Coupled wave-sediment model with SCHISM for Chesapeake Bay

Jiabi Du, Joseph Zhang, Zhengui Wang, Fei Ye, Jian Shen, Harry Wang, Nicole Cai

Special thanks to Julia Moriarty, Courtney Harris, Larry Sanford

Modeling Workgroup Quarterly Review
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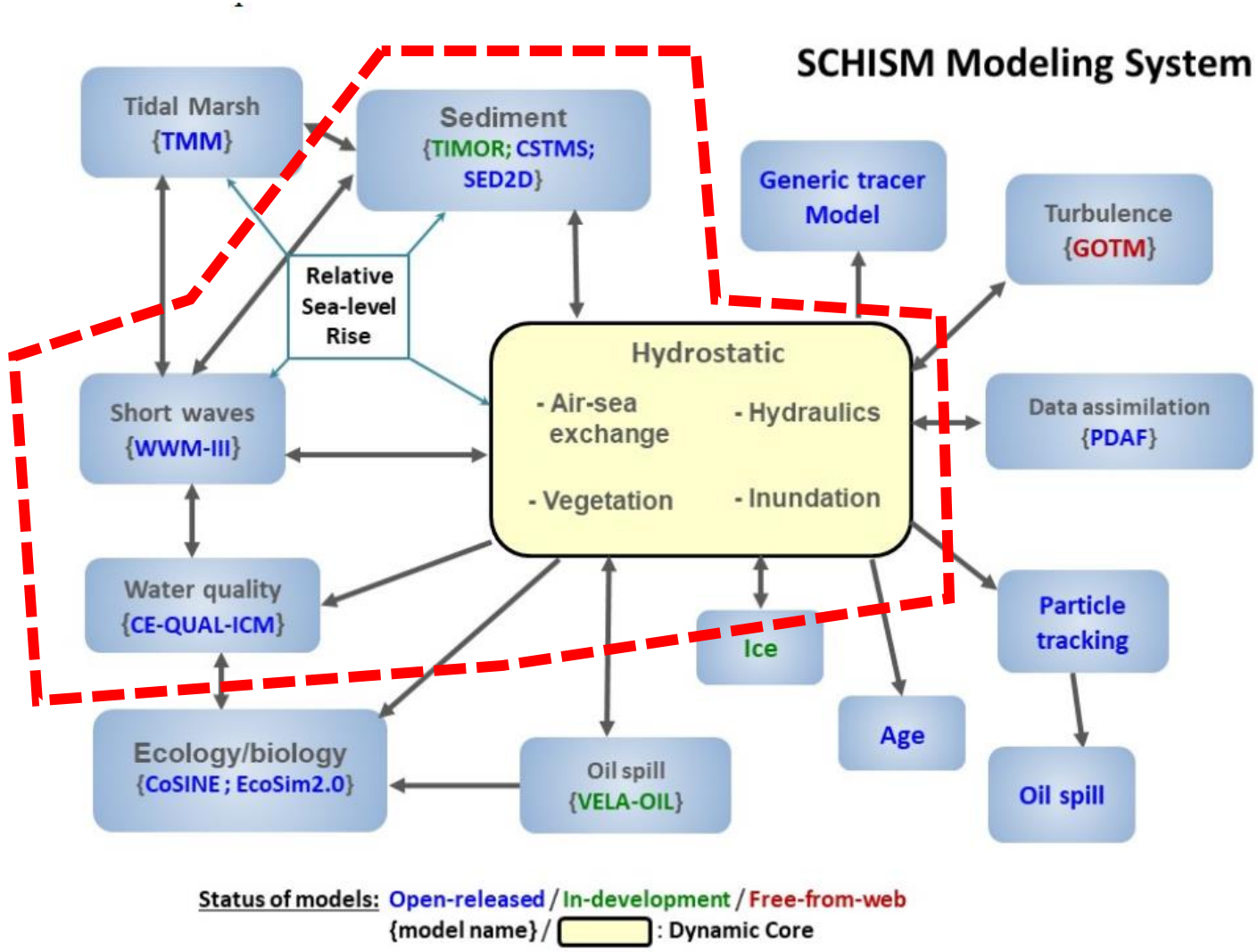
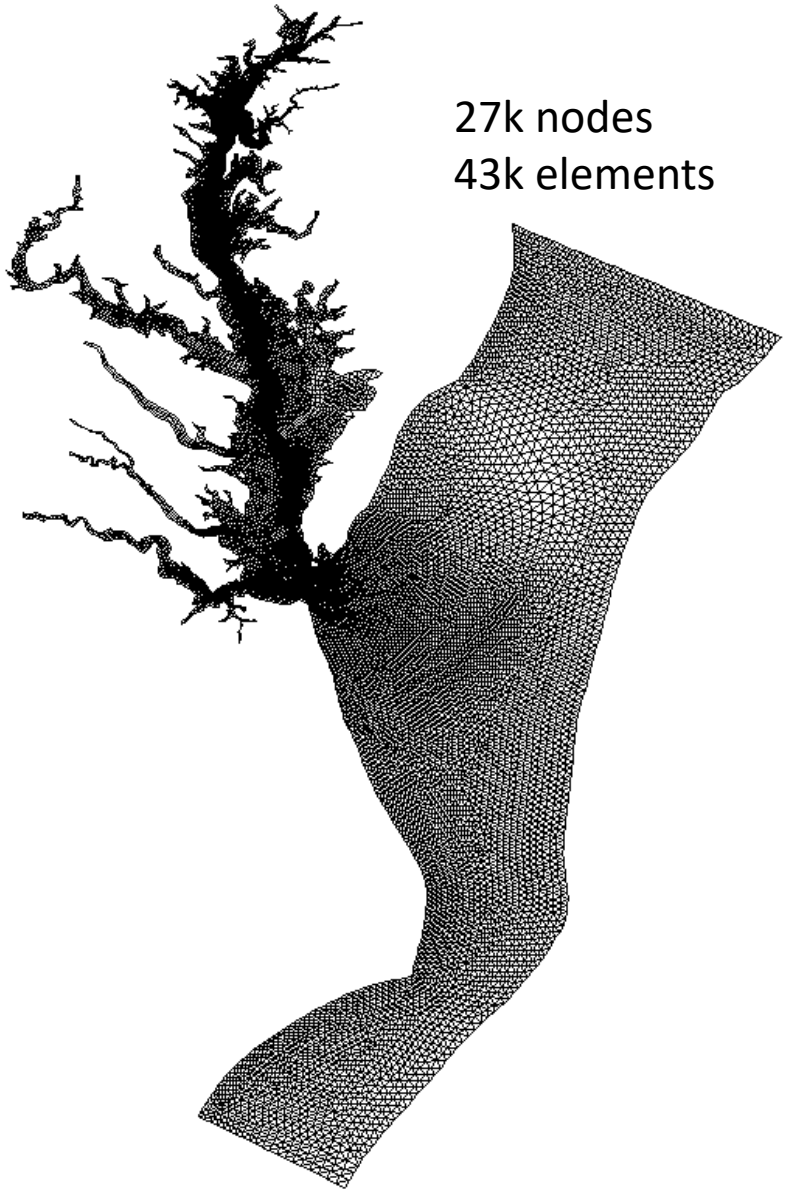
Motivation

- To provide spatially and temporally varying suspended sediment concentration for WQ model
- High-frequency variations of turbidity (and light condition) could significantly impact water quality



Wave model set-up

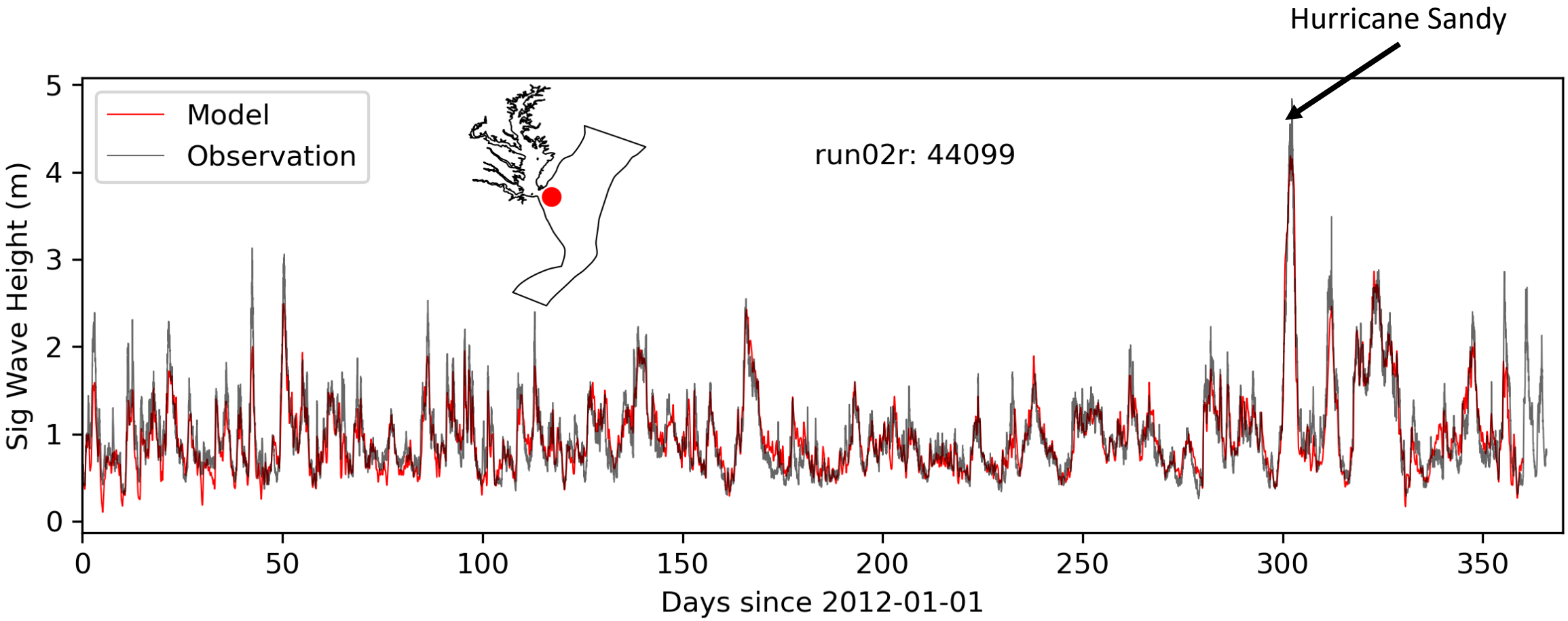
WindWaveModel (WWM)
Number of direction bins: 24
Number of frequency: 24
Open boundary condition: Ifremer global product



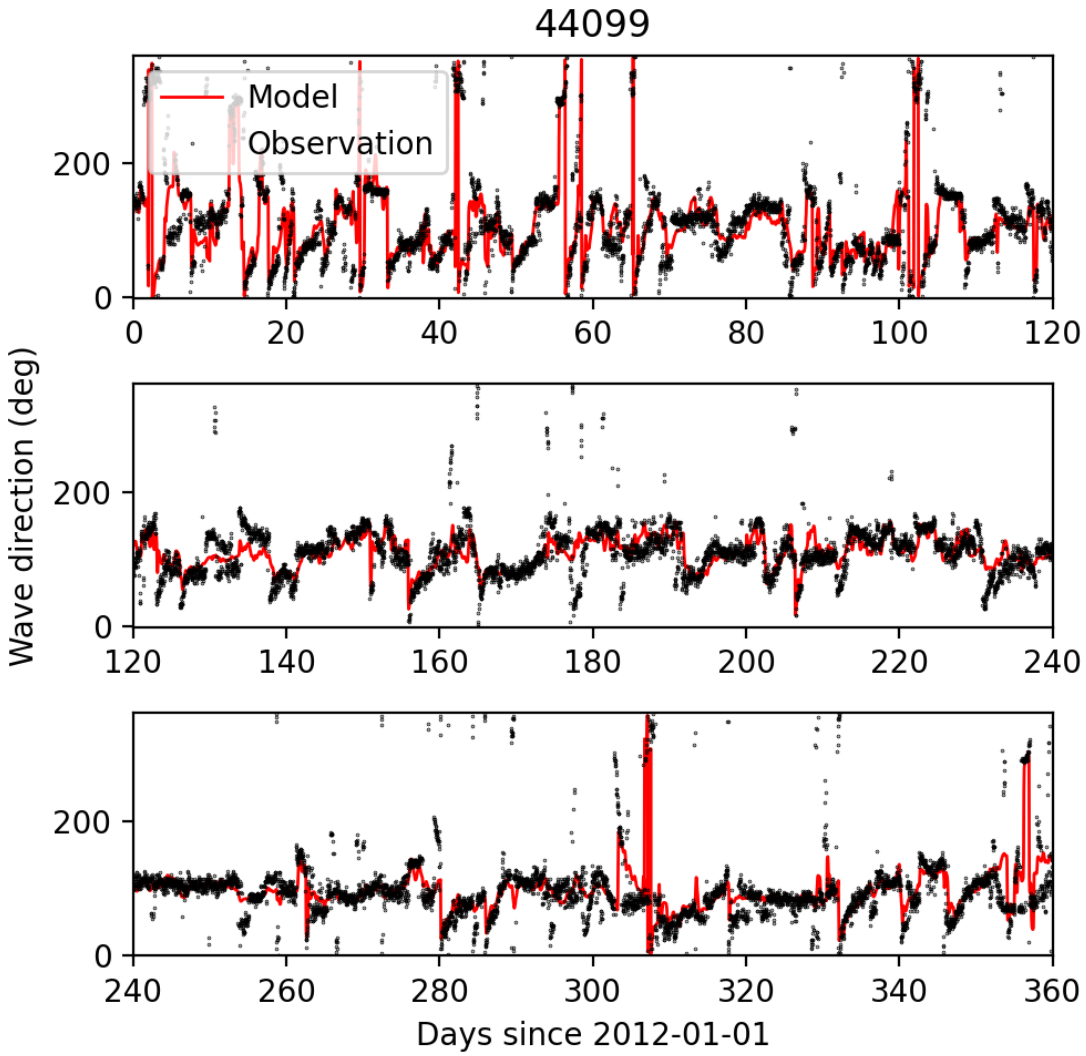
Computational Efficiency

Hydro+wave+sediment (4 classes)
16 hours for one-year run on 320 Cores (Femto HPC cluster, College of William & Mary)

