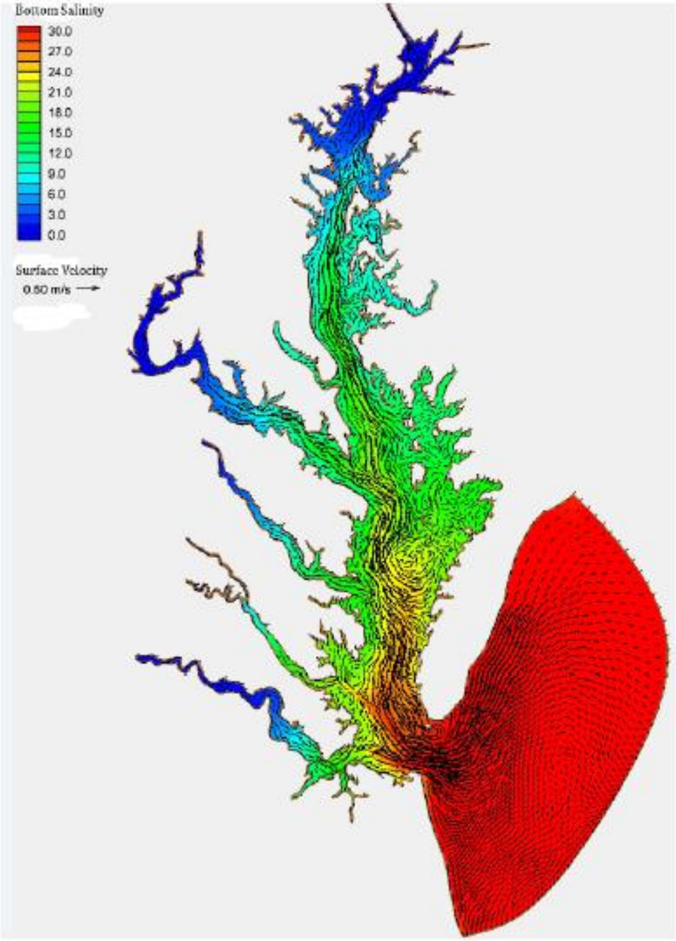

Fig. 1: Averaged surface velocity and bottom salinity from June to August 2004, generated by SELFE3D model for the entire Chesapeake Bay. With modest unstructured grid refinement, the model is already able to capture some small-scale flow structures in shallow areas,

Simulating Shallow Water Hydrodynamics Coupled with ICM Water Quality Model Using Finite Volume Method on Unstructured Grids

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- SELFE (Semi-implicit Eulerian-Lagrangian Finite Element) is next-generation unstructured-grid based modeling suite. SELFE is an open-source, community-supported modeling system, based on unstructured grids in the horizontal and hybrid terrain-following *S* coordinates and shaved Z coordinates in the vertical.
- The ICM model has now been fully incorporated into SELFE as a subroutine based on the finite-volume method.
- The coupled SELFE-Wind-Wave Model uses a parallel numerical framework to study the wave-current interaction processes based on unstructured meshes in geographical space.

