Estimated Nutrient Exchanges Among Coastal Estuaries in Restoration

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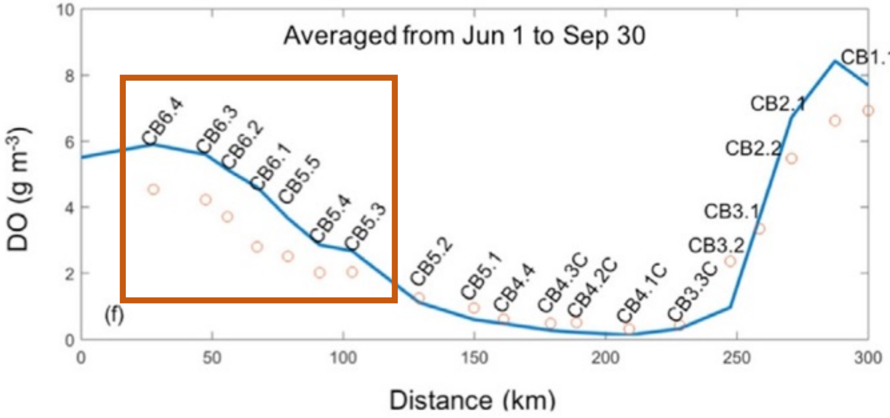
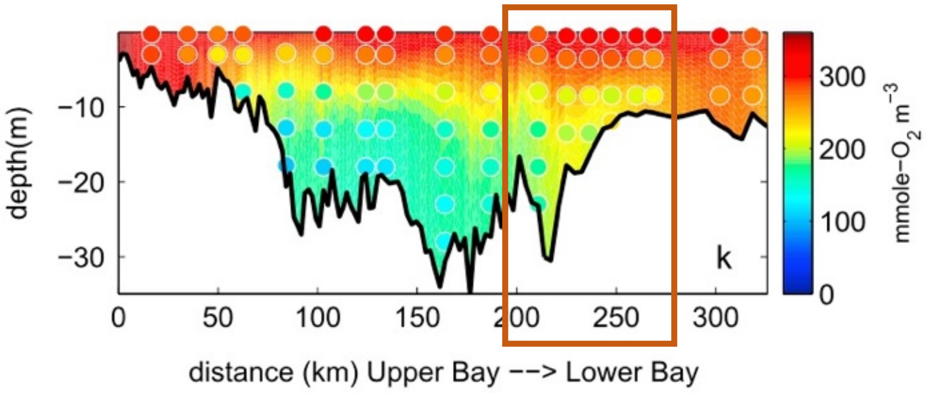
Modeling Quarterly Review, Oct 4, 2023

- Revisit the over-estimation of lower Bay DO
- Testing the remote influence and nutrient exchange from the other coastal water bodies along the US East Coast

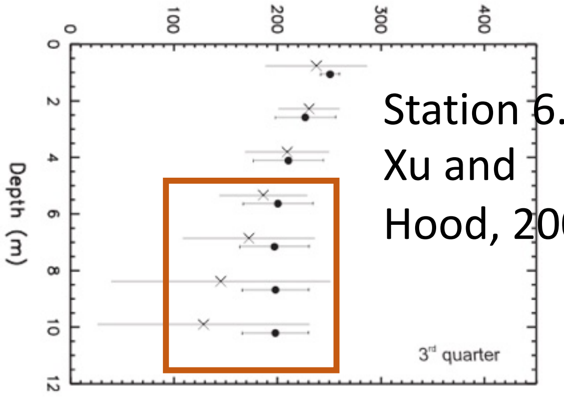
Overestimation of lower Bay DO in multiple models



SCHISM-ICM (Cai et al., 2020)

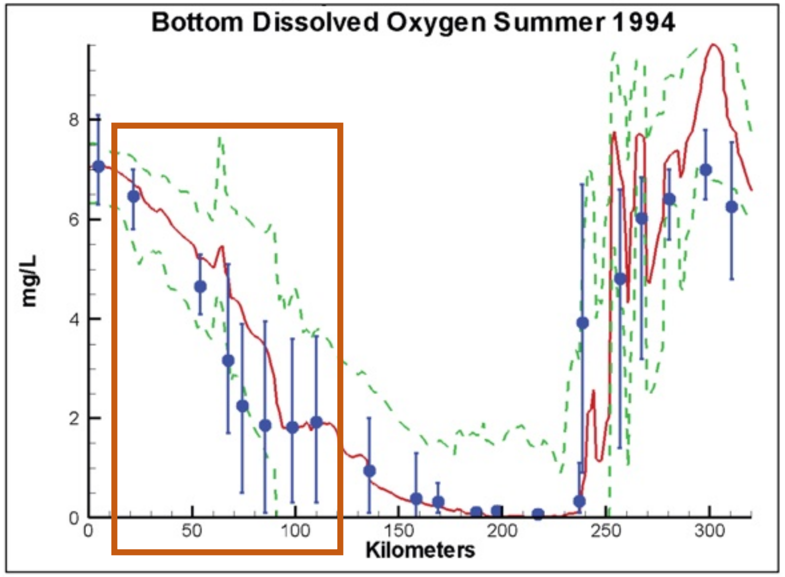


ROMS-ECB (Feng et al., 2015)

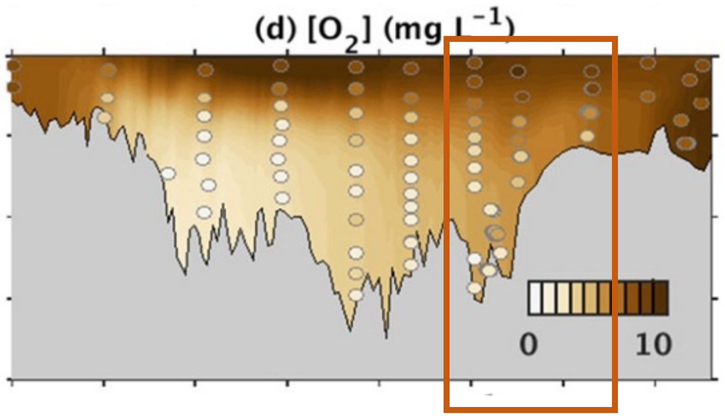


Station 6.3; Xu and Hood, 2006

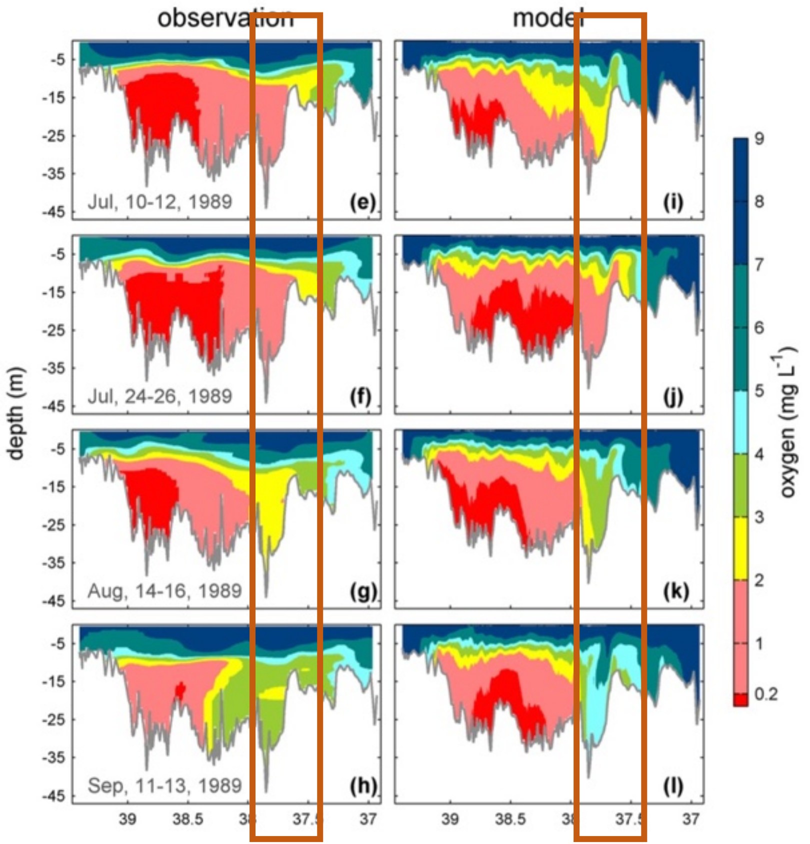
Figure 9-1. Computed (*red*) and observed (*blue*) bottom DO along Bay axis, summer 1994. Mar–Aug flow in Susquehanna River = 2,034 m³ s-1.



CH3D-ICM (Cerco and Noel, 2017)

