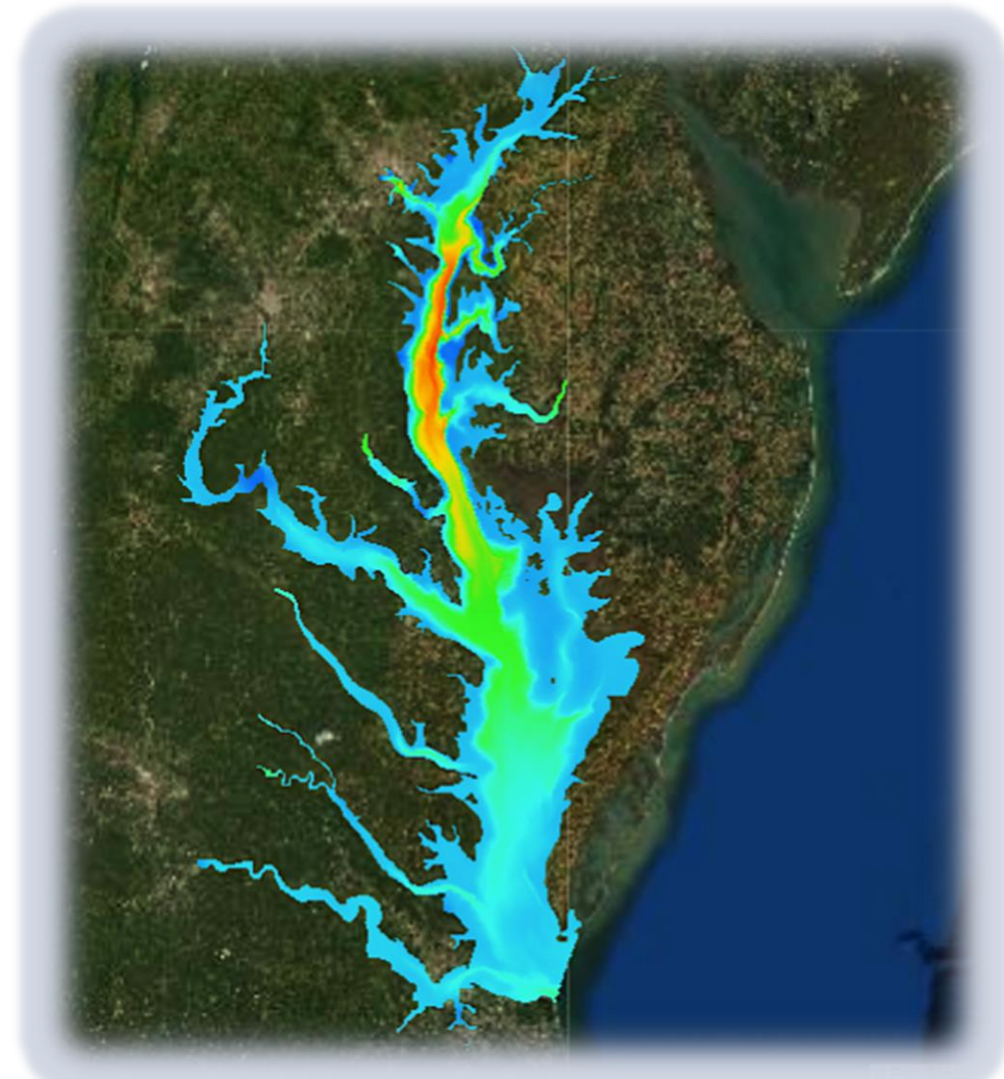


Assessing 2035 Climate Change Risk to the Chesapeake TMDL using a next-generation unstructured-grid model

VIMS team: Joseph Zhang, **Jian Shen**, Harry Wang,
Marjy Friedrichs, Zhengui Wang, Qubin Qin, Jiabi Du,
Pierre St-Laurent,
CBPO: Nicole Cai
UMCES team: Jeremy Testa

June 20-21, 2023



Outline

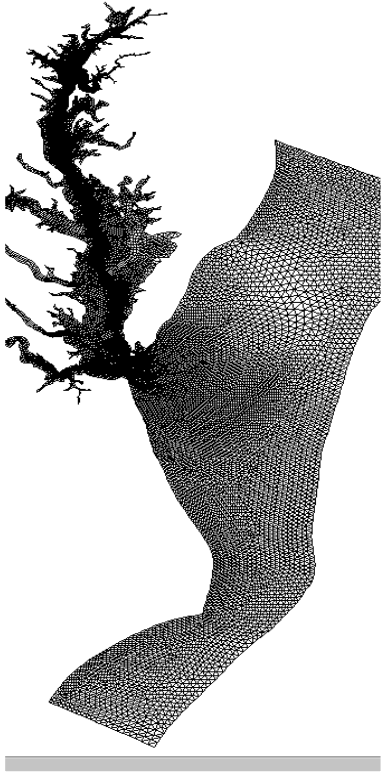
Progress summary

Focal studies during this period

Next phase

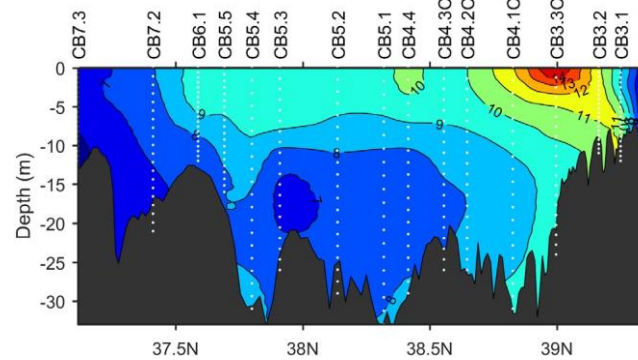
Project Progress

Hydrodynamic model



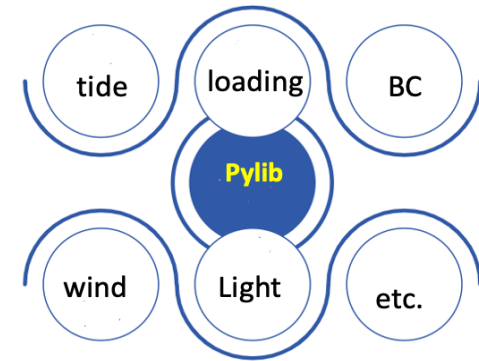
- Finalized model grid
- Conducted model calibration
- Tested wave model
- Tested sediment model

Water quality model



- Updated model code to include Bay ICM modification of kinetic processes
- Completed coding of water quality simulation in decoupled mode.

Tool box



- Developed toolbox
- Developed Pylib
- Automatically process MBM setup
- Model plots
- Model visualization tools

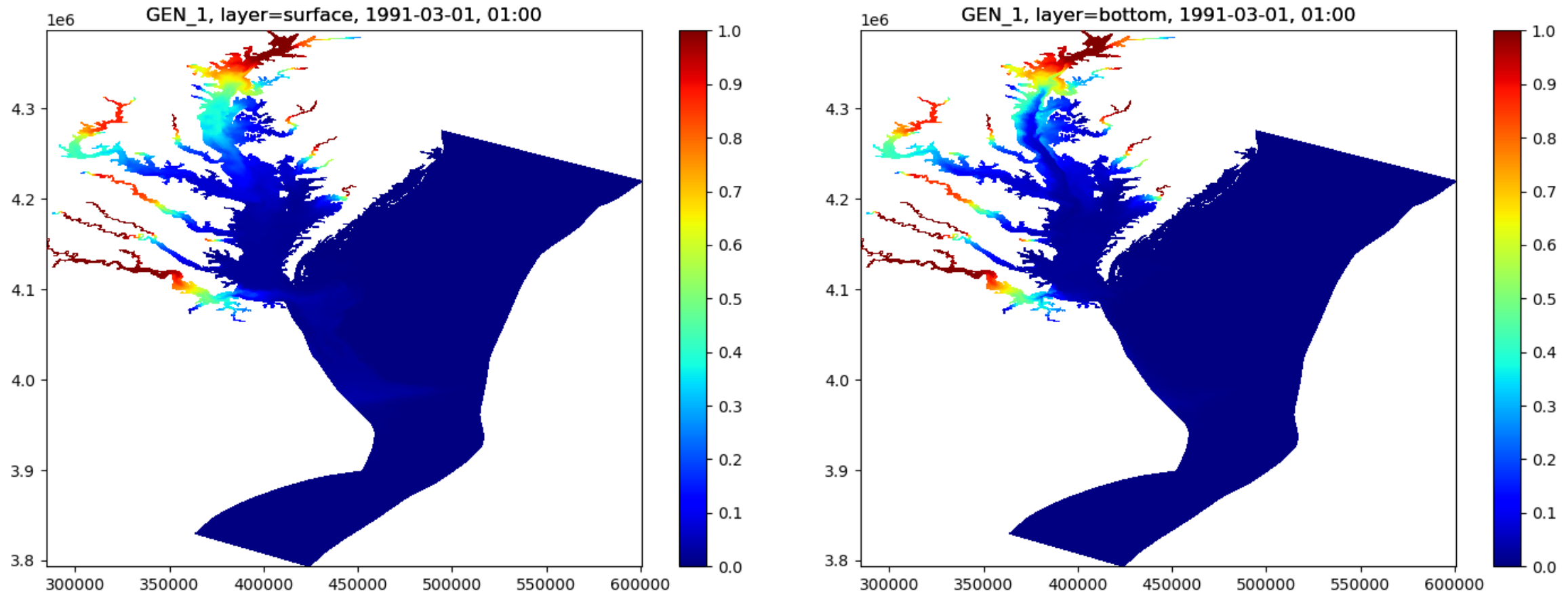
Study during this period: update ICM model

- ICM code update (kinetics)
 - Algal respiration
 - Grazing model
 - Light attenuation
 - Separate particulate and dissolved inorganic P
 - Add slow decay particulate P (i.e. bank erosion)
 - Varying model parameters by region (i.e. settling velocity, growth rate etc.)
 - Spatial varying parameters are handled by input file '*ICM_parameter.nc*'