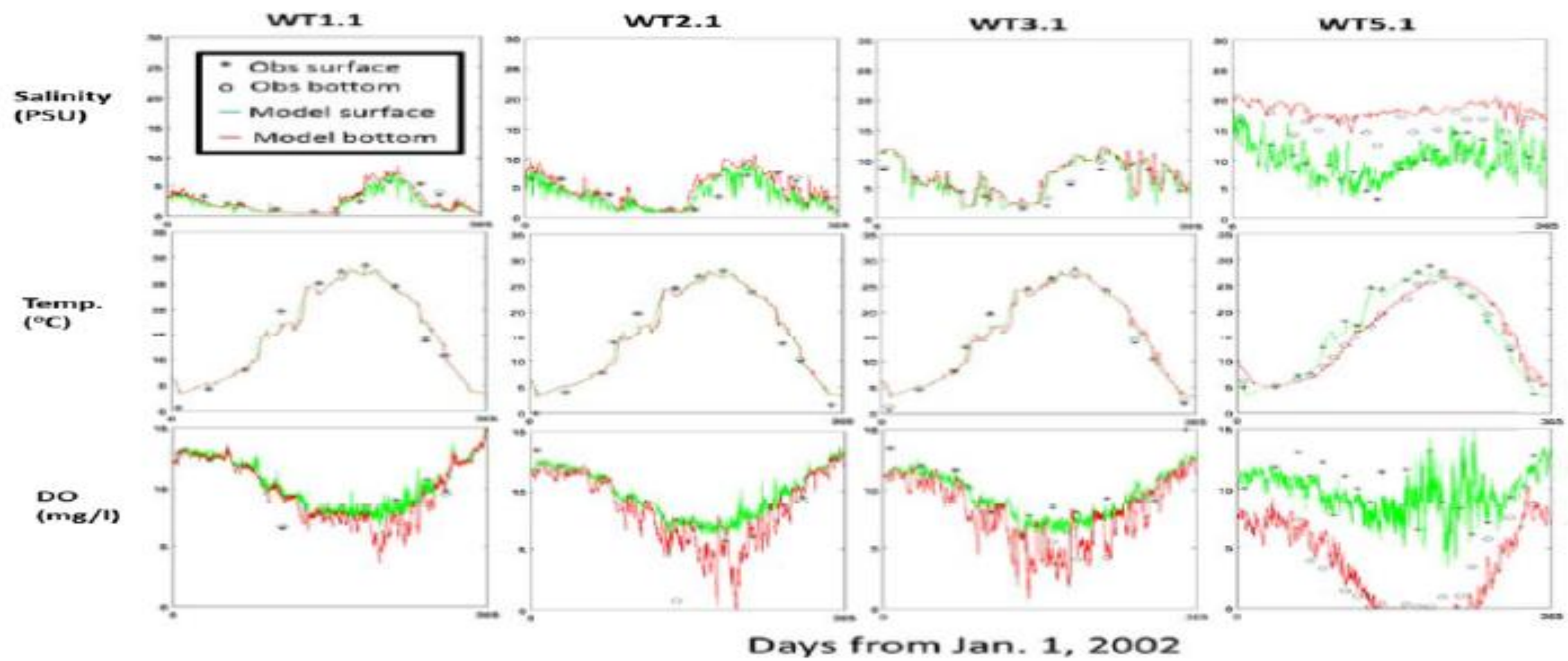


Fig. 2: Comparison of 3 water quality variables at 4 sites in Upper Bay (WT1.1, WT2.1 and WT3.1 in shallow areas, and WT5.1 in deeper channel) for year 2002.

Modeling the impacts of water quality on SAV and other living resources in the tidal Chesapeake Bay

Richard Zimmerman (ODU), Victoria Hill (ODU), John Klinck (ODU), Michael Dinniman (ODU), and Chuck Gallegos (SERC):

- The work will develop an appropriately scaled hydrodynamic simulation of shallow water environments based on the Regional Ocean Modeling System (ROMS) integrated with a mechanistic state-of-the-art bio-optical model of radiative transfer in optically complex waters and SAV canopies to simulate the distribution of water quality, and its impacts on SAV resources in the Chesapeake Bay.

- Zimmerman and Gallegos are the principal developers of the *GrassLight software* package, a state-of-the art solution of the radiative transfer equation for submerged environments by integrating the water quality model of Gallegos (1994, 2001) with the submerged plant canopy model of Zimmerman (2003b, 2006) to provide mechanistically-based predictors of spectral light attenuation and SAV performance.

Modeling the impacts of water quality on SAV and other living resources in the tidal Chesapeake Bay

Richard Zimmerman (ODU), Victoria Hill (ODU), John Klinck (ODU), Michael Dinniman (ODU), and Chuck Gallegos (SERC):

In addition to promising greater power in predicting SAV responses to the light environment than existing correlative approaches, the bio-optical model, based on the physics of radiative transfer and fundamental plant physiology, provides mechanistic insight into the processes that appear to yield different light requirements for sea grasses growing in different environments. (PIs have strong inclination toward sites with *Zostera* and salinities >14 ppt)