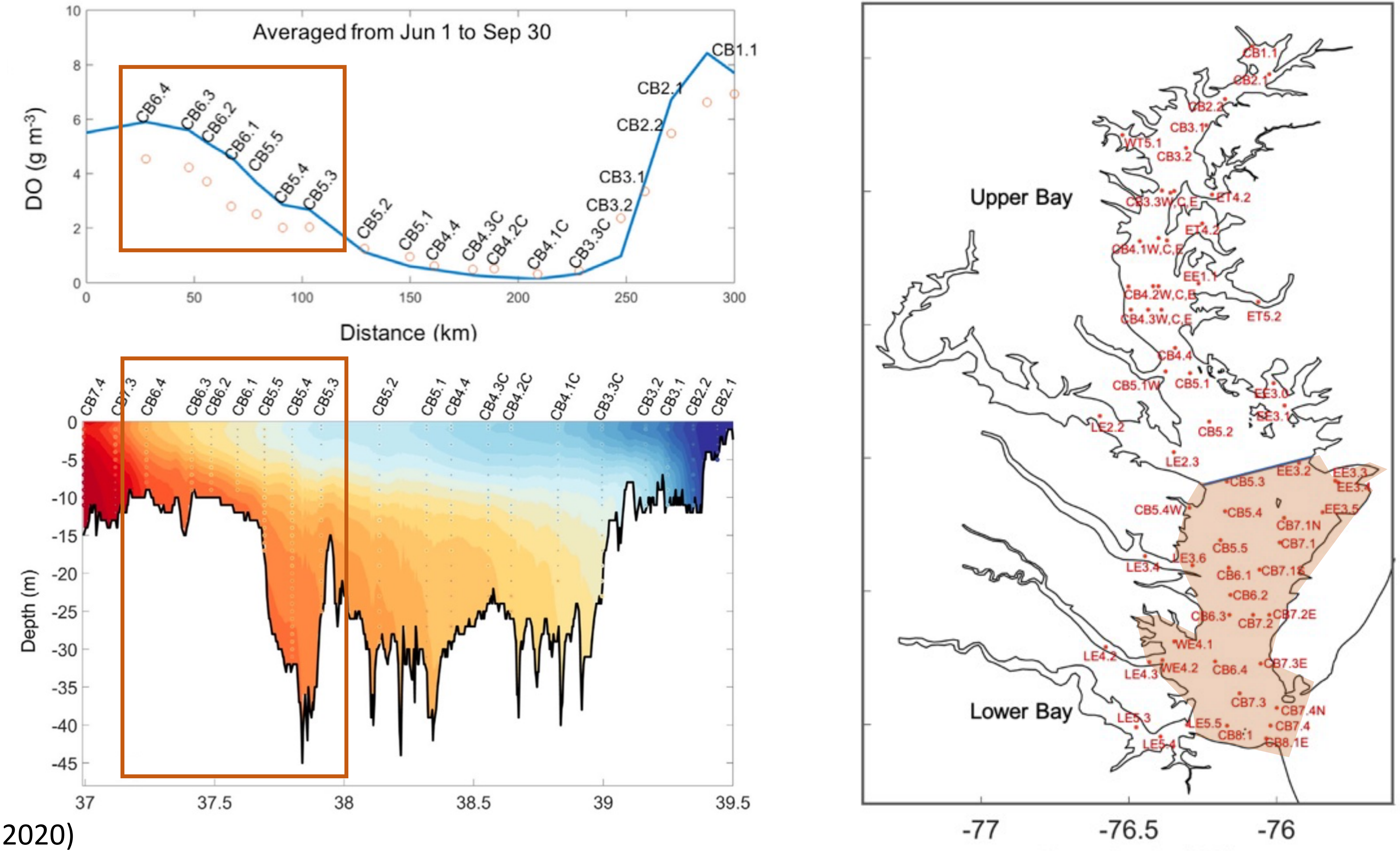


ROMS-ECB + POC resuspension (Moriarty et al., 2021)

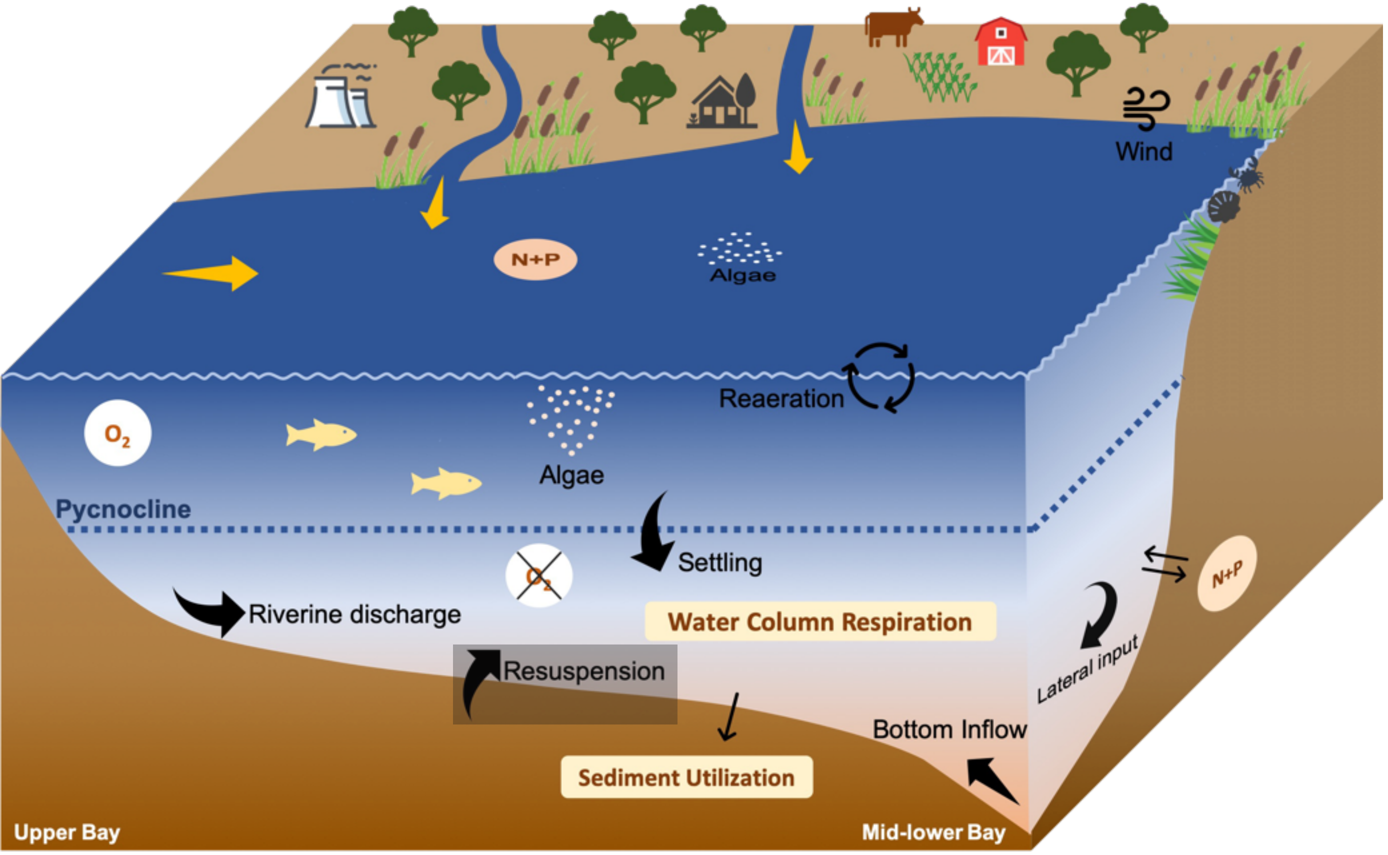


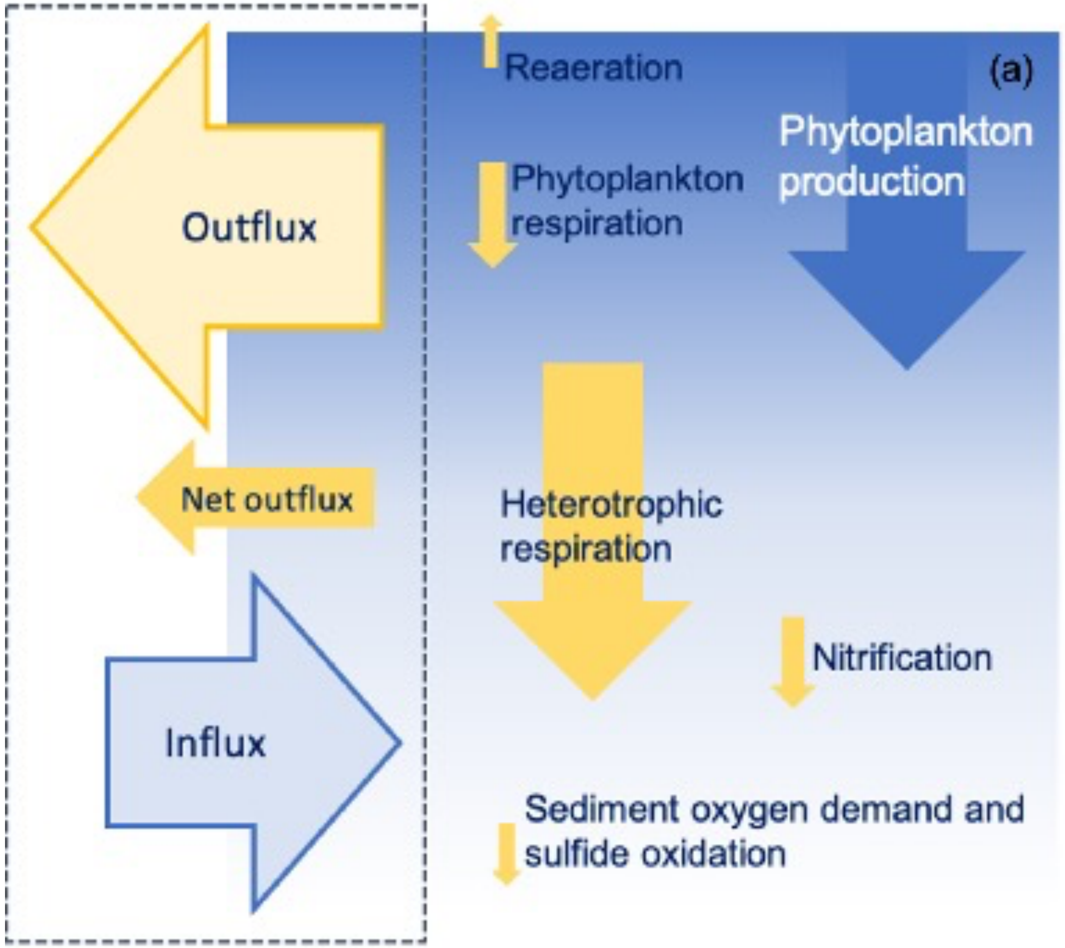
ROMS-RCA (Li et al., 2015)

Overestimation of lower Bay DO in multiple models



(Cai et al., 2020)


Wind
N+P
Algae
Reaeration
O2
Algae
Pycnocline
Settling
Riverine discharge
Water Column Respiration
Resuspension
Lateral input
N+P
Bottom Inflow
Sediment Utilization
Upper Bay
Mid-lower Bay


Reaeration
(a)
Phytoplankton production
Phytoplankton respiration
Outflux
Net outflux
Heterotrophic respiration
Nitrification
Influx
Sediment oxygen demand and sulfide oxidation