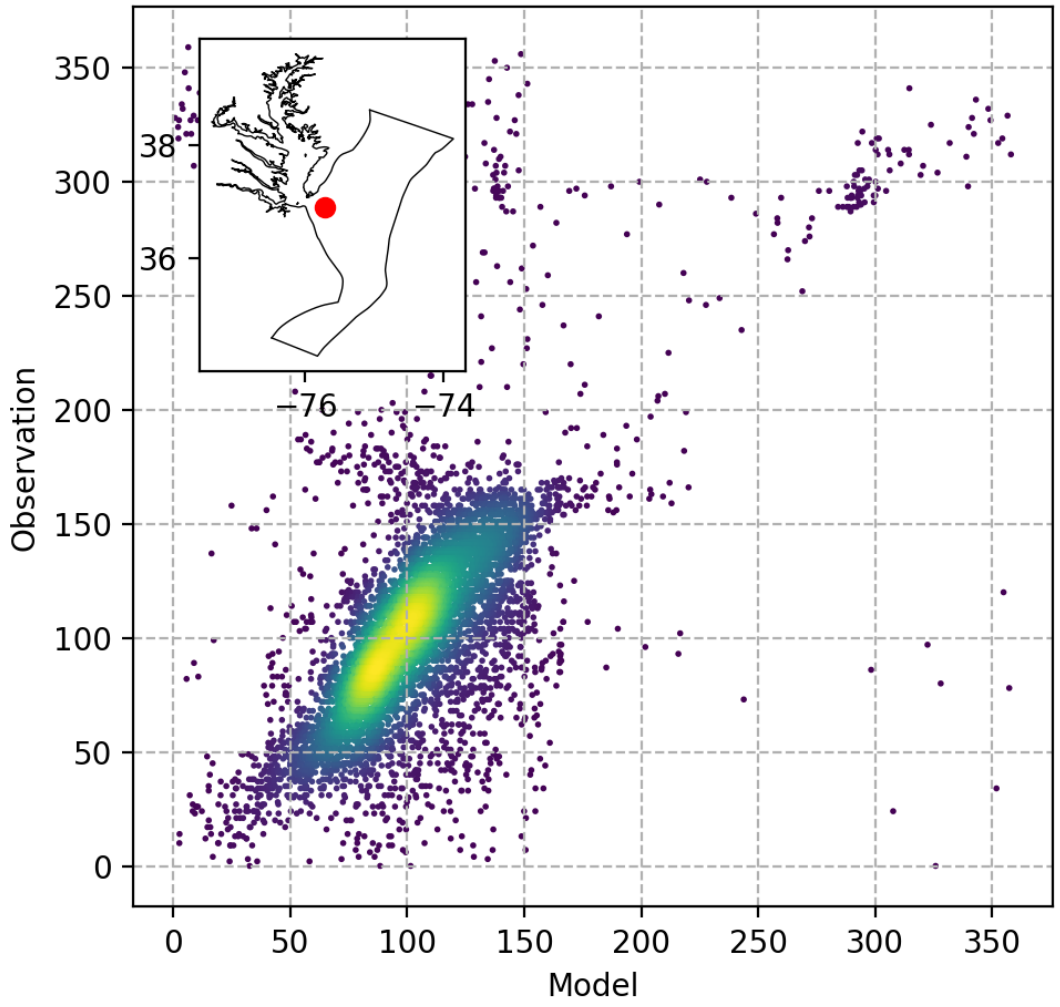
Wave model performance



Wave direction

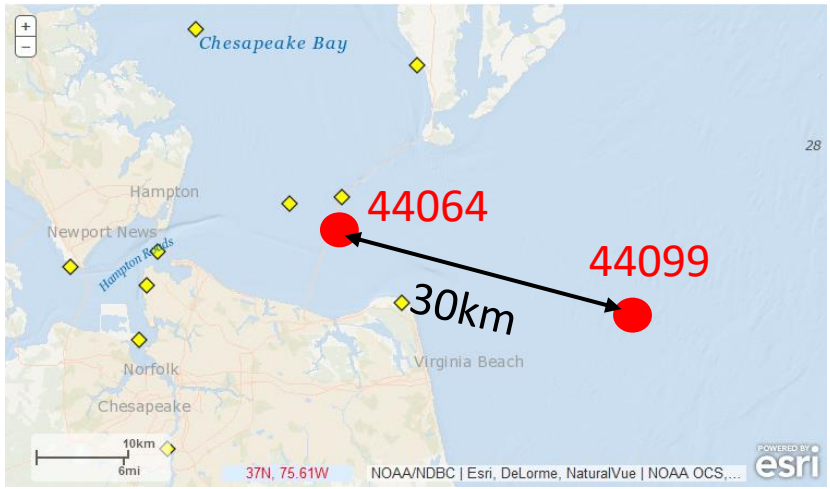


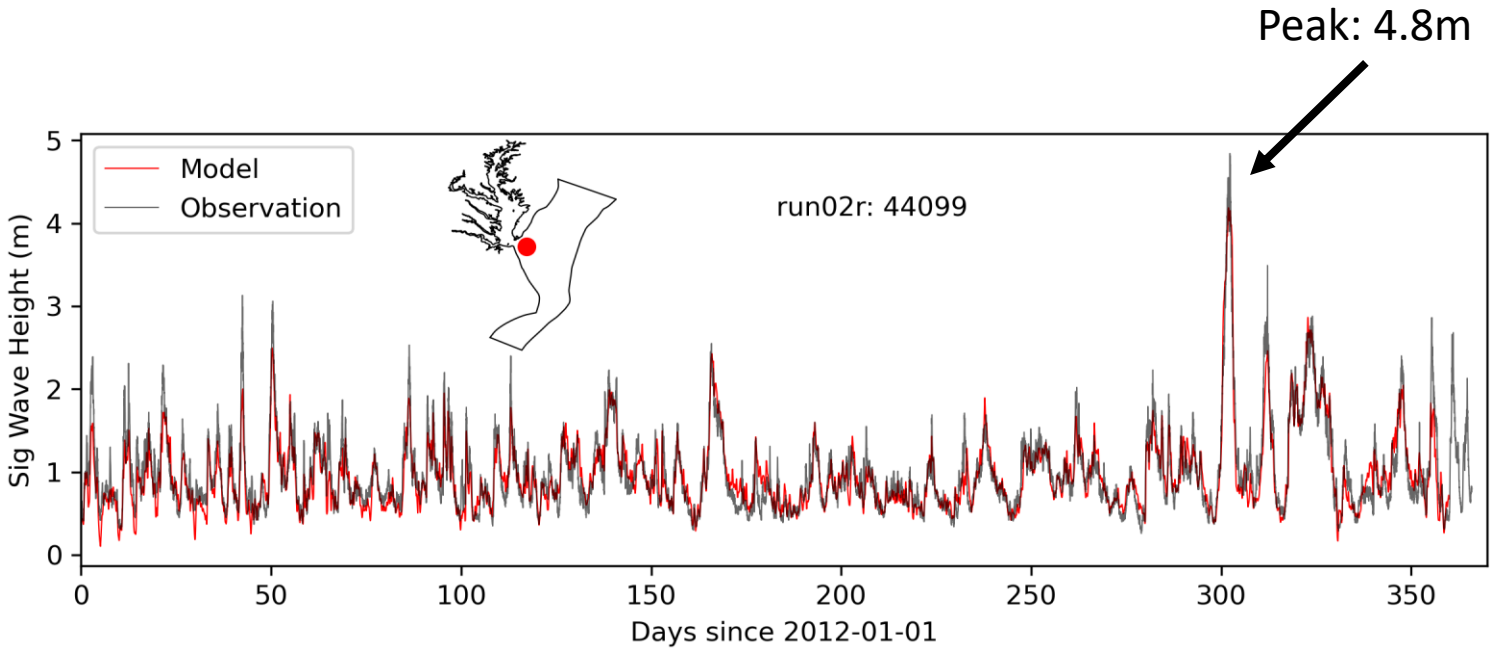
Density scatter plot (yellower color denotes more data points)