Study during this period: test decoupled simulation

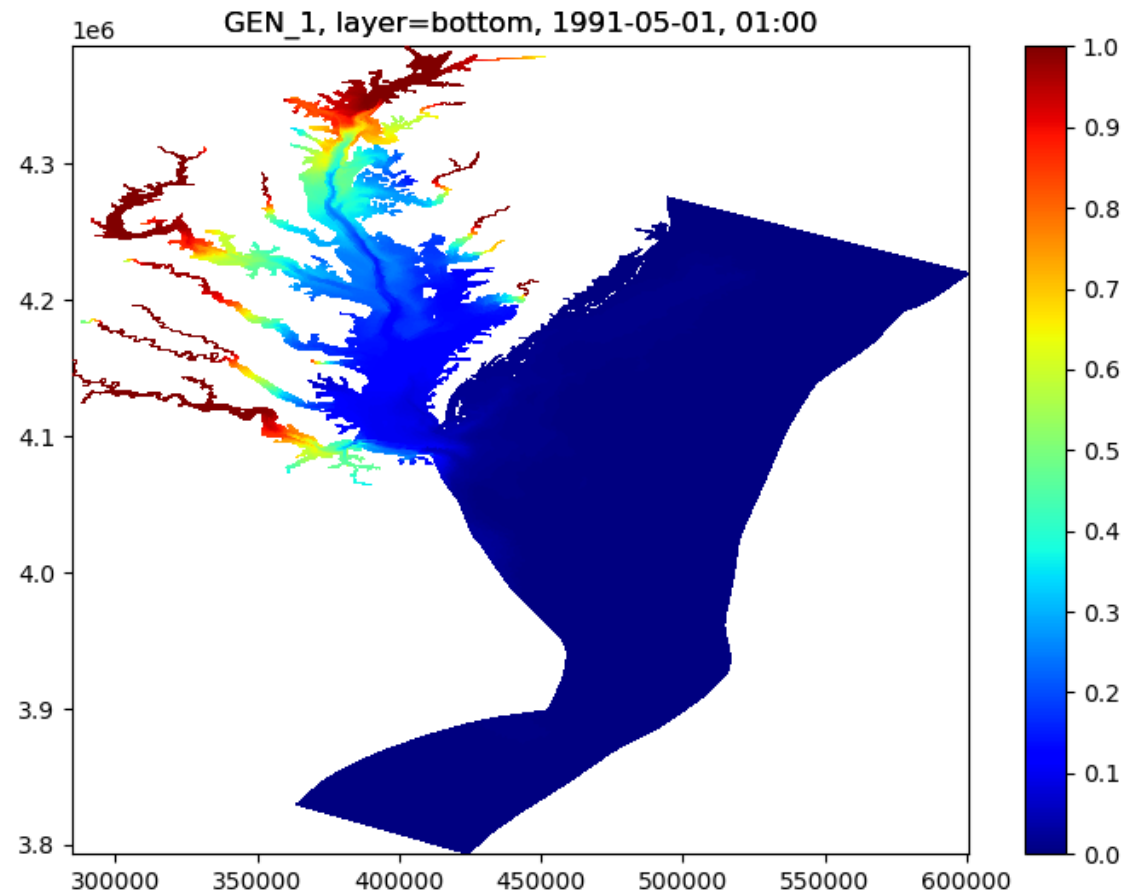
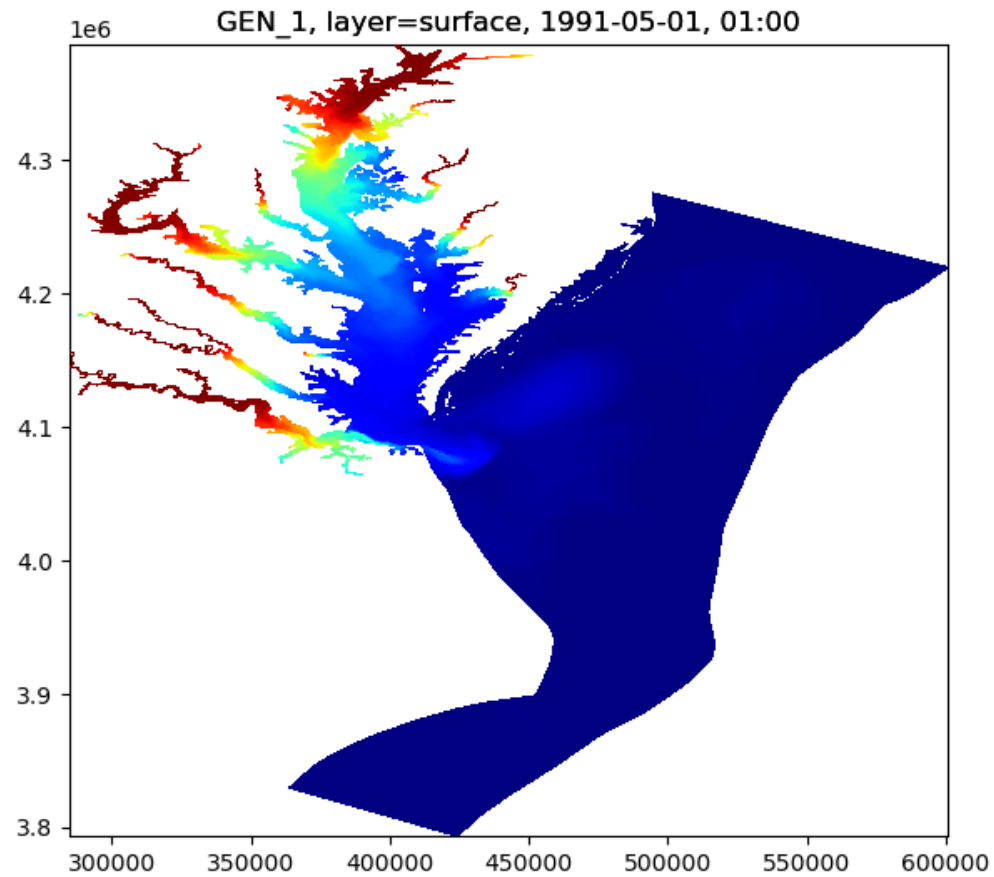
- Testing decoupled modeling approach of ICM
 - Save hourly dynamic fields for current, elevation, diffusion, wave, and suspended sediment
 - Use small time-step to run water quality model to maintain mass balance
 - Implemented TVD in transport algorithm
 - Use dye release at upstream to verify the accuracy of decoupled model transport

Horizontal dye distribution

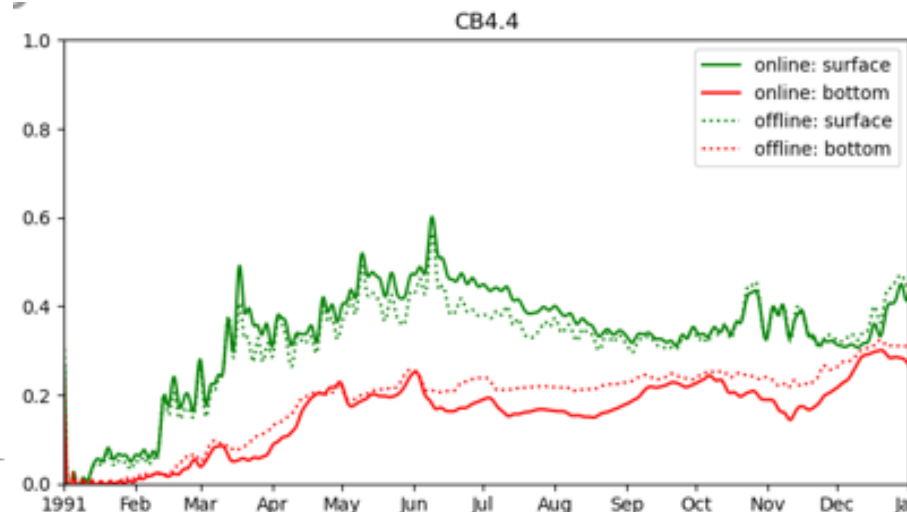
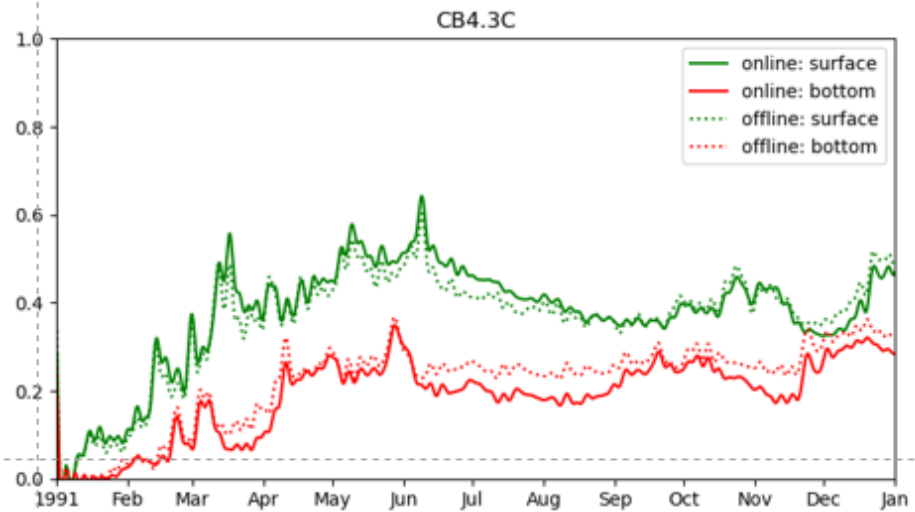
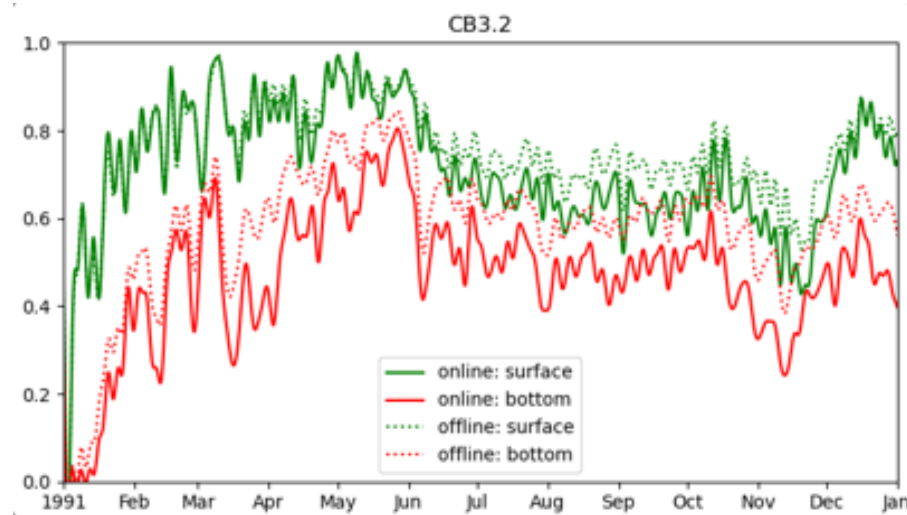
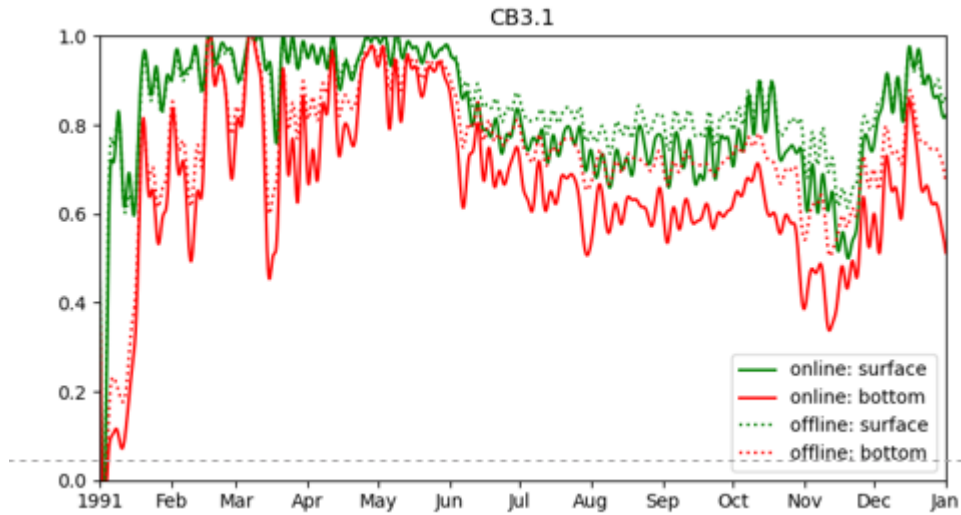