Initial calls for this

Lab work on samples from the Ariake Bay

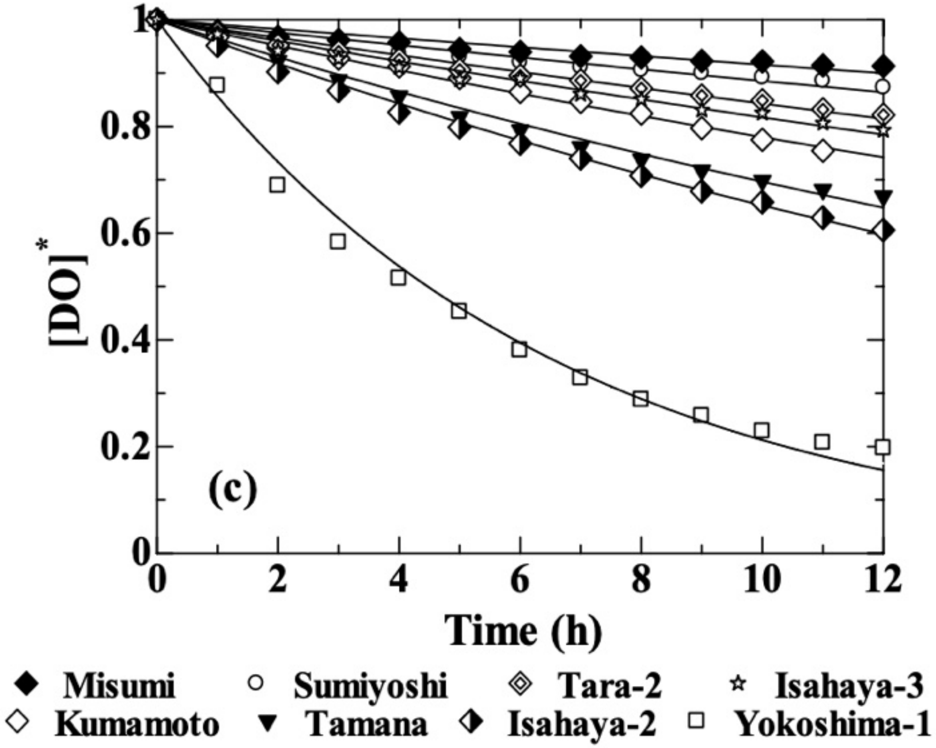


Fig.5 DO-depletion profiles.

(Li et al., 2009)

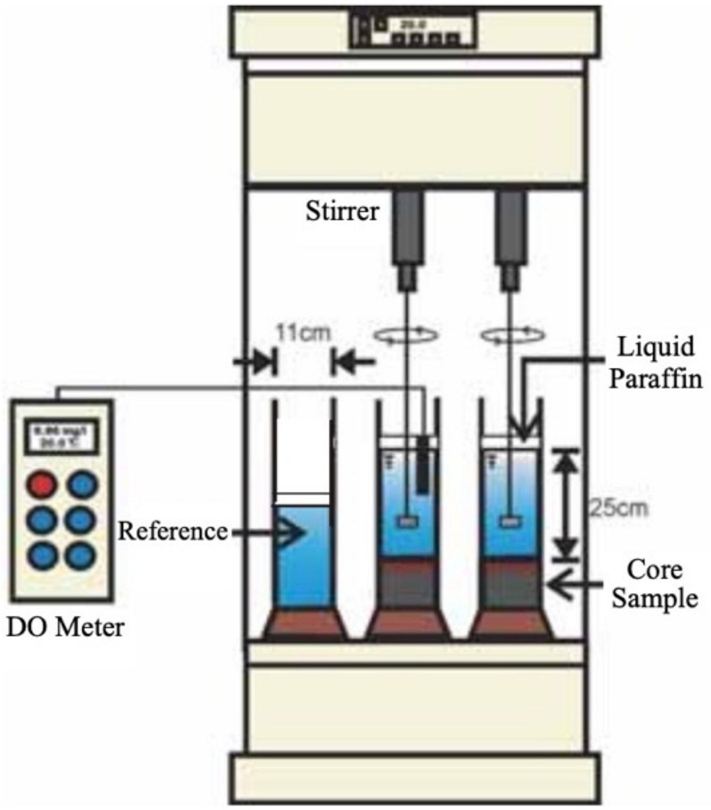
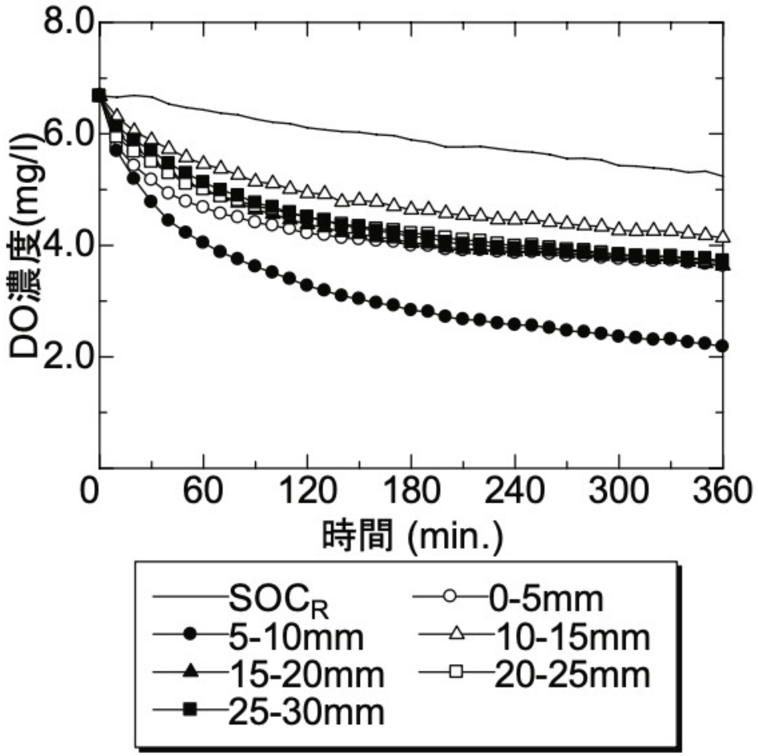


Fig.3 Experimental set-up for SOC measurements.



図–4 TOC_R計測実験の DO 濃度時系列

(Takashisa et al., 2009)

DO consumption is about **0.45 ~ 1.8 day^{-1}**

While the decay rate of DOC is smaller than 0.1 day^{-1} in the current models (e.g., 0.025 ~0.05 day^{-1} in CH3D-ICM, 0.05 day^{-1} in SCHISM-ICM)

Where does oxygen consumption come from?

15–25% of the increase in SOD between successively increasing experimental velocities is attributable to additional COD. However, for the sandy-mud experiment where velocities presumably exceeded the critical erosion threshold and resuspension was initiated, COD accounted for some 55% of the increment in total oxygen demand. Thus, when resuspension occurred in these sediments more than half of the resulting increased sediment oxygen demand was attributable to chemical oxidation of reduced substances diffusing from these sediments.

The mechanism, by which COD is enhanced with increasing water circulation, can be explained in direct, physical terms as the results of augmented diffusion of dissolved substances between sediment interstices and open water. This process has been clearly demonstrated, particularly under conditions of sediment resuspension (e.g. Revsbech *et al.*, 1980 a, b). Similarly, the enhanced biological respiration associated with increased circulation of overlying waters can be explained by increased diffusion of substrates to and end-products from the sites of biological activity. For example, at low oxygen tension (pO_2)

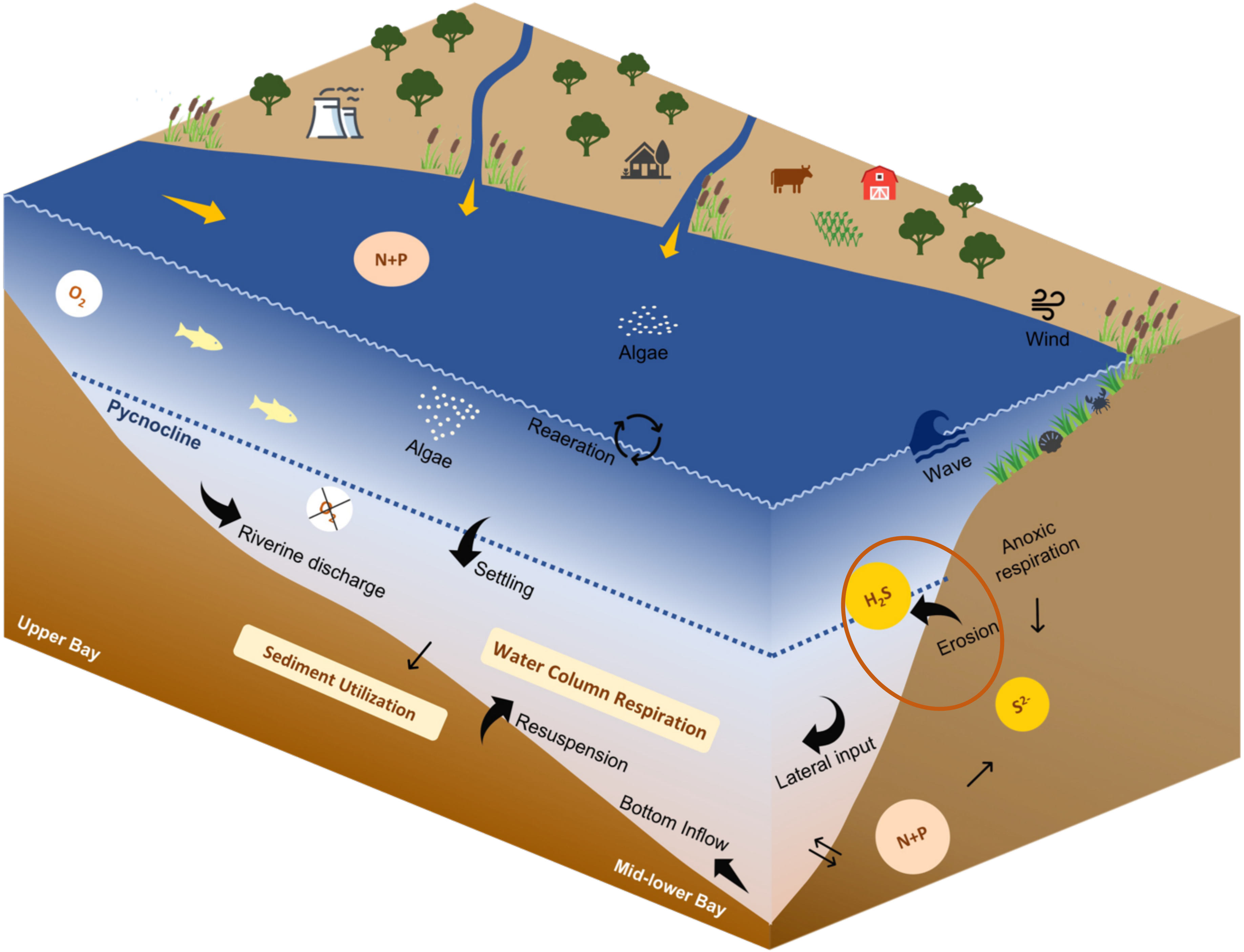
Boynton et al. (1981)