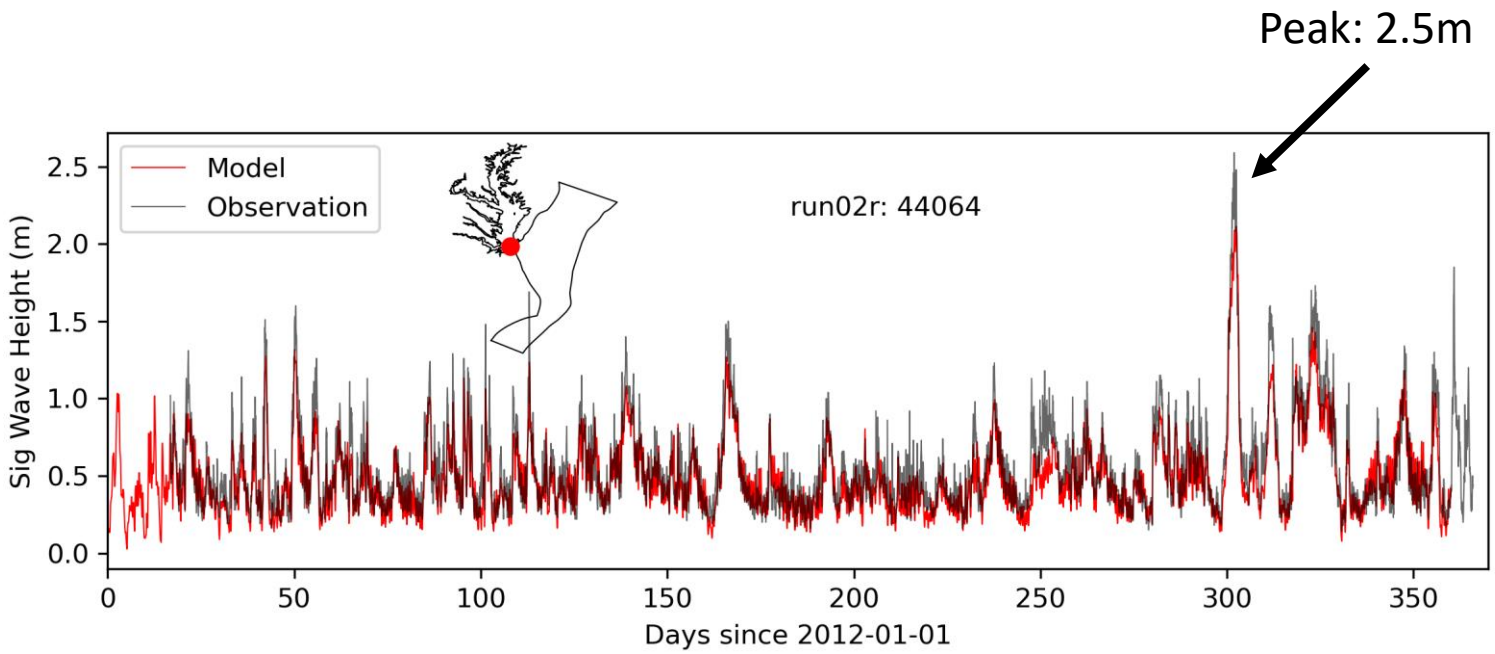


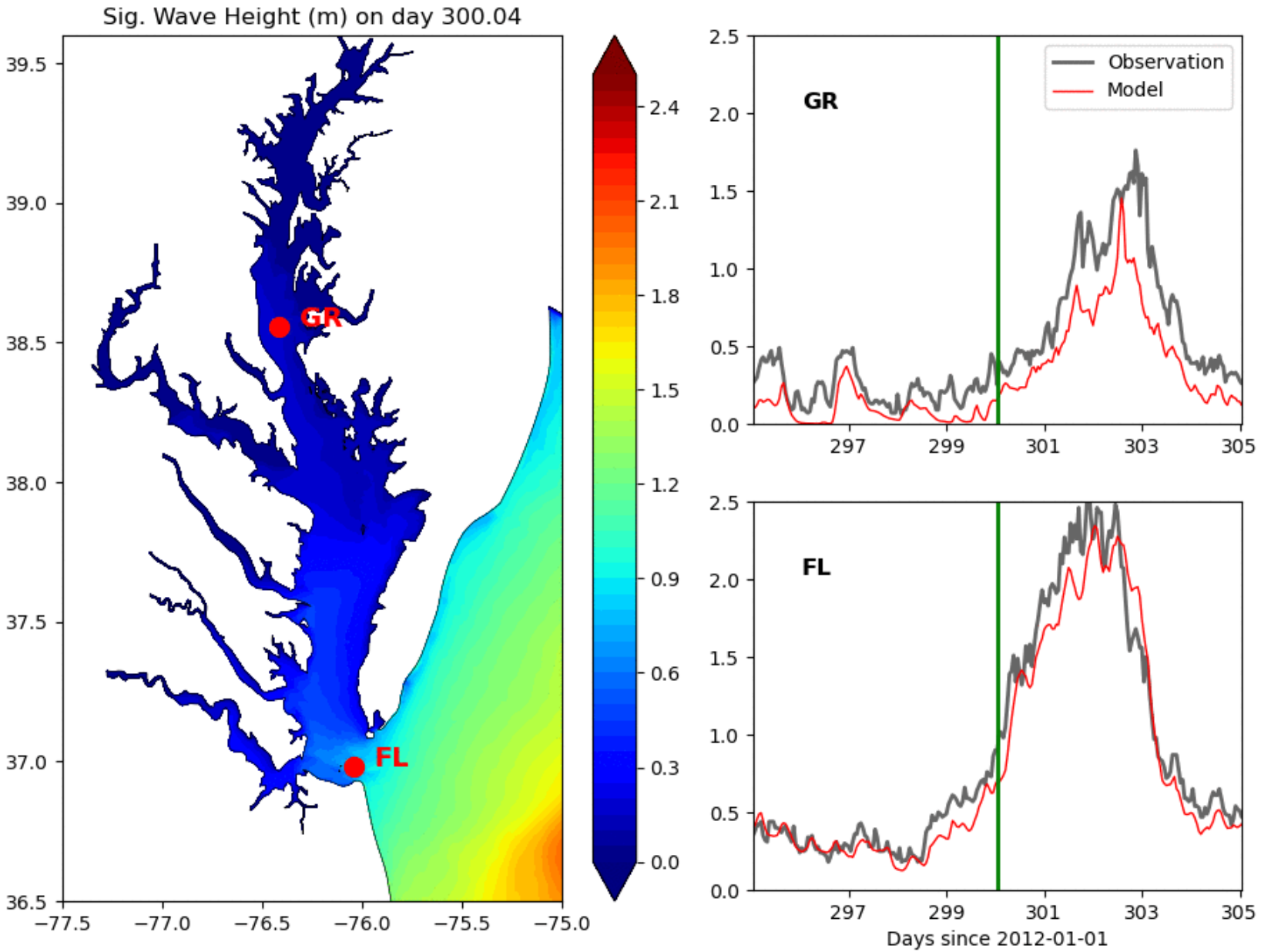
Quick attenuation of wave near the mouth

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







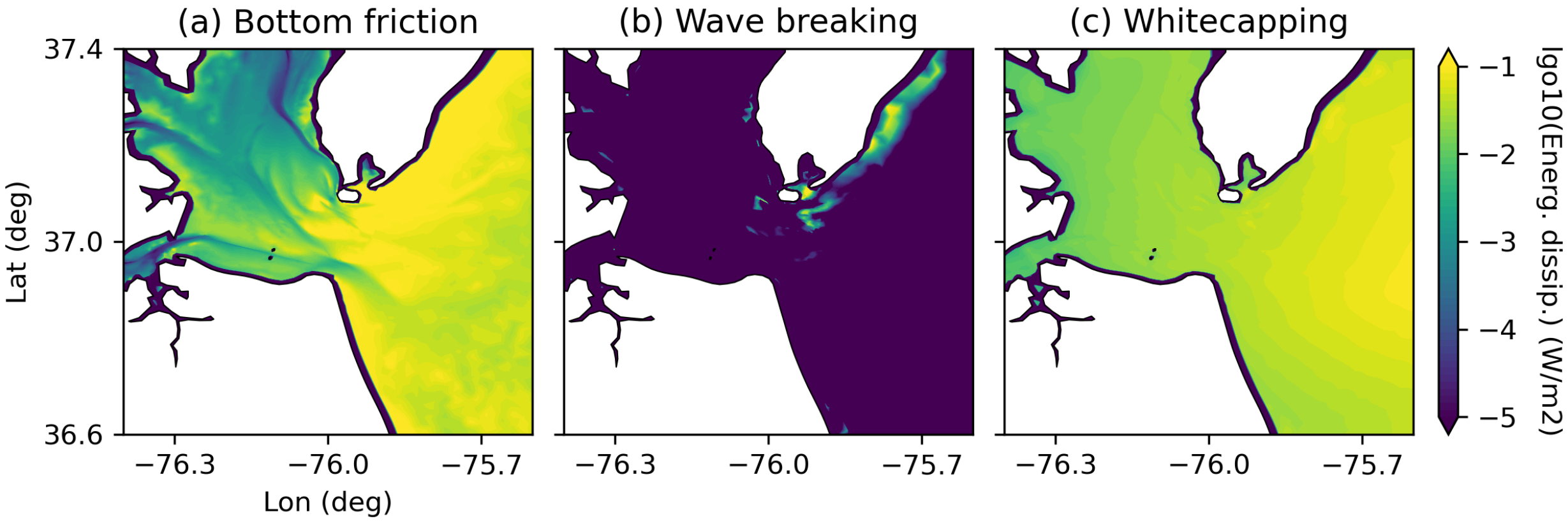


Wave height during Hurricane Sandy (2012)

- Quick decrease of wave height near the bay mouth
- Wave from coastal ocean impact the lower bay only.

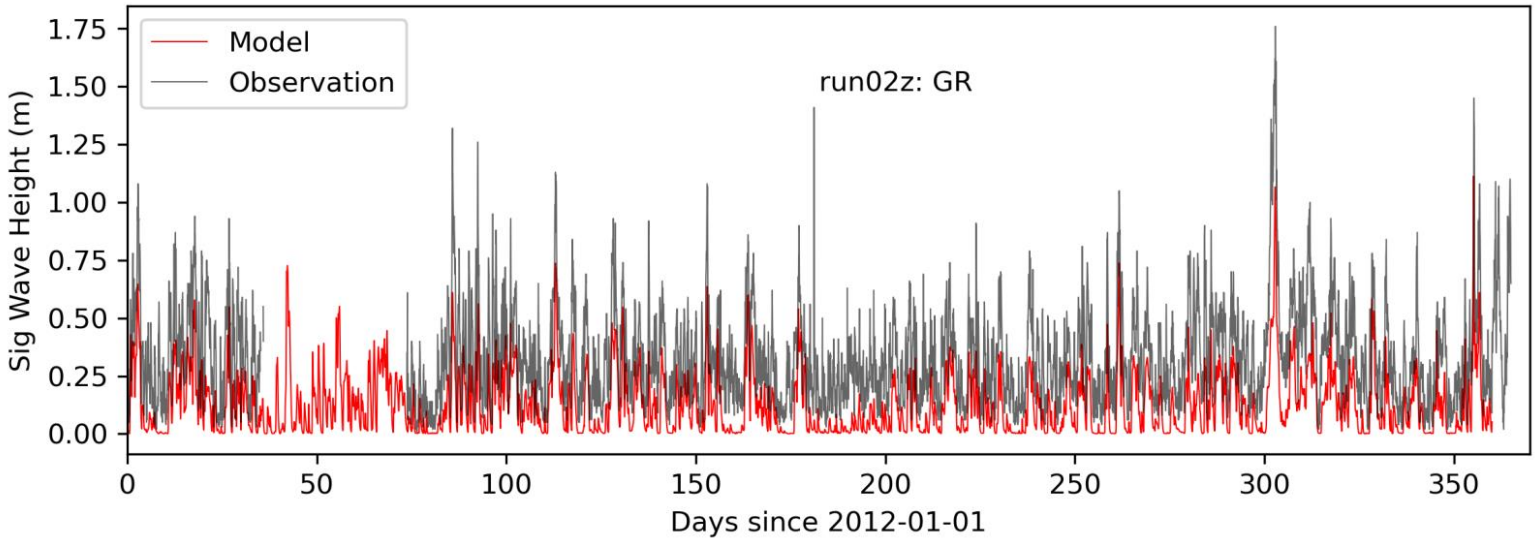
Wave energy dissipation near the mouth

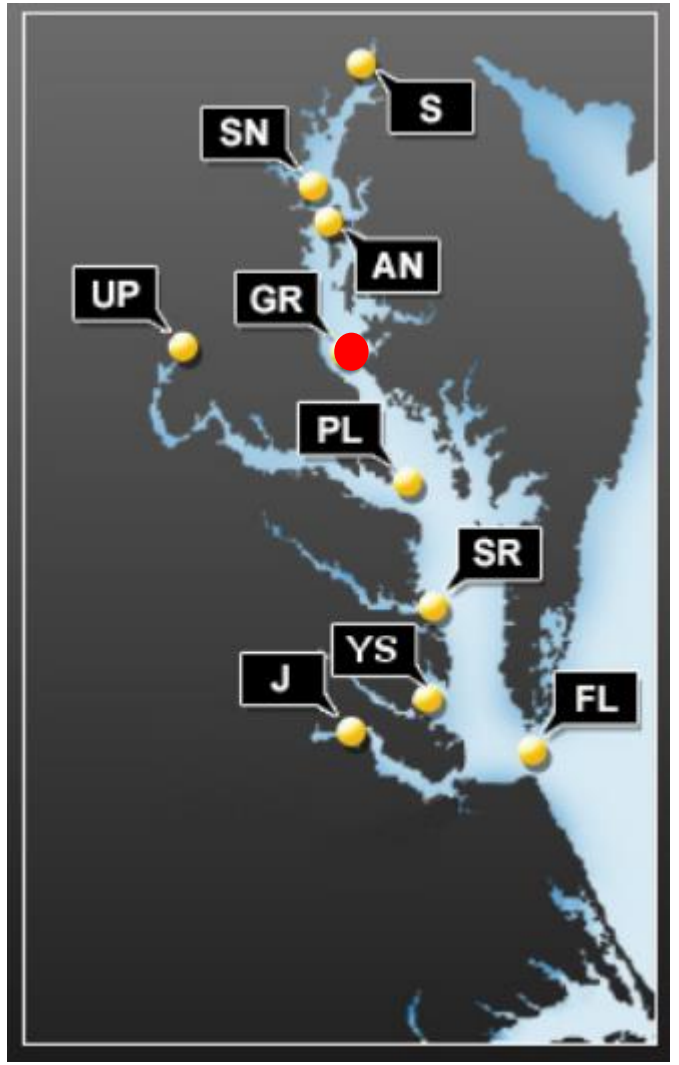
- Bottom friction is the major term, followed by whitecapping.
- Contribution from wave breaking is notable in the lower eastern shore.



Issue: Underestimation of wave height in the middle-upper bay

One possible reason is the error in atmospheric forcing. Currently, 3-hourly NARR is used.



