Fine-scale Patapsco/Back River Tributary Model for Simulating Effect of Sanitation Sewage Overflow (SSO) under Climate Change Conditions

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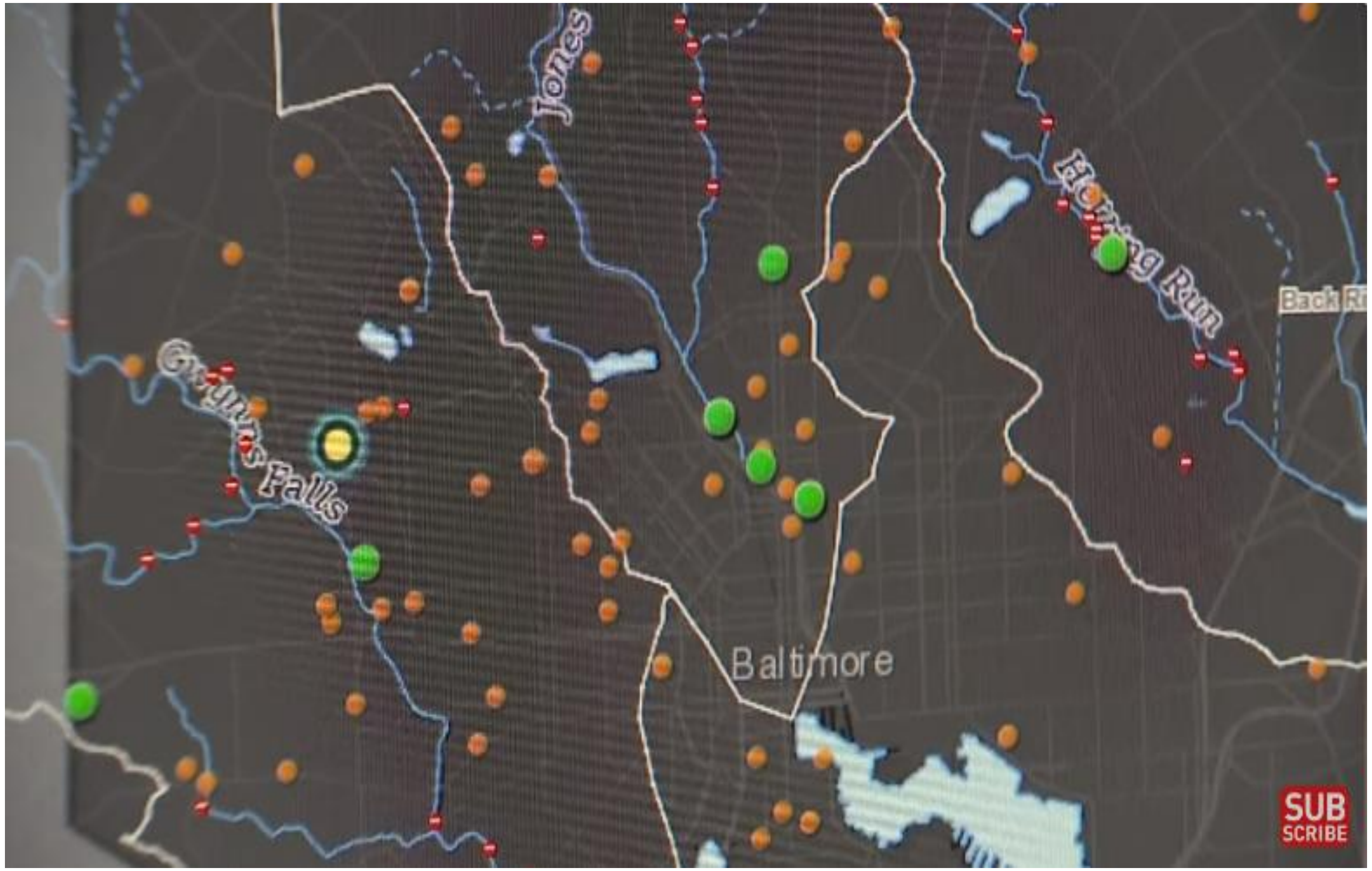
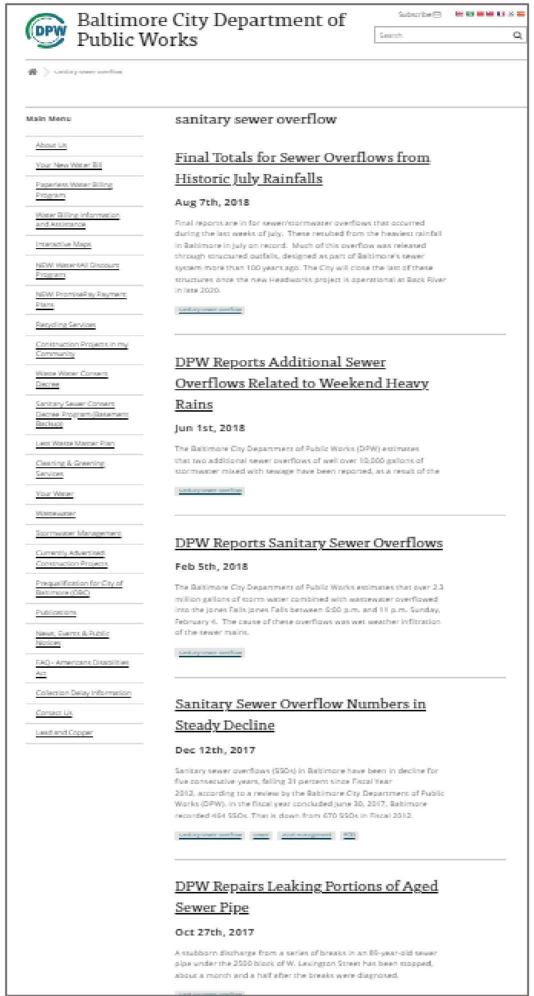
Motivation – two folds

1. BALTIMORE urban runoff -- Present Condition

   Jan 18, 2024: Baltimore City's sewage systems were overwhelmed and overflowing. According to Baltimore City'Department of Public Works (DPW), the combination of heavy rain and snowmelt spilled 14 million gallons of raw sewage into surrounding streams and rivers.



14 million gallons of sewage overflow spills into Baltimore waterways in one day (1 million Herring run, 4 million Jones Falls, 9 million Gwynns Falls) https://www.youtube.com/watch?v=cyKtOt5vbE4



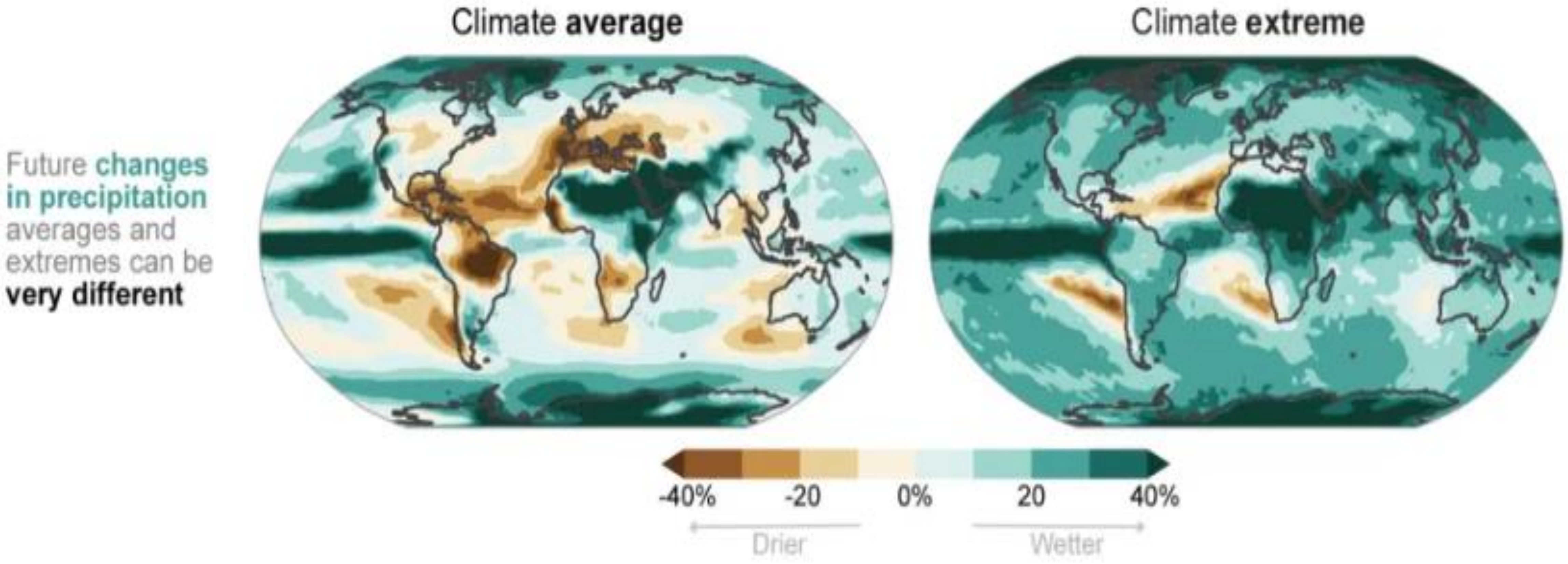
https://publicworks.baltimorecity.gov/taxonomy/term/2439

Sewage overflow into the Jones Falls -Baltimore MD at manhole overflow 67, April 6, 2017

2. Baltimore urban runoff under Climate Change

Changing Precipitation

A warmer average global temperature will cause the water cycle to "speed up" due to a higher rate of evaporation. More water vapor in the atmosphere will lead to more precipitation. Global average precipitation can increase by 7% for each degree of warming, which means we are looking at a future with much more rain and snow, and a higher risk of flooding to some regions. With 2°C temperature increase, heavy rain events are expected to become 1.7 times more likely, and 14% more intense. However, changes in precipitation will not be evenly distributed. Some locations will get more, and others will see less.



https://scied.ucar.edu/learning-zone/climate-change-impacts/predictions-future-global-climate#:~:text=Global%20average%20precipitation%20can%20increase,%2C%20and%2014%25%20more%20intense.

Outline:

I. Fine-scale Patapsco/Back River Tributary Model

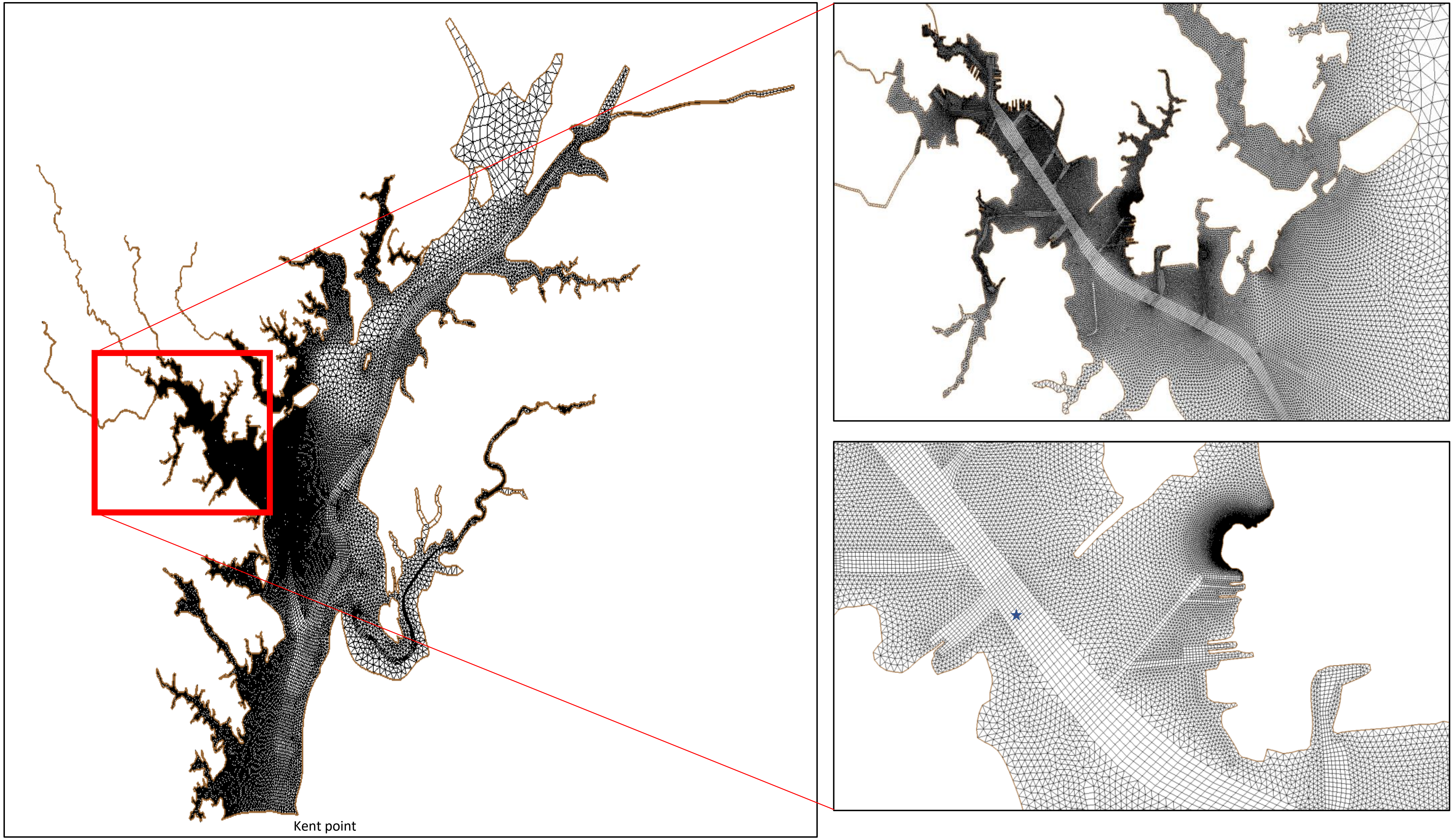
II. Preliminary calibration

III. Applications

IV. Summary

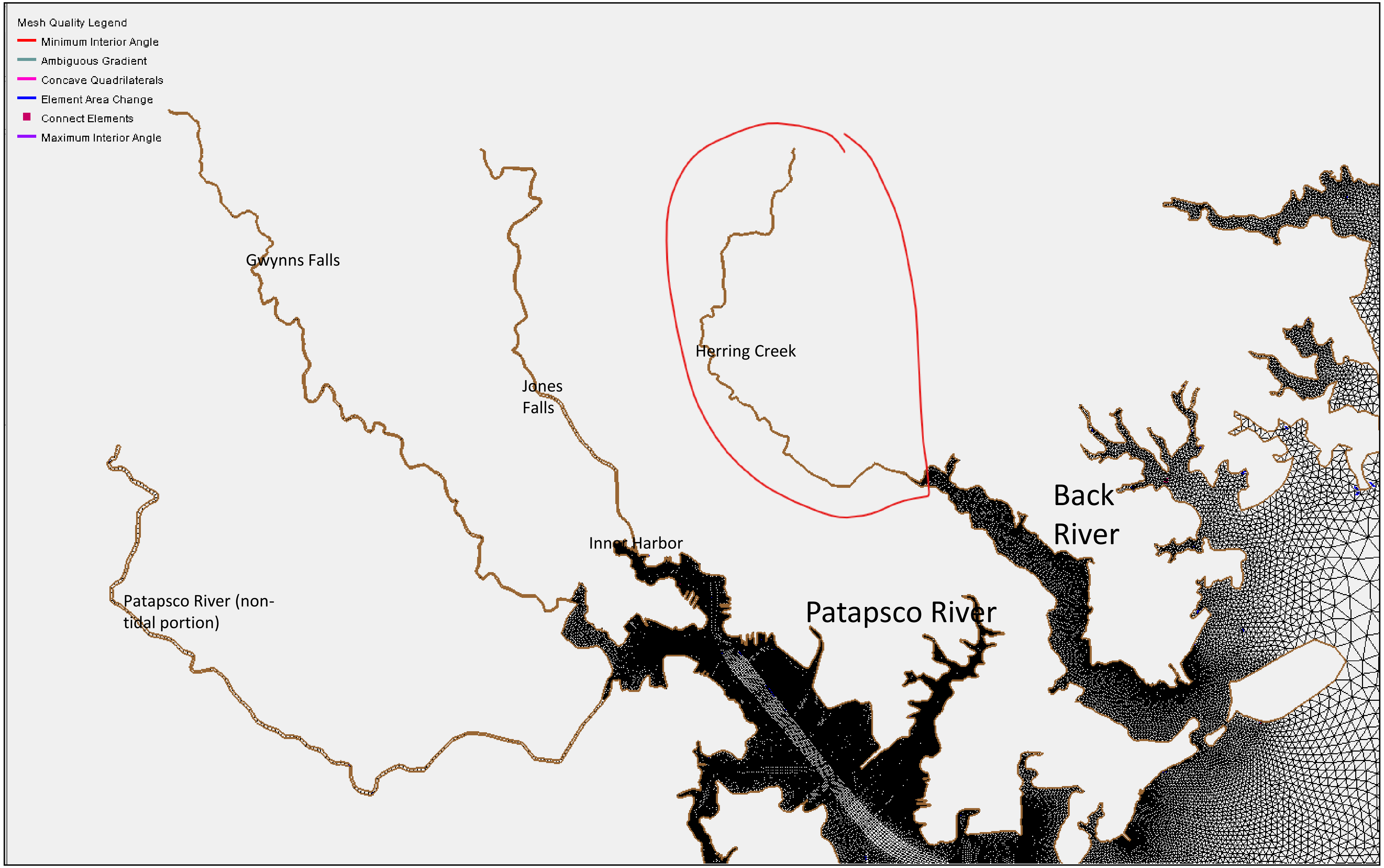
I. Fine-scale Patapsco/Back River modleing

(1) 3D SCHISM model domain



Overall resolution 50-100 m with a total of 61 k grid cells

Figure 1: The model domain to be used in evaluating near-field mixing and far-field dilution factors in (a) Upper Chesapeake Bay (b) Baltimore Harbor (c) Sparrow Point and Bear Creek.



The MTM fine-grid includes 4 major streams in Baltimore area: Herring Creek, Jones Falls, Gwynns Falls, and non-tidal Patapsco River, intended for receiving urban watershed loads.

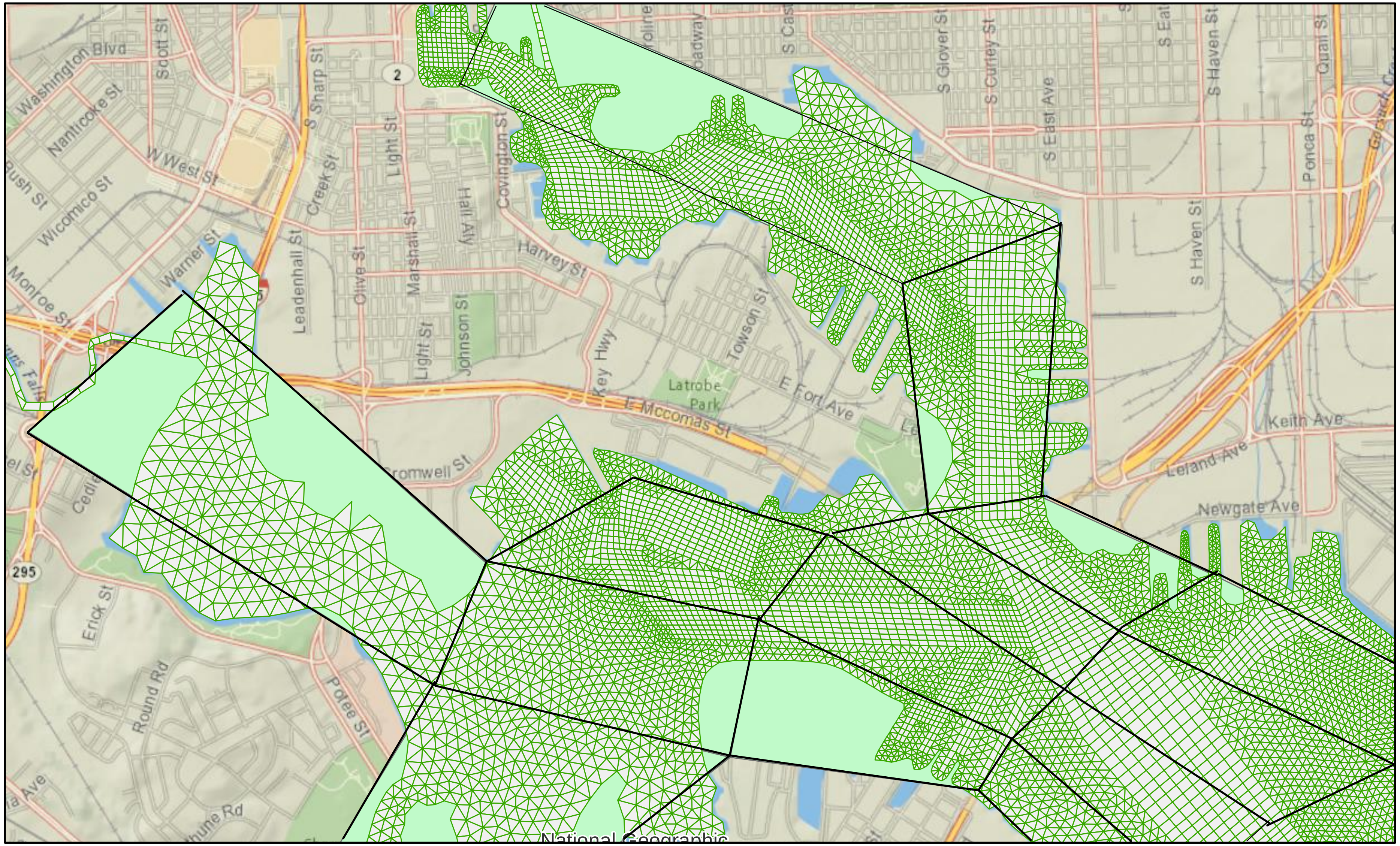
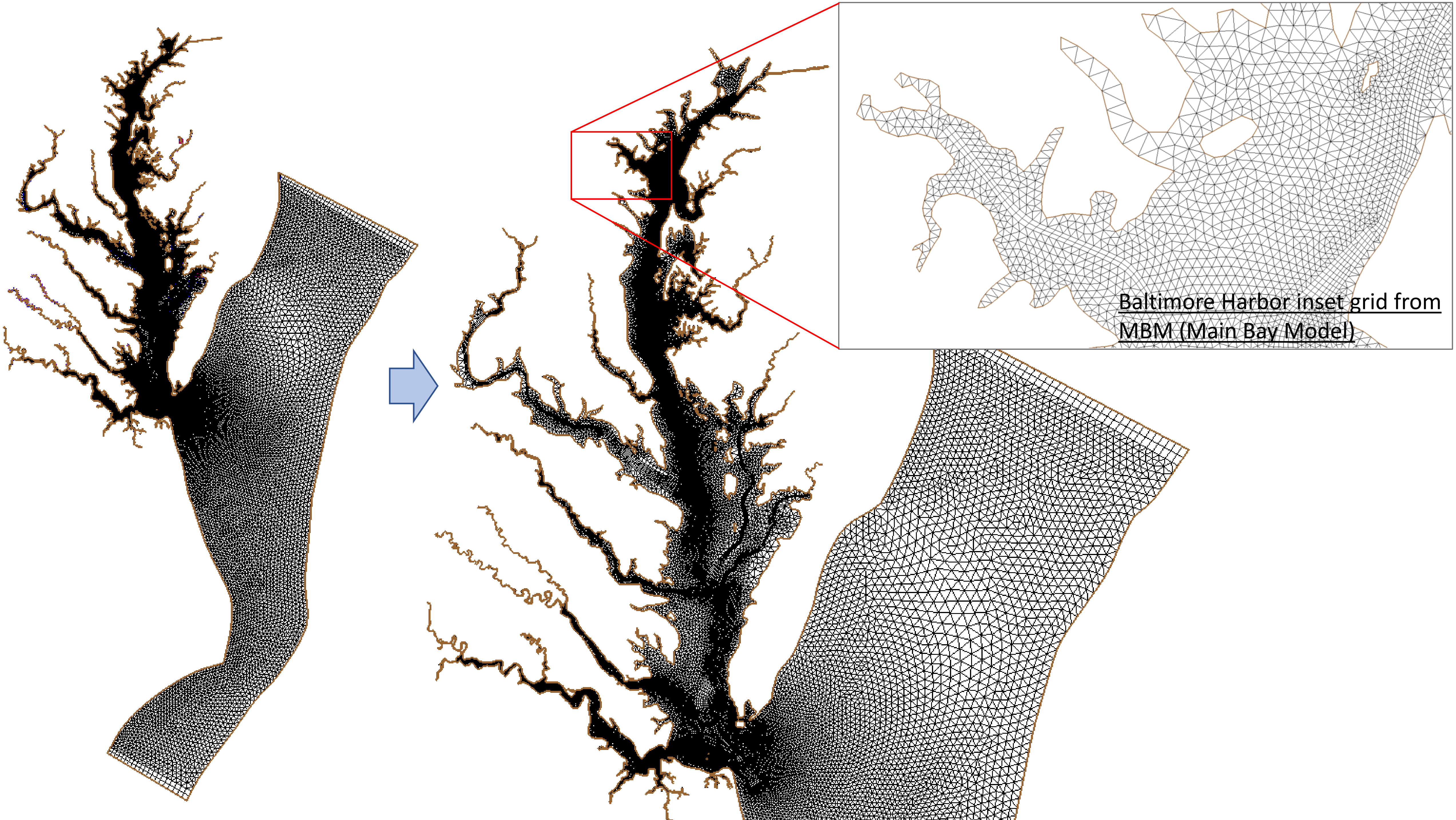


