

The review of progress for 1th Quarter of 2nd year on the Patapsco/Back MTM Program

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Outline:

- I. Estimating Inorganic Suspended Solids (ISS) from monitoring data
- II. Calibration 1 – Under- calibration TSS
- III. Calibration 2 – Over- calibration TSS
- IV. Iterative calibration using ISS and VSS for TSS calibration
- V. Summary

Calibration of TSS in MTM Patapsco/Back River

“TSS” is an important parameter for hydrodynamic and water quality calibration because it

- (1) Links hydrodynamics, sediment transport, and the biogeochemistry of the **benthic sediment and pelagic processes**
- (2) Governs water column’s **light**, oxygen, nutrient, and contaminant processes
- (3) Serves as a measurable, integrative variable for calibrating complex water quality interactions particularly those governing light availability and habitat suitability for submerged aquatic vegetation (**SAV**).

The issue

“**Operationally**, because TSS consists of both inorganic and organic components, inorganic suspended sediment (ISS) is desired to be derived directly from observations to enable calibration of the inorganic fraction of TSS during the physical (hydrodynamic–sediment transport) modeling stage. The calibration of the organic component: volatile suspended sediment (VSS) can then be performed in the subsequent water quality modeling stage.”

Proposed solution:

“By **separating ISS and VSS**, the original nonlinear calibration—characterized by interference between parameters—can be transformed into a linear, sequential process, substantially reducing calibration time and effort, especially for the complex sediment environment”

I. Estimating Inorganic Suspended Solids from Monitoring Data

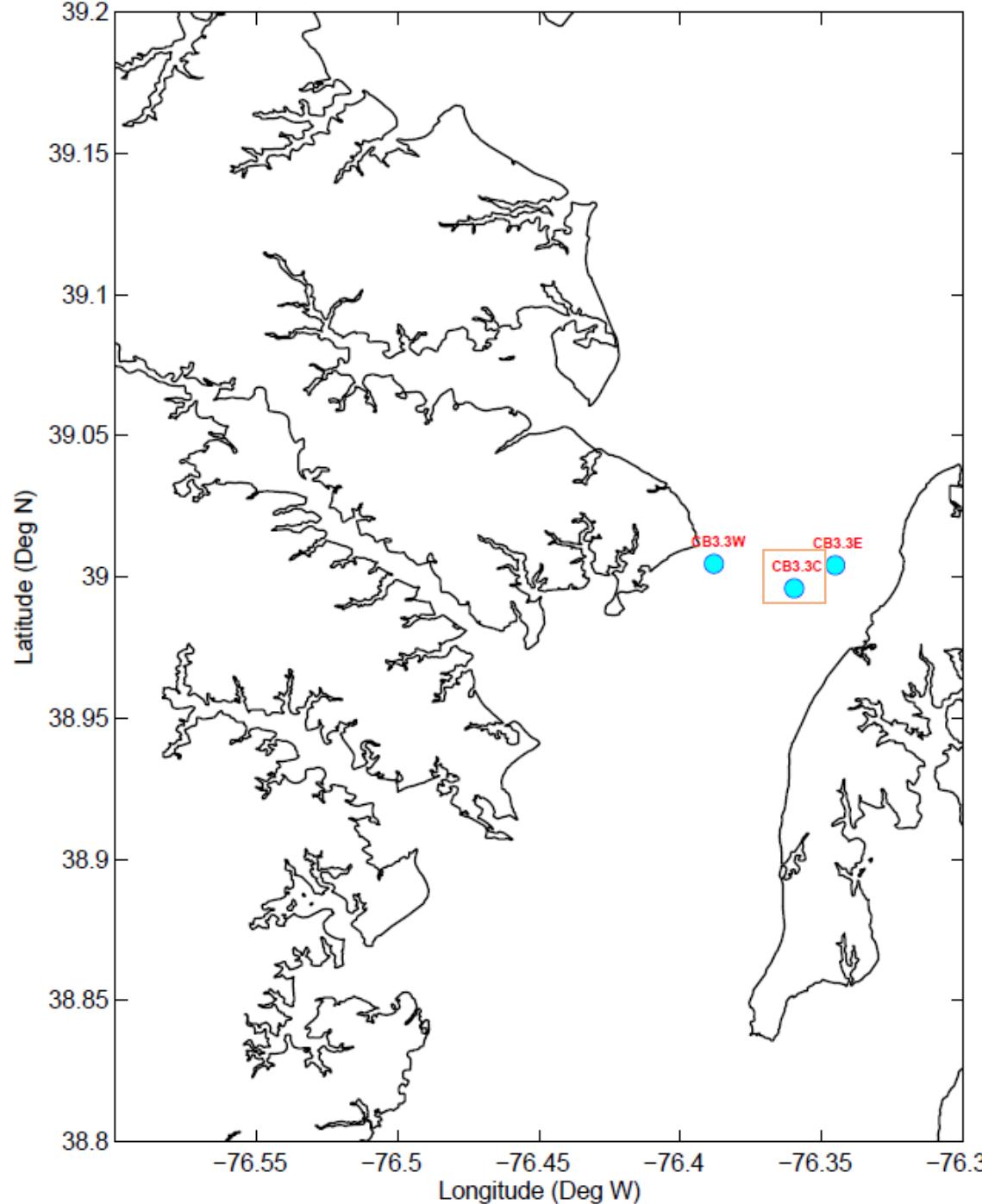
Problem: How do we get estimates of ISS to validate sediment transport models?