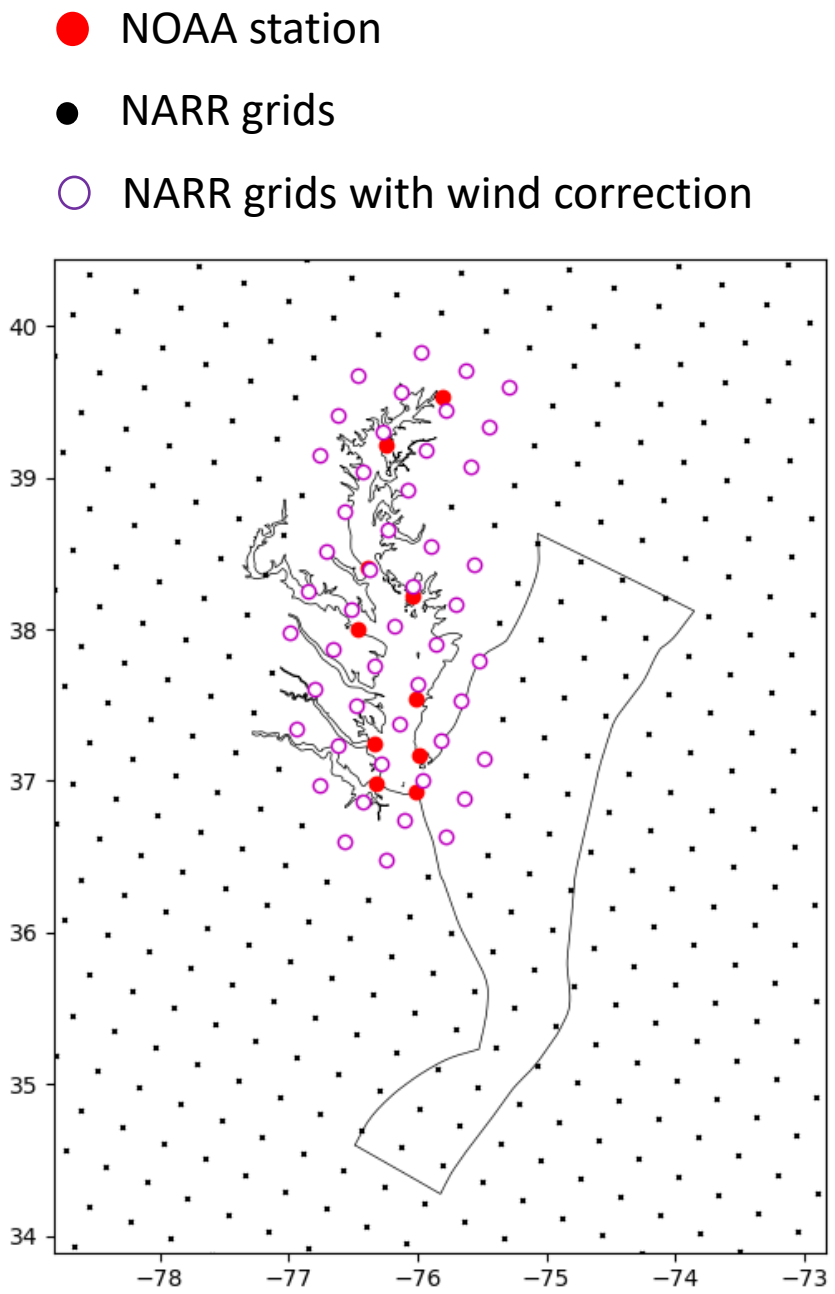


Wind correction

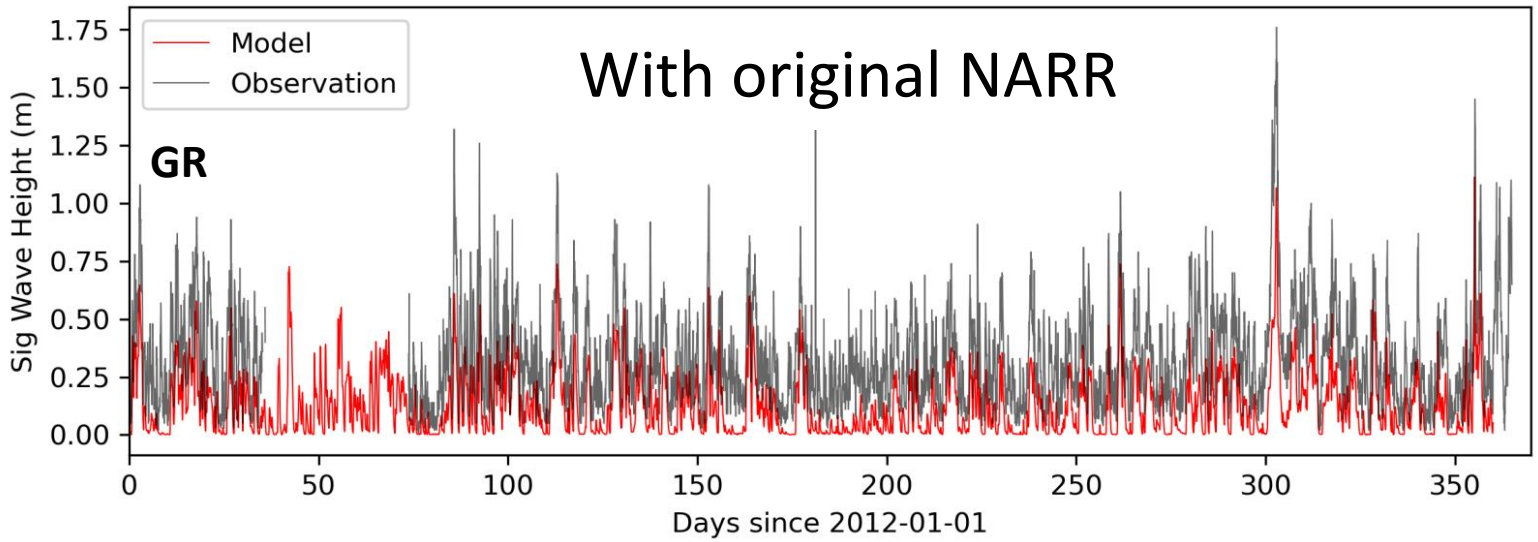
Local wind adjustment scheme

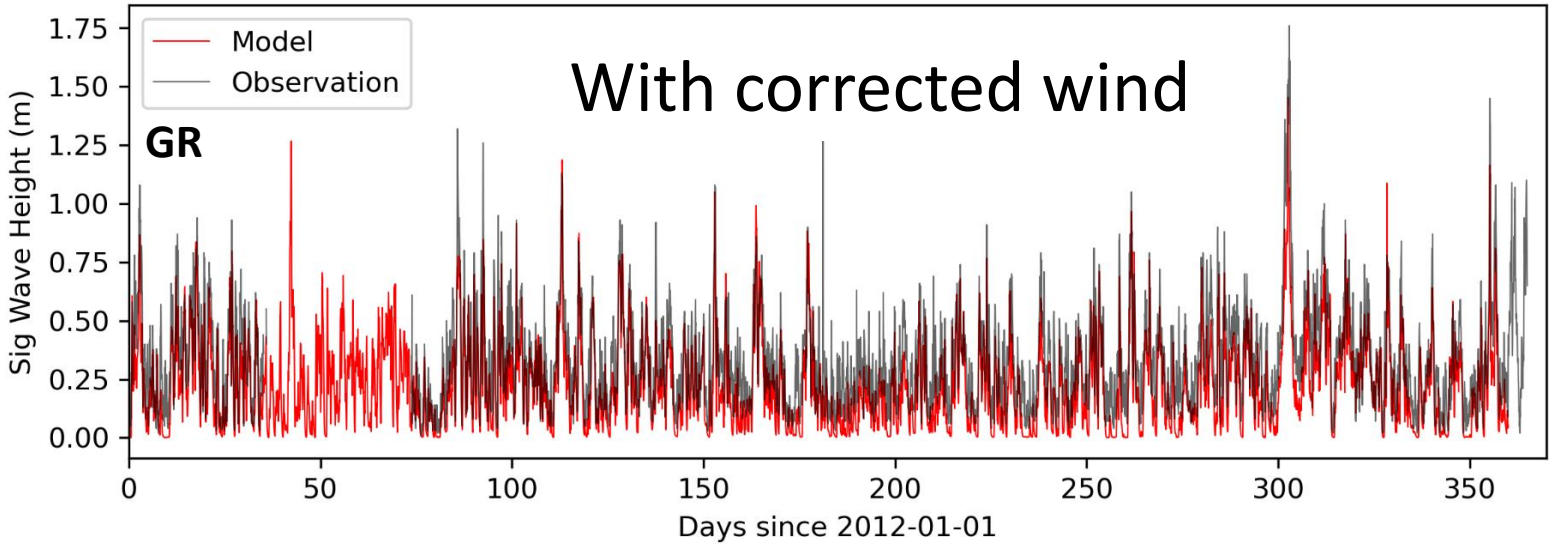
1) Interpolate 3-hourly NARR wind to 1-hourly wind
2) Local wind adjusted by observed wind from NOAA gauging stations for each hour.
3) Wind on NARR grids within 0.5 degree (50km) away from any NOAA station (with available data) will be corrected
4) Inverse distance method is used for interpolation

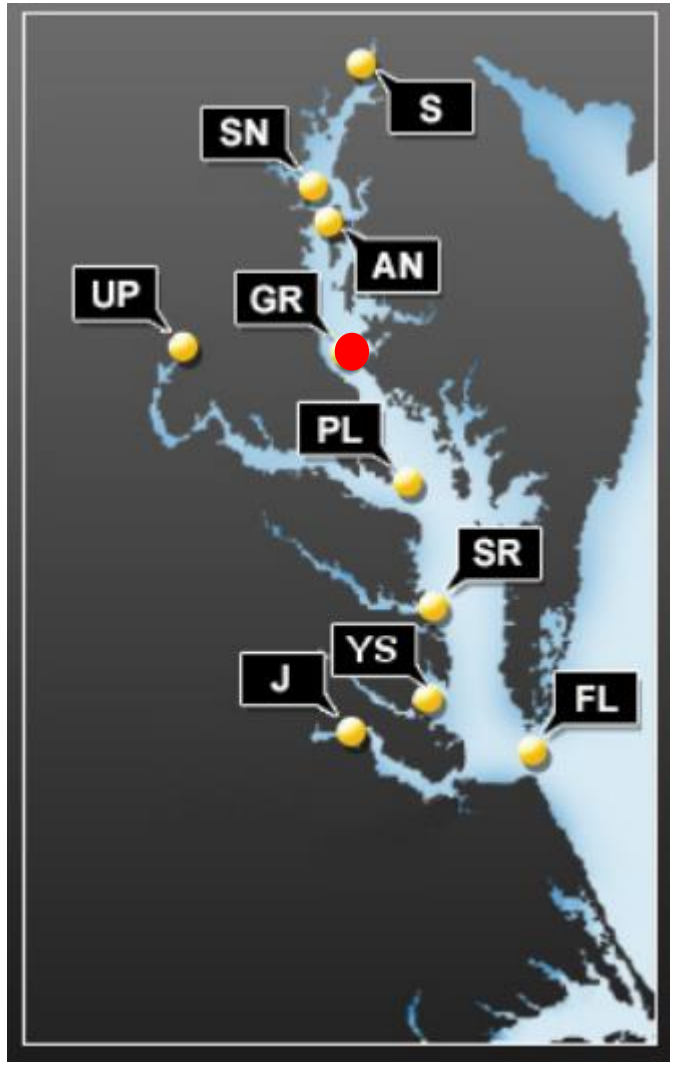
In the future, wind correction may be applied to other coastal regions



Much better performance with corrected wind





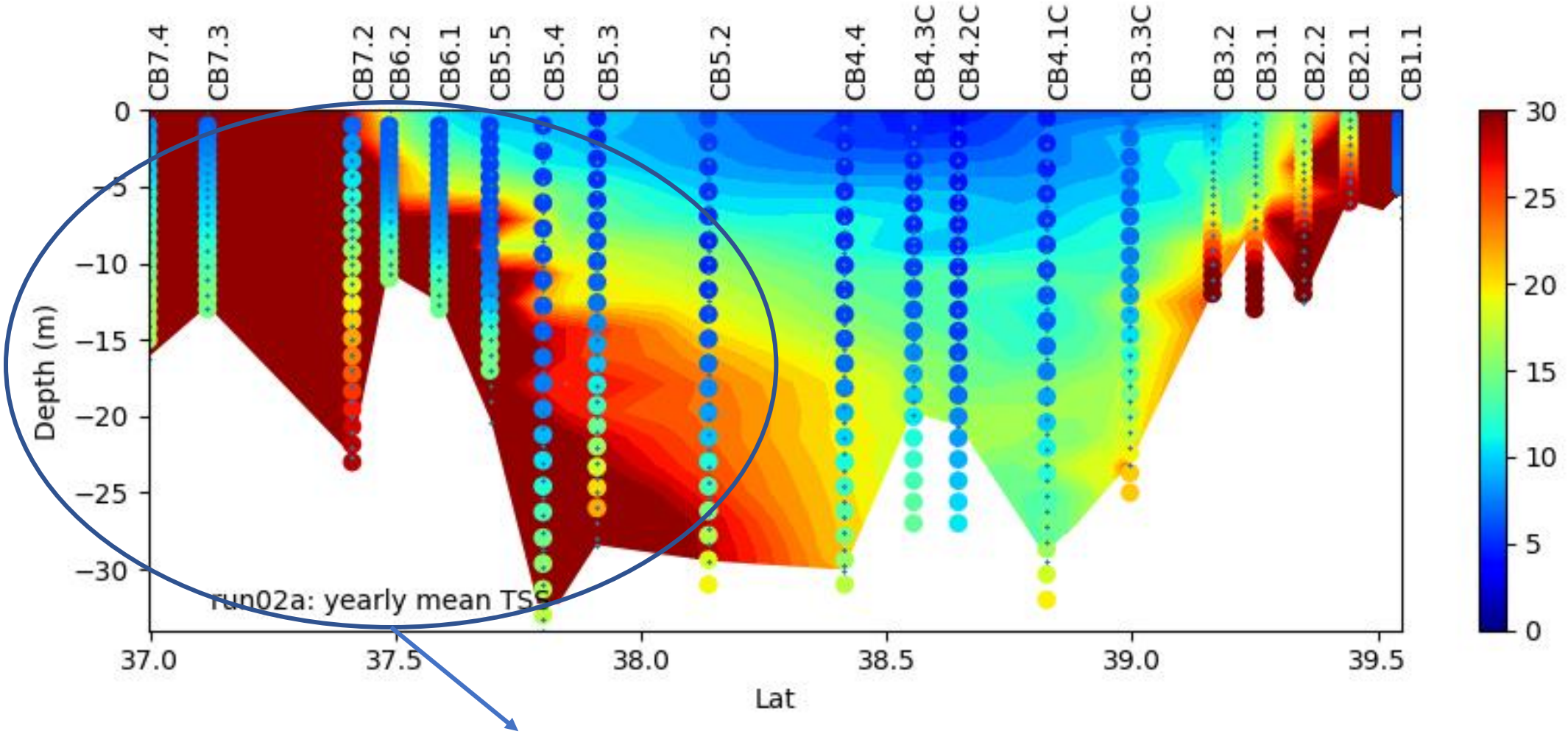


Sediment model set up

- Coupled with Hydro + Wave
- 4 sediment classes: settling velocity, critical shear stress, and sediment fractions following Moriarty et al. (2021)
- 1 bed layer
- Morphology turned off