Decoupled model result

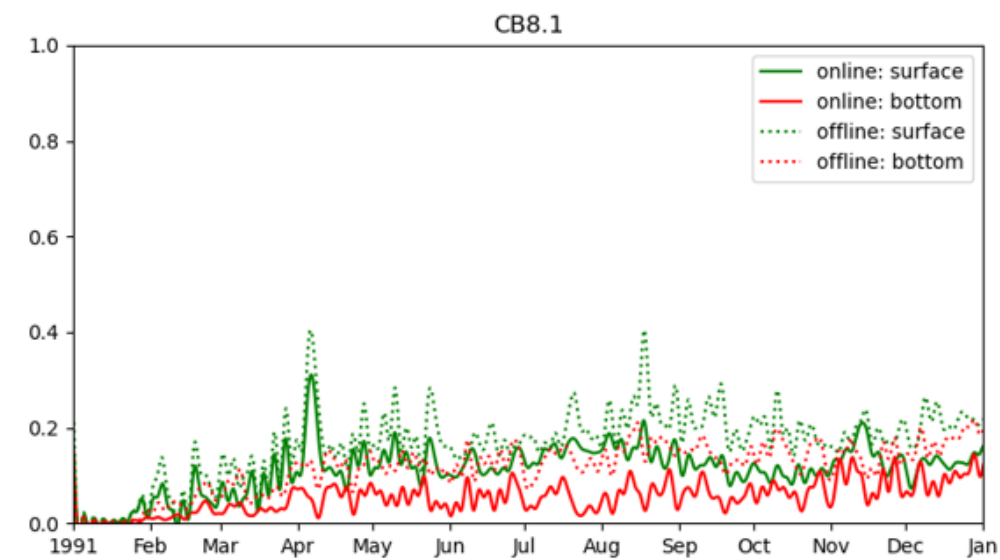
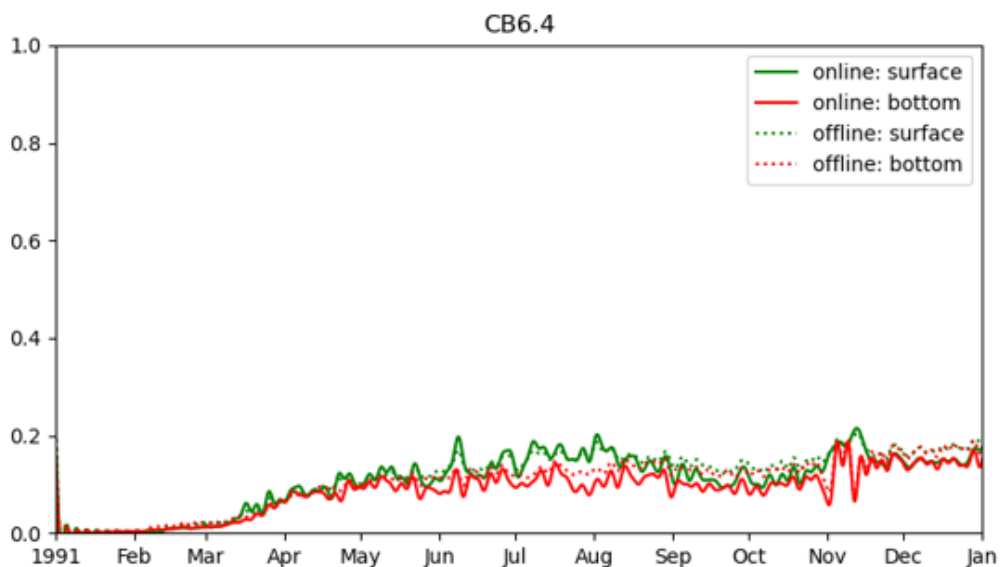
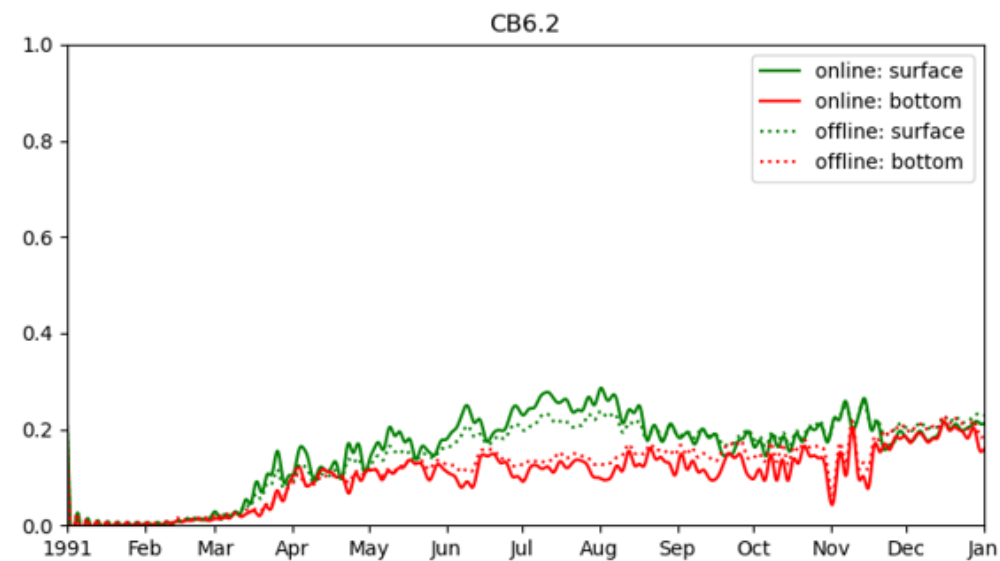
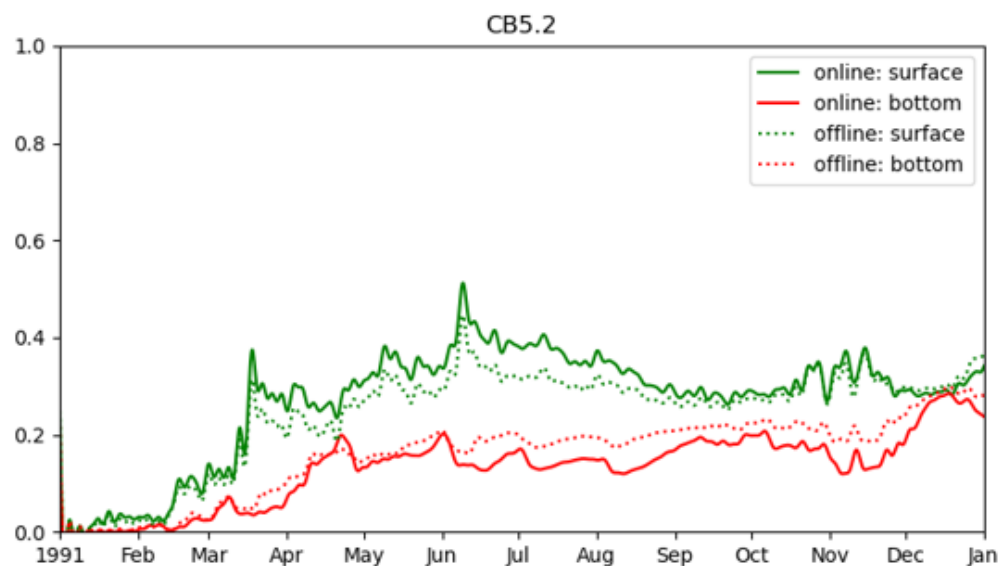
Horizontal dye distribution



Compare time series at selected stations



Compare time series at selected stations



Toolbox

- Pylib
 - Python library tools for managing SCHISM model workflow
 - Data processes
 - Grid related tools
 - Set ocean boundary and river boundary conditions
 - Model set-up tool
 - Automatically processing boundary, flow, loading, surface fluxes with visualization tools
 - Visualization of water quality model results
 - Horizontal plots of model state variables
 - Animation of model results
 - Time series at selected location

Pylib online documentation and examples

The screenshot displays the Pylib online documentation interface. At the top, there's a header with the Pylib logo, the text "pylibs tutorial.ipynb", and a star icon. Below this is a navigation bar with "File", "Edit", "View", "Insert", "Runtime", "Tools", and "Help" menus. A status bar indicates "Changes will not be saved". On the right, there are "Share", "Settings", and a user profile icon labeled "J.". Below the navigation bar, there's a "Table of contents" sidebar on the left and a main content area on the right. The sidebar lists various sections: "Introduction of pylibs", "1. Pylibs Installation", "2. Import Pylibs", "3. Pylibs Structure", and "4. mylib functions/classes". The main content area shows the "Introduction of pylibs" section, which includes a list of bullet points: "this document is a tutorial on how to use using pylibs with examples.", "pylibs is a very light python library, aimed to integrate most of the frequently used functions/objects/scripts in one place.", and "It mainly includes two types of functions: self-defined functions for various purpose and functions to handling pre/post-processing SCHISM model input/output. Particularly, it has many functions to manipulate information related to SCHISM grid." Below this, there's a section titled "Code Style: Our Goals" with a list of bullet points: "good readability", "easy to use, easy to maintain", and "concise and compact codes". Further down, there's a section titled "List of functions and classes" with a link to "video: install mambaforge and pylibs on windows". At the bottom, there's a section titled "1. Pylibs Installation" with a link to "Method 1: pip install from the Github repository".

pylibs tutorial.ipynb ☆

File Edit View Insert Runtime Tools Help Changes will not be saved

Share ⚙️ J.

Table of contents

Introduction of pylibs

- Code Style: Our Goals
- List of functions and classes

1. Pylibs Installation

- Method 1: pip install from the Github repository
- Method 3: PYTHONPATH
- Example: Install pylibs on Google Colab
- Download sample files

2. Import Pylibs

- 2.1 explicit import
- 2.2 implicit import

3. Pylibs Structure

- 3.1. File structure
- 3.2. List of pylib functions and classes
- 3.3. Add your own function/classes to Pylibs

4. mylib functions/classes

- 4.1 data capsule
- 4.2. format of database in pylibs
- 4.3 time manipulation
- 4.4. data analysis
- 4.5. harmonic analysis
- 4.6. ...

Introduction of pylibs

- this document is a tutorial on how to use using pylibs with examples.
- pylibs is a very light python library, aimed to integrate most of the frequently used functions/objects/scripts in one place.
- It mainly includes two types of functions:
 - self-defined functions for various purpose
 - functions to handling pre/post-processing SCHISM model input/output. Particularly, it has many functions to manipulate information related to SCHISM grid.

Code Style: Our Goals

- good **readability**
- easy to **use**, easy to **maintain**
- concise and compact codes

List of functions and classes

(click the link above will direct to the list of pylib functions/classes/methods)

1. Pylibs Installation

[video: install mambaforge and pylibs on windows](#)

Method 1: pip install from the Github repository

Examples



pylibs tutorial.ipynb ☆

File Edit View Insert Runtime Tools Help Changes will not be saved



Table of contents



- 4.10 DEM related
- 4.11. plot
- 4.12 system related
- 4.13. misc
- 5. schism_file functions/classes
 - 5.1. hgrid
 - 5.1.1. attributes of hgrid
 - 5.1.2. methods of hgrid
 - 5.1.2.1. plot**
 - 5.1.2.2. interpolation
 - 5.1.2.3. geometry
 - 5.1.2.4. boundary
 - 5.1.2.5. read
 - 5.1.2.6. write
 - 5.1.2.7. grid manipulation
 - 5.1.2.8. shapefile
 - 5.2. vgrid
 - 5.3. save hgrid and vgrid

+ Code + Text Copy to Drive

```
✓ [1] #Examples 5.1.2.1.1
      #usage of plot

      figure(figsize=[18,12])
      #method 1: grid
      subplot(2,3,1)
      gd.plot()

      #method 2: bathymetry
      subplot(2,3,2)
      gd.plot(fmt=1)

      #method 3: combine specifications
      subplot(2,3,3)
      gd.plot(fmt=1,ec='k',lw=0.05,clim=[0,50],ticks=11)
      setp(gca(),xticks=[],yticks=[],xlim=[3.5e5,4.5e5],ylim=[4.05e6,4.3e6])
      gcf().tight_layout()

      #method 4: plot with other value
      pvi=gd.dp.copy()
      fpz=pvi<5; pvi[fpz]=1
      fpz=(pvi>=5)*(pvi<10); pvi[fpz]=2
      fpz=(pvi>=10)*(pvi<30); pvi[fpz]=3
      fpz=(pvi>=30)*(pvi<100); pvi[fpz]=4
      fpz=pvi>=100; pvi[fpz]=5
```

Add more tools to Toolbox

- Tested automatic setup model and workflow
 - Combine all tools include tide, salinity, temperature at open boundary and heat flux at surface to generate boundary condition
 - Revise the tool to convert watershed model output (phase 6) to ICM loading input
 - The tool allows to set model for online coupled and decoupled modes to run ICM model
 - It is convenient when changing model grid

Model setup tool: Setup.py

- `p.StartT=datetime(1991,1,1); p.EndT=datetime(1992,12,31)` #simulation time
- `p.base='../RUNbase'`
- `p.grid_dir='/sciclone/data10/wangzg/CBP/grid/v3'` #directory of hgrid & vgrid; `p.grid_dir=p.base` if it is None
- `p.flag['ICM']= 1` #ICM model (1: 21 variables; 10: 21-variable offline mode; 2: 17 variables; 20: 17-variable offline mode)
- `p.flag['SED']= 0` #SED3D model
- `p.flag['WWM']= 0` #Wave model