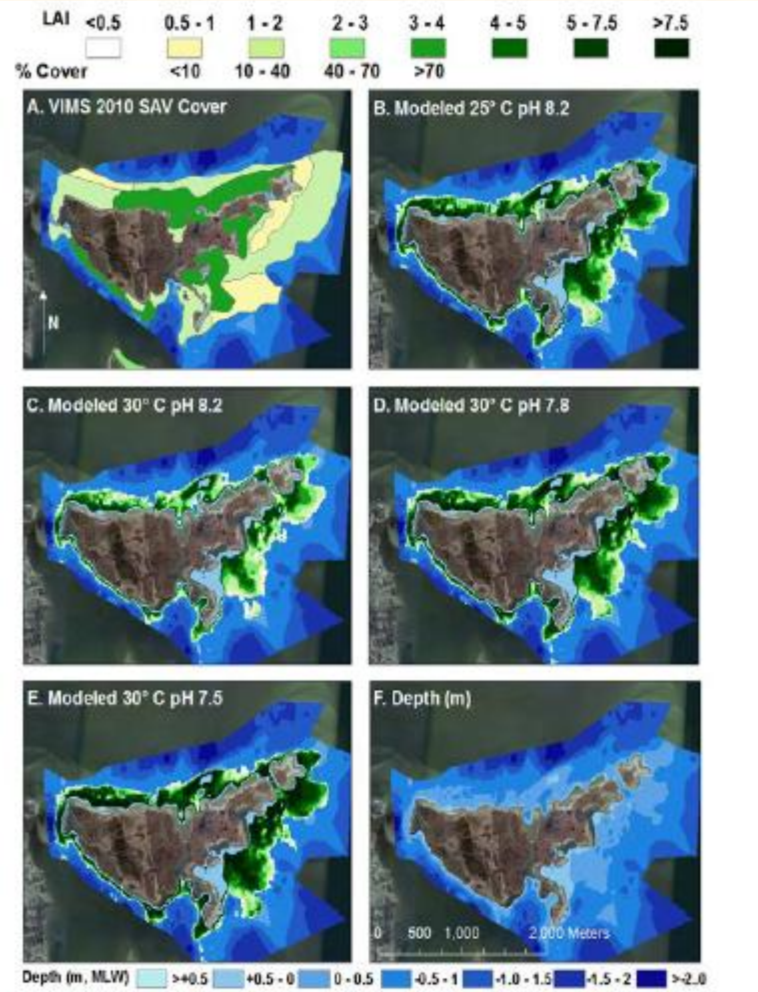


Figure 1. Maps of SAV cover at Goodwin Islands NERR in 2010 provided by the VIMS SAV project (A) and predicted by GL_2.11 for various climate scenarios (B – E). F. DEM based on our acoustic bathymetric survey used for the model calculations.

Activity 2: Comparison of Shallow-water Models for Use in Supporting Chesapeake Bay Management Decision-making

Estimated Funding: $80,000 over two years to complete an independent model inter-comparison of the shallow-water models developed under Activity 1. It is expected that the costs will be low in the first year, supporting limited coordination with model application development teams. The majority of the funds will be directed towards the second year to complete the independent model evaluation work once the shallow-water models are developed.

Applicants are encouraged to describe how they would support efforts to progressively enhance the entire multiple model evaluation and application process over time.

The model comparison applicant will:

- Use state-of-the-art metrics to assess the relative skill of each of the shallow-water models, particularly with respect to the simulation of the parameters key to assessing attainment of the Chesapeake Bay water quality standards for water clarity, SAV, open-water dissolved oxygen, and chlorophyll *a, and based on available CBP monitoring data.*

- **Report the team’s findings and recommendations to the CBP Partnership’s Modeling Workgroup.**

Comparison of Shallow-water Models for Use in Supporting Chesapeake Bay Management Decision-making
Marjorie Friedrichs (VIMS), Raleigh Hood (UMCES)

The overall objectives of the proposed project are:
(1) to assess the relative skill of multiple linked hydrodynamic+water quality models in terms of their ability to reproduce observations of various hydrodynamic and water quality variables at select shallow water sites in the Bay,
(2) to compare the modeled Submerged Aquatic Vegetation (SAV) computed from an empirical SAV model for each participating hydrodynamic+water quality model, and
(3) to compare results of nutrient reduction strategies applied to these multiple estuarine models at these select sites.

The effort builds directly on the results and lessons learned from prior work assessing the relative skill of multiple hydrodynamic+water quality estuarine models. The project compared the skill of multiple Chesapeake Bay models using hindcasting for parameters such as: salinity, temperature, stratification, and dissolved oxygen.

Comparison of Shallow-water Models for Use in Supporting Chesapeake Bay Management Decision-making
Marjorie Friedrichs (VIMS), Raleigh Hood (UMCES)

Target diagrams were used to illustrate total model data misfit or "root mean squared error" (RMSE), which is plotted as the distance between each model symbol and the center of the plot. Thus the farther a model symbol is from the center or "bull's eye" of the target, the lower the reliability of that particular model.