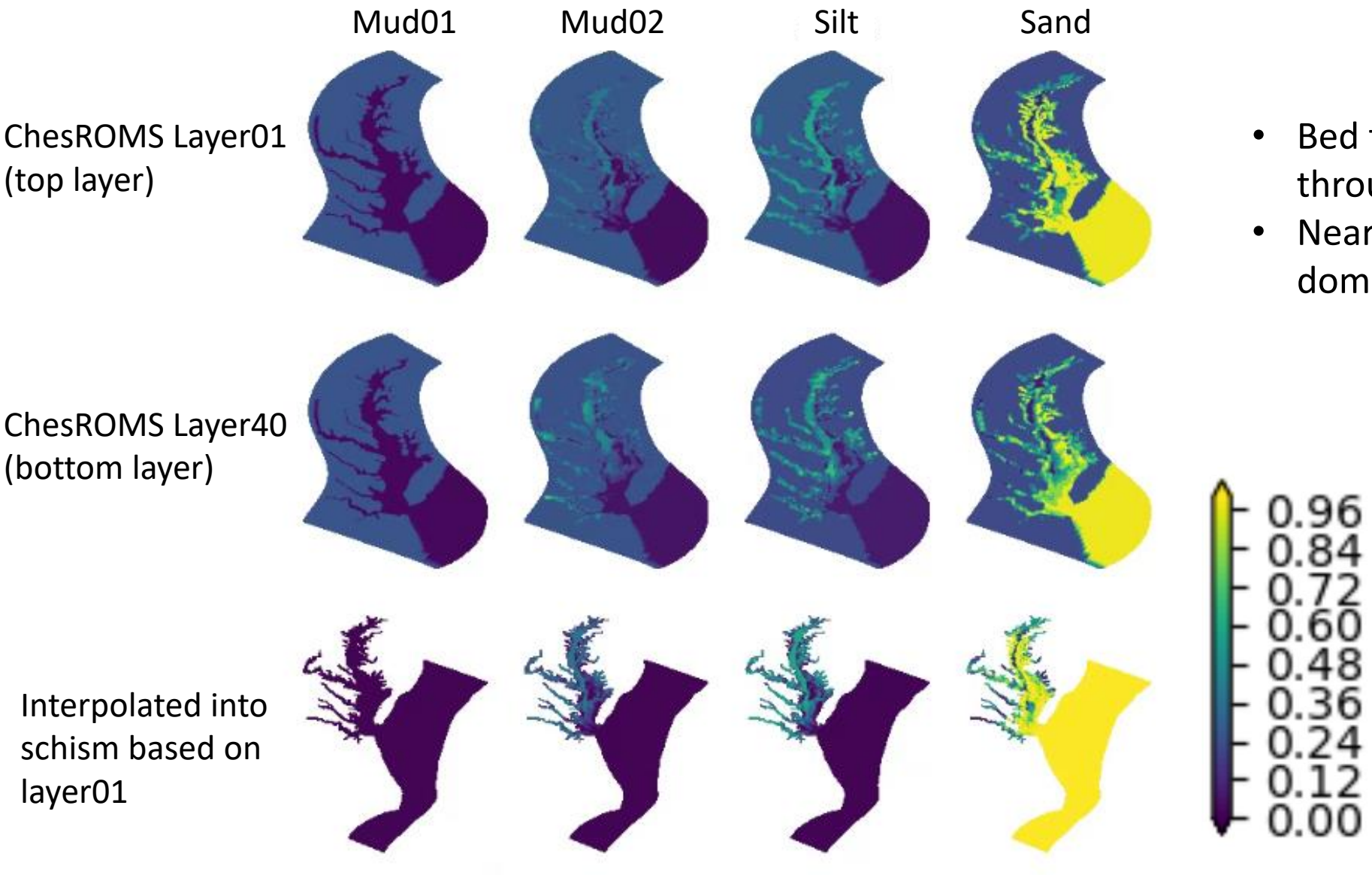
Accurate initial condition for sediment fractions is key!

With spatially uniform sediment fraction (25% for each class)



Issue: Too much suspended near the mouth where wave and bottom shear stress are large

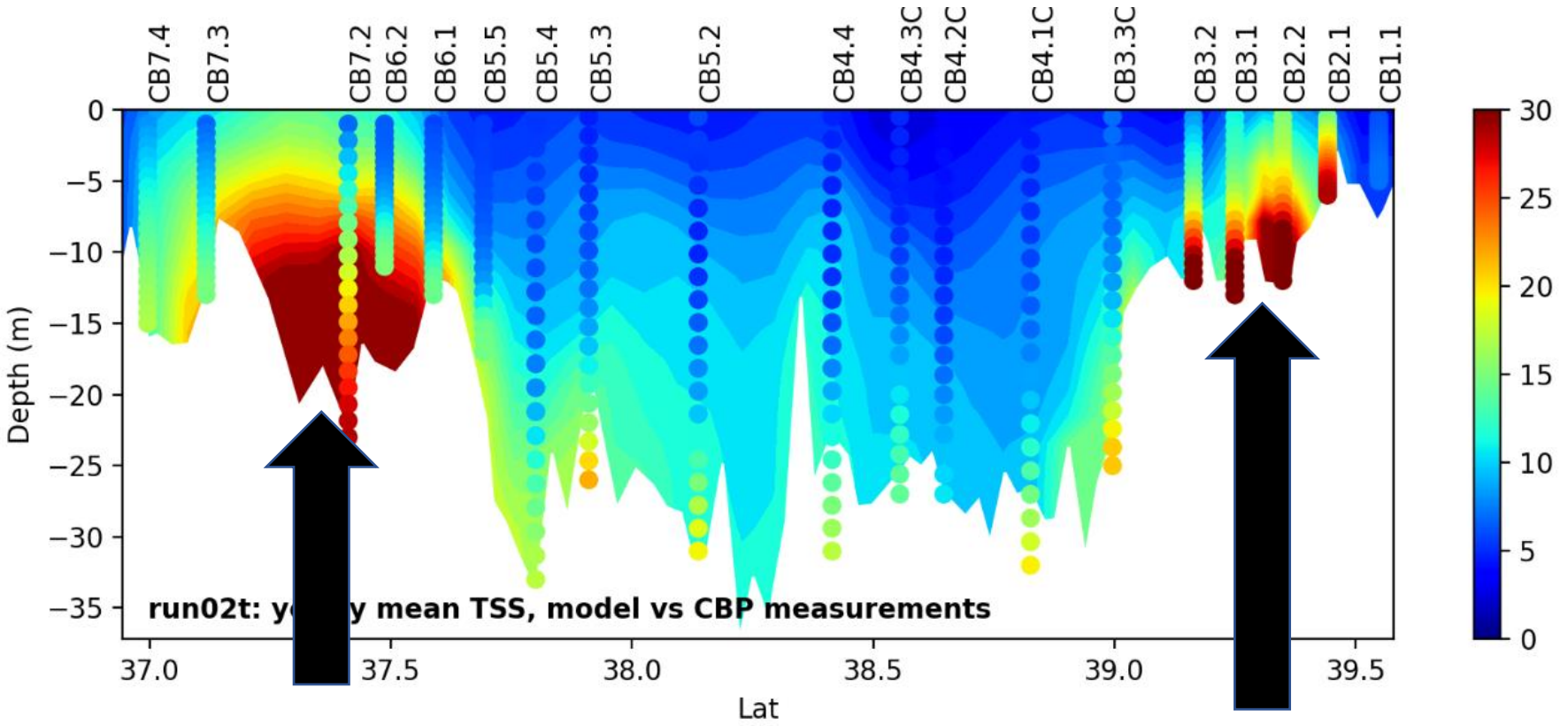
Initial bed fractions interpolated from Moriarty et al. (2021)



- Bed fraction varies greatly throughout the bay.
- Near the mouth, sand is dominant

Modeled vs measured yearly mean TSS in 2012

With spatially varying sediment fraction

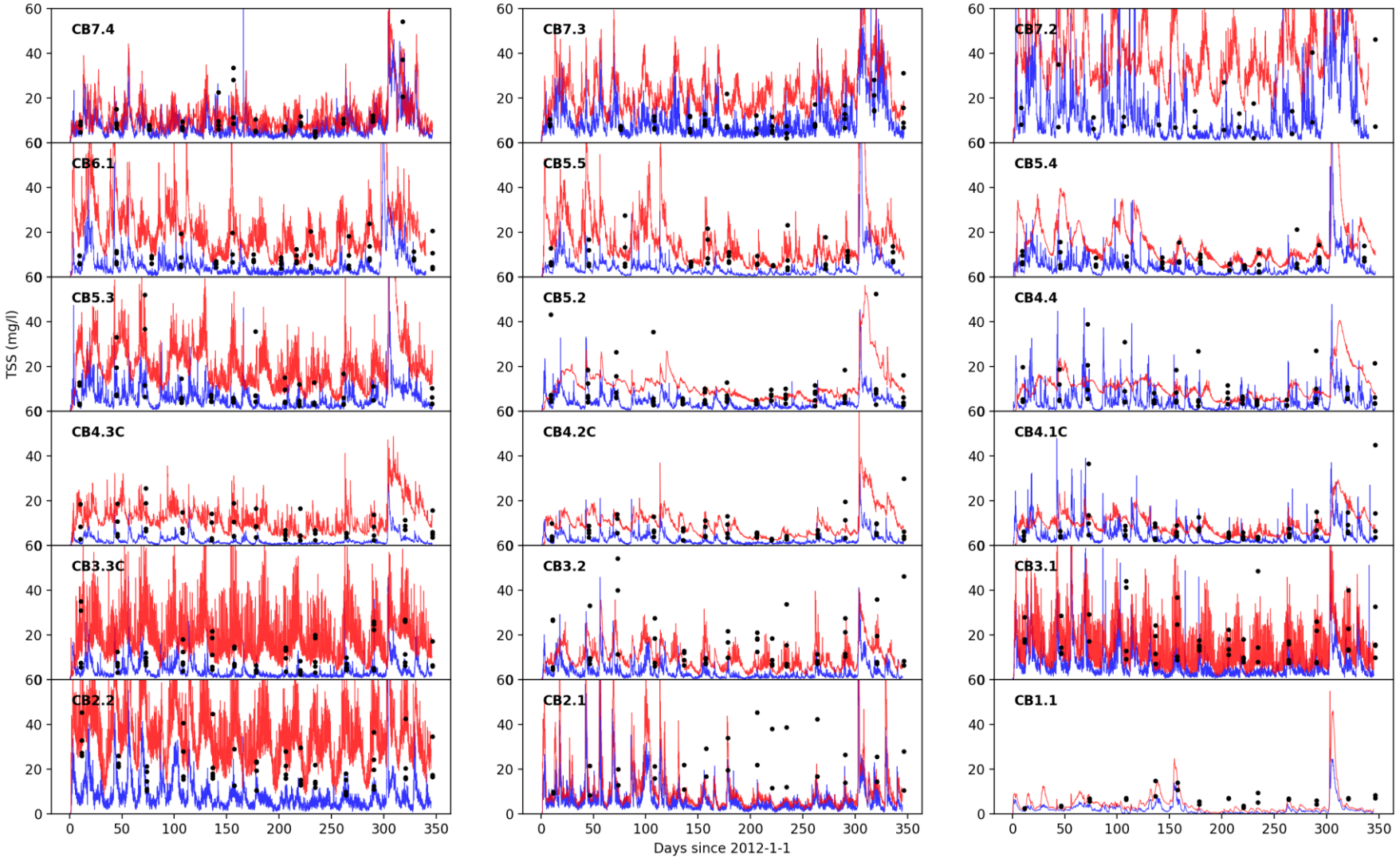


- Lower bay
- strong wave
- shallow bathymetry

Turbidity maximum zone
Bottom sediment trapped

- Overall, model results match observations.
- Well capture two high bottom TSS areas

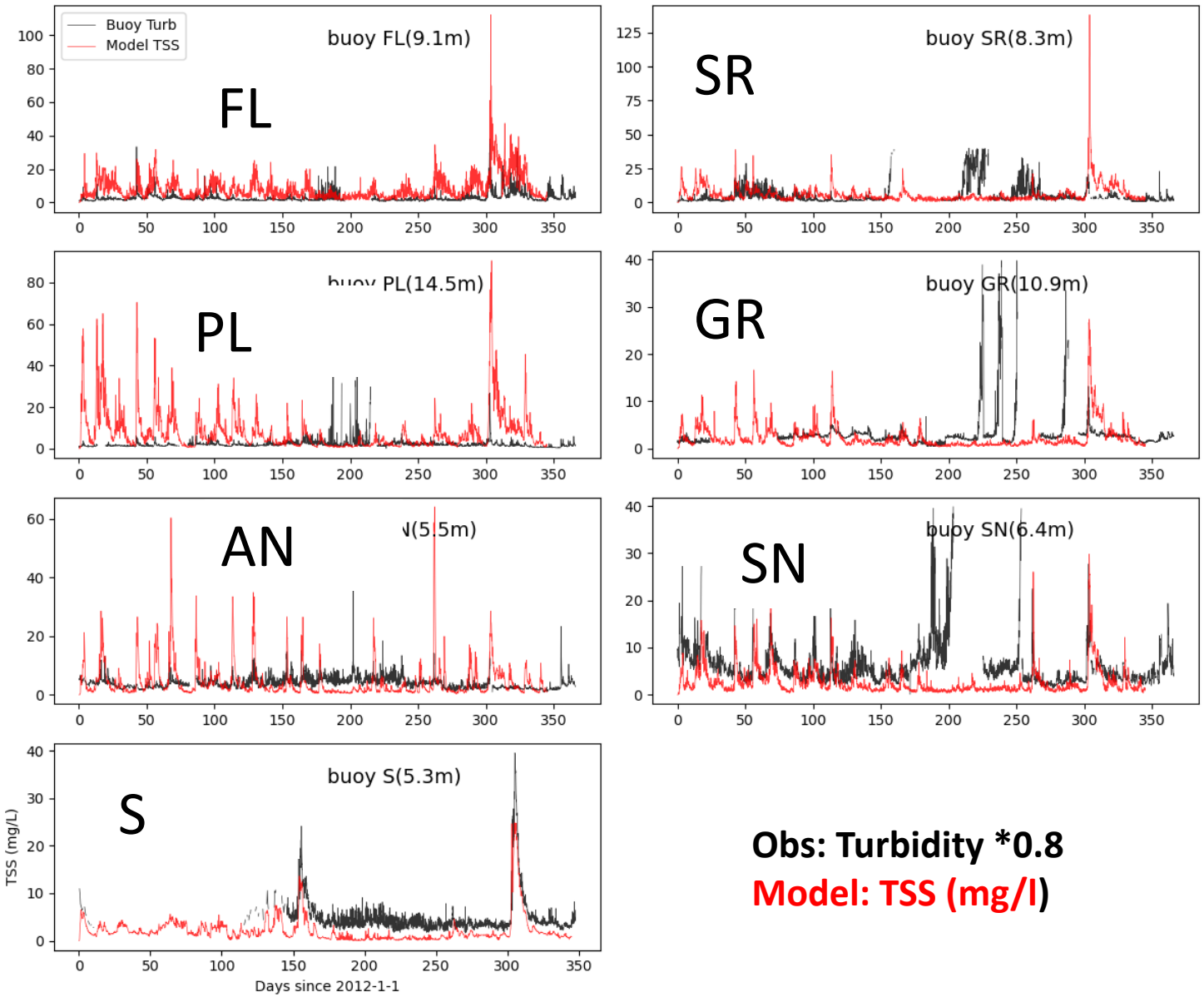
Time series of modeled and CBP measured TSS