- `p.flag['elev2D.th.nc'] = 1` #hydro
- `p.flag['TEM_3D.th.nc'] = 1` #hydro
- `p.flag['TEM_nu.nc'] = 1` #hydro
- `p.flag['SAL_3D.th.nc'] = 1` #hydro
- `p.flag['SAL_nu.nc'] = 1` #hydro
- `p.flag['sflux'] = 1` #hydro
- `p.flag['albedo.gr3'] = 1` #hydro
- `p.flag['drag.gr3'] = 1` #hydro
- `p.flag['watertype.gr3'] = 1` #hydro

- For large files, the tool use soft link to provide link between database and current run directly
- It is easy to build workflow to conduct model model calibrations and scenario runs

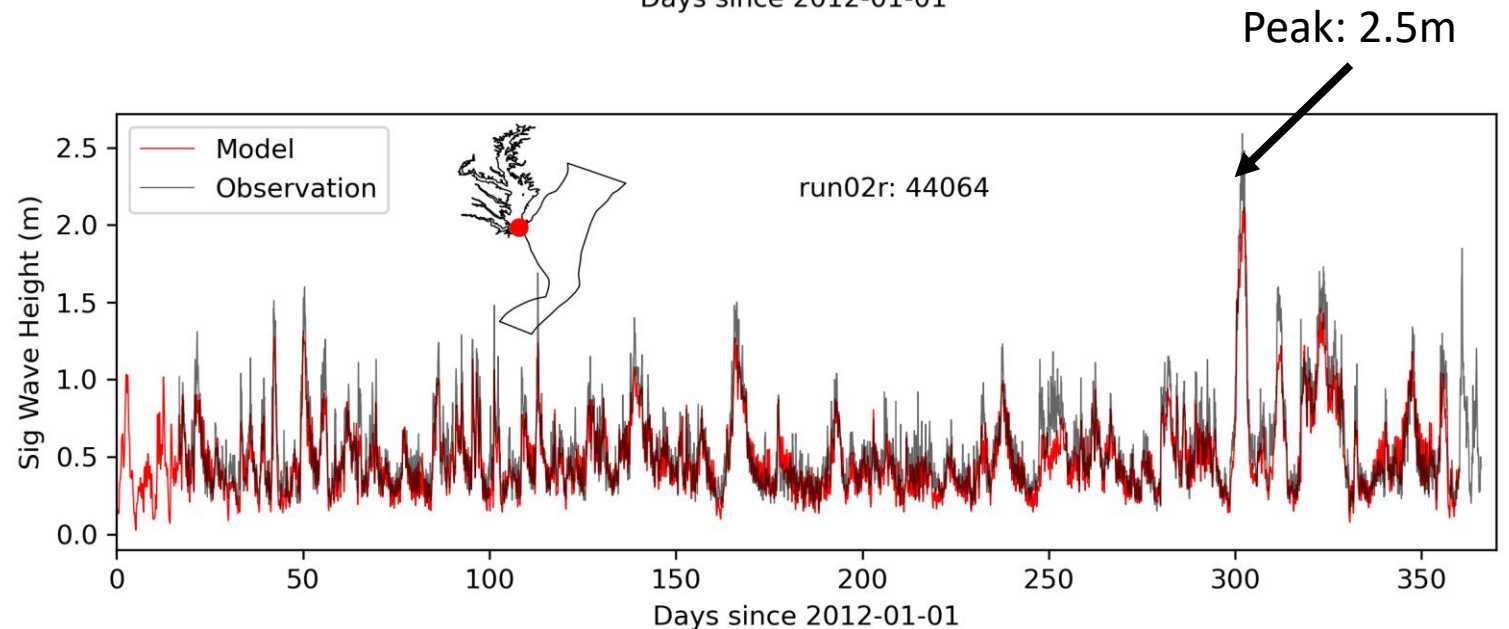
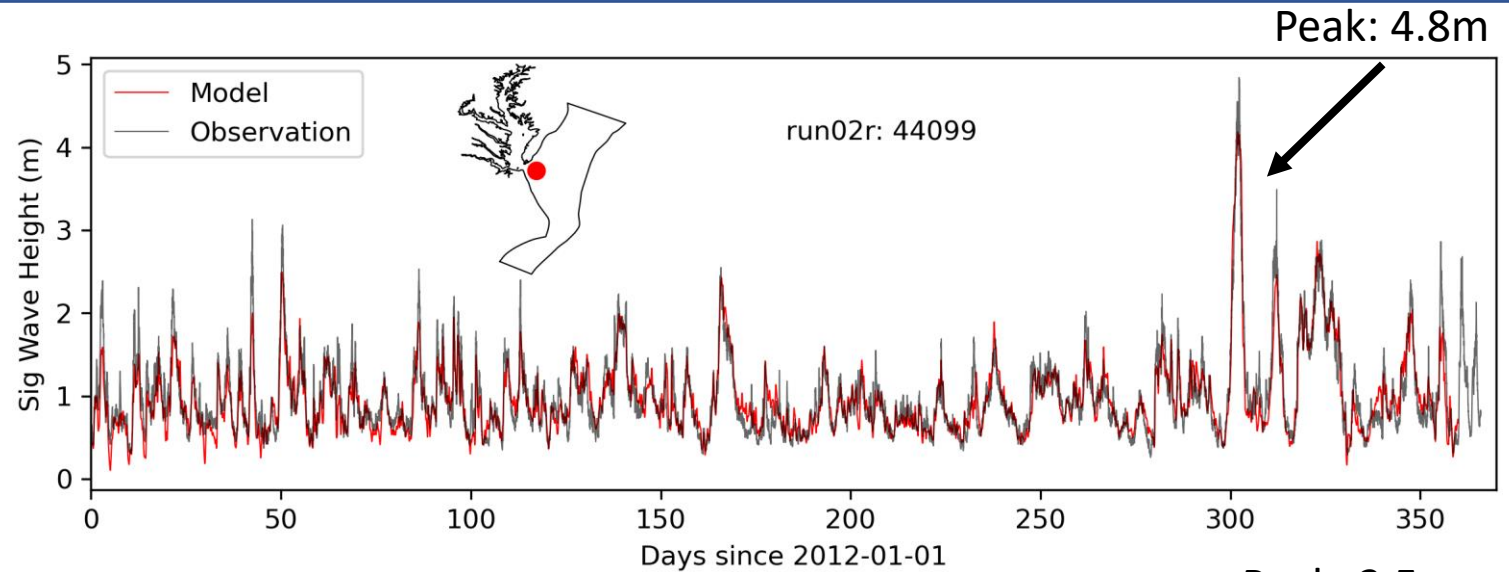
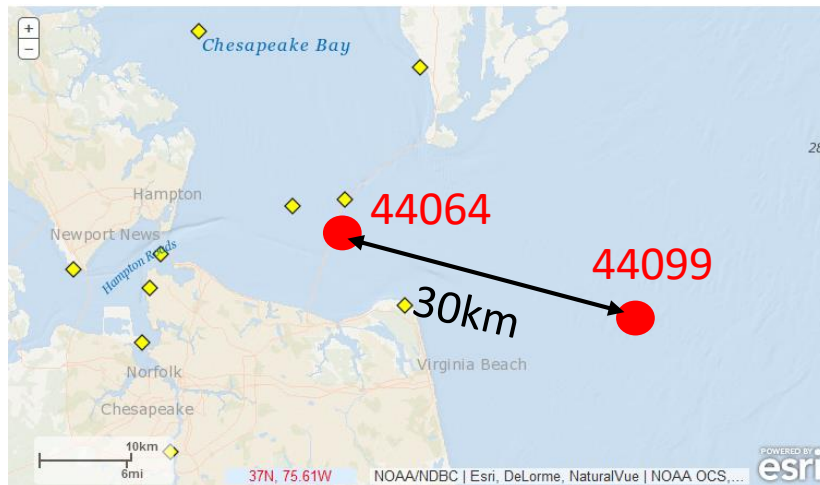
Develop **data-driven** wave model to improve efficiency

- Wave model simulation has a high computation cost
 - Previous studies used empirical wave model to save computation time
 - Is it feasible to build a data model to simulate wave with high spatial resolution?
-
- Use 5-year daily mean significant wave height (1991-1995) to train data model with same high spatial resolution of MBM model grid
 - Use different model simulations to test data model
 - Use NOAA buoy data to verify the data model
 - It has the potential to use data model for suspended sediment model

Numerical wave model simulation results

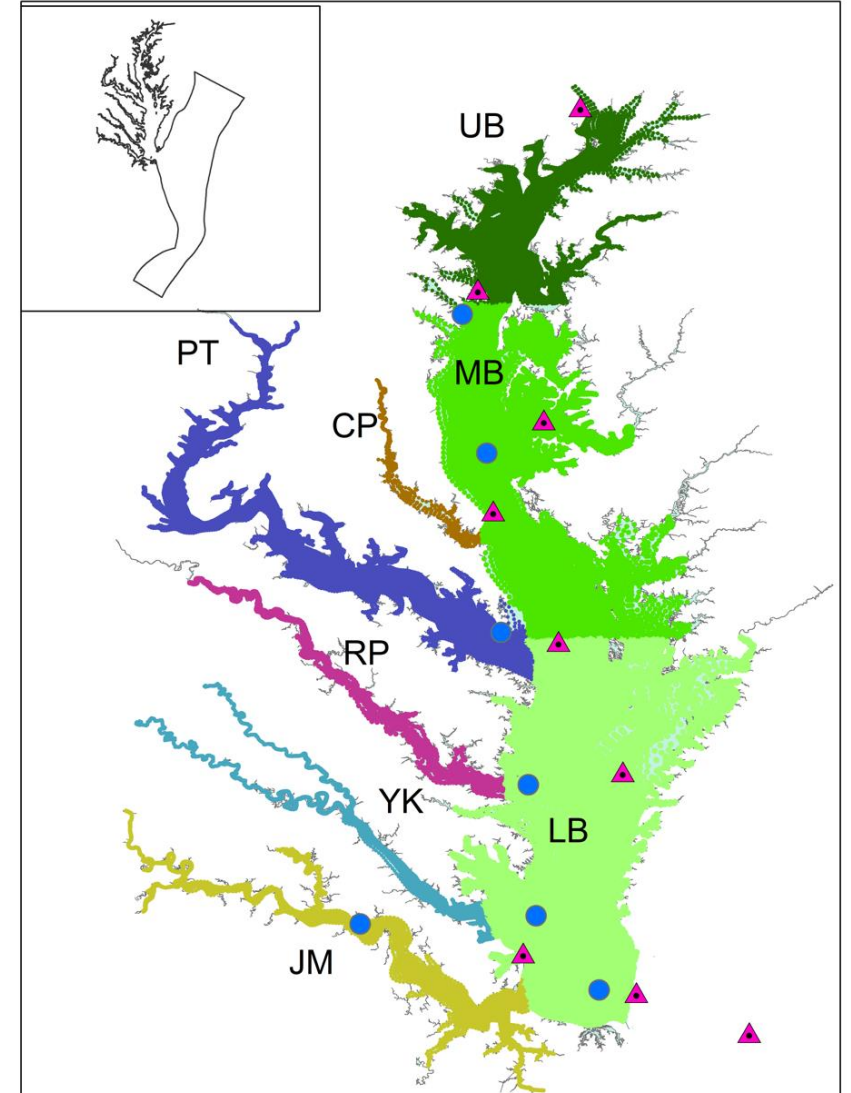
Quick attenuation of wave near the mouth

- Within ~30km, significant wave height decreases from 4.8m to 2.5m during Sandy
- Well reproduced by the model