Original simulation of H_2S (COD) in ICM

- Reduced matter from sediment anaerobic respiration released through **steady diffusion**
- Primarily a supplement of the SOD when DO is not sufficient in the bottom water (SOD is minor under hypoxia)

> Chemical oxygen demand is the concentration of reduced substances that are produced by reactions in anoxic bottom sediments. The primary component of chemical oxygen demand in saline water is sulfide. A cycle occurs in which sulfate is reduced to sulfide in the sediments and reoxidized to sulfate in the water column. In fresh water, methane might be released to the water column by bottom sediments. Both sulfide and methane are quantified in units of oxygen demand and are treated with the same kinetics formulation (equation 37):

CH3D-ICM (Cerco and Noel, 2017)



N+P
O_2
Algae
Wind
Pycnocline
Algae
Reaeration
Wave
O_2
Riverine discharge
Settling
H_2S
Anoxic respiration
Erosion
Upper Bay
Sediment Utilization
Water Column Respiration
S^{2-}
Resuspension
Lateral input
Bottom Inflow
N+P
Mid-lower Bay

First hypothesis:
Resuspension-driven convection

A simplified method to simulate the enhanced H_2S fluxes

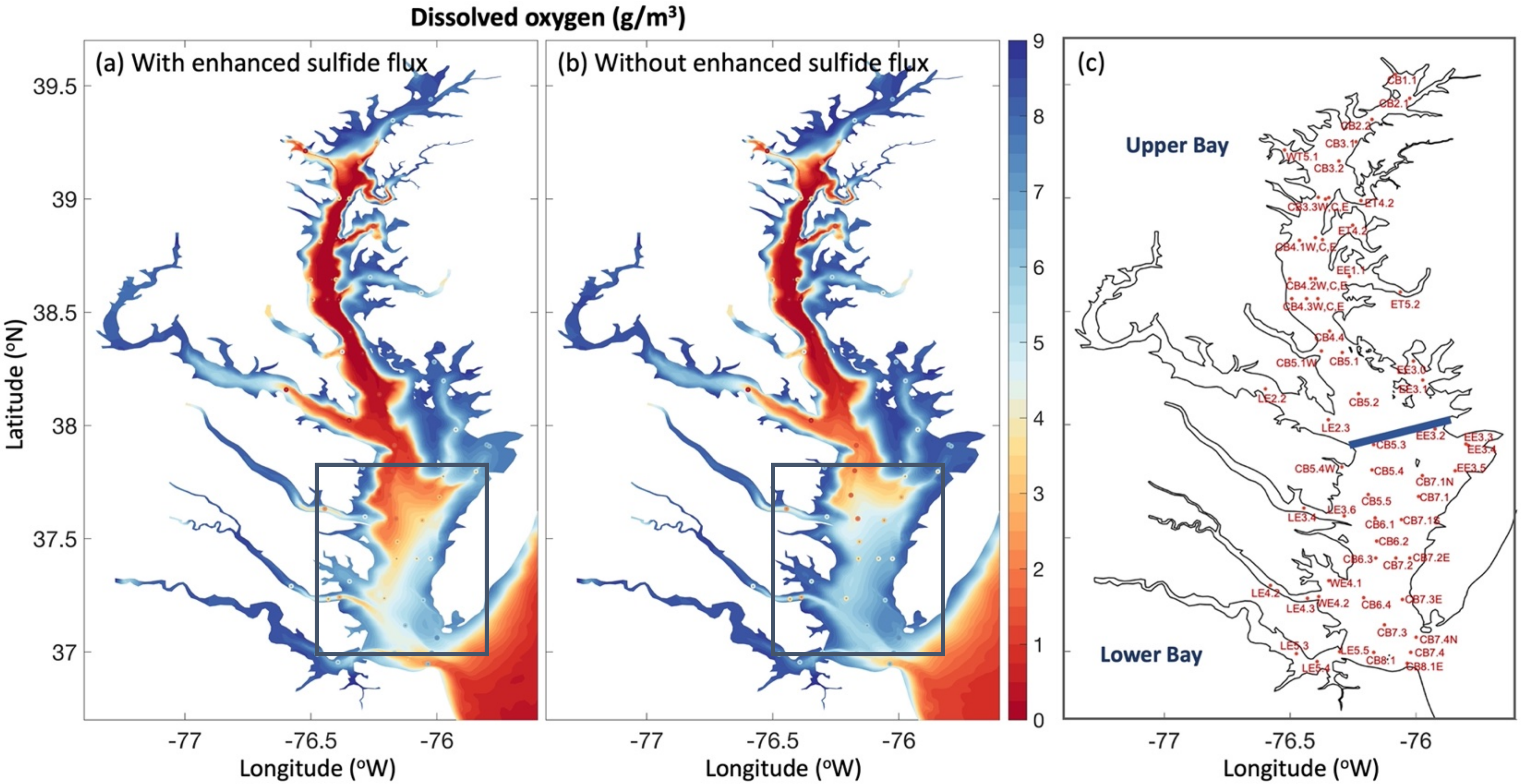
$$FluxS = \begin{cases} M \cdot (1-\phi) \cdot f \cdot \frac{\tau-\tau_c}{\tau_c} \cdot \frac{c_S}{\rho_{sed}} \cdot 86400, & when\ \tau \geq \tau_c \\ 0, & when\ \tau < \tau_c \end{cases}$$

- $FluxS$ is sulfide from the bottom when the sediment is eroded (g m^{-2} day^{-1})
- M is the erosion rate parameter representing seabed erodibility (kg m^{-2} s^{-1})
- ϕ is seabed porosity
- f is the fraction of the seabed layer with the sulfur component
- τ is bed shear stress from waves and currents
- τ_c is critical shear stress (Pa)
- c_s is the concentration of sulfide in the sediment (g m^{-3})
- ρ_{sed} is sediment density (kg m^{-3})

Similar format for the erosion formula as in Moriarty et al. (2017)