bottom

surface

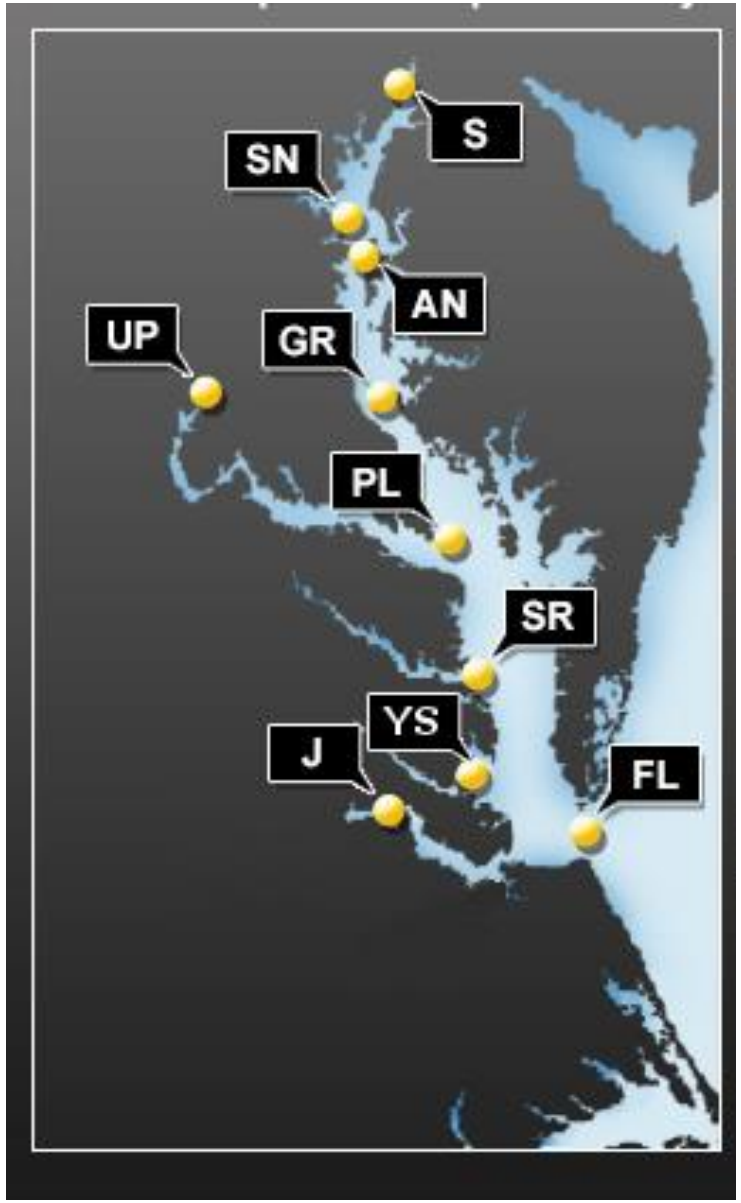
Compared with Turbidity measurement at buoys



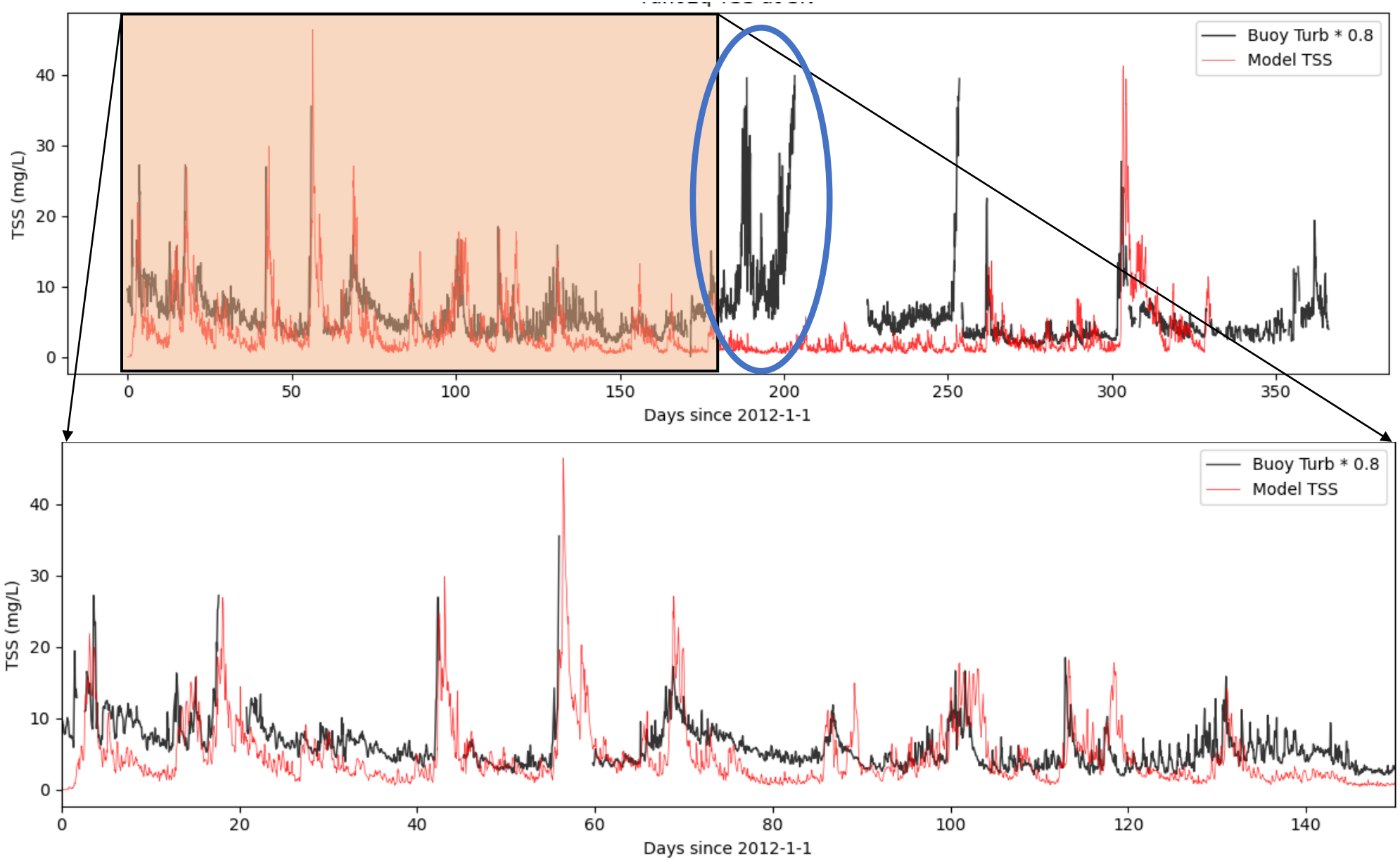
Obs: Turbidity *0.8

Model: TSS (mg/l)

[Chesapeake Bay Interpretive Buoy System]

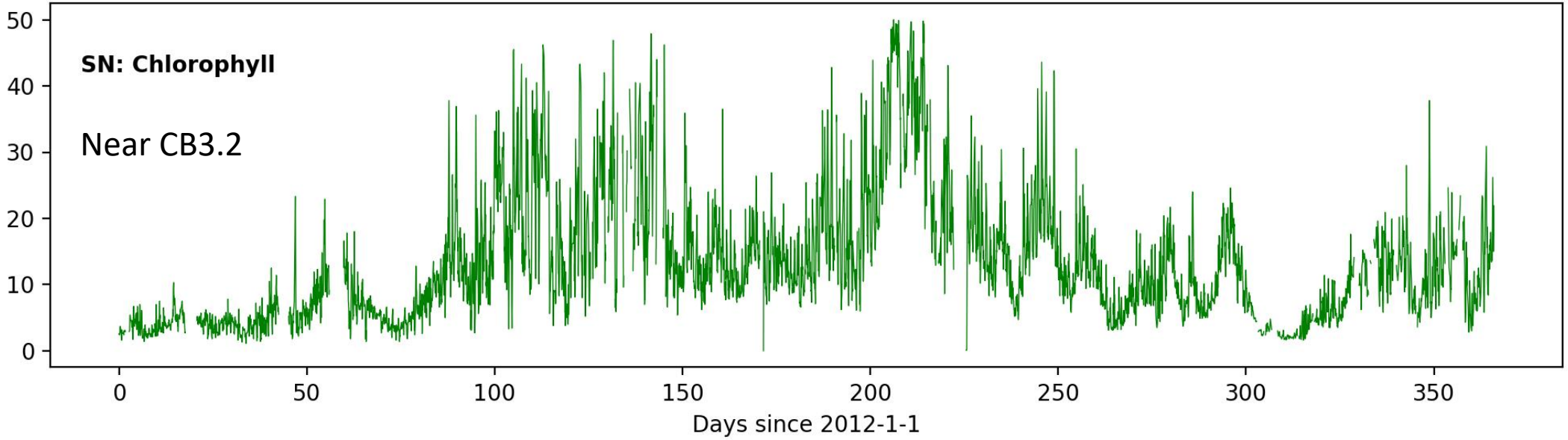


Compared with high frequency continuous buoy data



Buoy SN
Near CB3.2

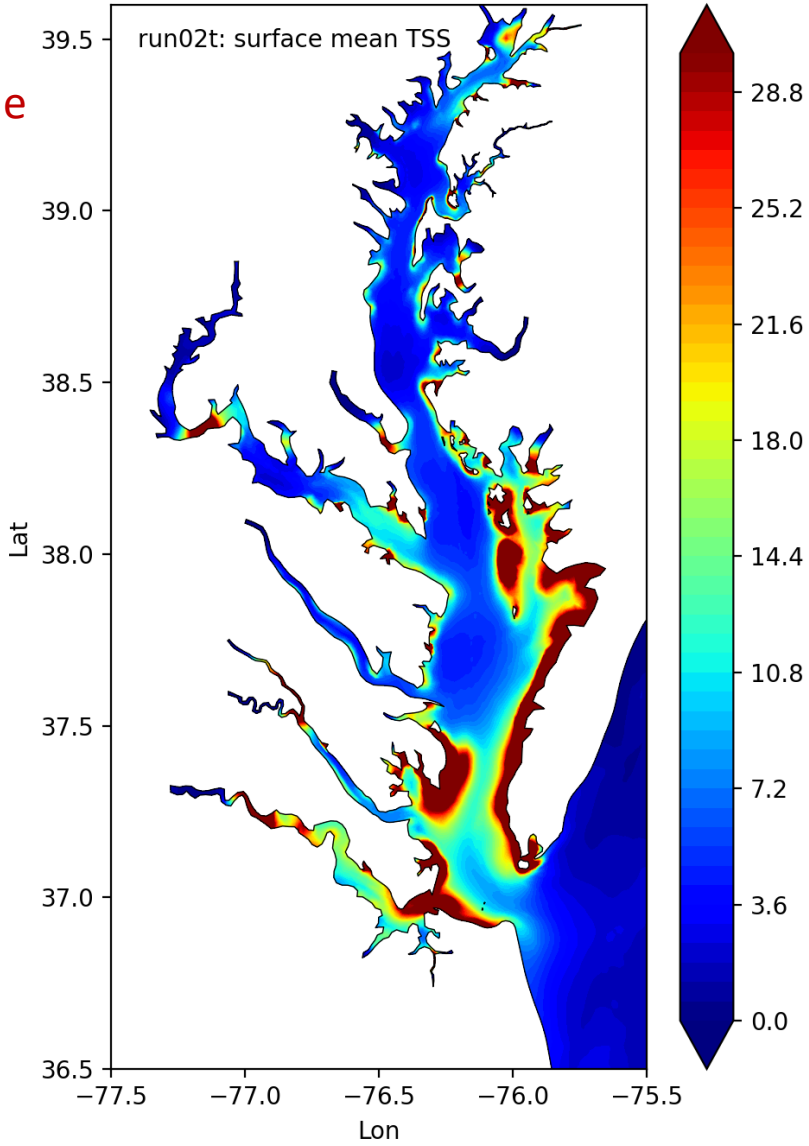
A summer algal bloom likely contributed to the high Turbidity around day 200