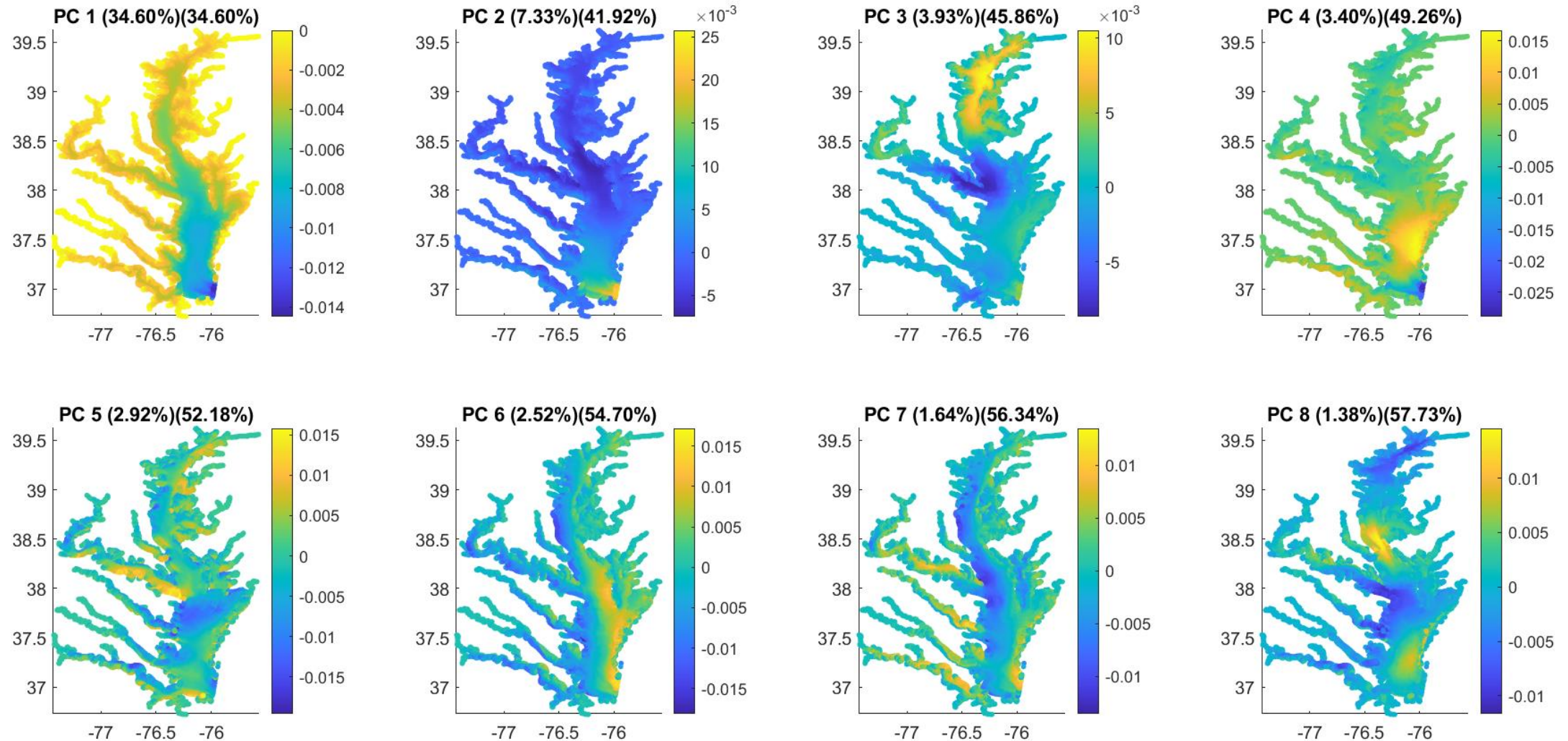


Data wave model

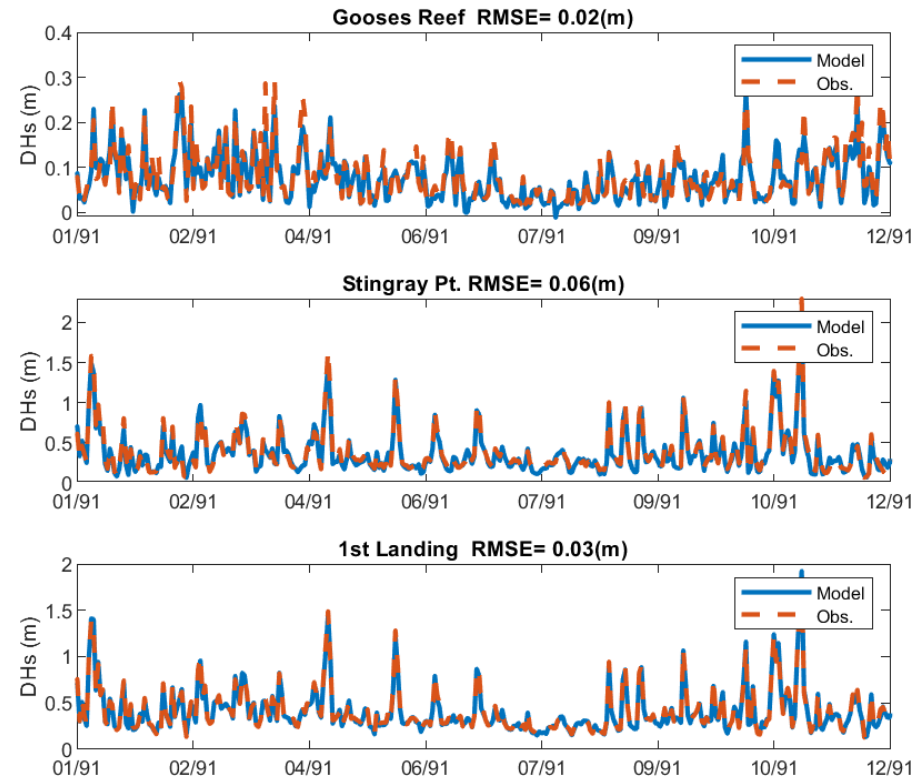
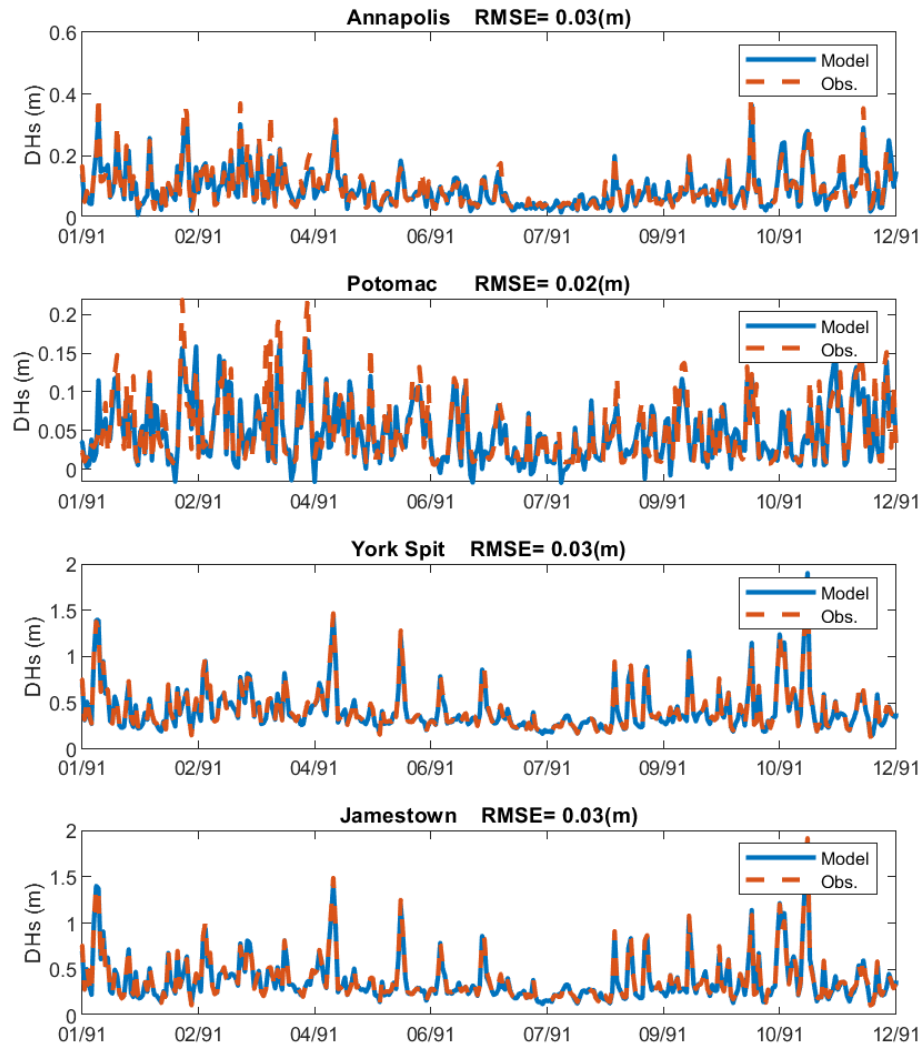
- Use SVD to reduce dimension and separate both spatial and temporal principal components
- Train dominant temporal principal components
- Train model use daily wind at 9 wind stations