CBP Monitoring program collects three relevant variables:

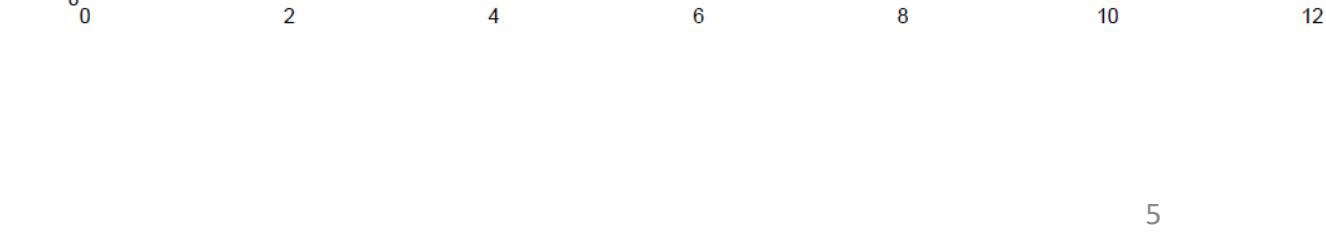
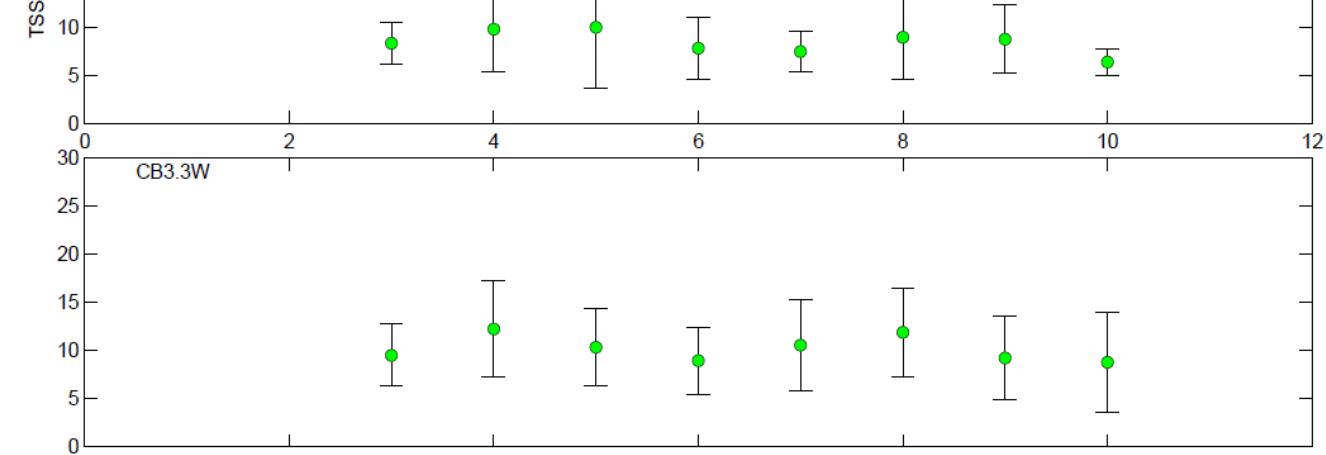
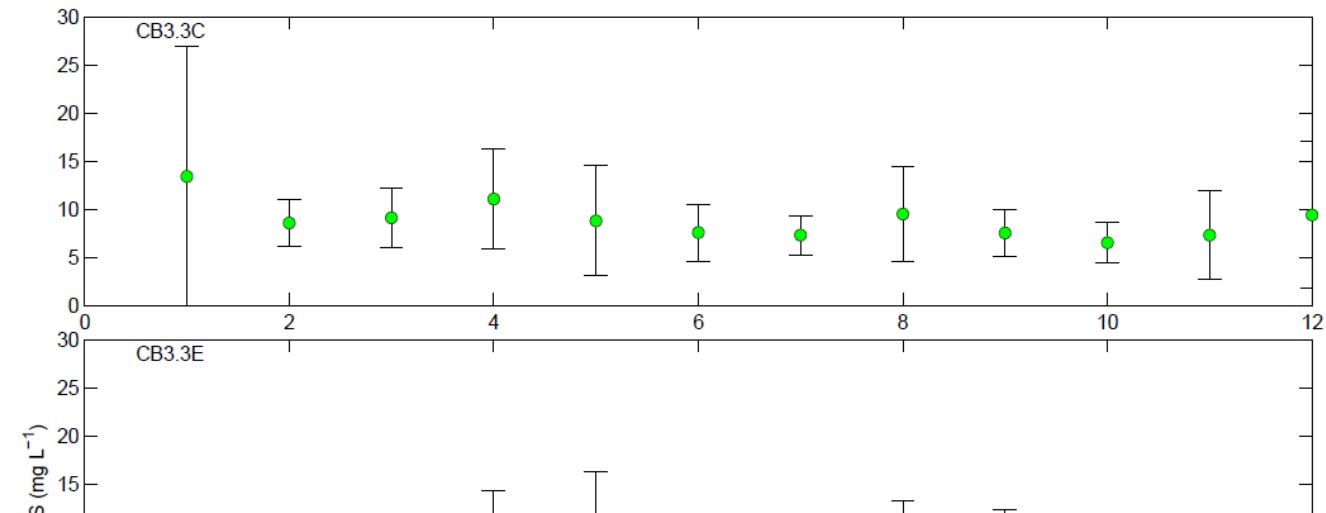
TSS = total suspended solids	= inorganic plus organic material.	Regularly measured
VSS = volatile suspended solids	= solids that combust (organic)	Rarely measured
PC = particulate carbon	= concentration of particulate carbon (in CB, ~organic)	Regularly measured