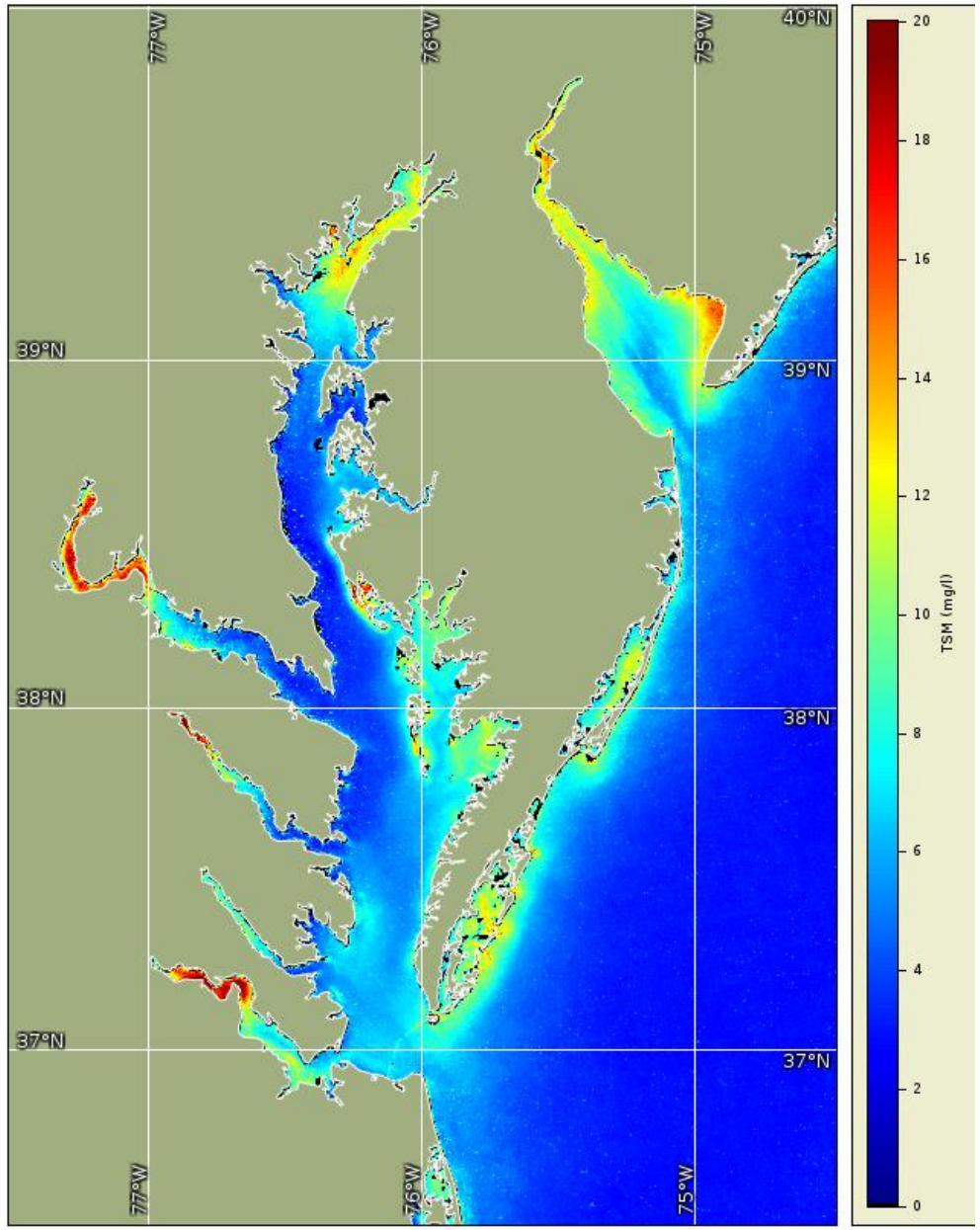
Potential issue:
Higher TSS along the coastline compared to satellite data

May be induced by in accurate bed fraction

Modeled yearly mean

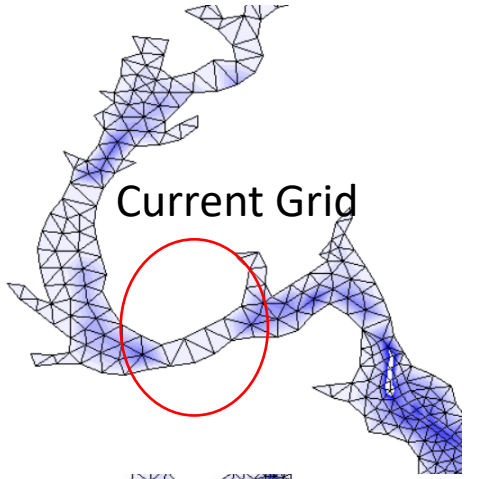


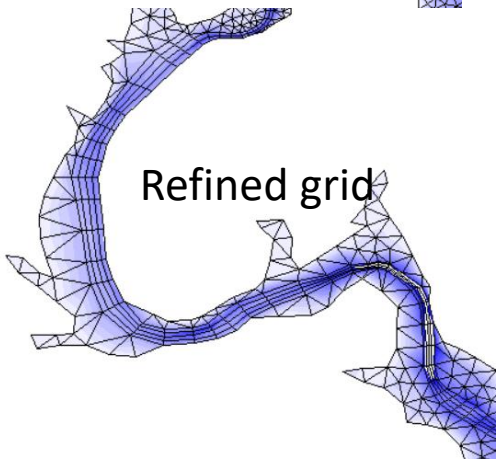
2012 Yearly mean surface TSS from NOAA CoastWatch



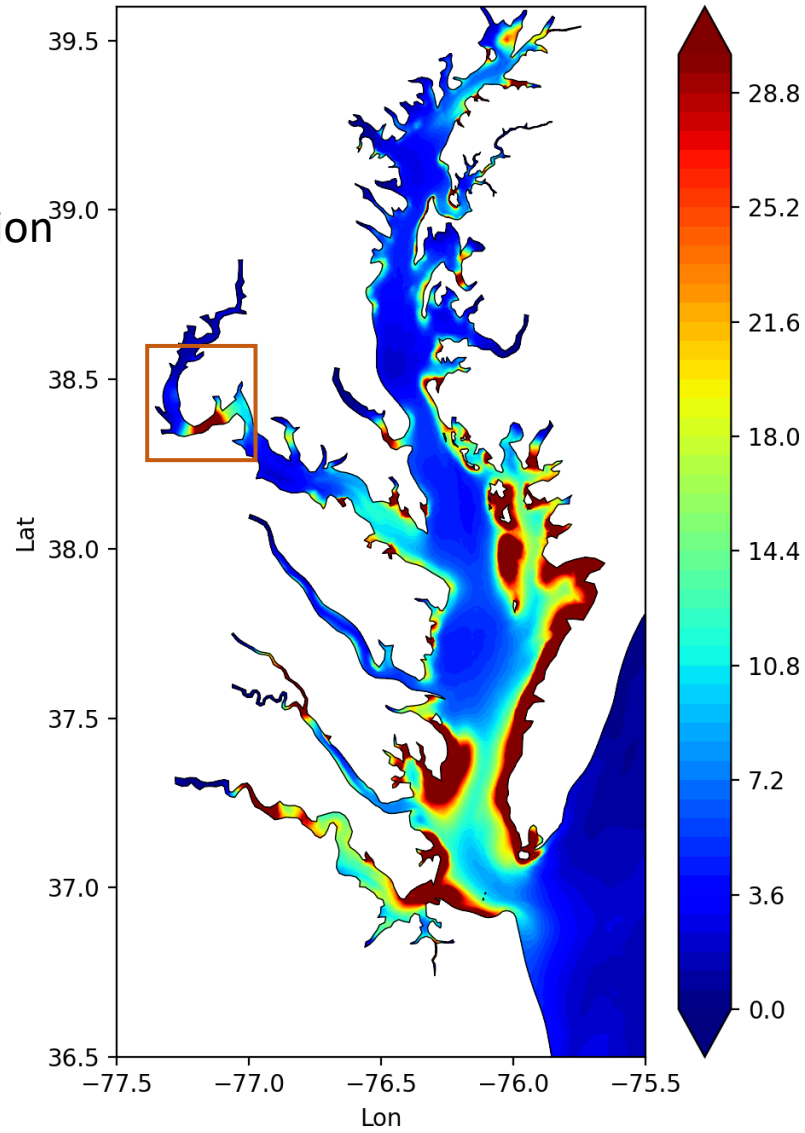
Potential issue:
Higher TSS in middle of major rivers