Spatial distribution of principal components

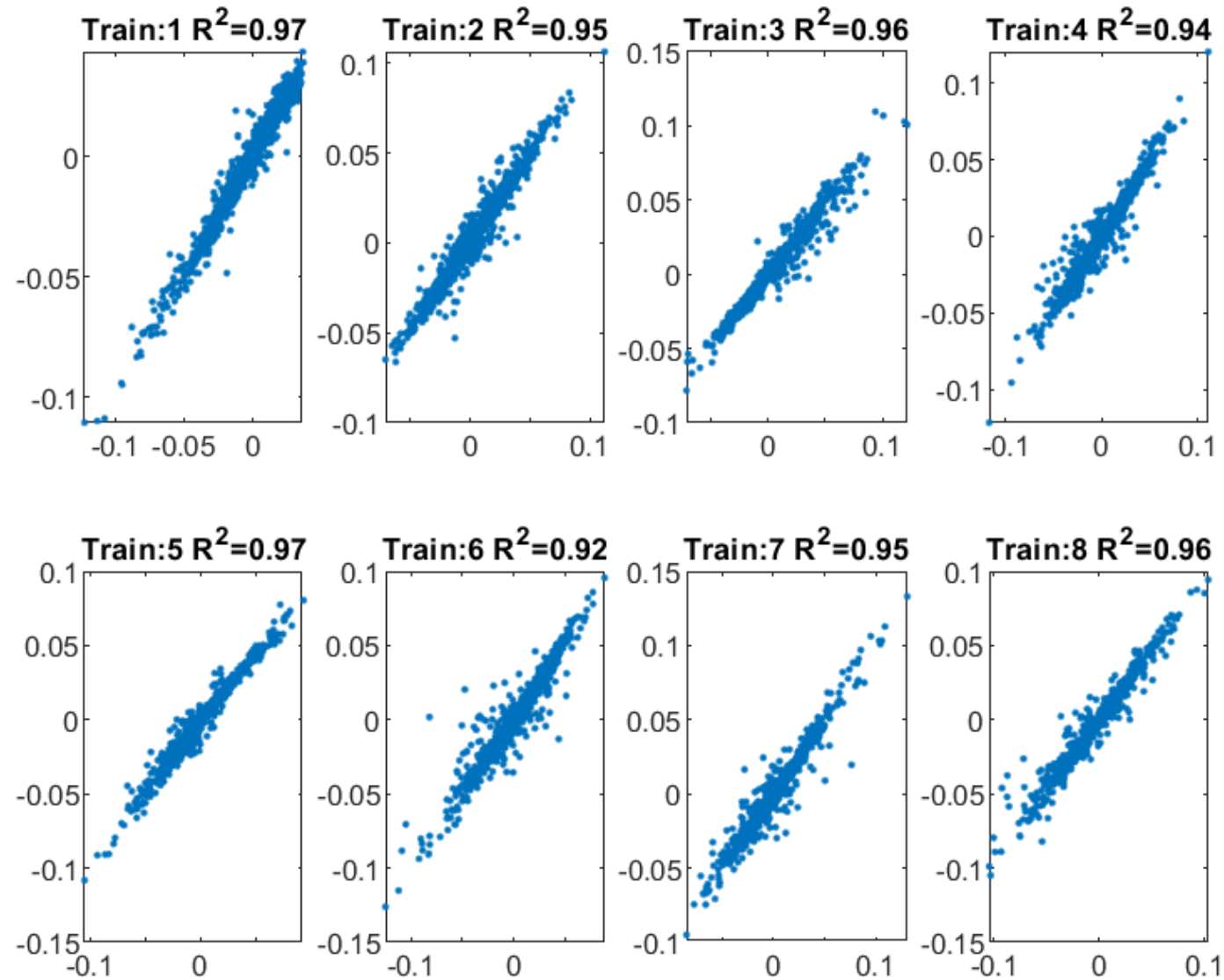


Compare 8-PCs against numerical model results

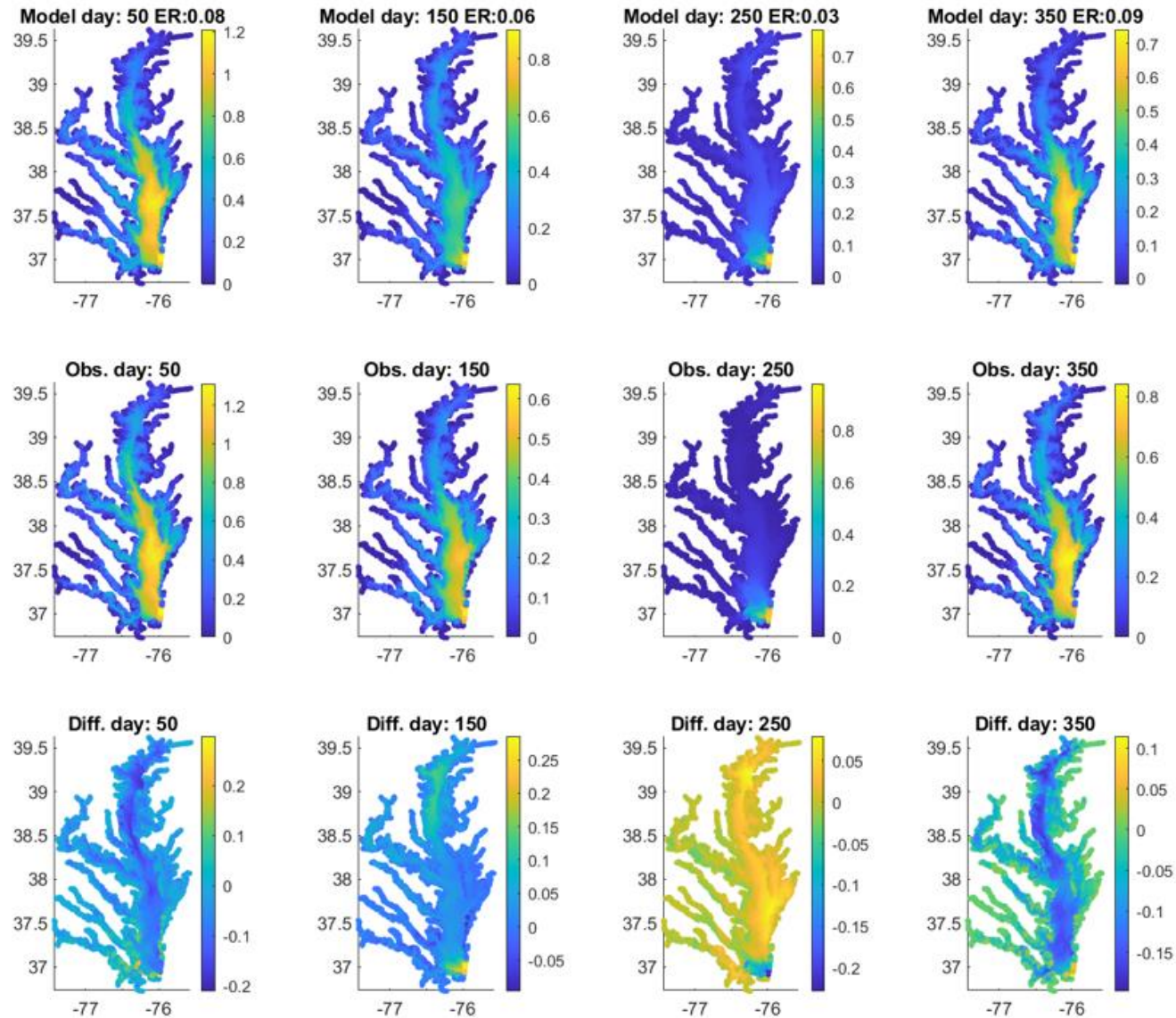


Obs. Referred numerical model outputs (used as observation for modeling training)

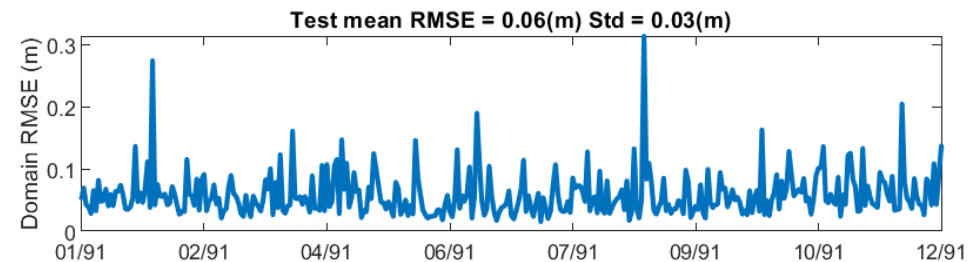
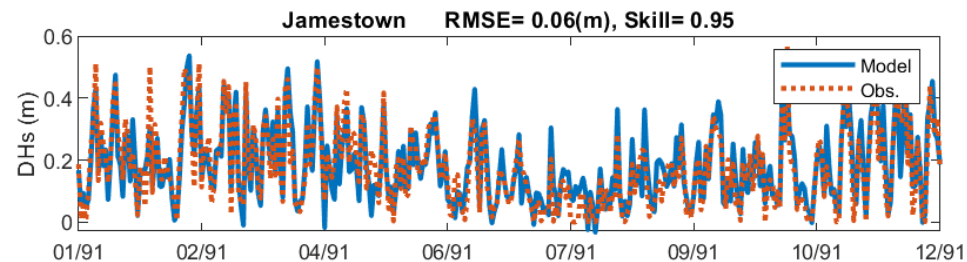
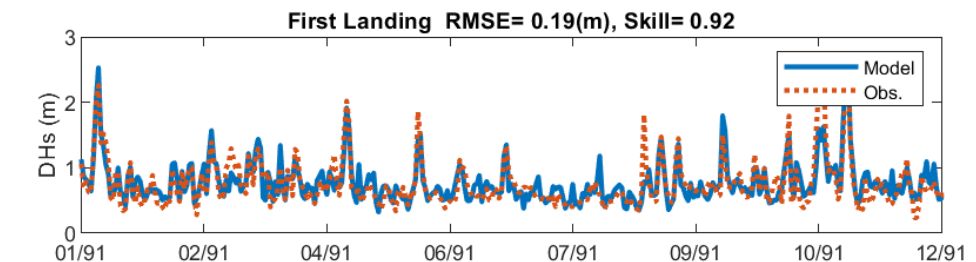
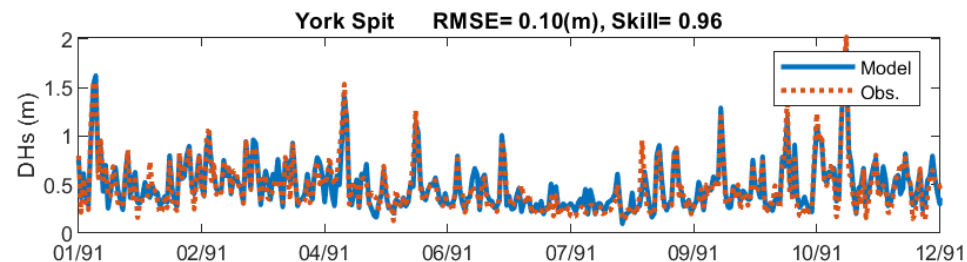
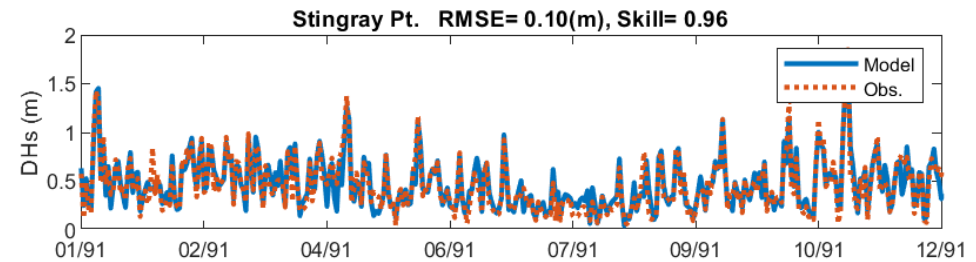
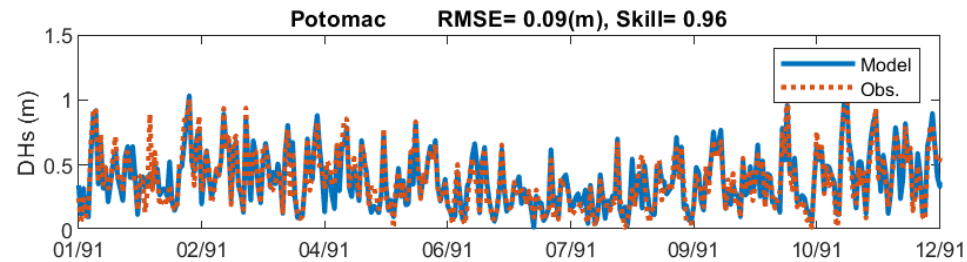
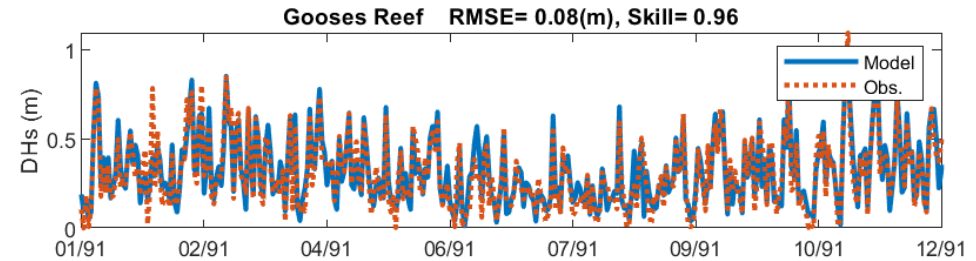
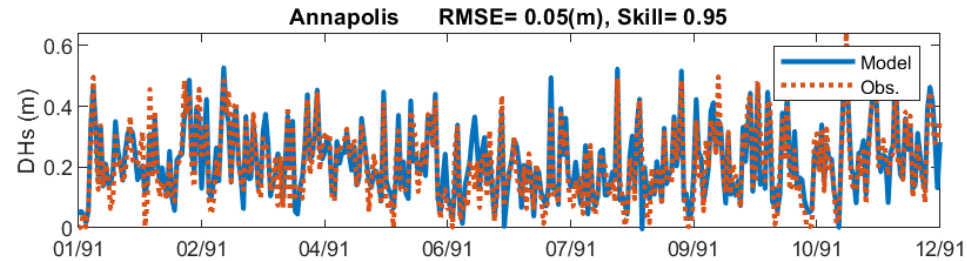
Training results