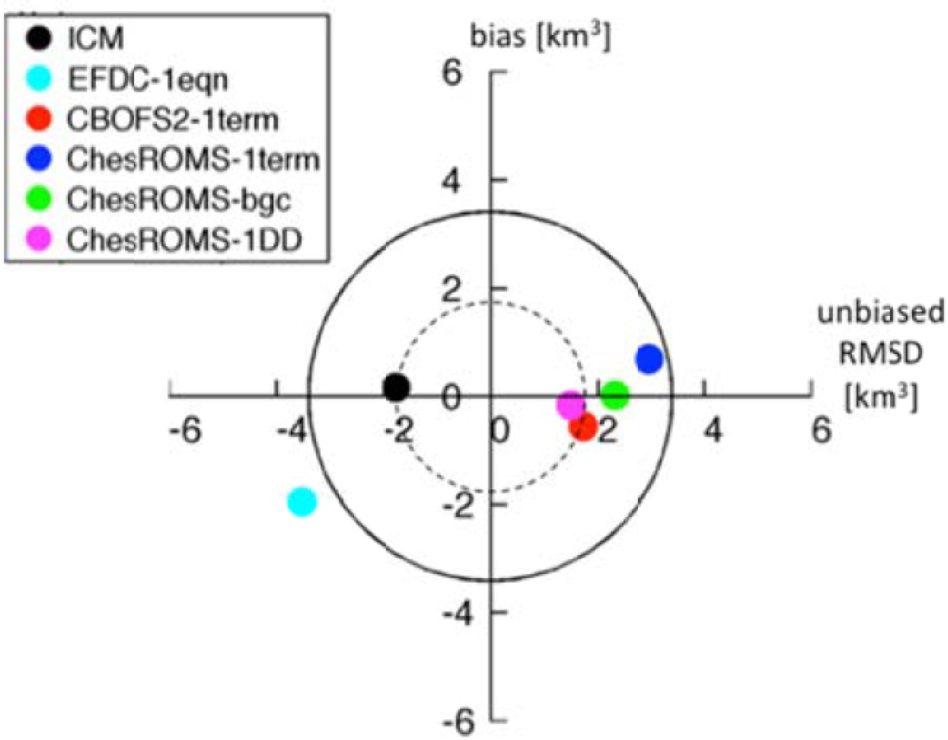
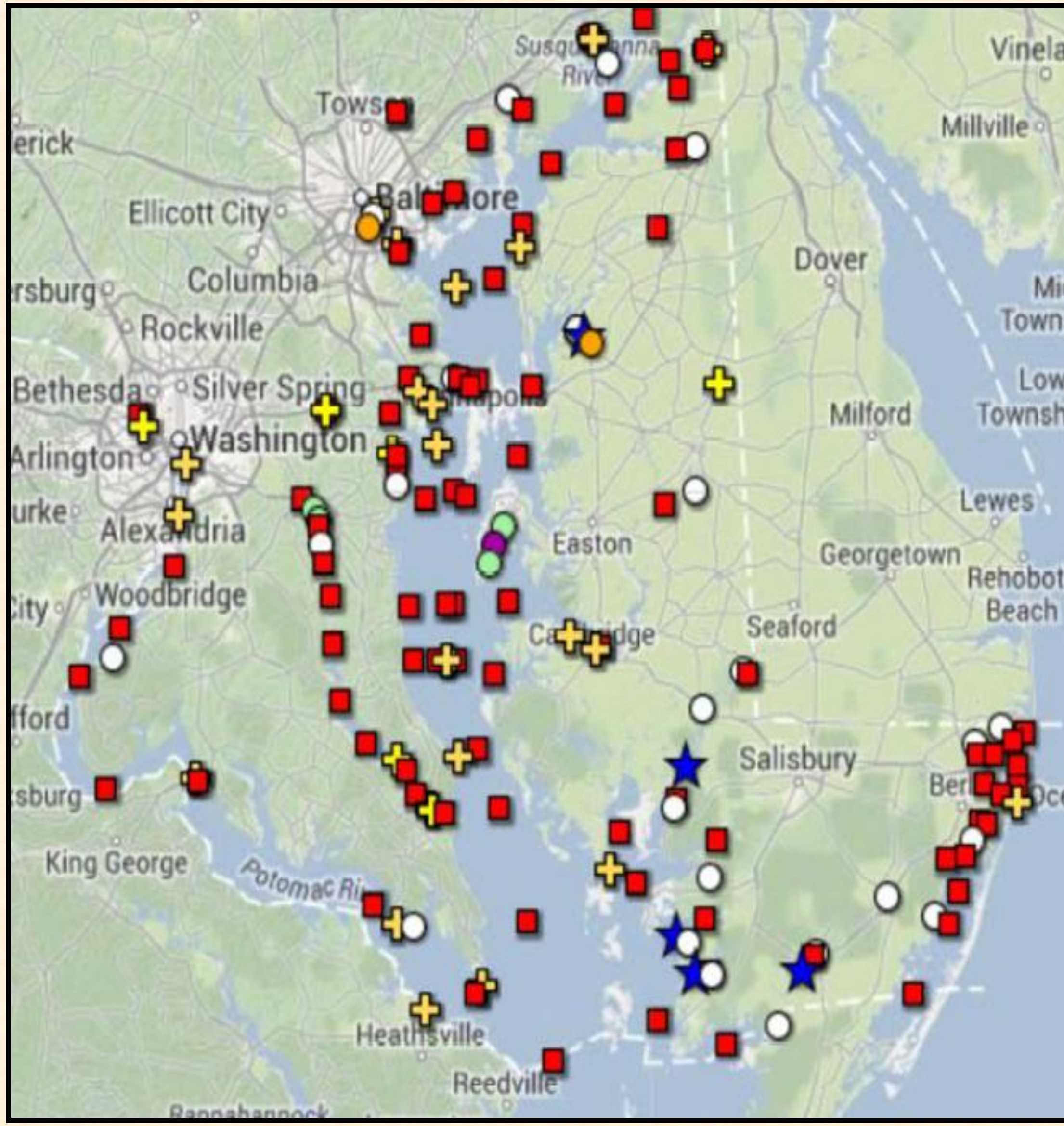