Figure 2 (a): **Coarse Black quadrilateral cells are CH3D grid; the Green is MTM fine-unstructured-grid with mixed triangle/quadrilateral grids.** **Blue is additional areas fine grid covered.**


Baltimore Harbor inset grid from
MBM (Main Bay Model)

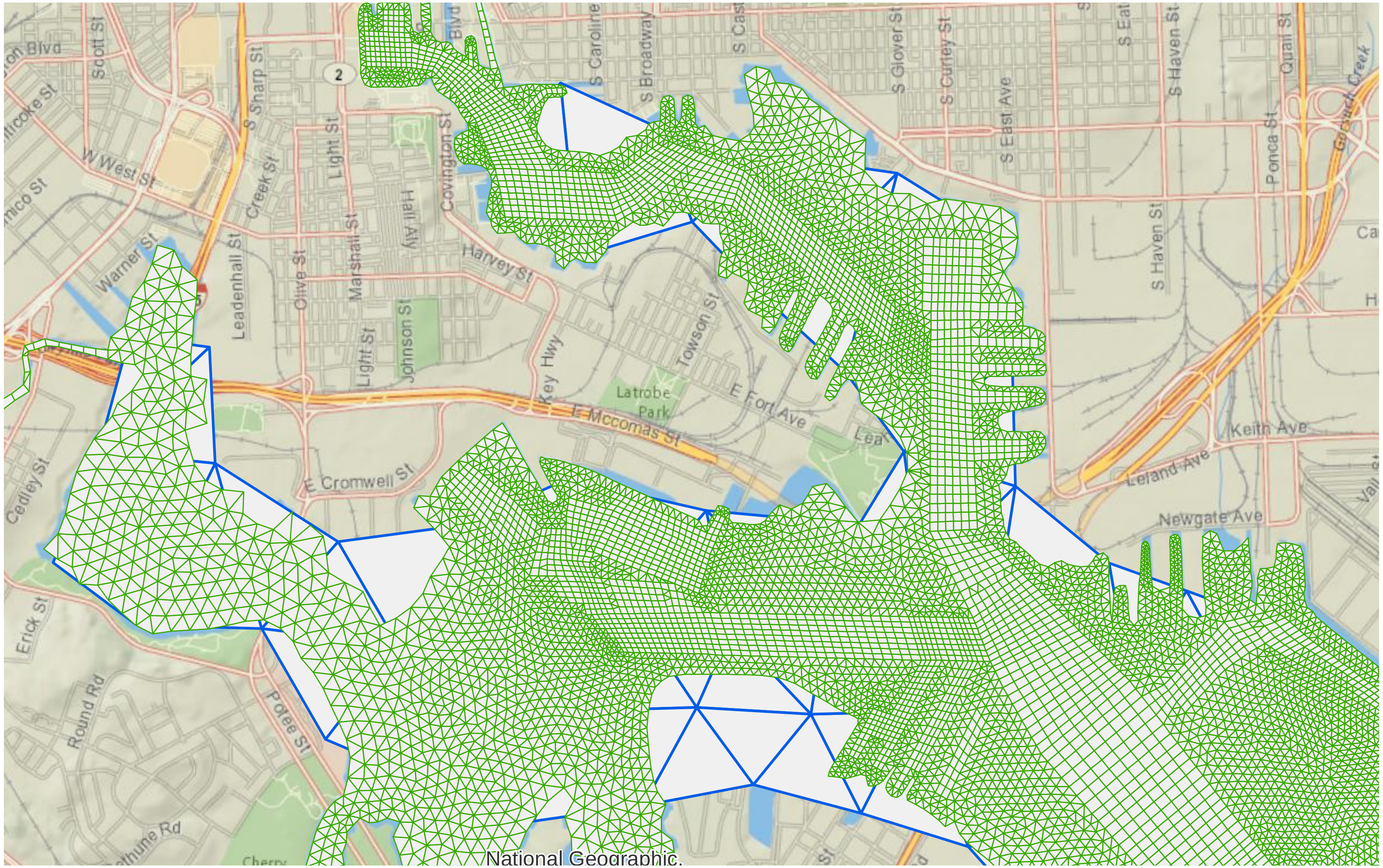
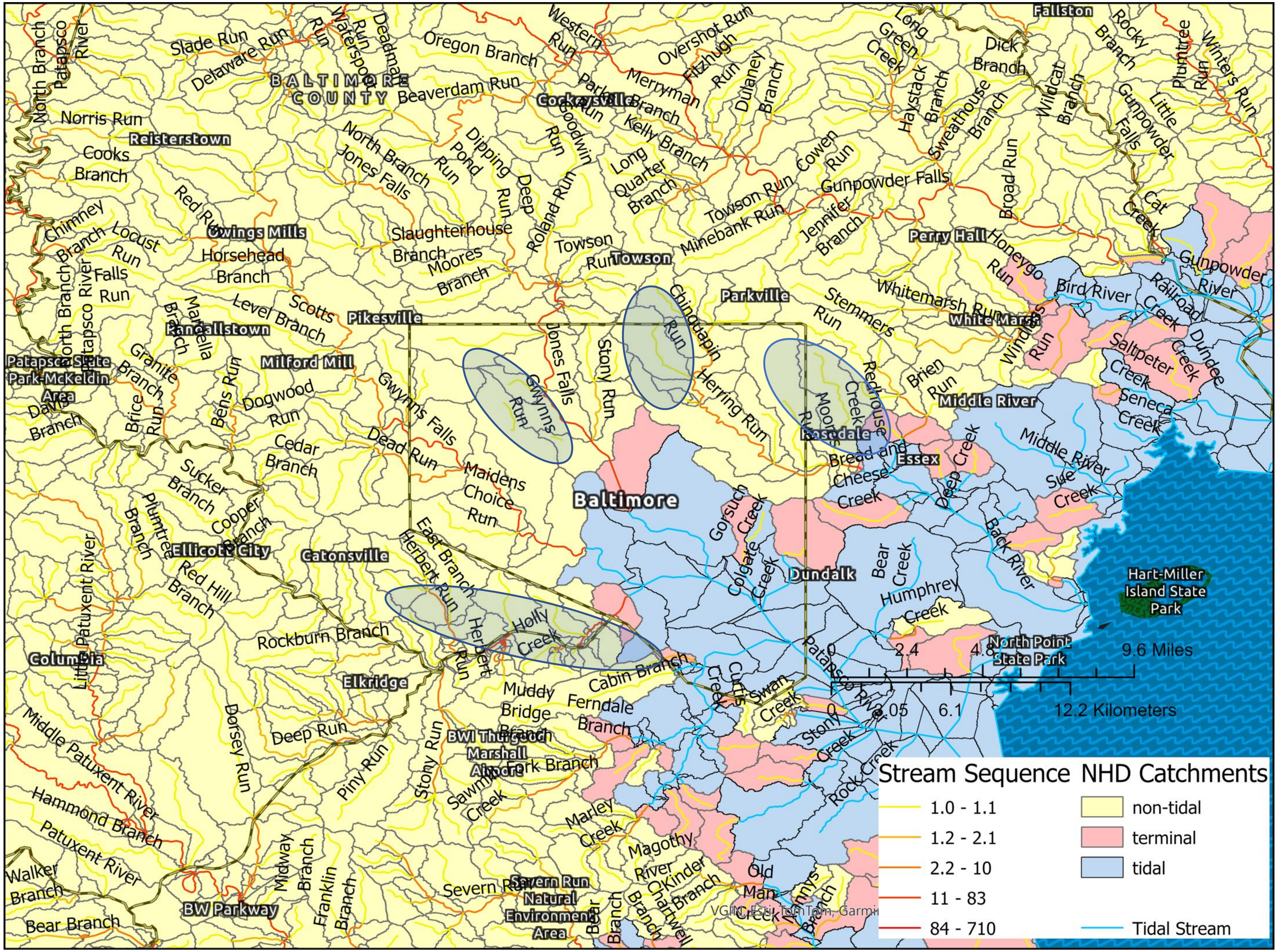
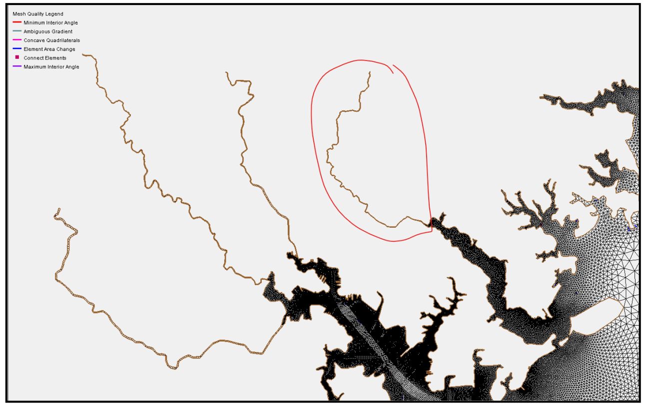


Figure 2(b): **Blue lines are MBM grid; the Green is MTM fine-unstructured-grid with mixed triangle /quadrilateral grids.**

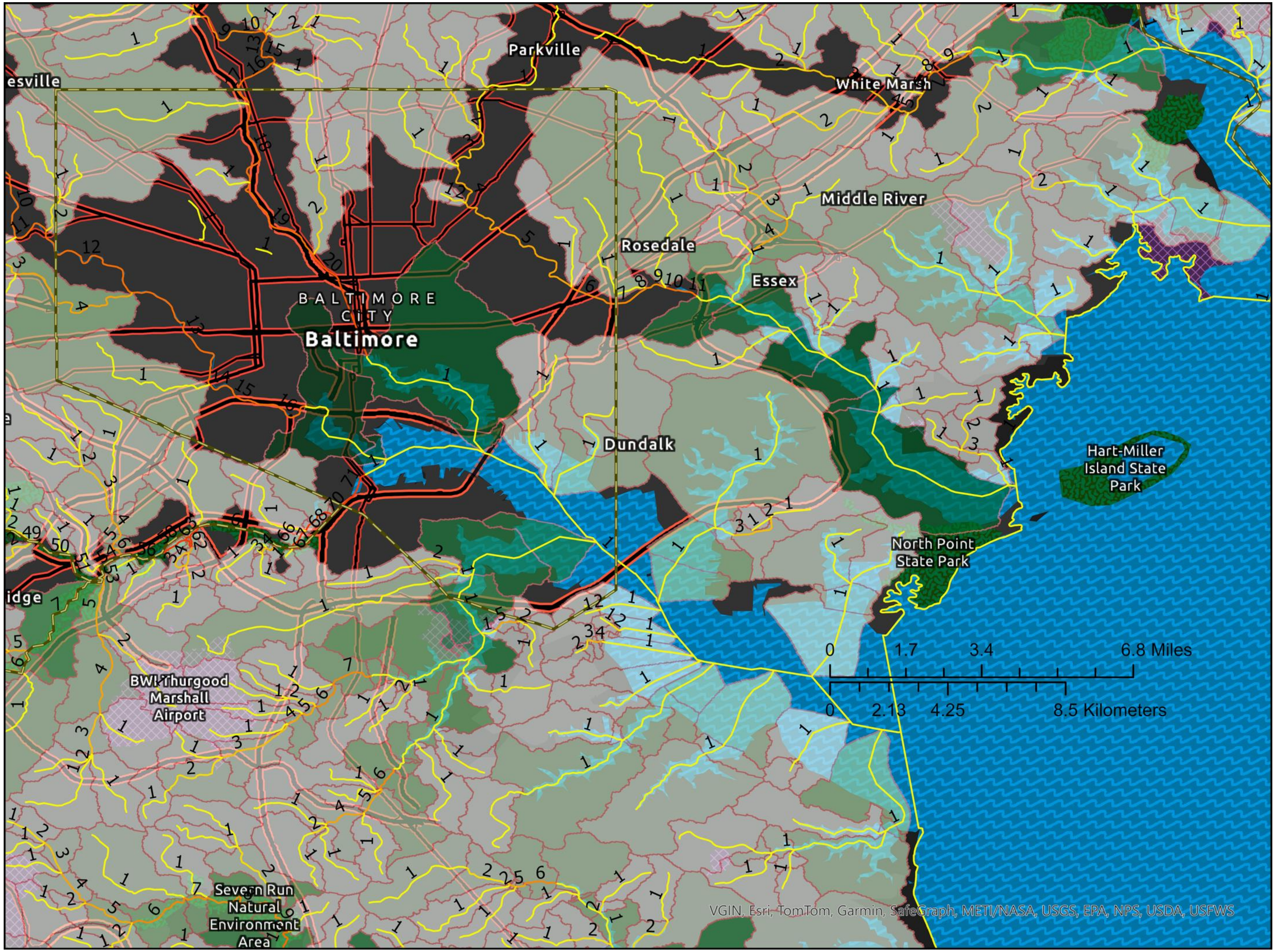


Receiving EPA phase-7 urban watershed flow

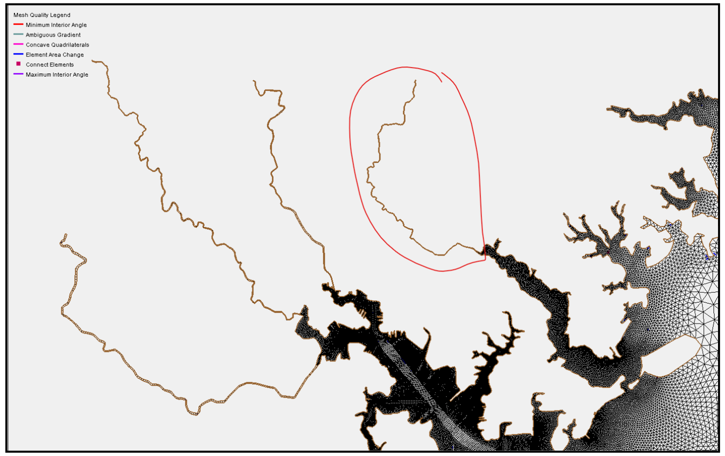


Provided by EPA Chesapeake Bay Program

Figure 3 (a): Baltimore Harbor watershed NHD (National Hydrography Data) catchment map