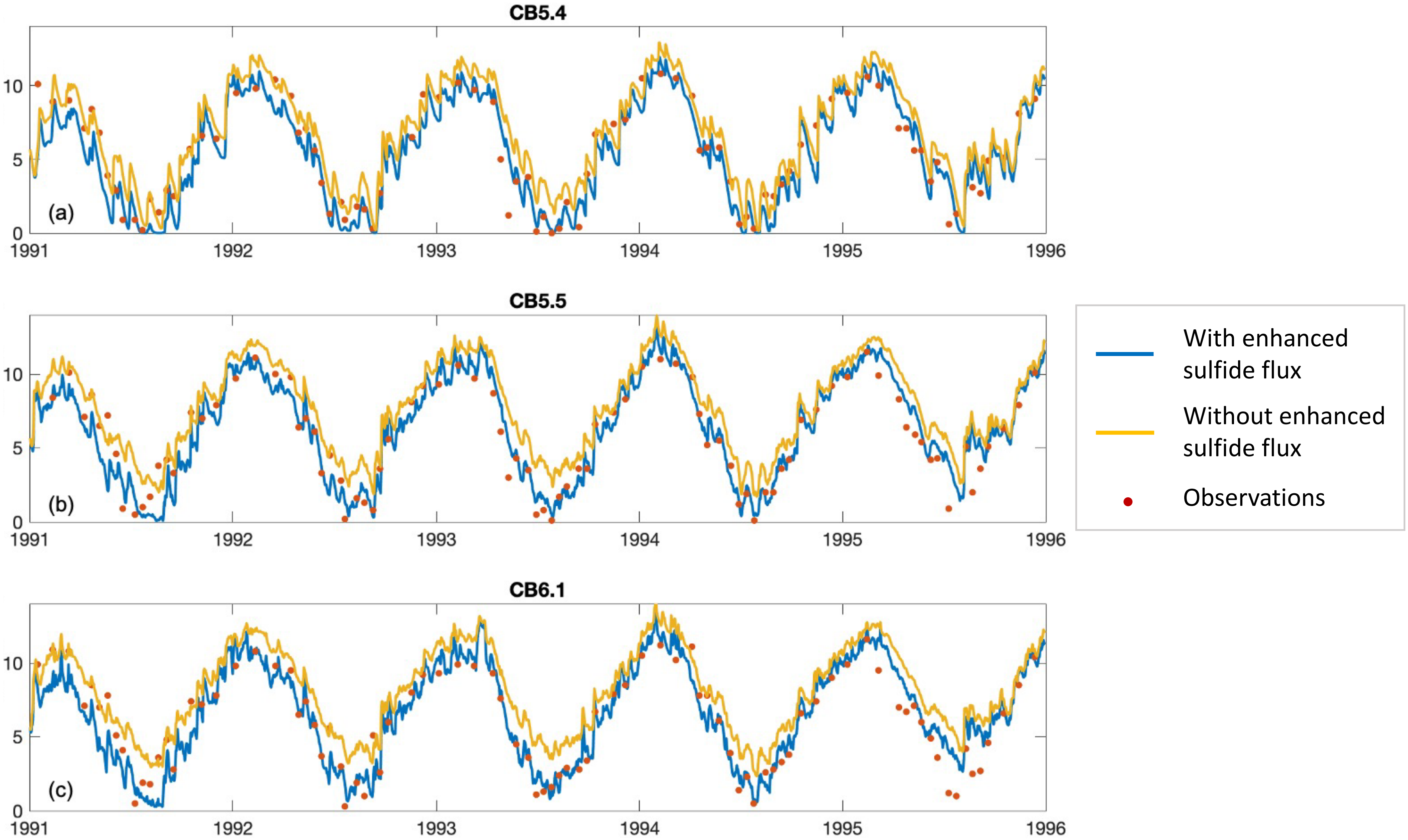
Results

Significant improvement in lower Bay bottom DO



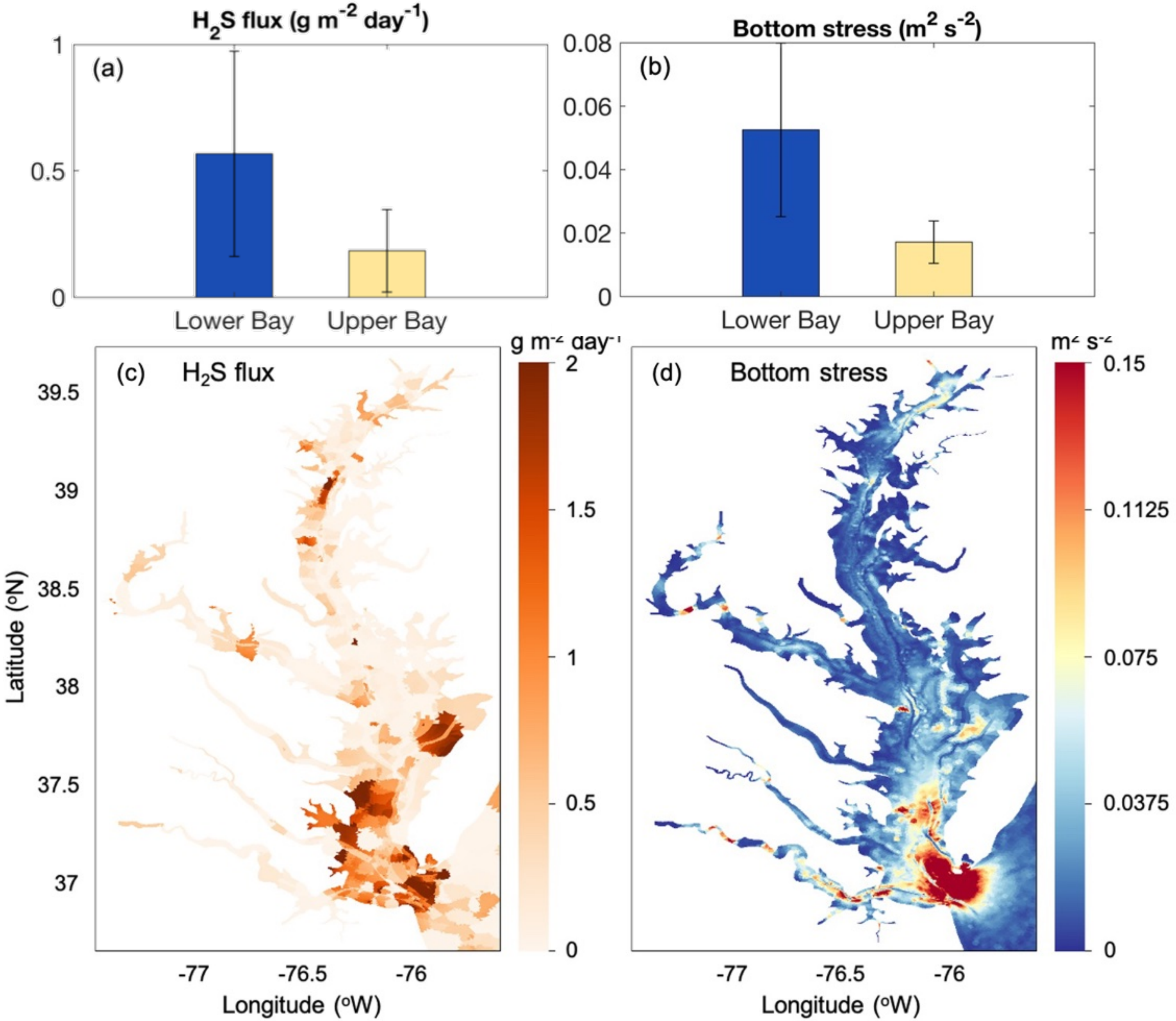
Results

Significant improvement in lower Bay bottom DO



Results

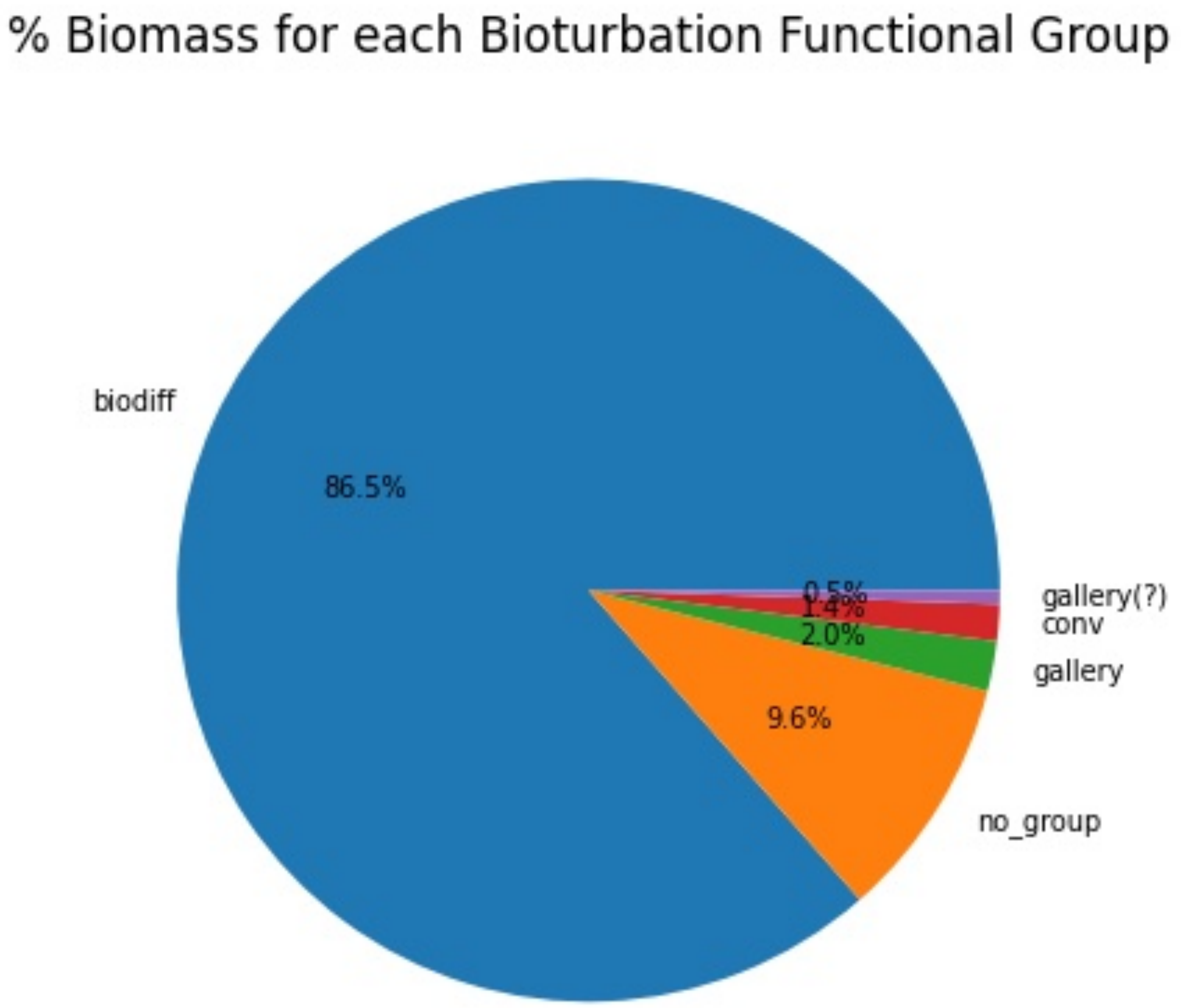
- Lower Bay has more erosion events
- Sulfide fluxes concentrate in the low Bay



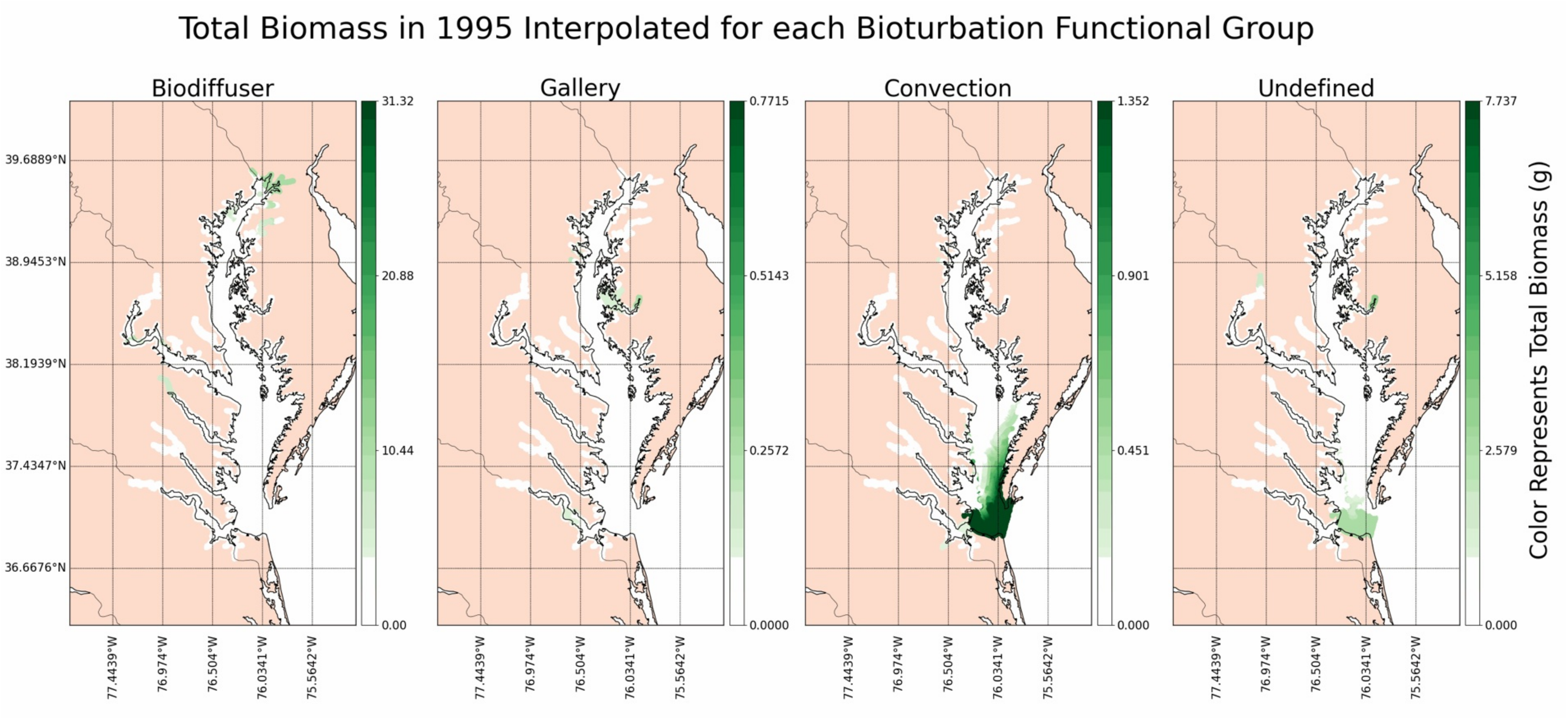
Second hypothesis:
Benthos-driven convection