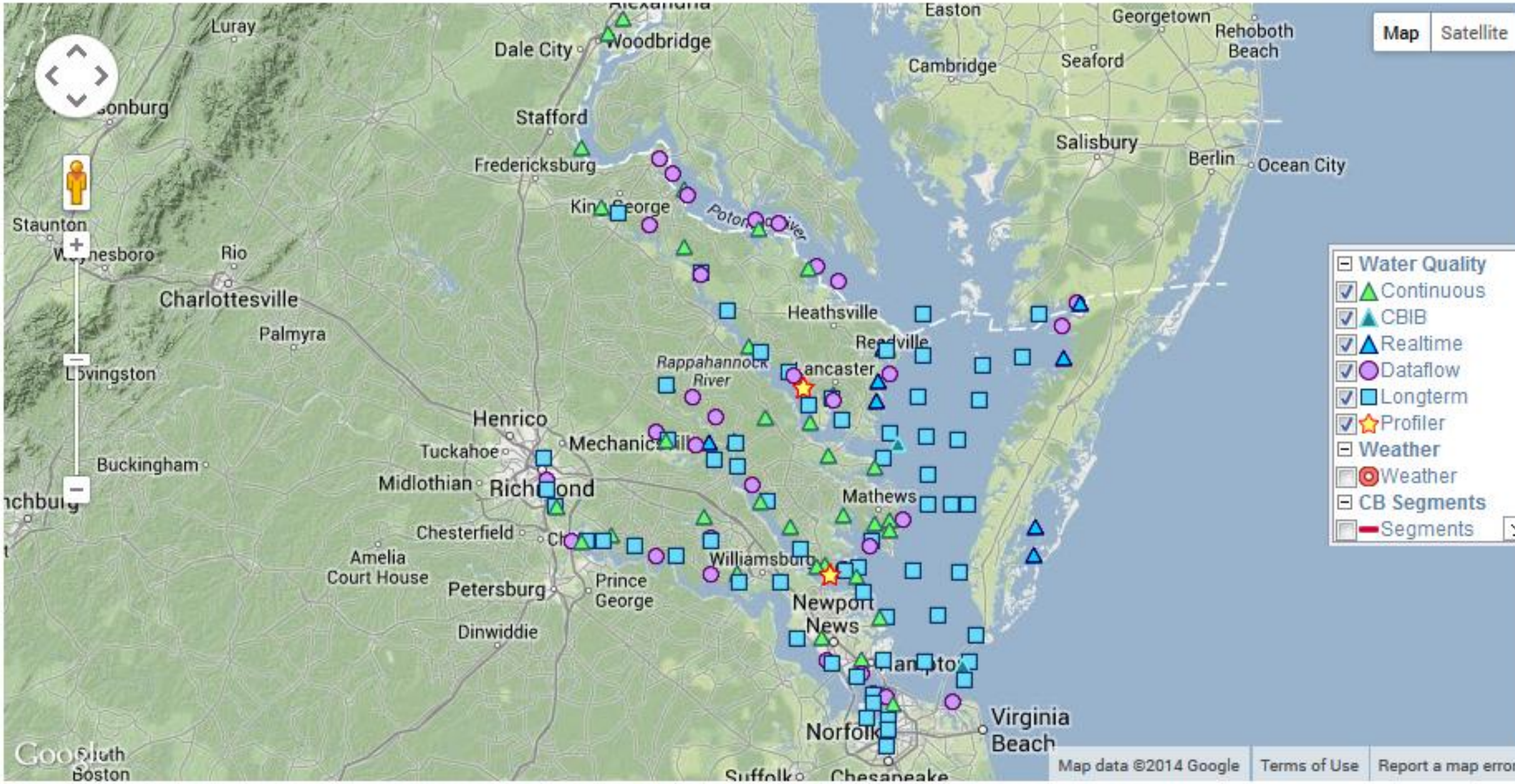
Fig. 1. Target diagram illustrating relative performance of five alternative linked hydrodynamic+water quality models to the CBP model, in terms of reproducing 2004 hypoxic volume. The x-axis represents over/under estimation of the mean hypoxic volume and the y-axis represents the over/under estimation of hypoxic volume variability. The distance from the center of the bulls-eye represents the total RMSE of each model (Jolliff et al., 2009; Friedrichs et al., 2012).