If you have TSS and VSS data, you can estimate inorganic suspended solids

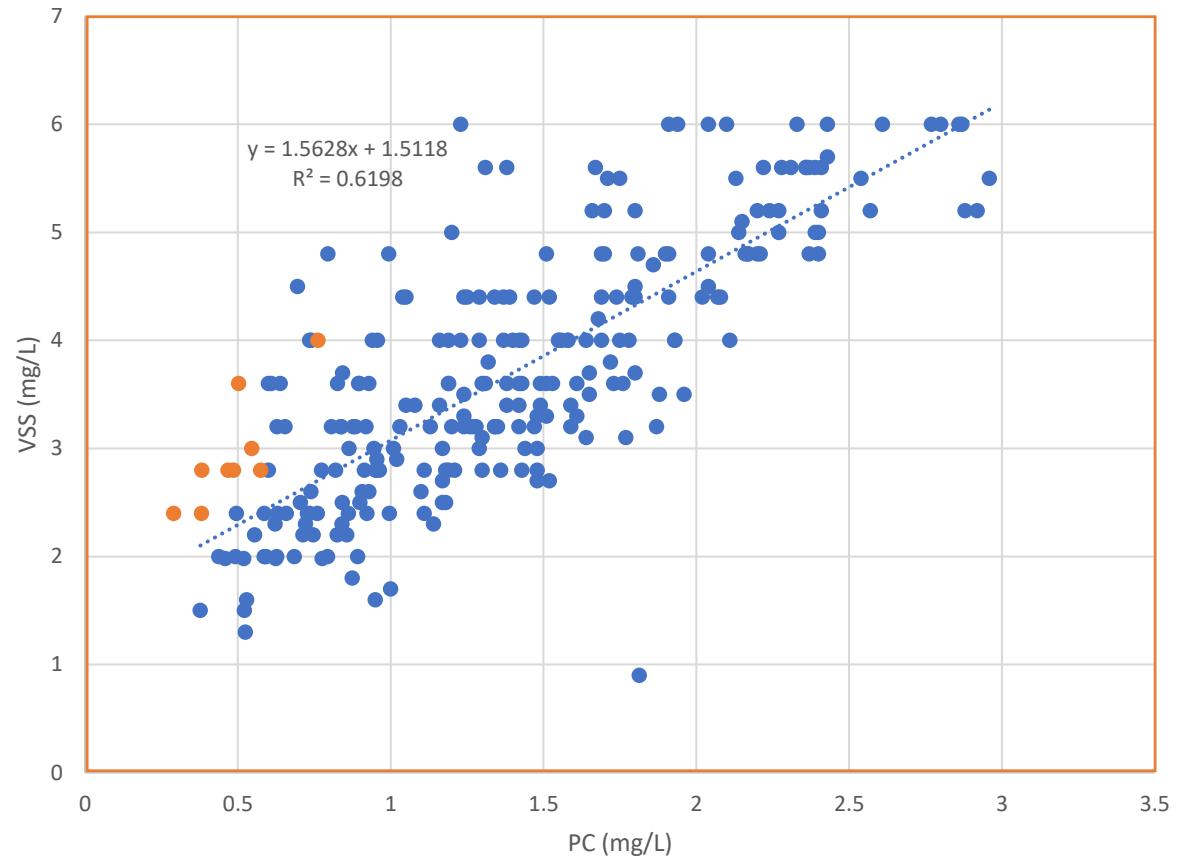