Receiving EPA phase-7 urban watershed flow



Provided by EPA Chesapeake Bay Program

Figure 3(b): Baltimore Harbor watershed and drainage network based on Strahler ordering of streams

II. SCHISM hydrodynamic model preliminary calibration

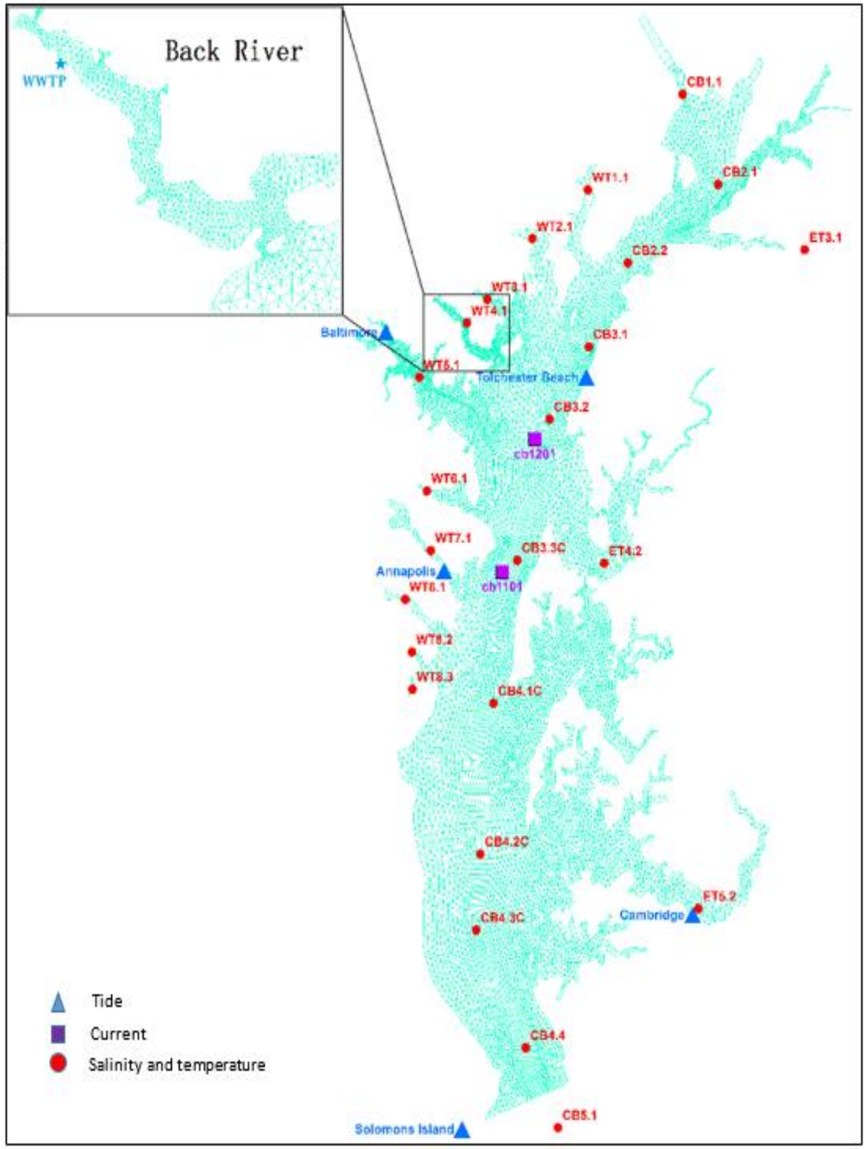


Figure 4: The Upper Bay SCHISM modeling grid with observation stations locations

Water Levels

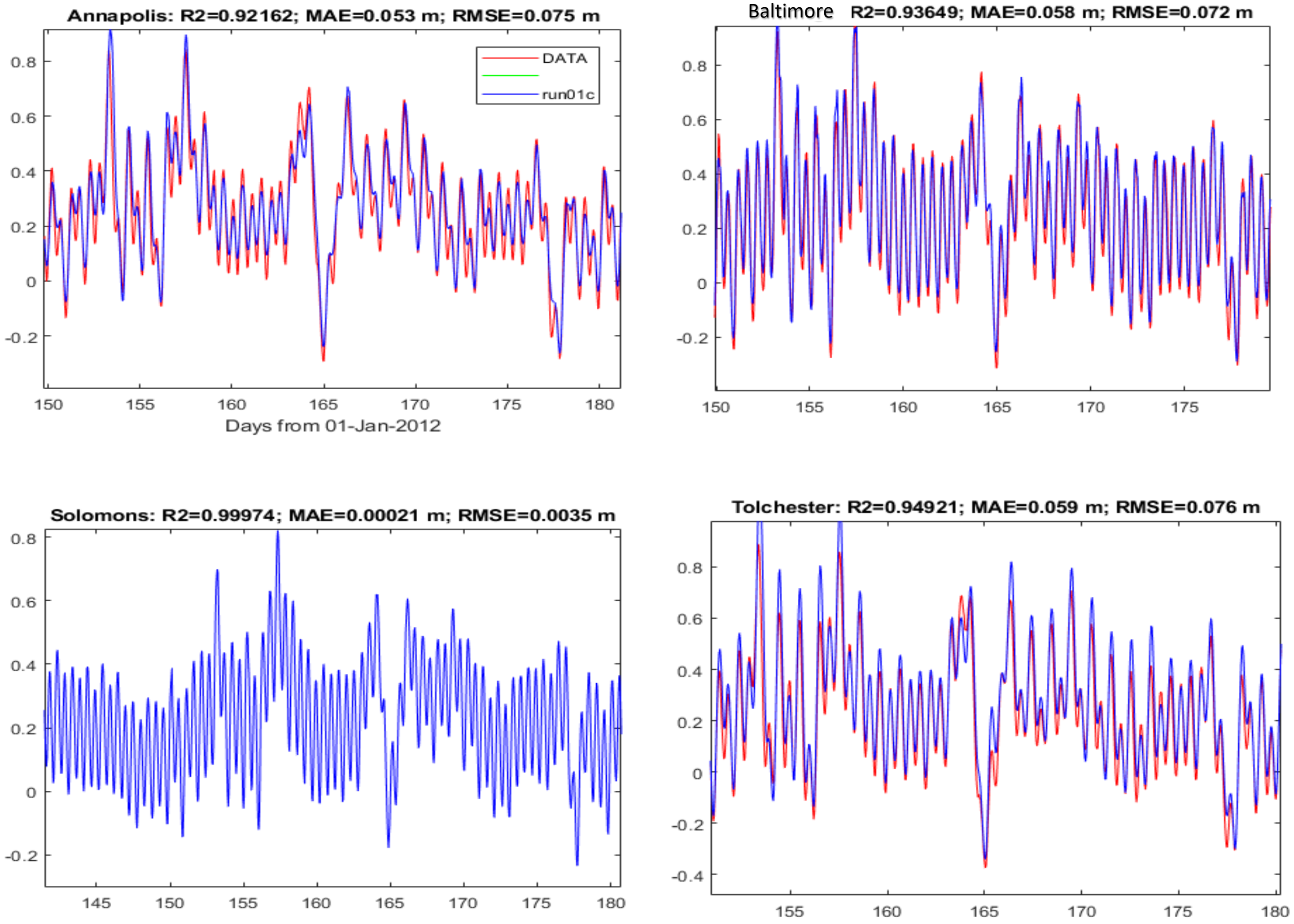
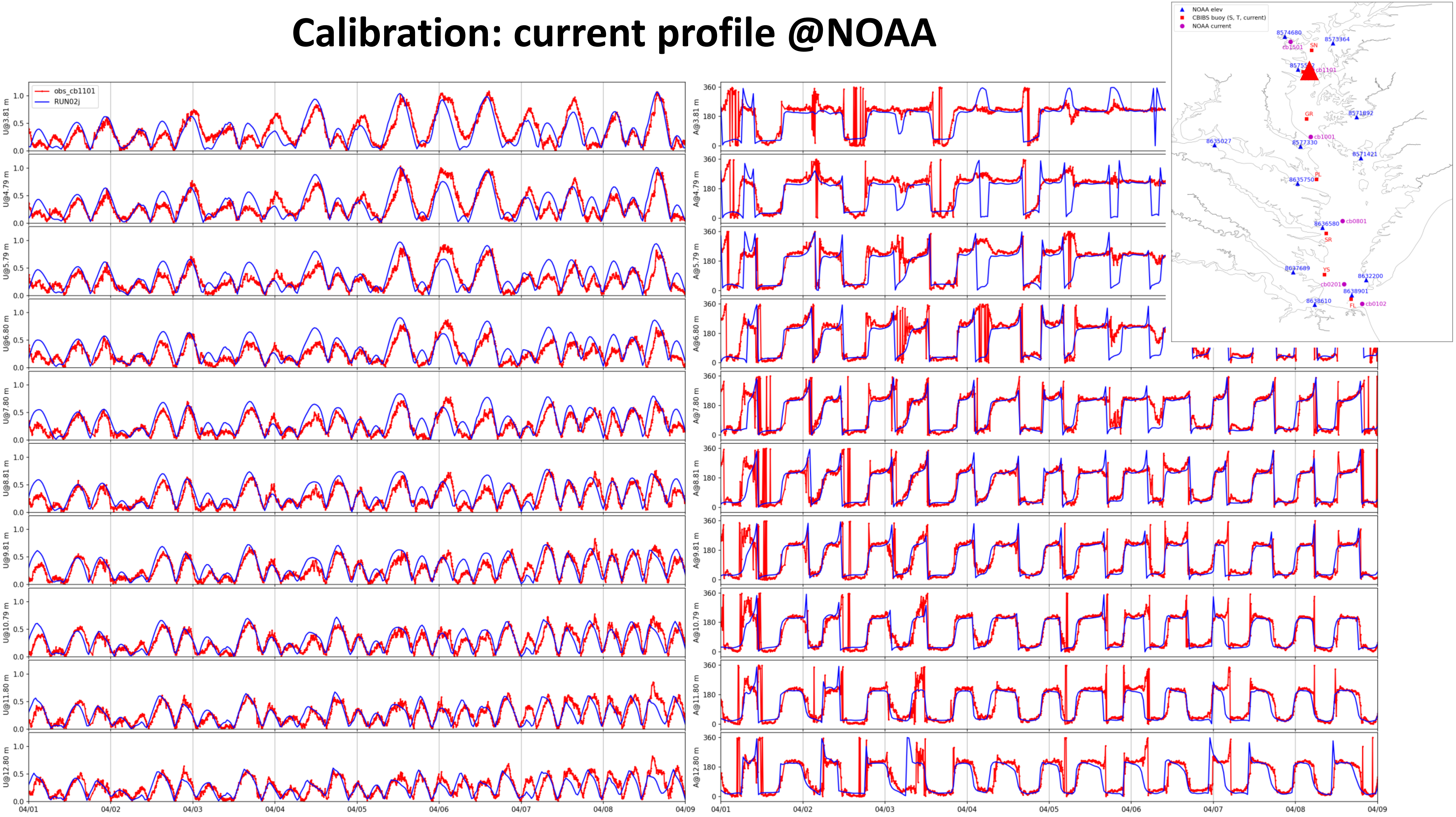
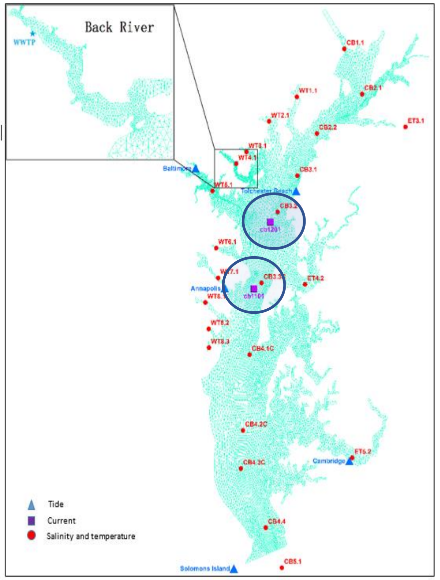