Dominant benthic function groups

- More than 2000 species in total
- About 120 species have sensible existence or biomass

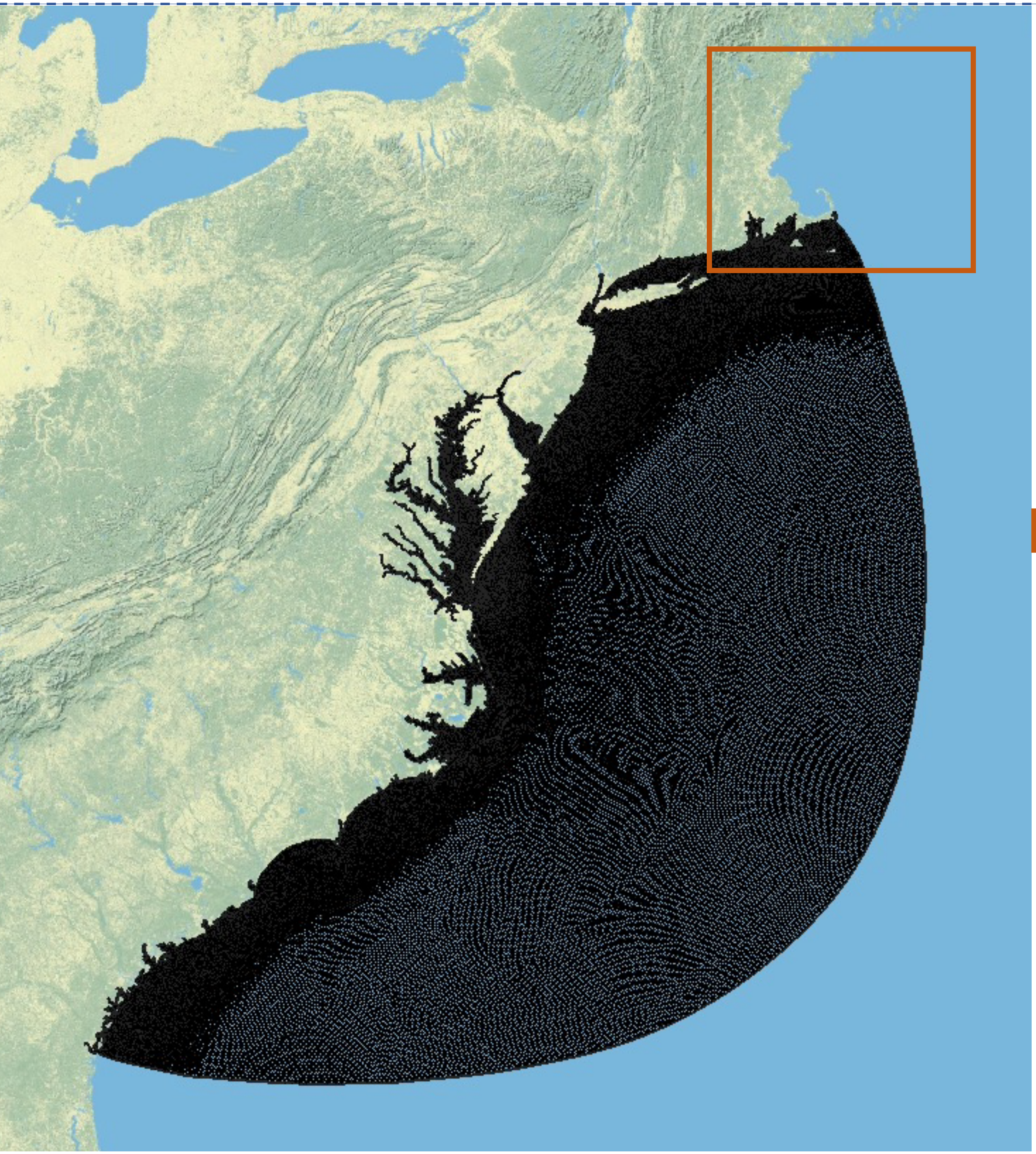


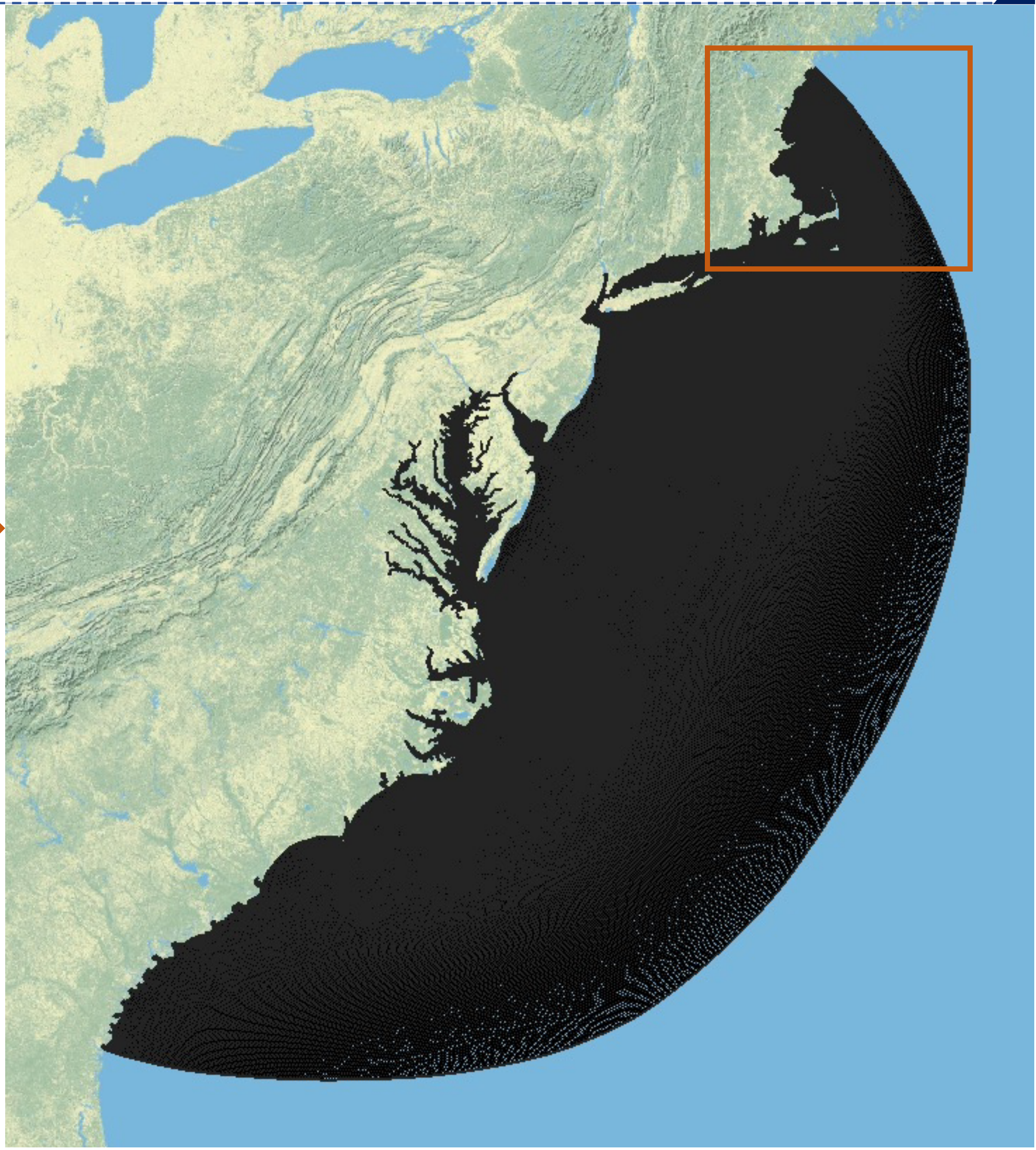
Spatial distribution over the past decades



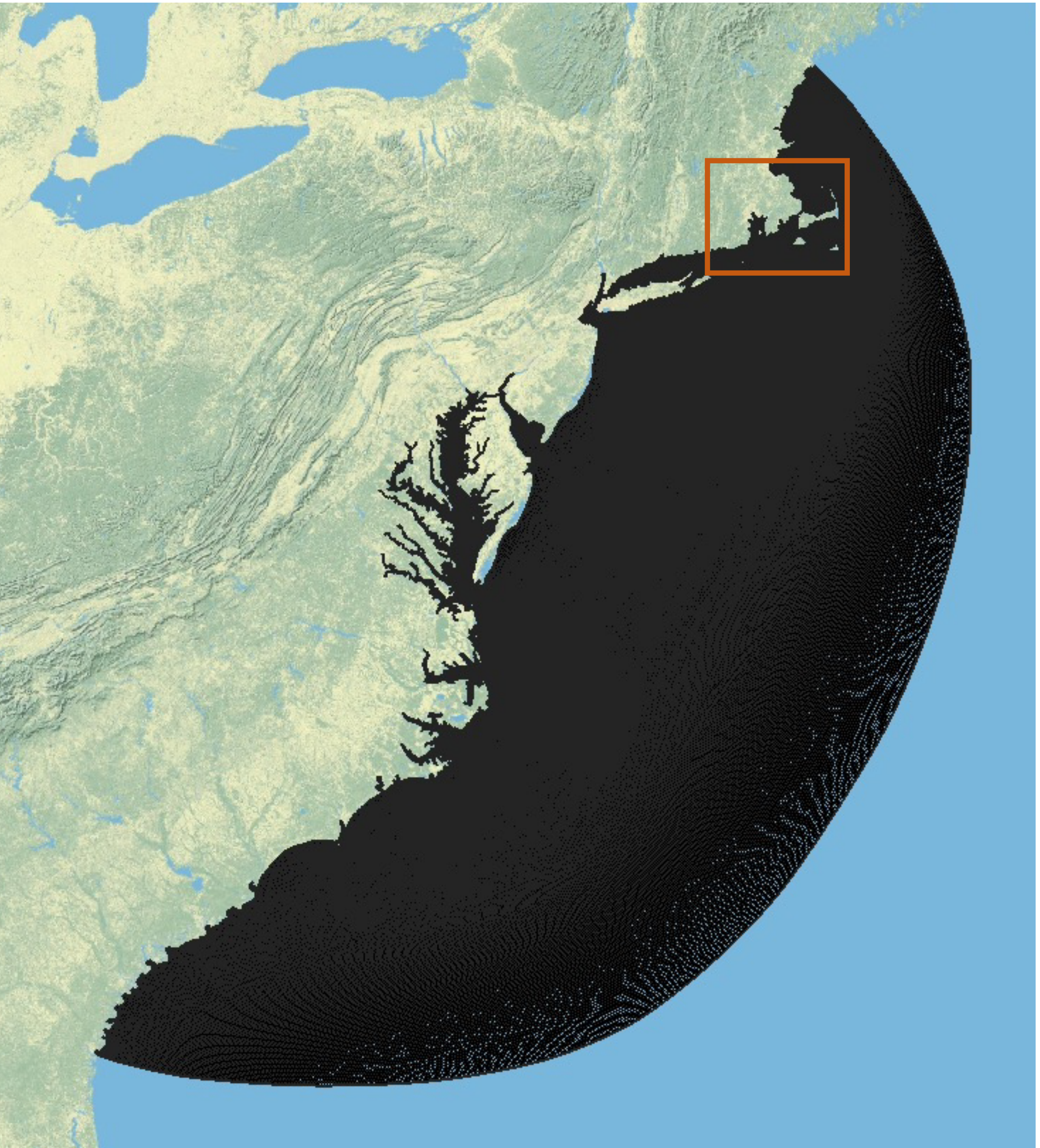
Testing the remote influence and nutrient exchange from the other coastal water bodies along the US East Coast