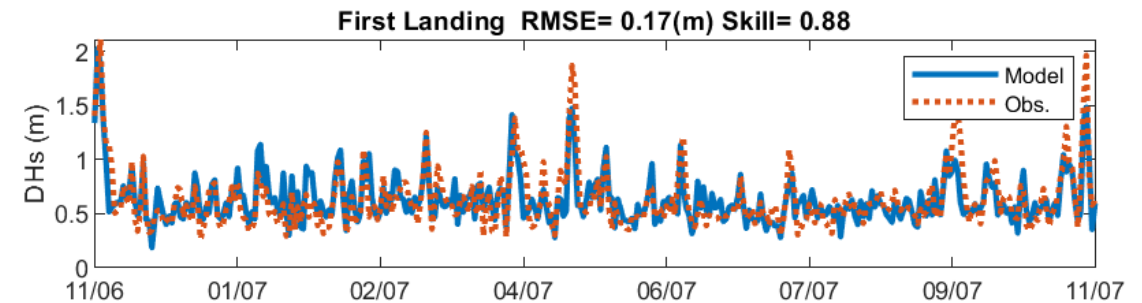
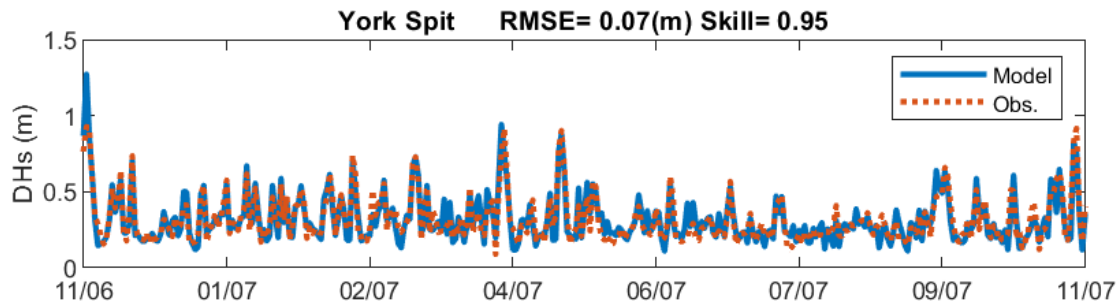
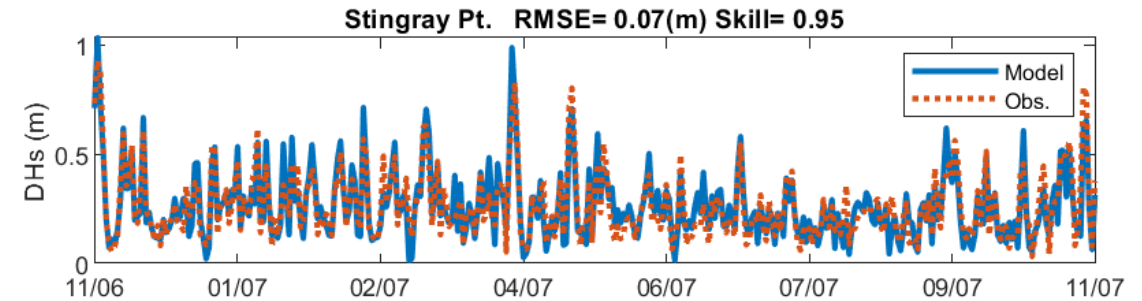
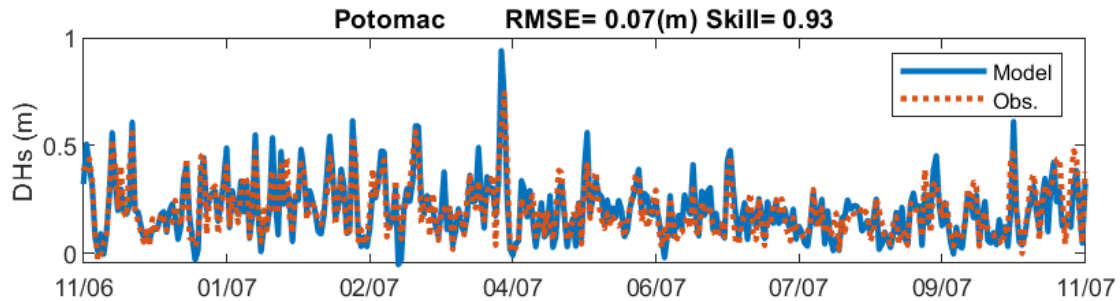
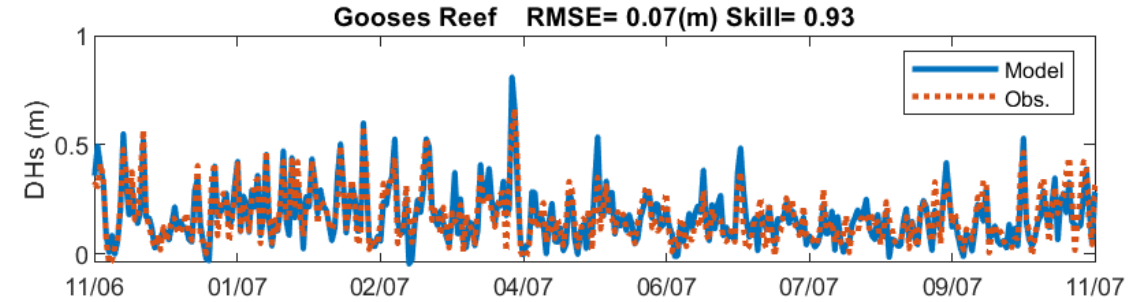
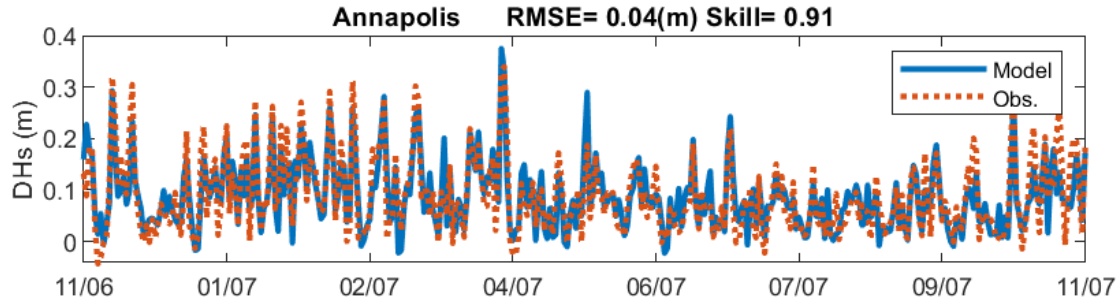
Comparison of data model and numerical model



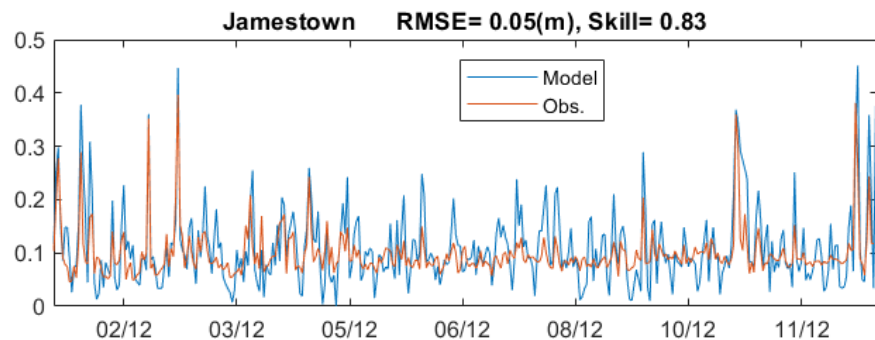
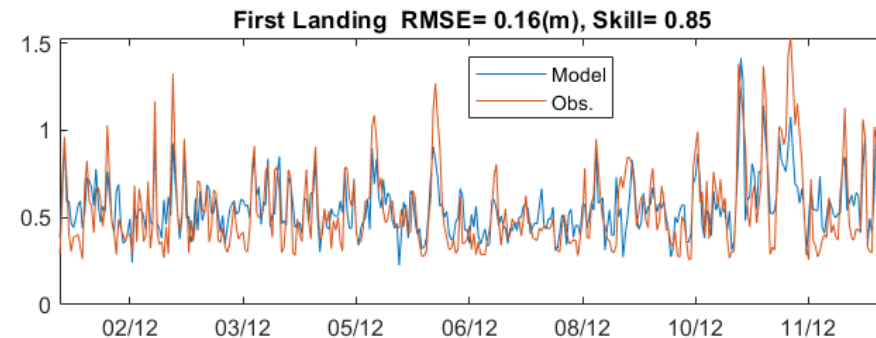
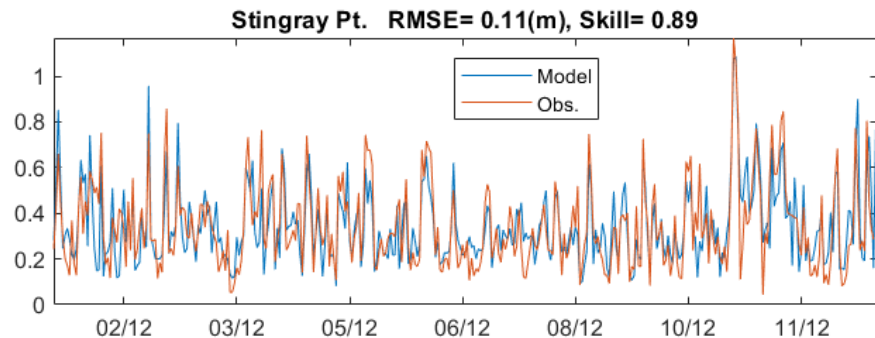
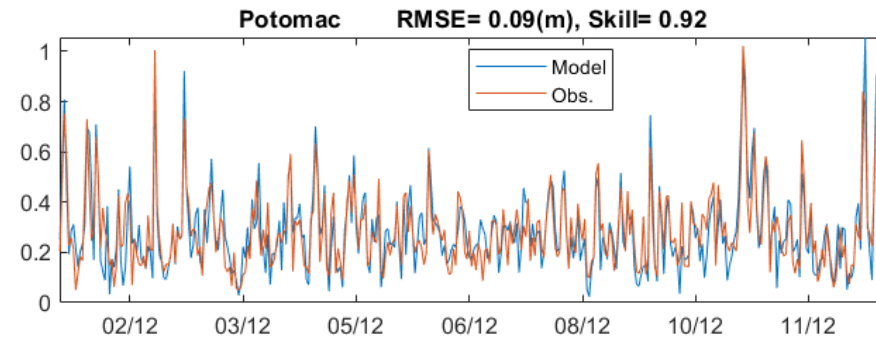
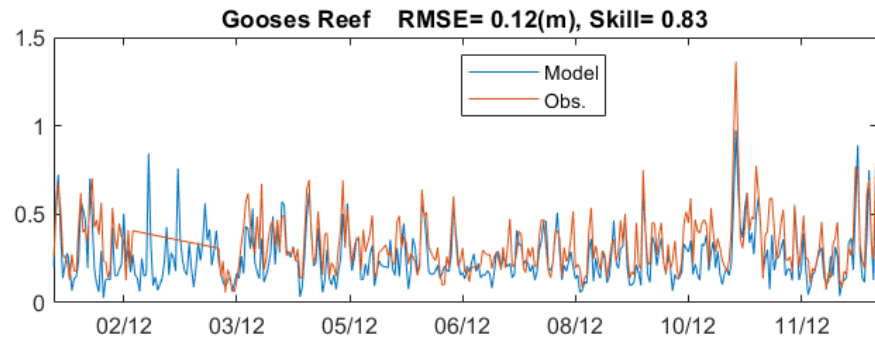
Comparison of data model and numerical model