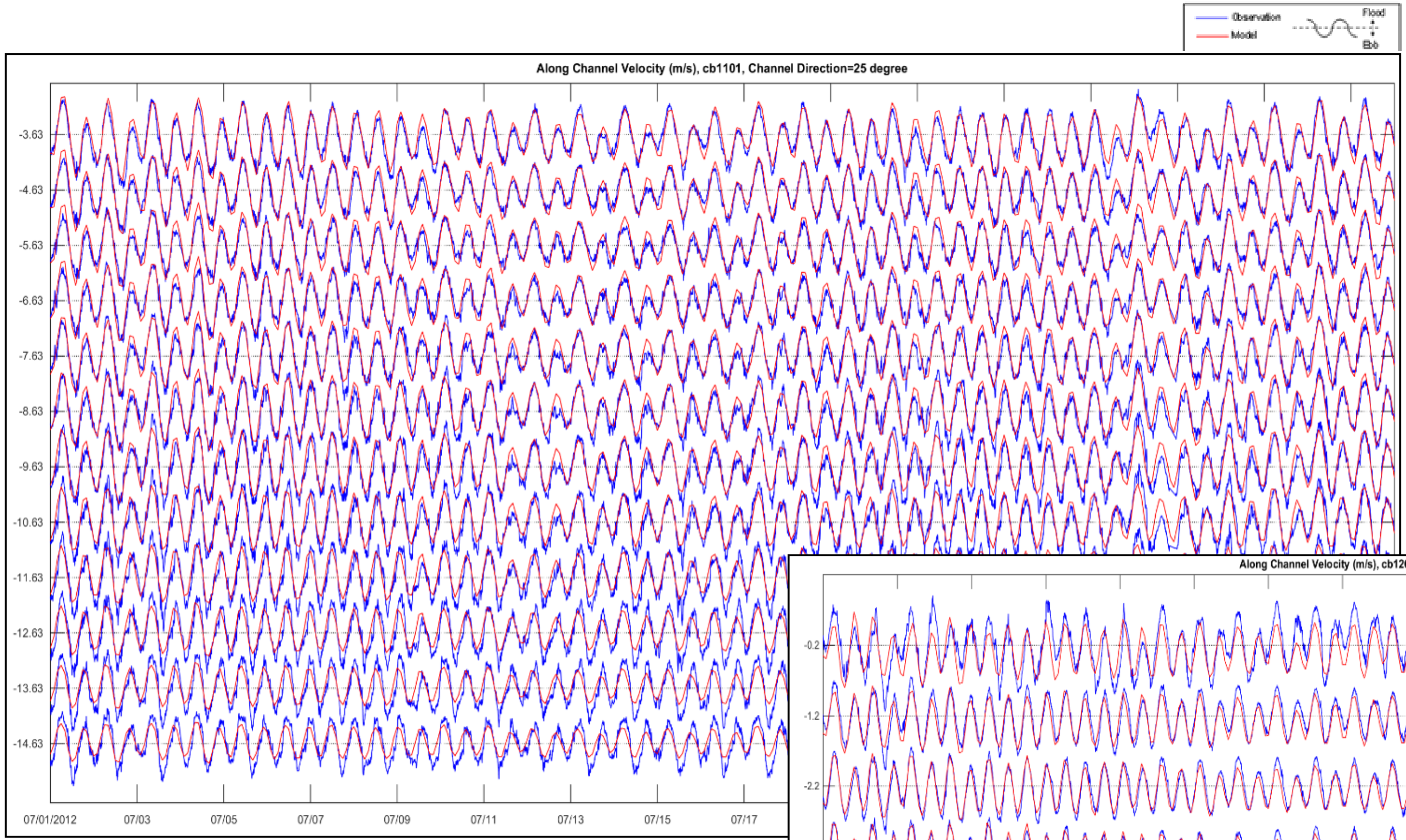
Figure 5(a) : The modeled versus observed water elevation during June and July, 2012

Calibration: current profile @NOAA



Along channel Velocities





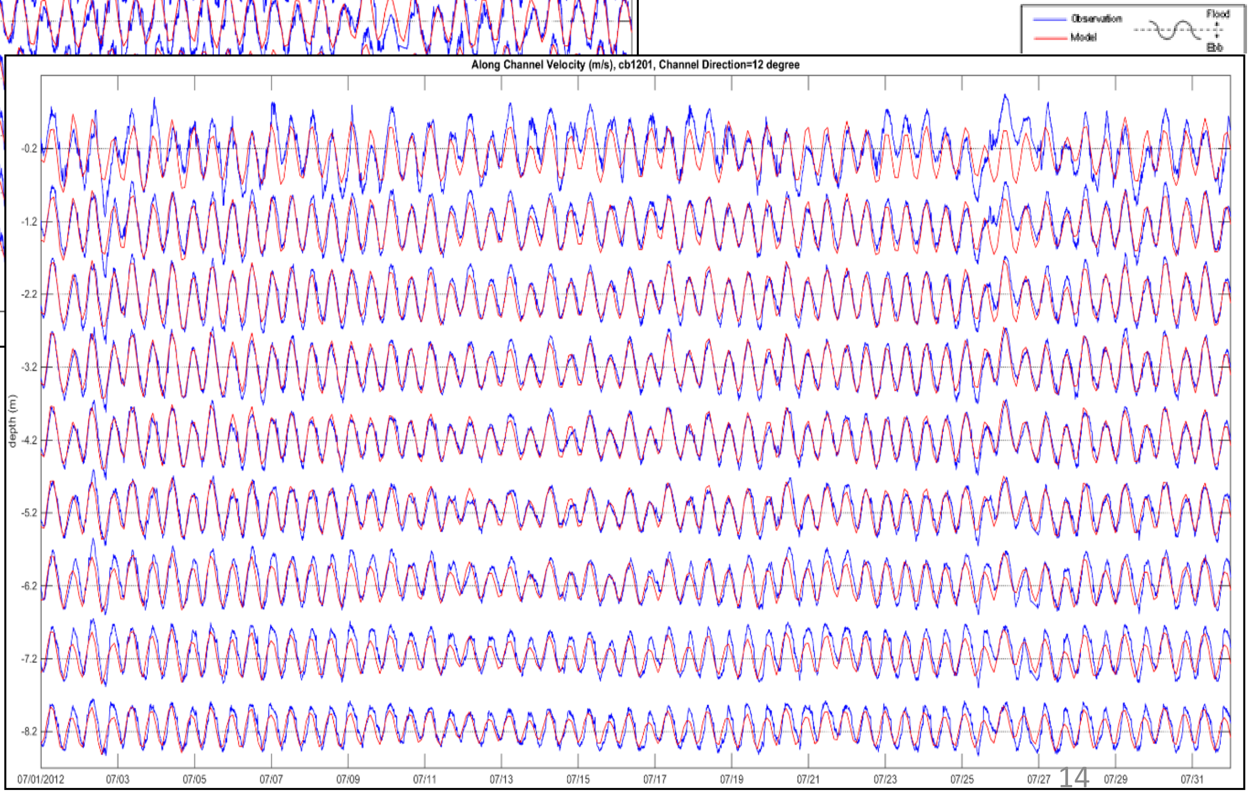


Figure 5(b) : The modeled versus observed ADCP along channel current velocity during June and July, 2012 (top) at station cb1201 (bottom) at cb1101.

<u>Temperatures</u>

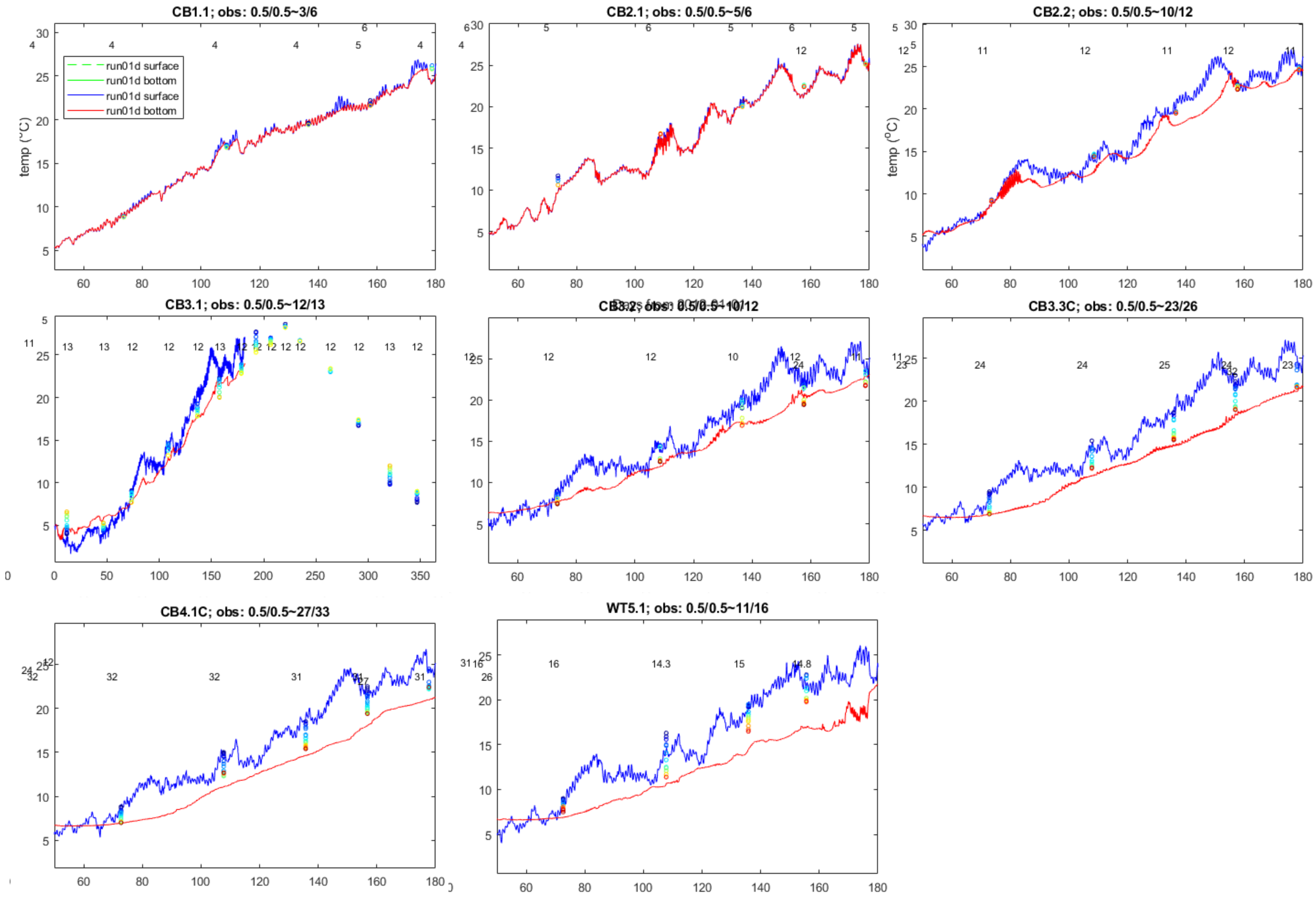


Figure 5 (c): The modeled versus observed temperature in the Upper Bay during 2012