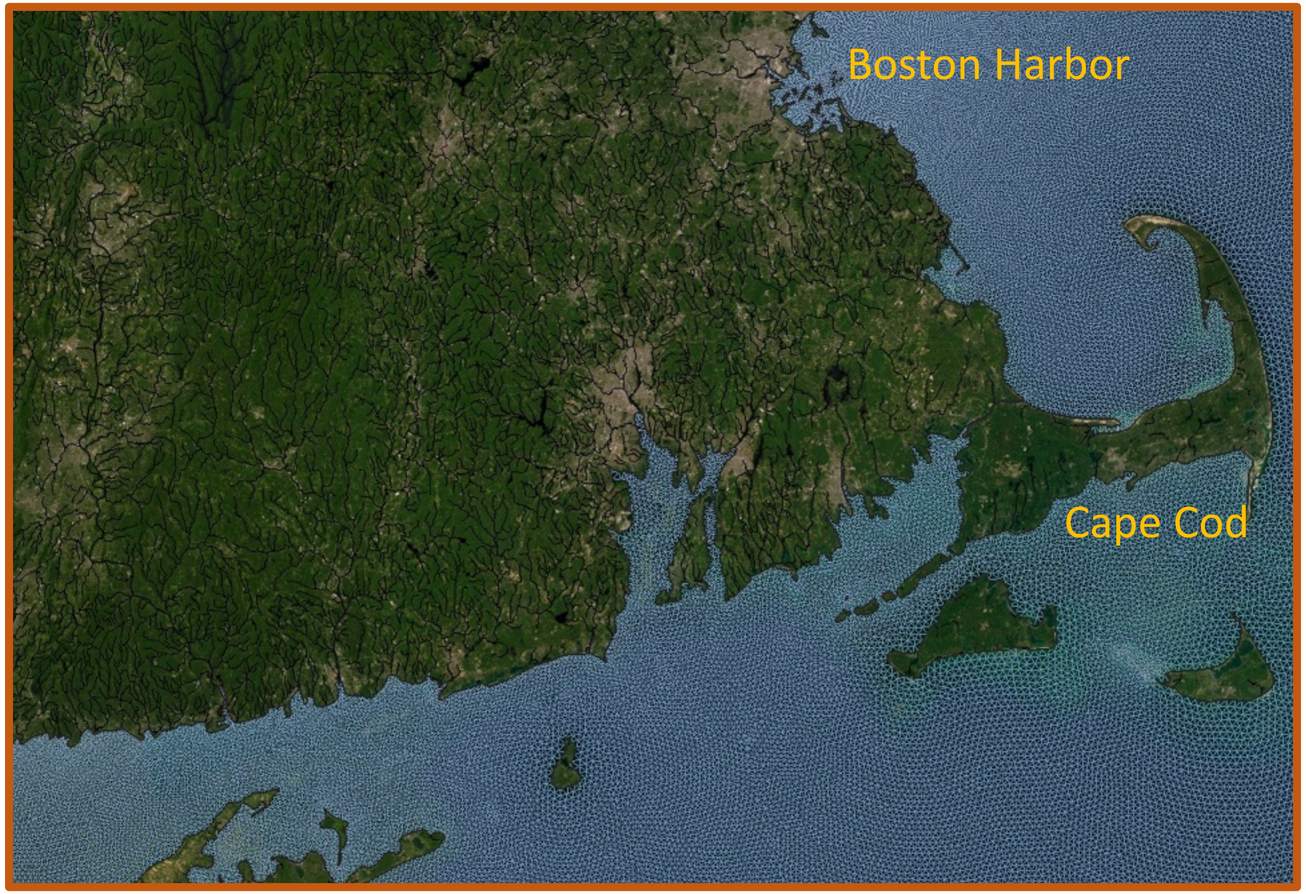
Updated US East Coast domain



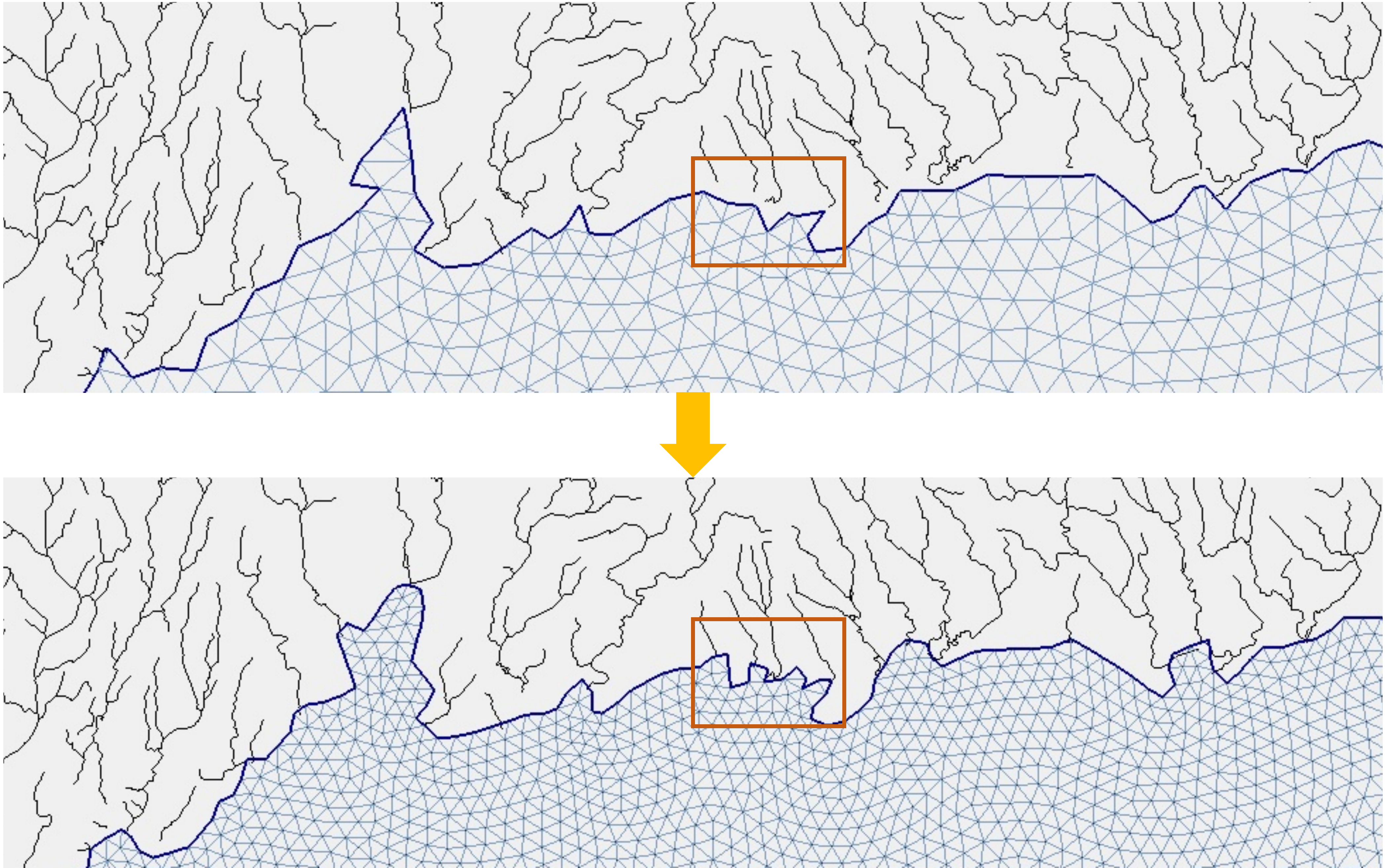


Details of model grids near Cape Cod and Boston Harbor

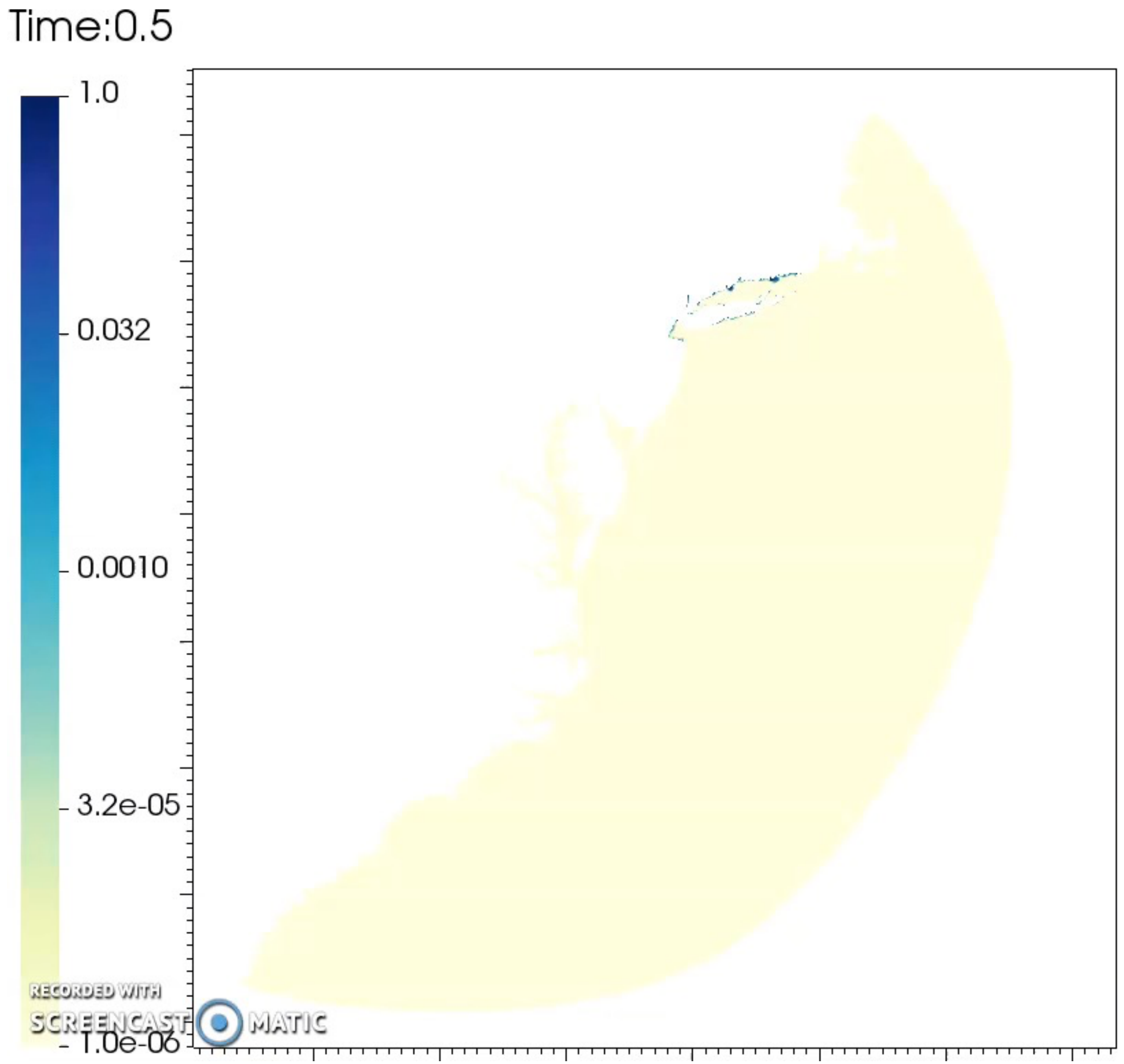


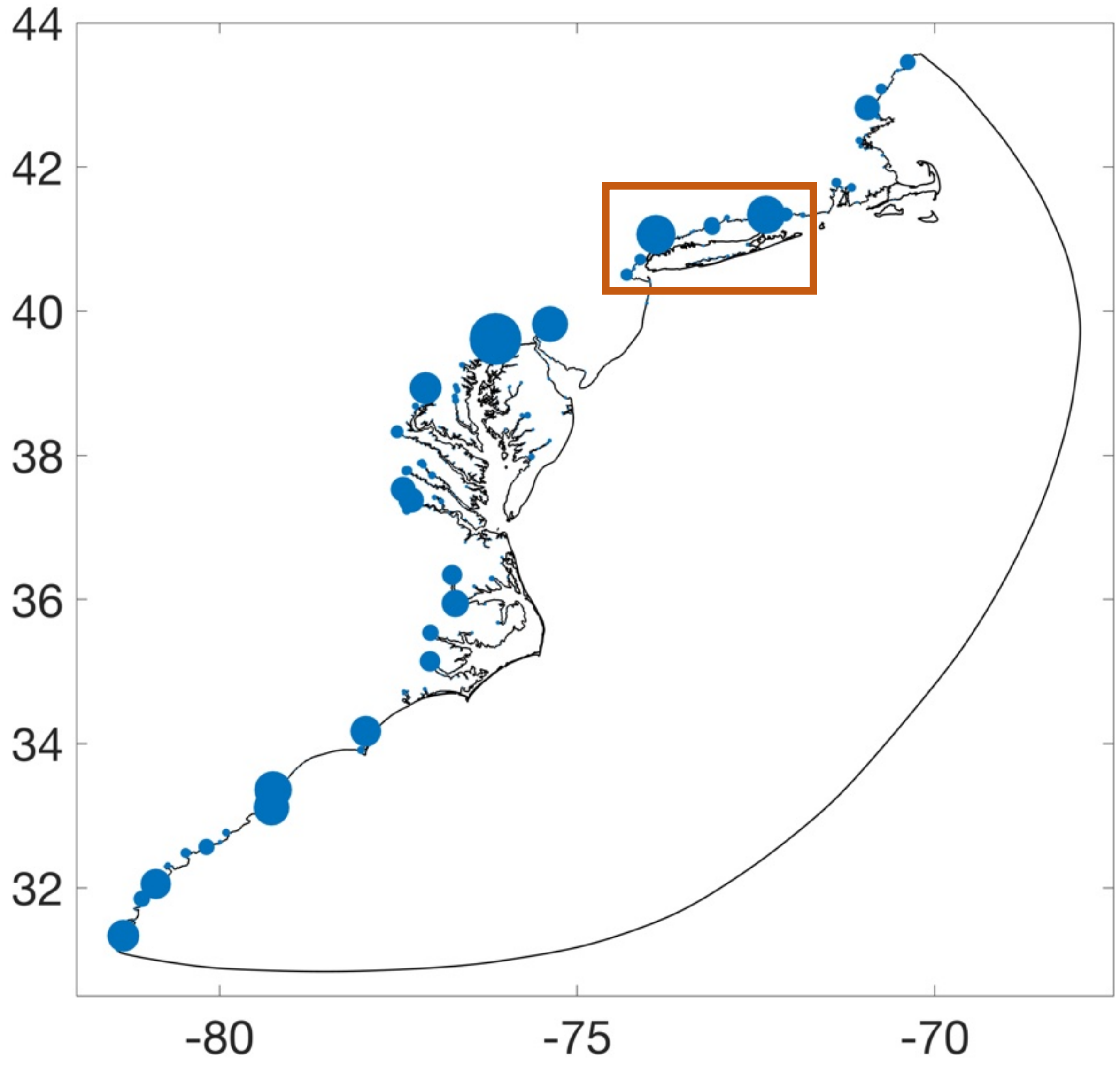