DNR Eyes on the Bay



Station Legend

- Long-Term Fixed Station
- Dataflow / Water Quality Mapping Segment
- Continuous Monitoring Station with Real-time Telemetry
- Continuous Monitoring Station without Telemetry
- Vertical Profiler
- National Data Buoy Center or NOAA buoys (Click for current weather/water conditions)
- Partner Sites
- State Highway Weather Data
- Continuous Monitoring Station that is not Currently Active

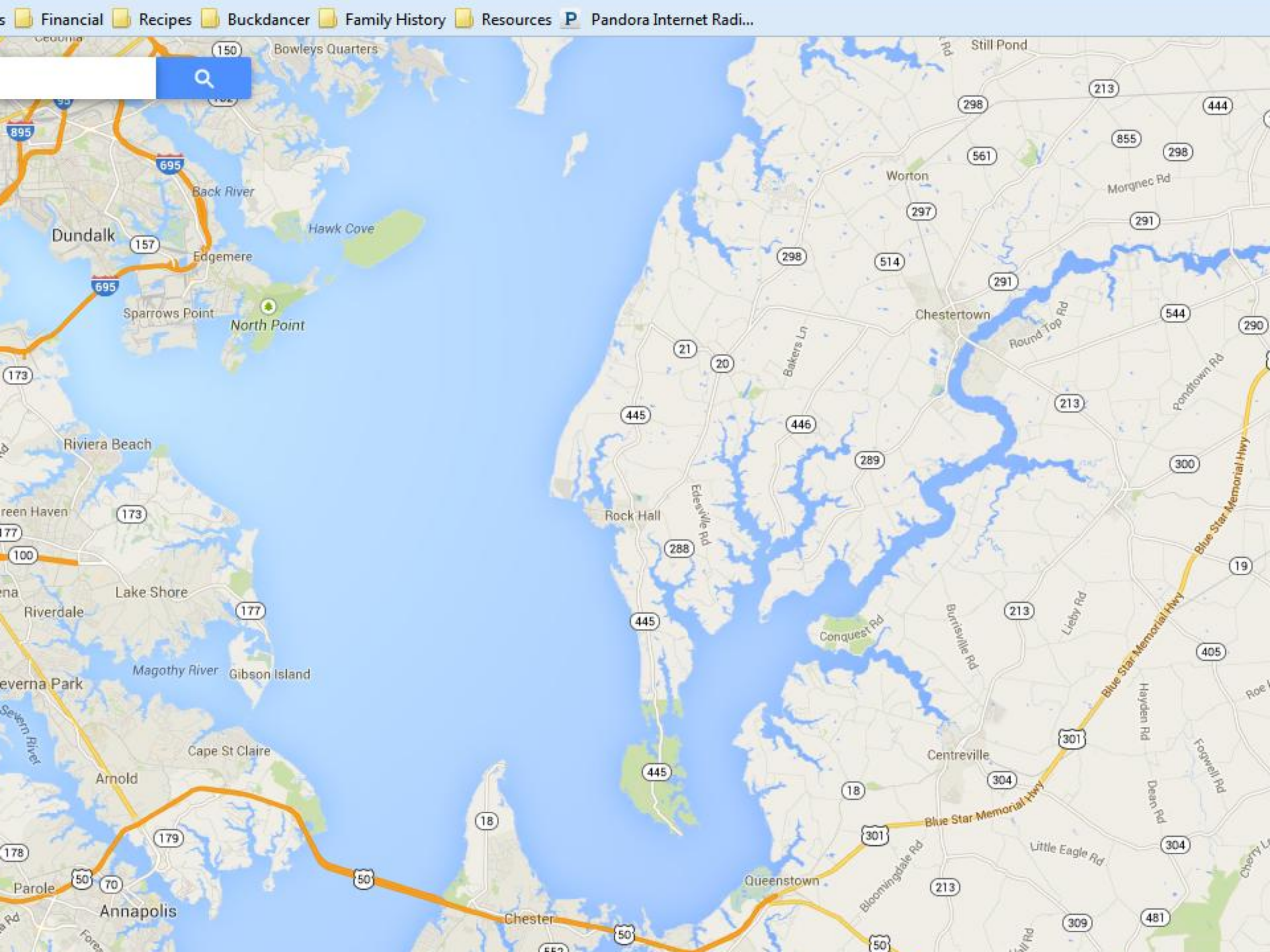


--- To view data, click on the map above or select from the listings below ---

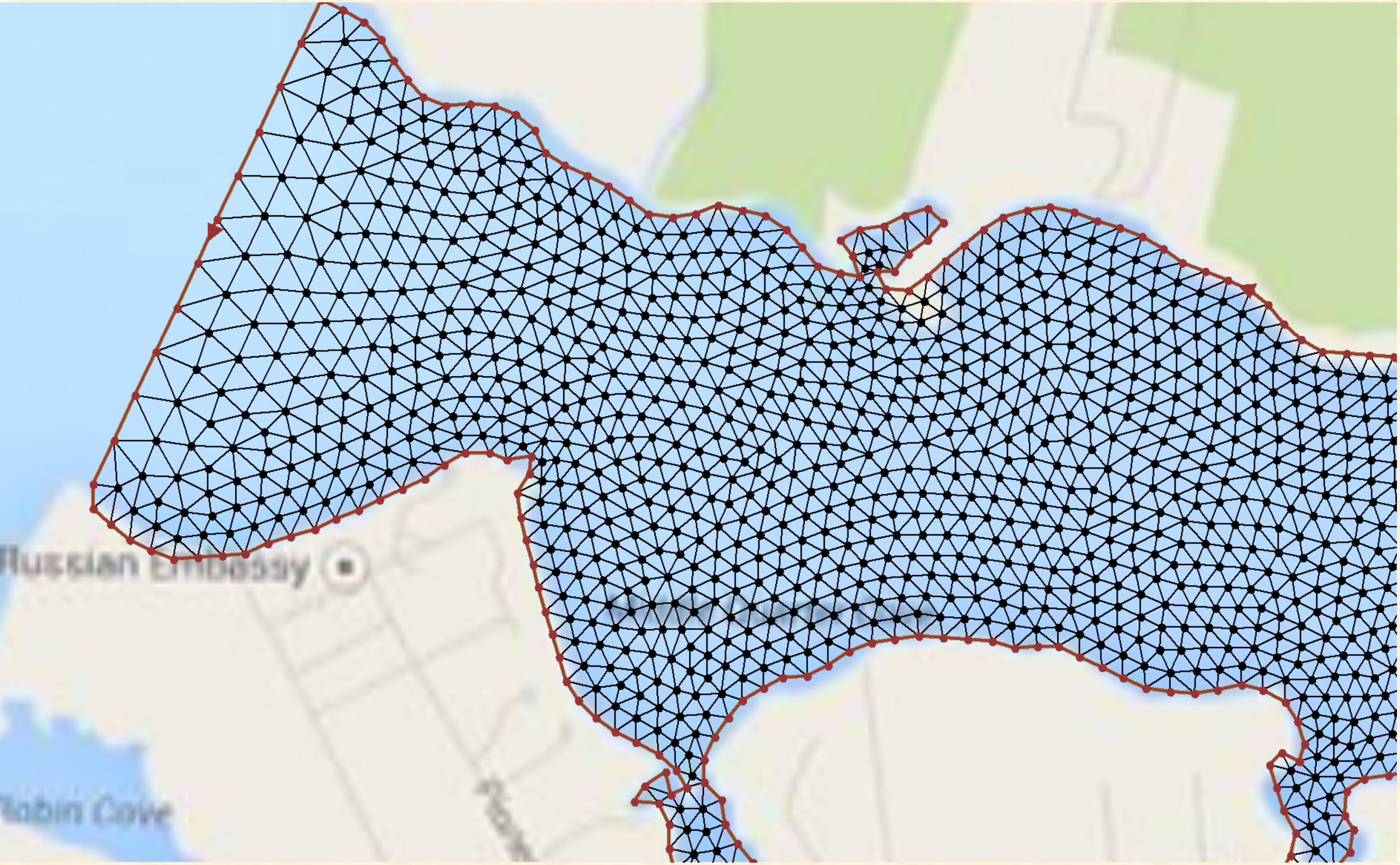
- Select a continuous station - **or** - Select a dataflow cruise - **or** - Select a longterm station -

Options for sites:

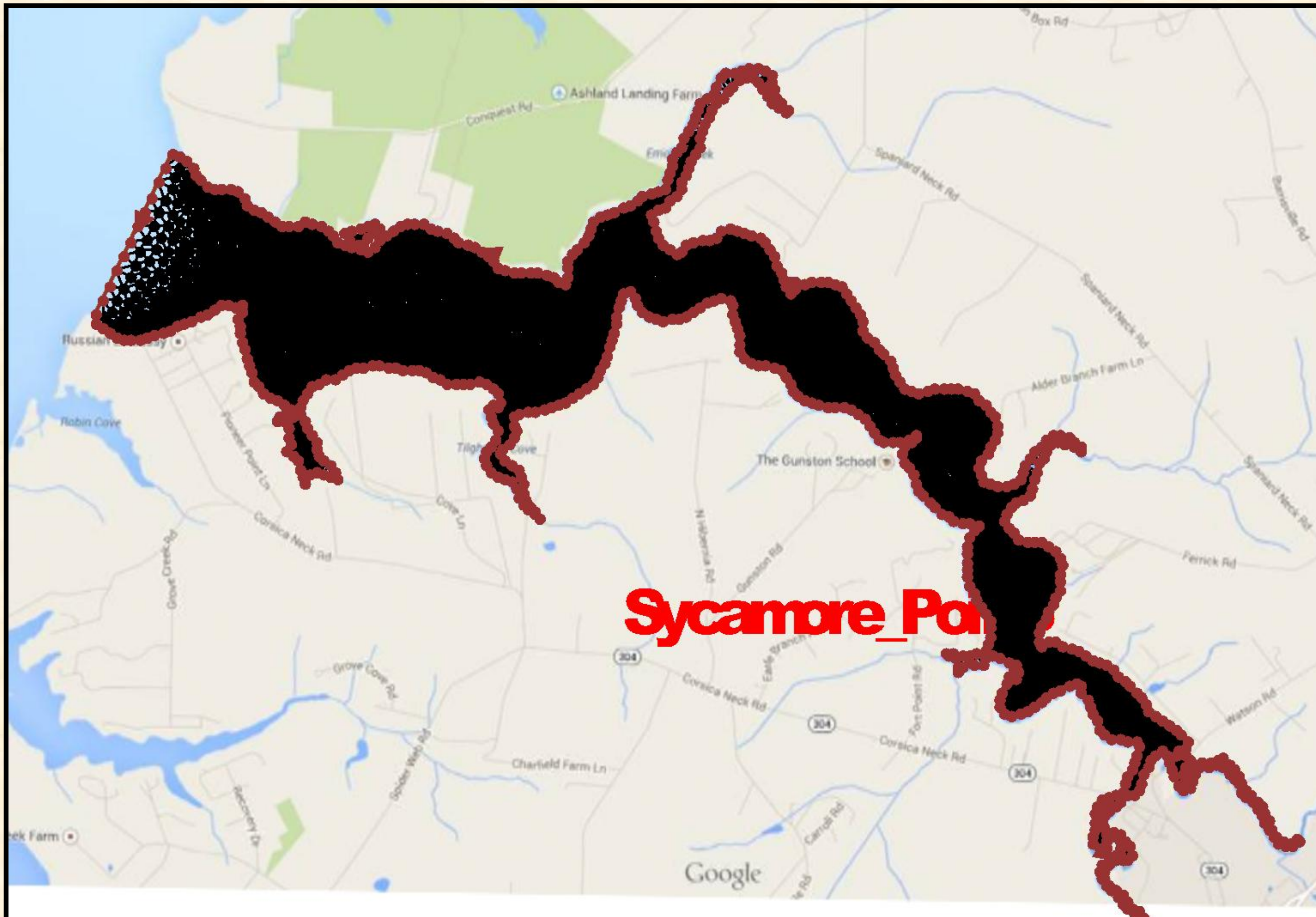
- Small embayment option, e.g., Corsica
- Whole tributary option, e.g., York or Patuxent with nested grid.
- Combination option, e.g., all in for the small site and those that want to, and can, do nested grid for the tributary.


Financial
Recipes
Buckdancer
Family History
Resources
Pandora Internet Radi...
Bowleys Quarters
Still Pond
Worton
Morgnec Rd
Back River
Hawk Cove
Dundalk
Edgemere
Sparrows Point
North Point
Chestertown
Round Top Rd
Bakers Ln
Pondtown Rd
Riviera Beach
Rock Hall
Edesville Rd
Blue Star Memorial Hwy
Lake Shore
Riverdale
Conquest Rd
Burrisville Rd
Lieby Rd
Magothy River
Gibson Island
Severna Park
Severn River
Hayden Rd
Cape St Claire
Centreville
Fogwell Rd
Arnold
Dean Rd
Little Eagle Rd
Bloomingdale Rd
Queenstown
Parole
Annapolis
Chester

50m resolution on coast, 100m open boundary: 993 nodes, 2870 cells



50m resolution on coast, 100m open boundary: 2870 nodes, 4993 cells



Status & Next Steps:

- administrative and technical review for 2 awards
- awaiting submission of 2 work plans
- award grants
- select sites
- CBPO Modeling Team prepares boundary conditions once site selection is complete.
- Activity 1 Study Teams begin work
- STAC WS late in 2014

Status & Next Steps:

- Quarterly Review in July and presentations by PIs.
- Shallow water session C. Cerco - *Modeling the Shallows in Chesapeake Bay* in **Chesapeake Modeling Symposium 2014.**
- RFP and all work plans on Modeling WG website.
- All boundary conditions and input data on Modeling WG web site.
- All shallow water presentations on Modeling WG website.