Salinities

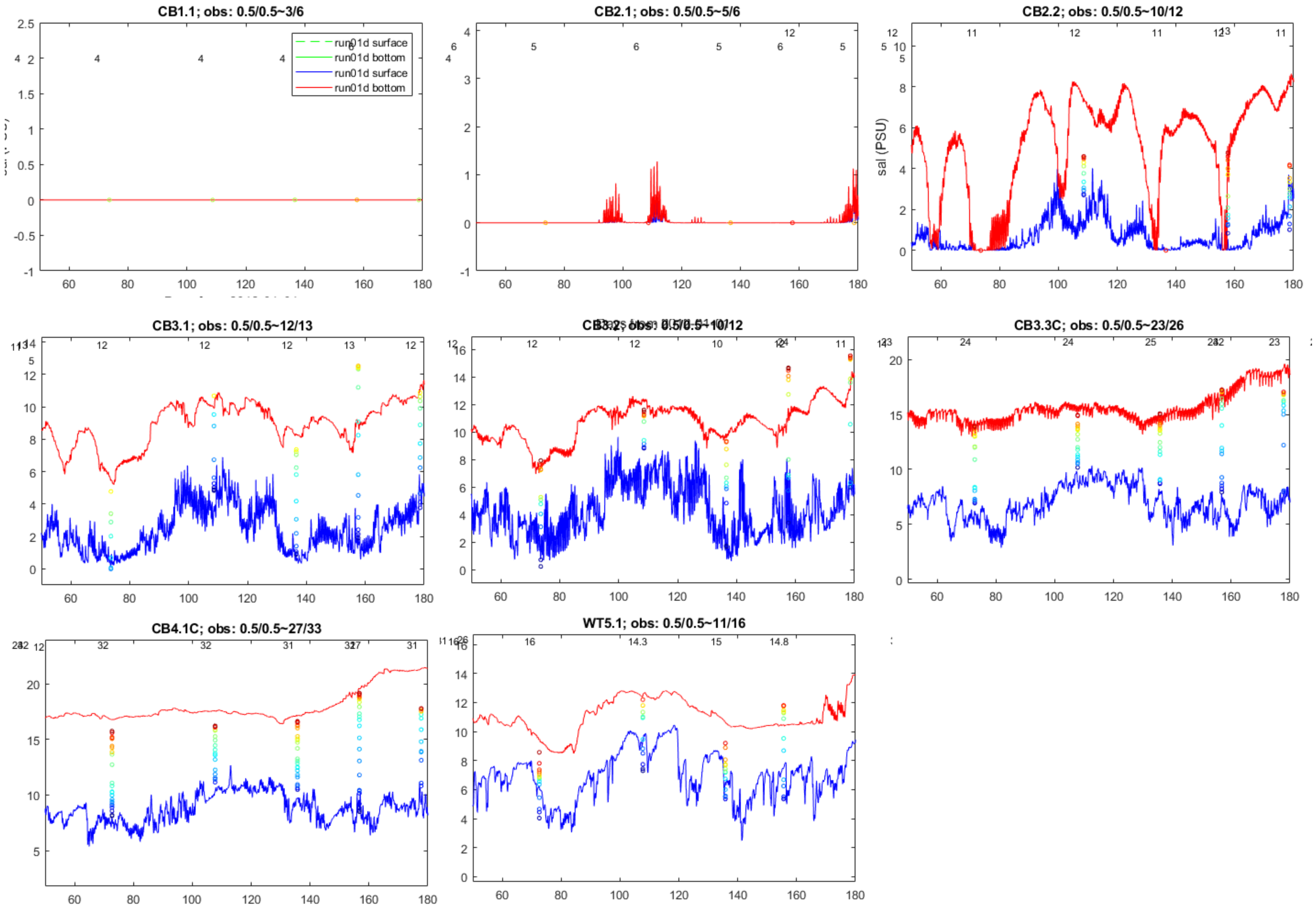
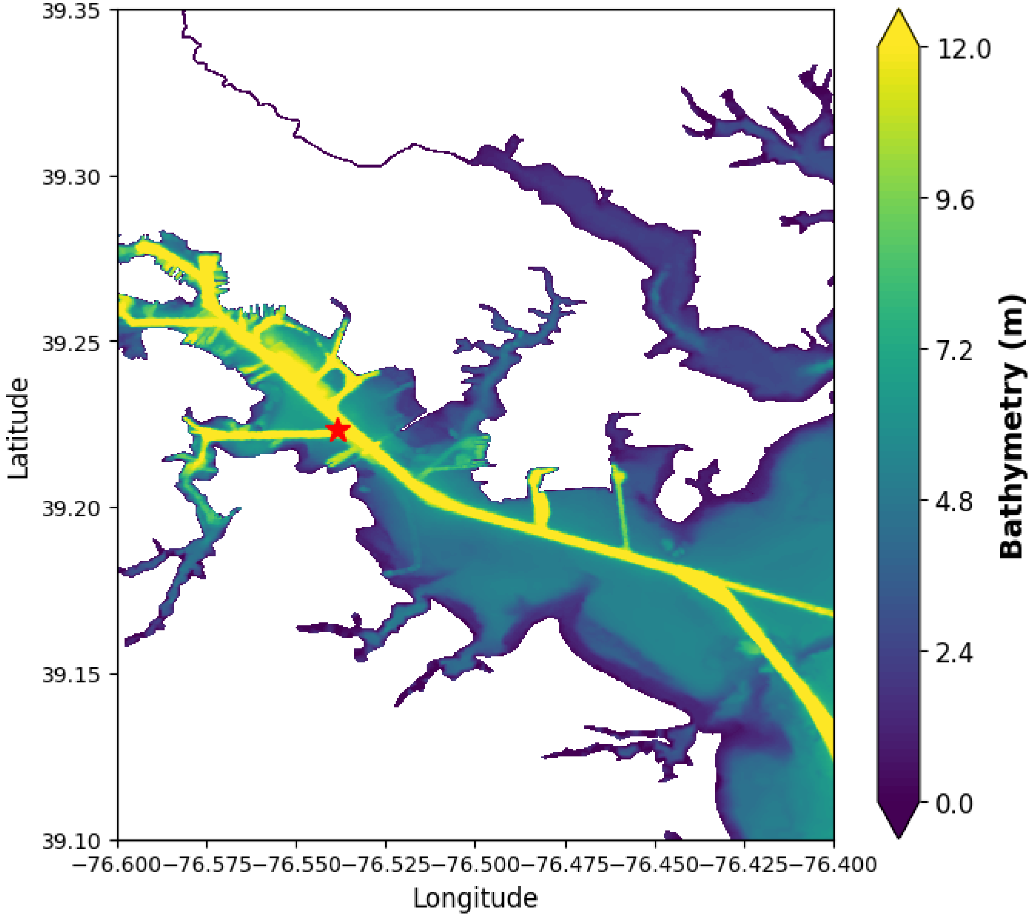
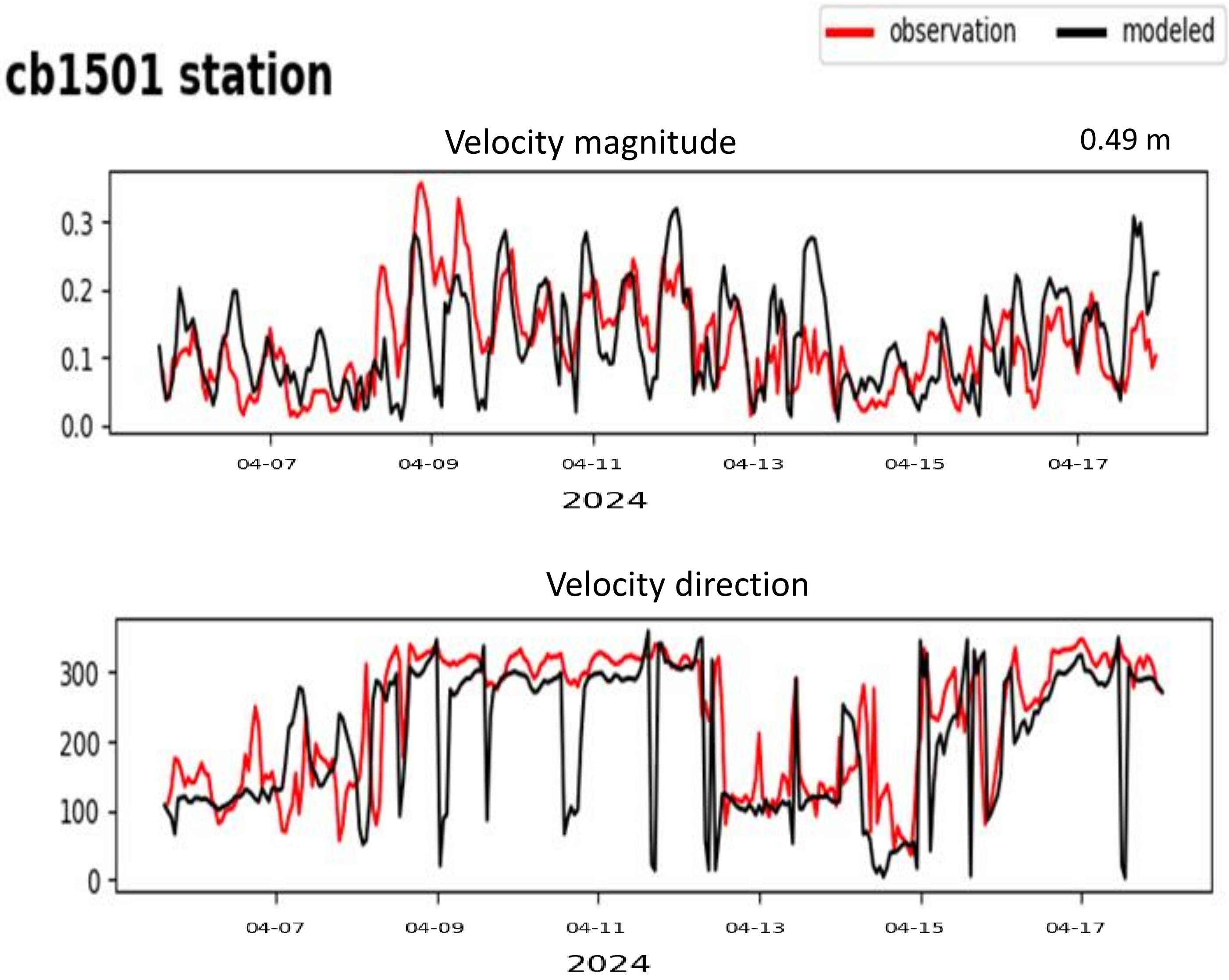


Figure 5 (d): The modeled versus observed salinities in the Upper Bay during 2012

III. Application - in 1/2024 - 4/2024

Station Location:





- # Mean three-layered circulation

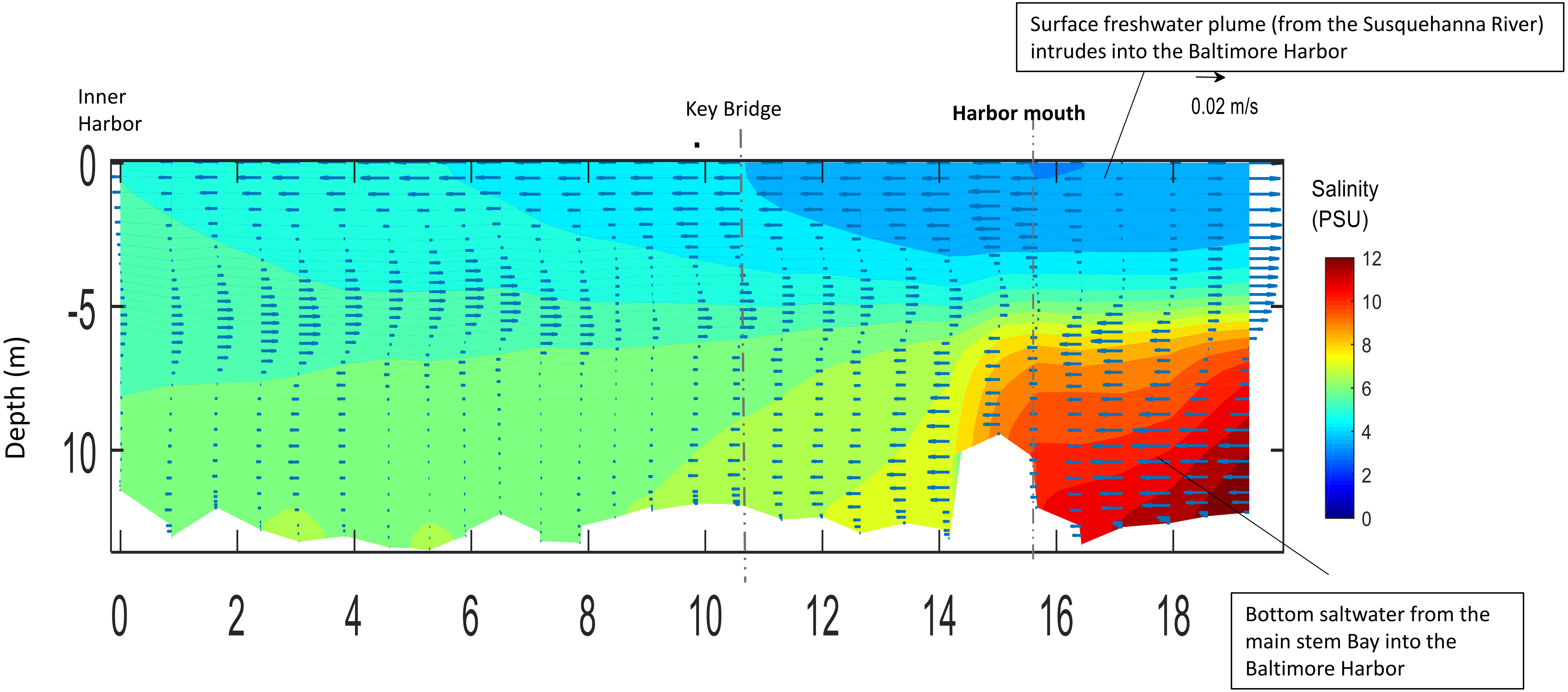
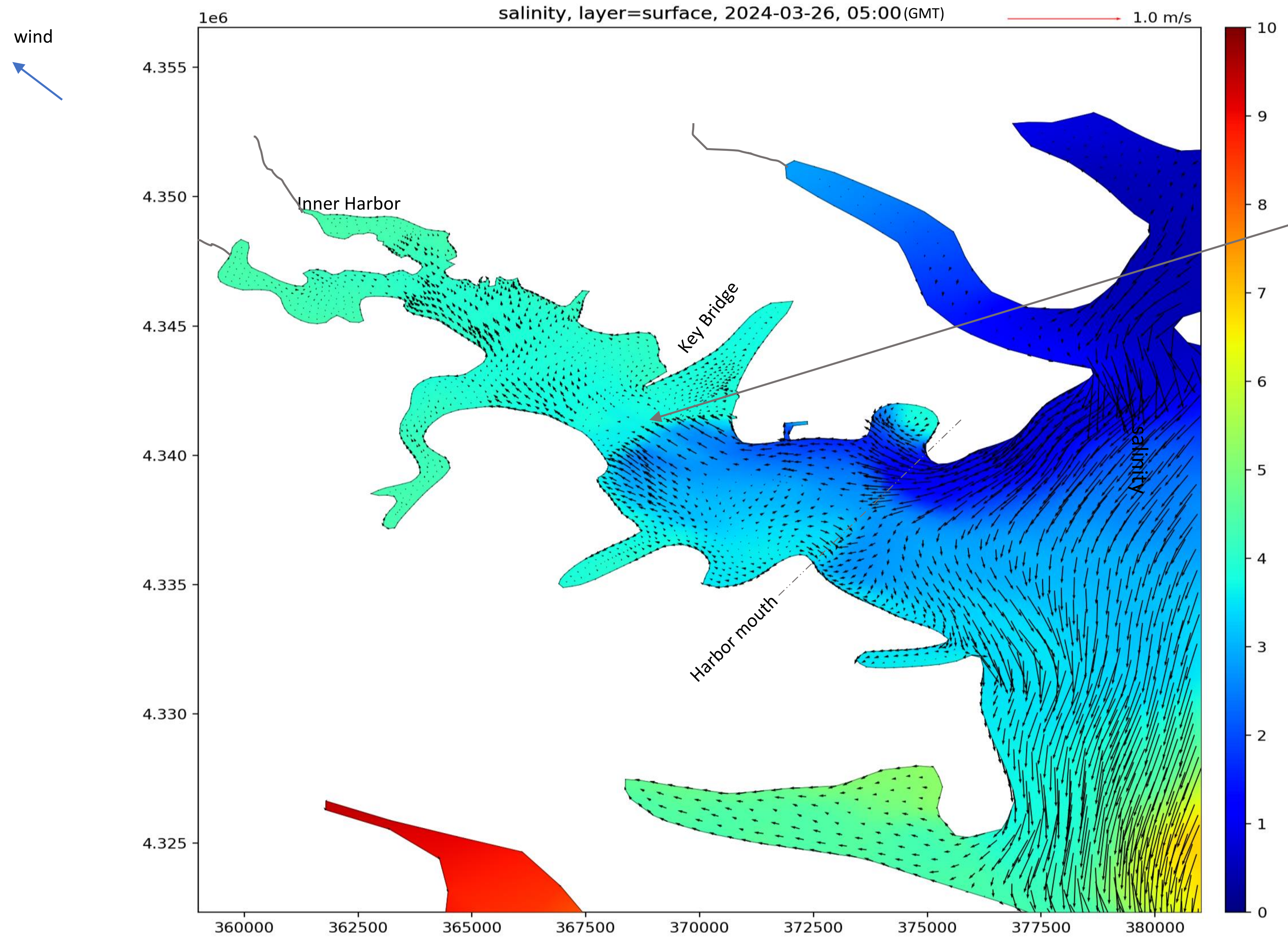