Comparison of data model and 2nd numerical model



Comparison of data model and NOAA buoy station



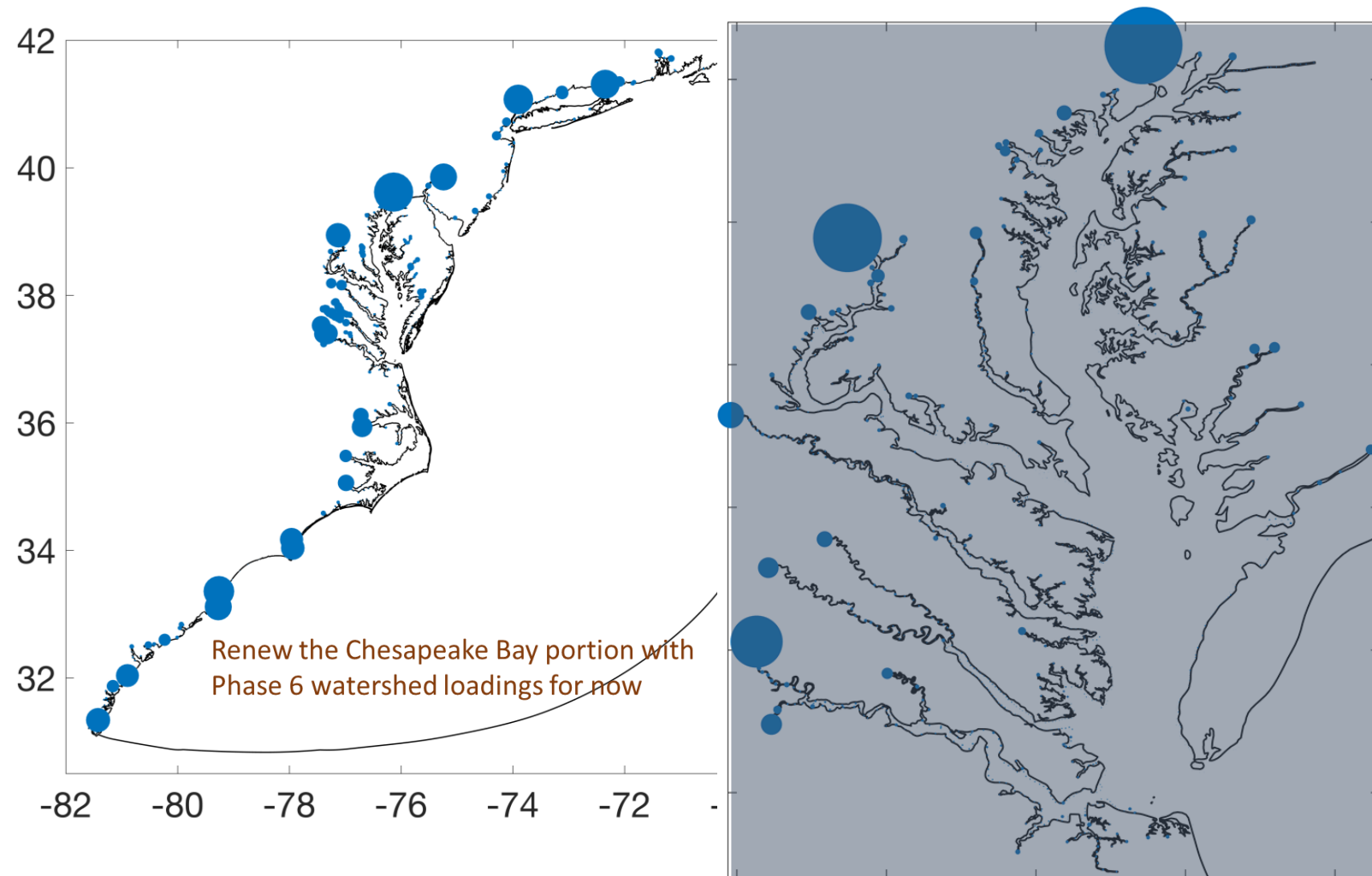
Obs. Are NOAA buoy real time observations

Next phase: ICM model calibration

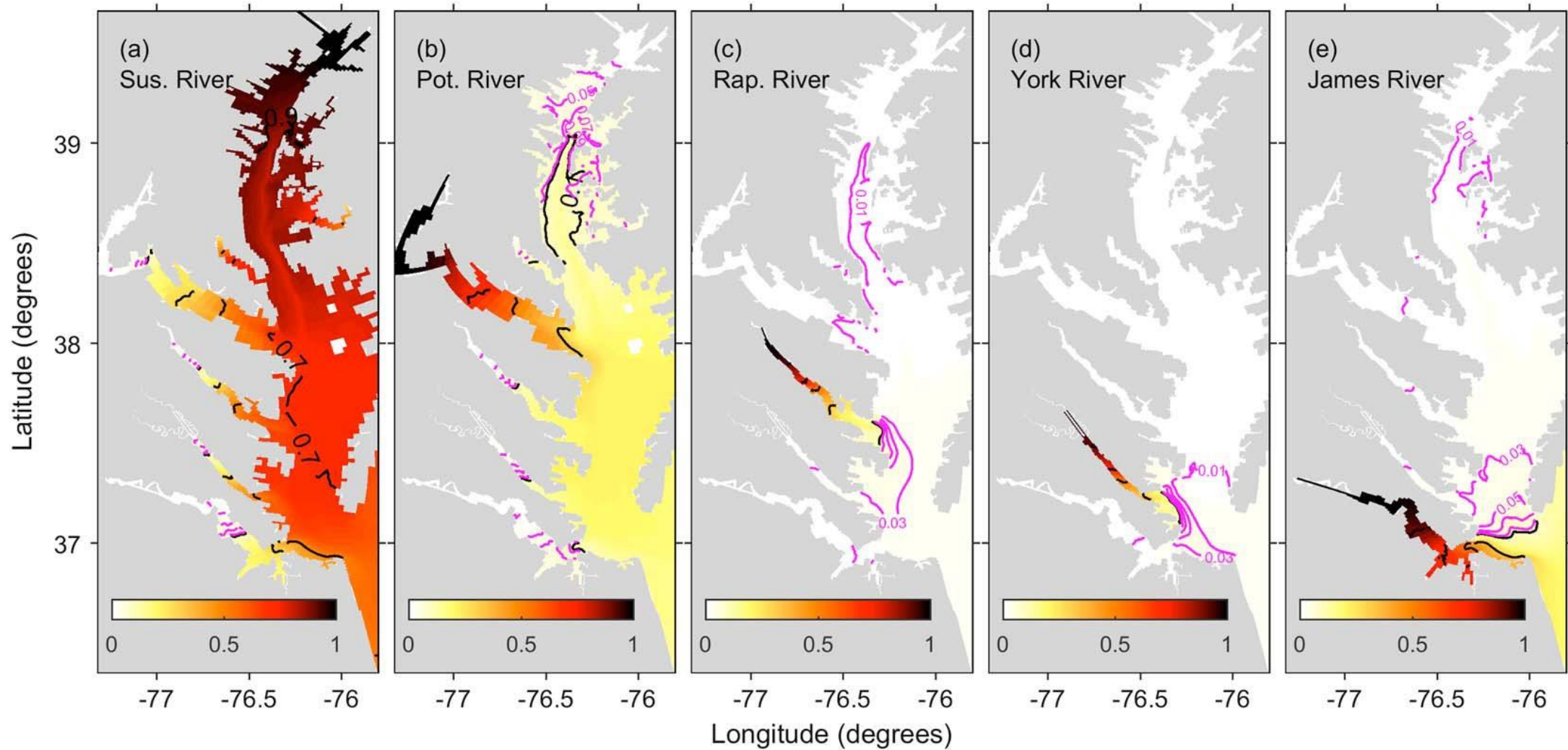
- Calibration of water quality model (phase 1)
 - Use phase 6 watershed loading
 - Calibrate model without including wetland (DO or nutrient loads)
 - Calibrate model without including SAV and oyster
 - Using spatial settling velocity and growth rate if it is needed
- Calibration of water quality model (phase 2)
 - Calibrate water quality model including wetland
 - Calibrate water quality model including SAV
- Calibration of water quality model (phase 3)
 - Calibrate of water quality including oyster

Next phase: Source contribution

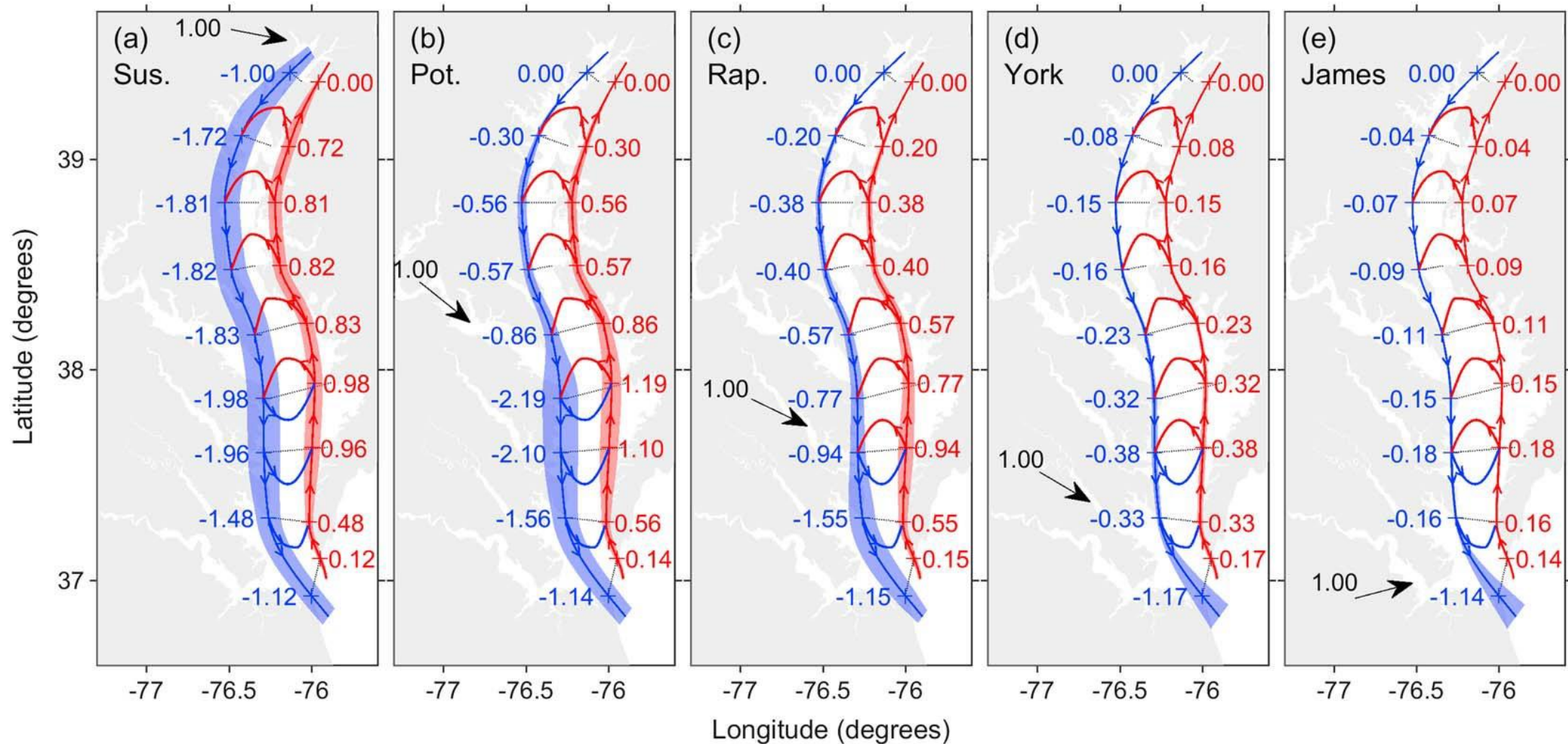
- We know the characteristics of sources contributions from major rivers inside Bay and how materials are transported
- We are less clear about the source contributions outside of the Bay
- We have MAB mesh, which is running for other projects



Next phase: Source contribution



Next phase: Source contribution



Next phase: Source contribution

- Use dye study to understand the source contribution
 - Delaware Bay (CN channel)
 - Contribution of Delaware loading from open boundary
 - Contribution of East costal embayments
 - Contribution of open boundary condition (climate change)

Comments and Suggestions

*Thank
you !*