Likely induced under representation of local bathymetry

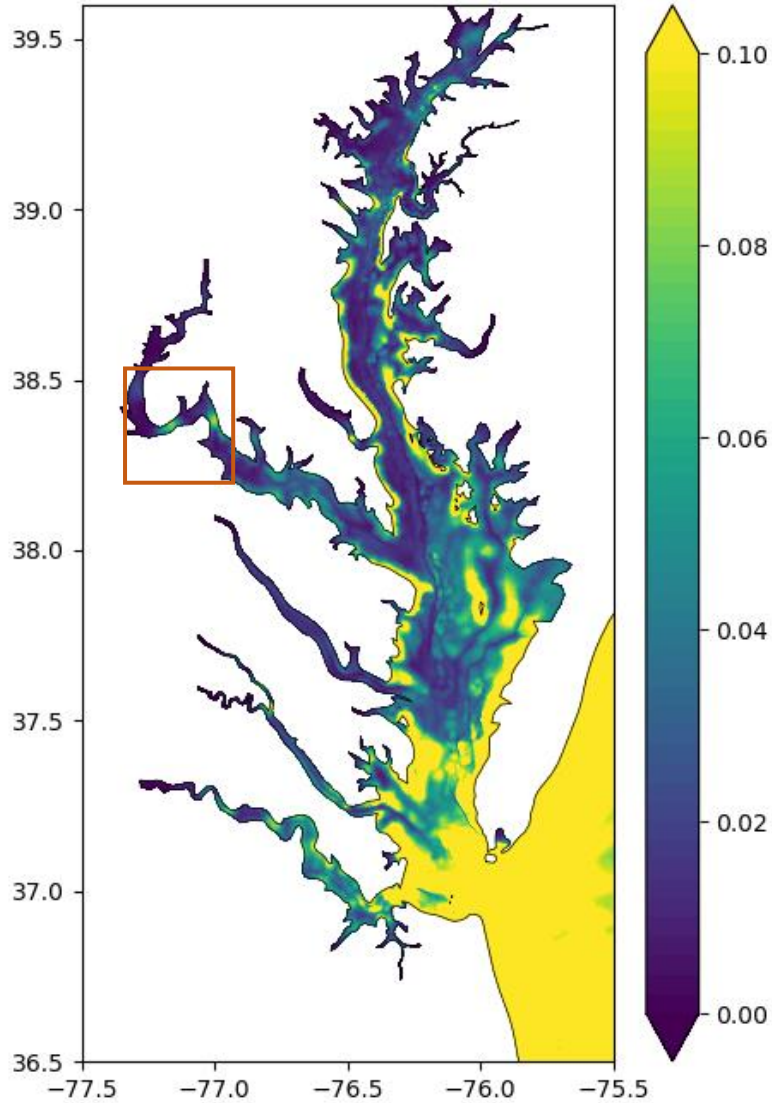




Mean surface TSS

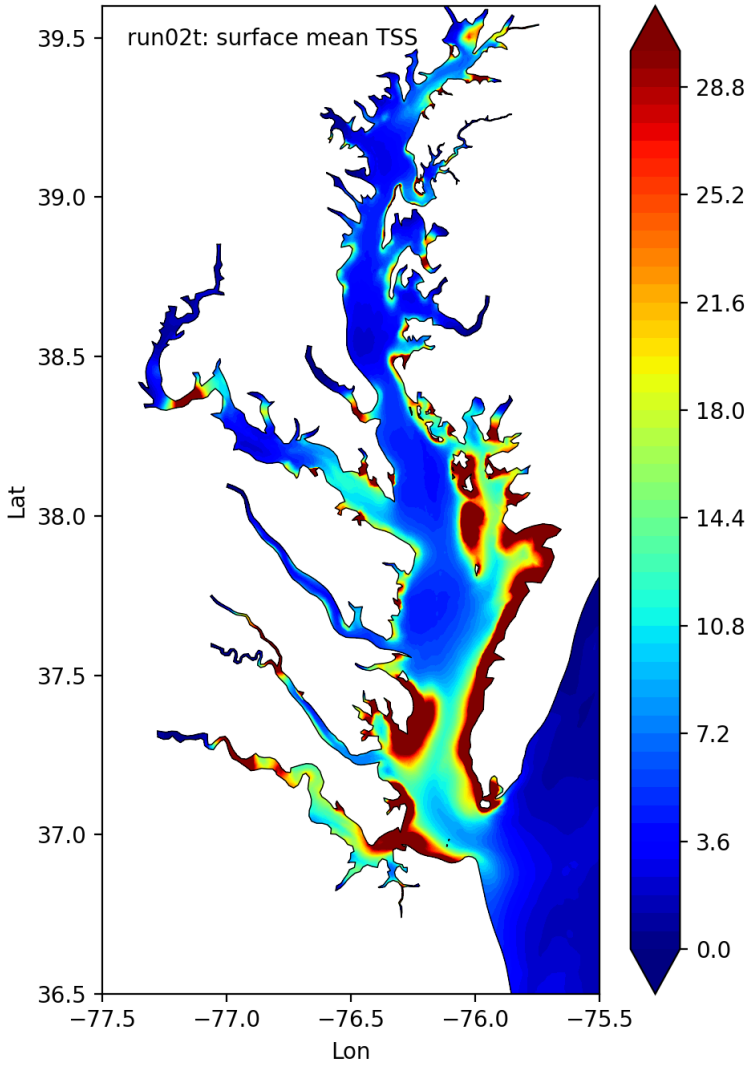


Mean bottom shear stress

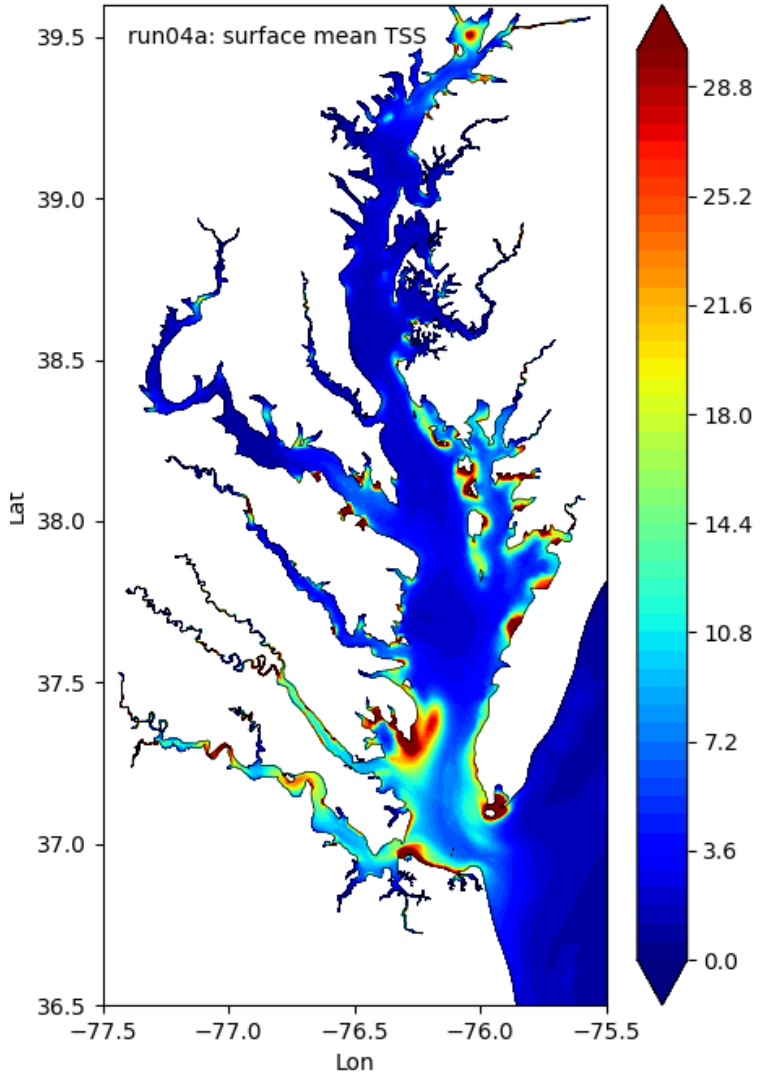


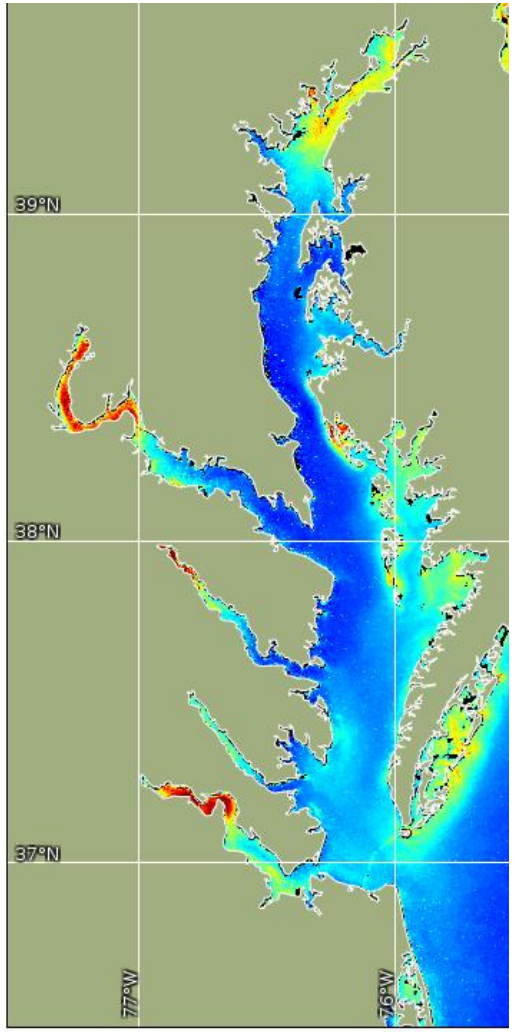
Yearly mean (2012) surface TSS

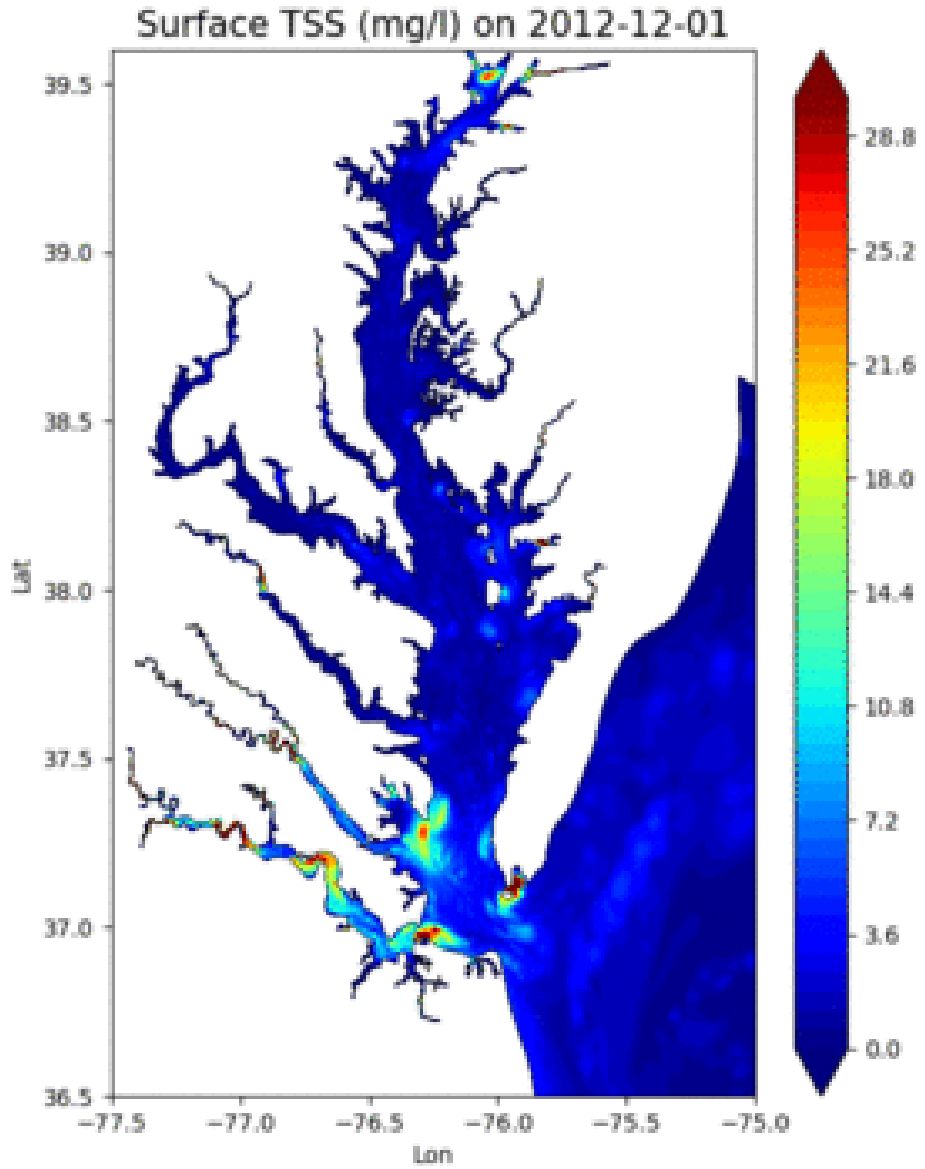
Grid V3



Grid V4

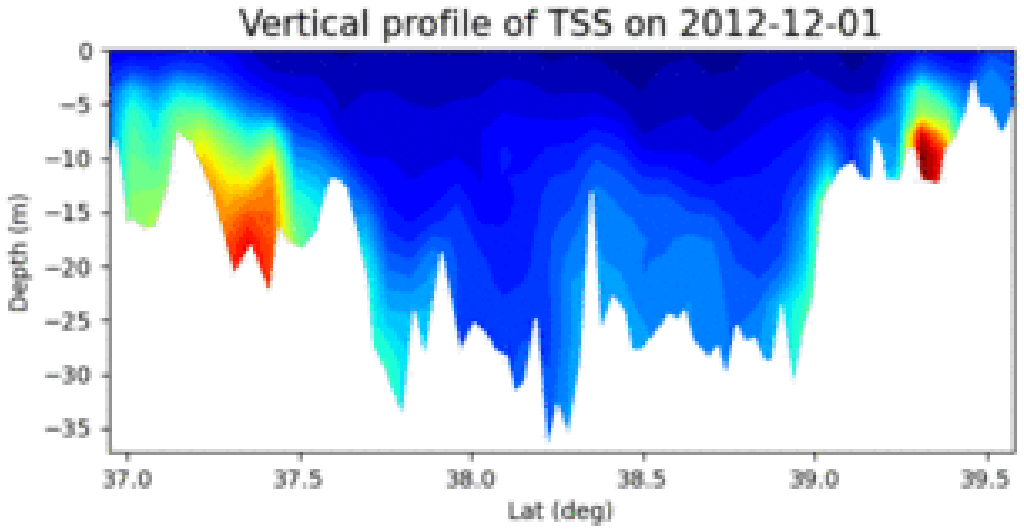






Grid V4

TSS in December of 2012



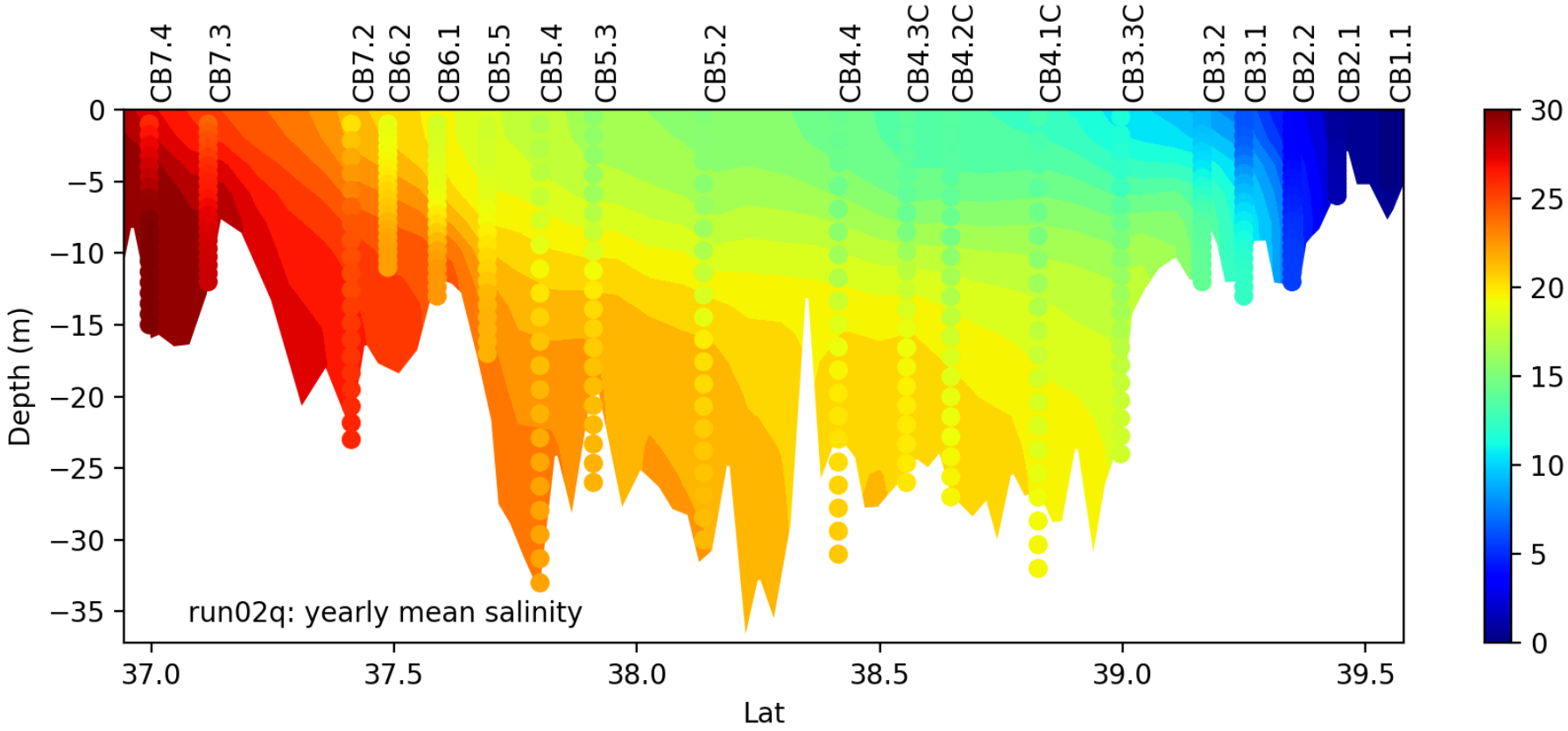
Summary

- The SCHISM model system is able to provide reasonably accurate TSS to feed water quality model.

- **Lesson learned**:
  1) Sediment bed fraction is critical, especially in the wave-strong lower bay
  2) Using observed wind leads to a better performance of wave model

- **Future works:**
  1) Further tuning wave and sediment model
  2) Refine near shore and tributary grids

Salinity along the bay's mainstem



Salinity comparison