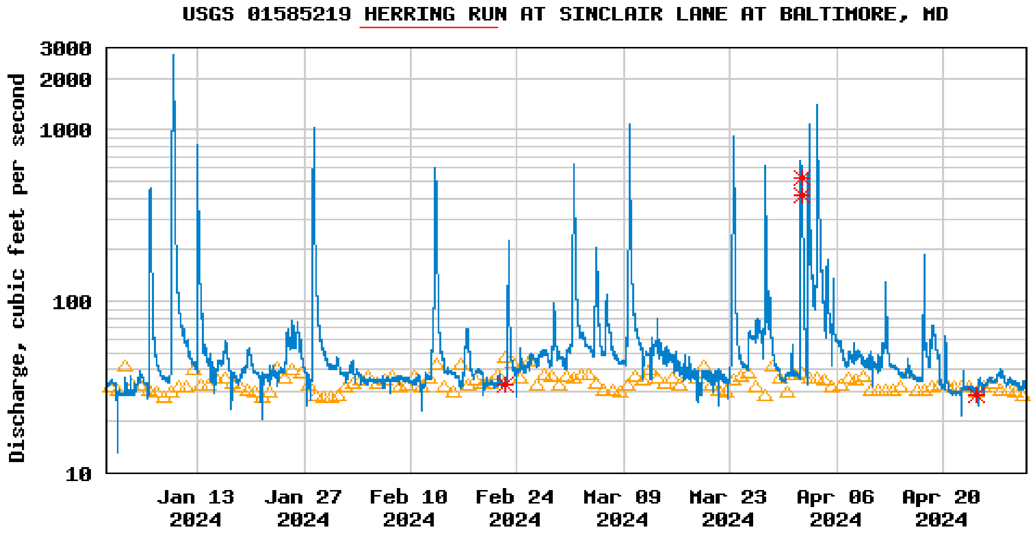
Figure: Simulated monthly (50 tidal cycle) mean average salinity distribution and 3-layered circulation pattern inside the Baltimore Harbor (0-15 km) and the adjacent Bay (15-18 km) during April, 2024

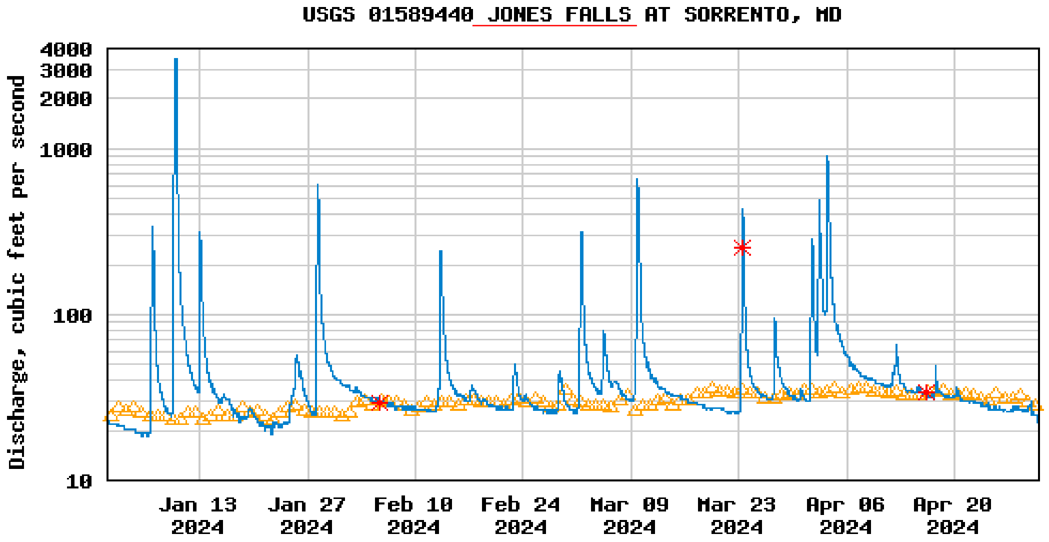
- **Surface current in the Harbor** (during slack before ebb)

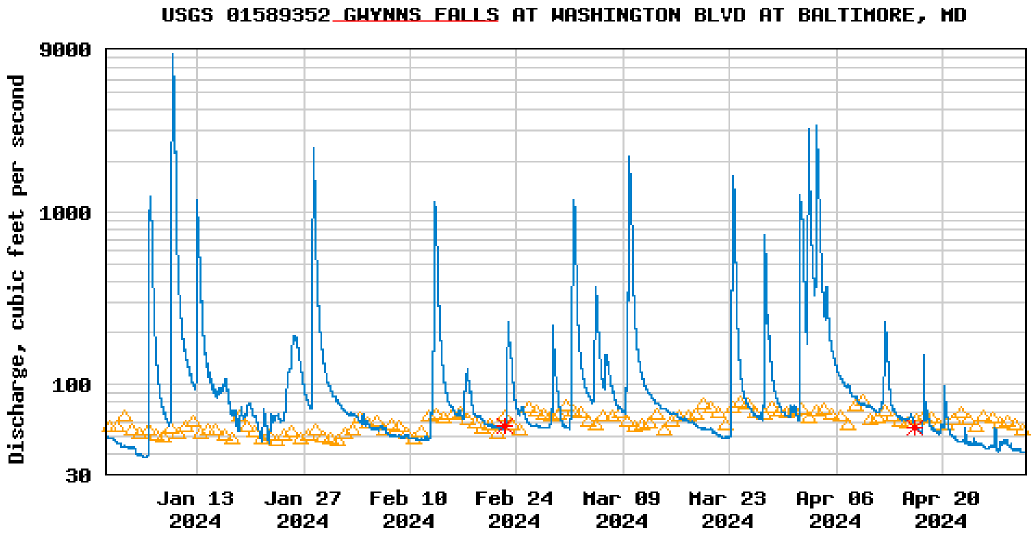


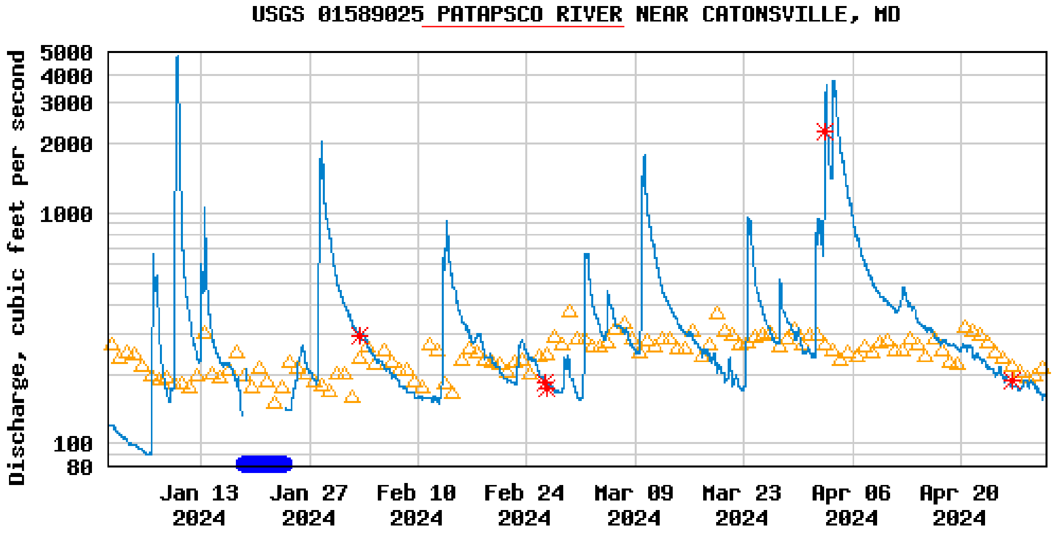
- The strong front/eddy existed near the Key bridge
- Showing the intrusion of the surface current for a three-layer circulation

- **Flashy river discharges from Herring Run, Jones Falls, Gwynns Falls, and Patapsco River – Urban Runoffs**