Renewed linkage between SCHISM and NOAA National Water Model

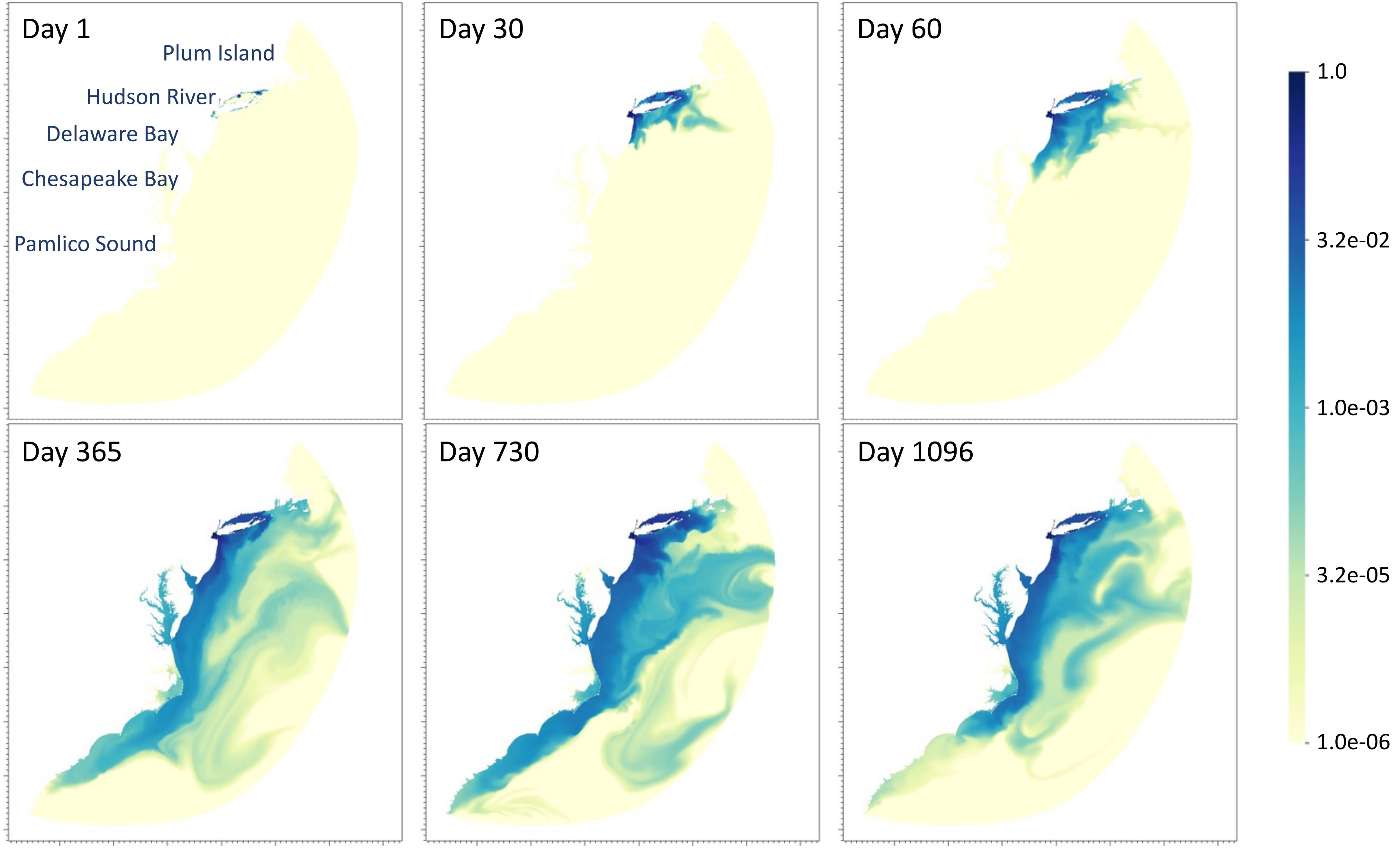


Sources from Long Island Sound





Sources from Long Island Sound



To be continued …

- Model validation and calibration
- Statistic and ML analysis
- Details of multiple sources to be presented