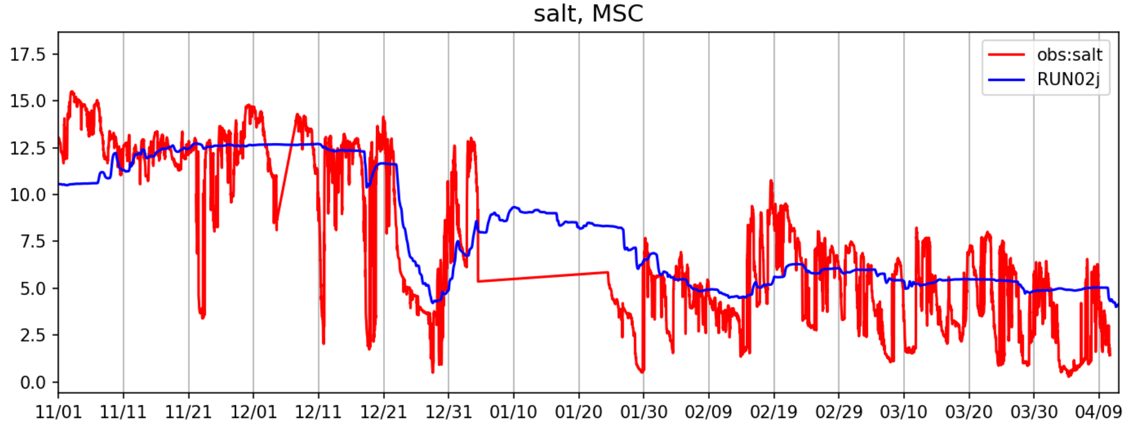


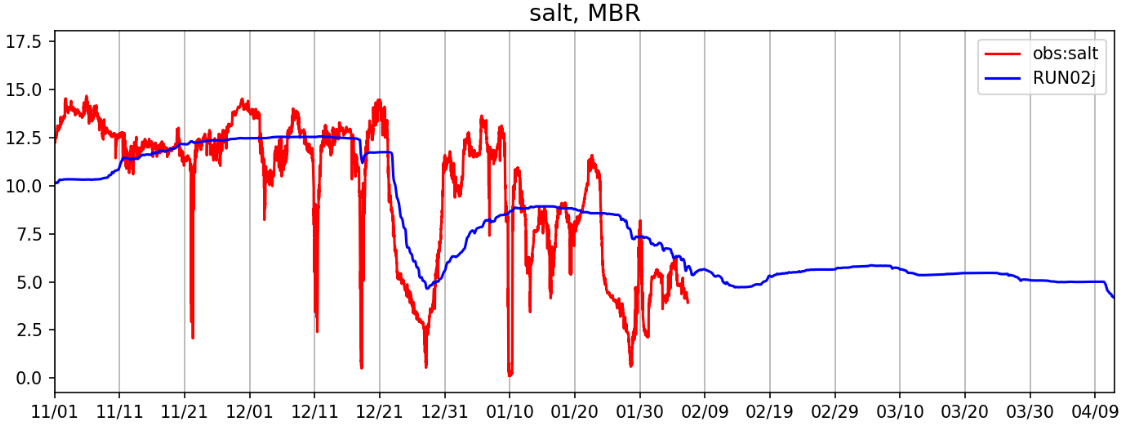


Salinity comparison at Inner Harbor

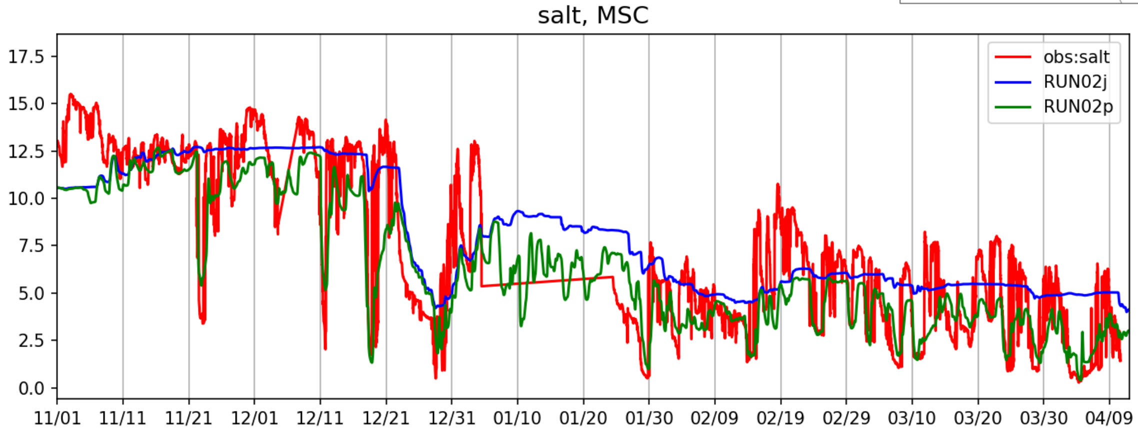
Zhengui Wang and Joseph Zhang

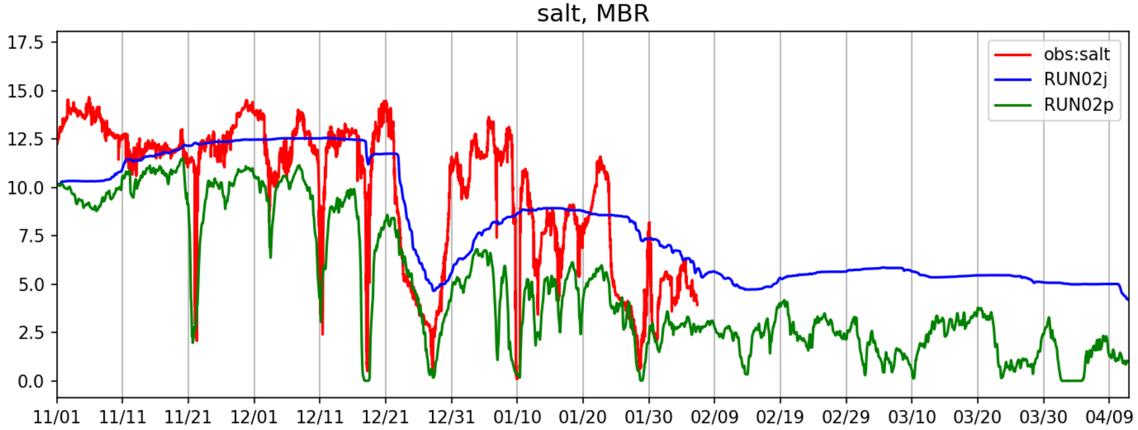
Without urban stream flow



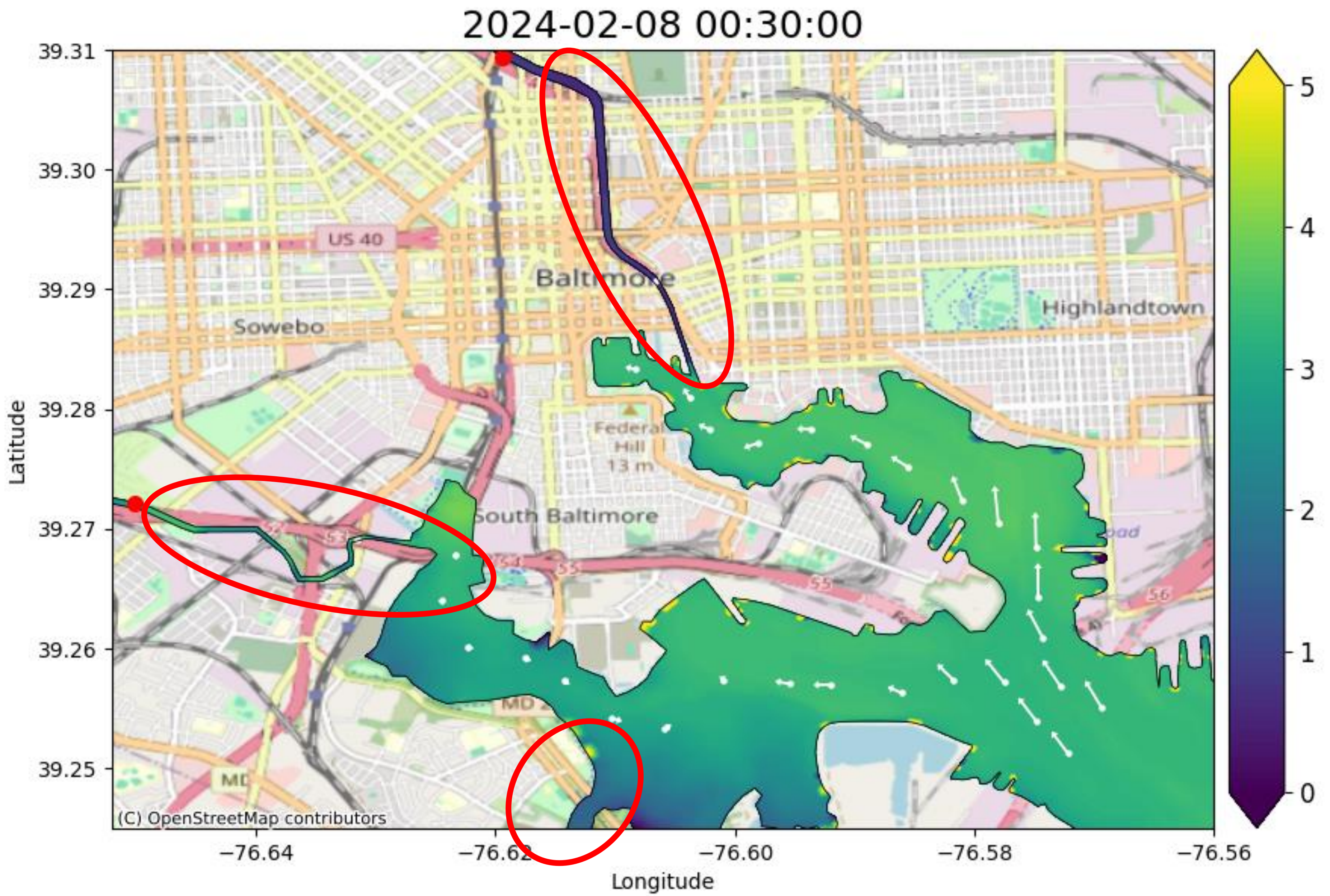


With urban stream flow inputs





Nitrogen



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39.29
39.28
39.27
39.26
39.25
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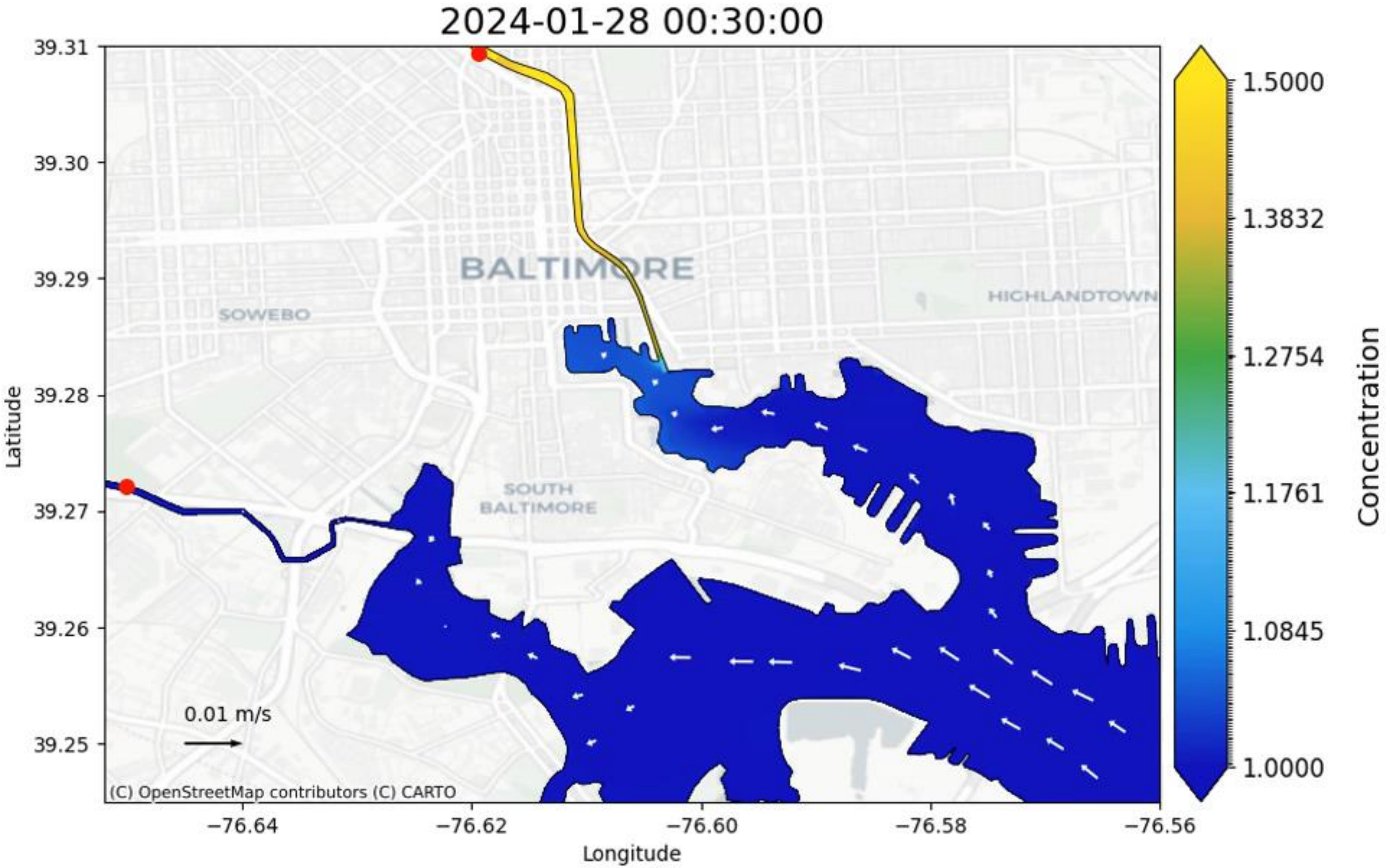
−76.62
−76.60
−76.58
−76.56
Longitude
0
1
2
3
4
5
US 40
Baltimore
Highlandtown
Sowebo
Federal Hill 13 m
South Baltimore
(C) OpenStreetMap contributors

Nitrogen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−76.64
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Longitude
BALTIMORE
SOWEBO
HIGHLANDTOWN
SOUTH BALTIMORE
0.01 m/s
(C) OpenStreetMap contributors (C) CARTO
1.5000
1.3832
1.2754
1.1761
1.0845
1.0000
Concentration

IV. Summary:

1. The Patapsco/Back MTM fine-resolution model was generated, including 4 urban streams as part of the MTM tributary model. The overall resolution ranges from 50 – 100 m with total number of grid cells close to 61k grid cells.

2. The model was calibrated for January 2012 – June 30 2012 and verified for April 2024 with reasonable skill on water level, velocity, salinity, temperature, and mean three-layered circulation.

3. The model was used to simulate SSO events in late January and early February 2024 and demonstrated impact on the Inner Harbor.