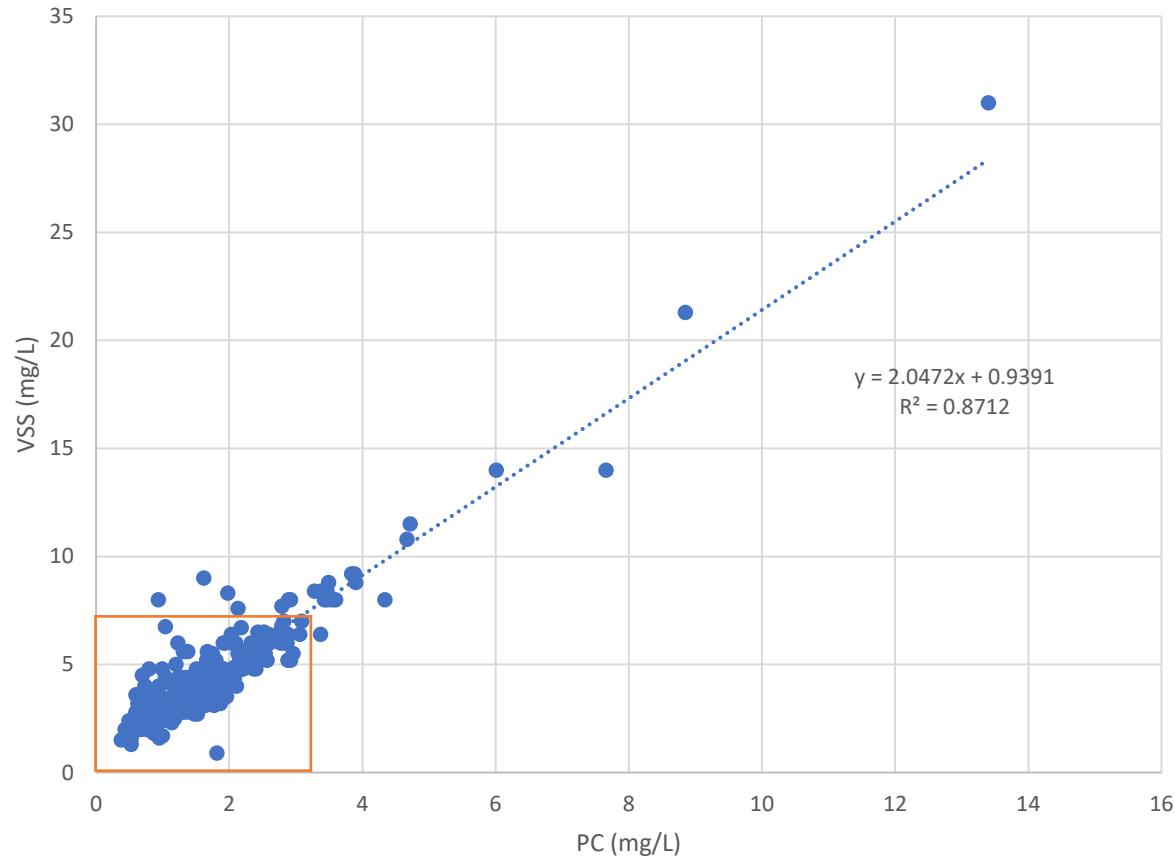
$$ISS = TSS - VSS$$



Relevant TSS, PC and VSS Data



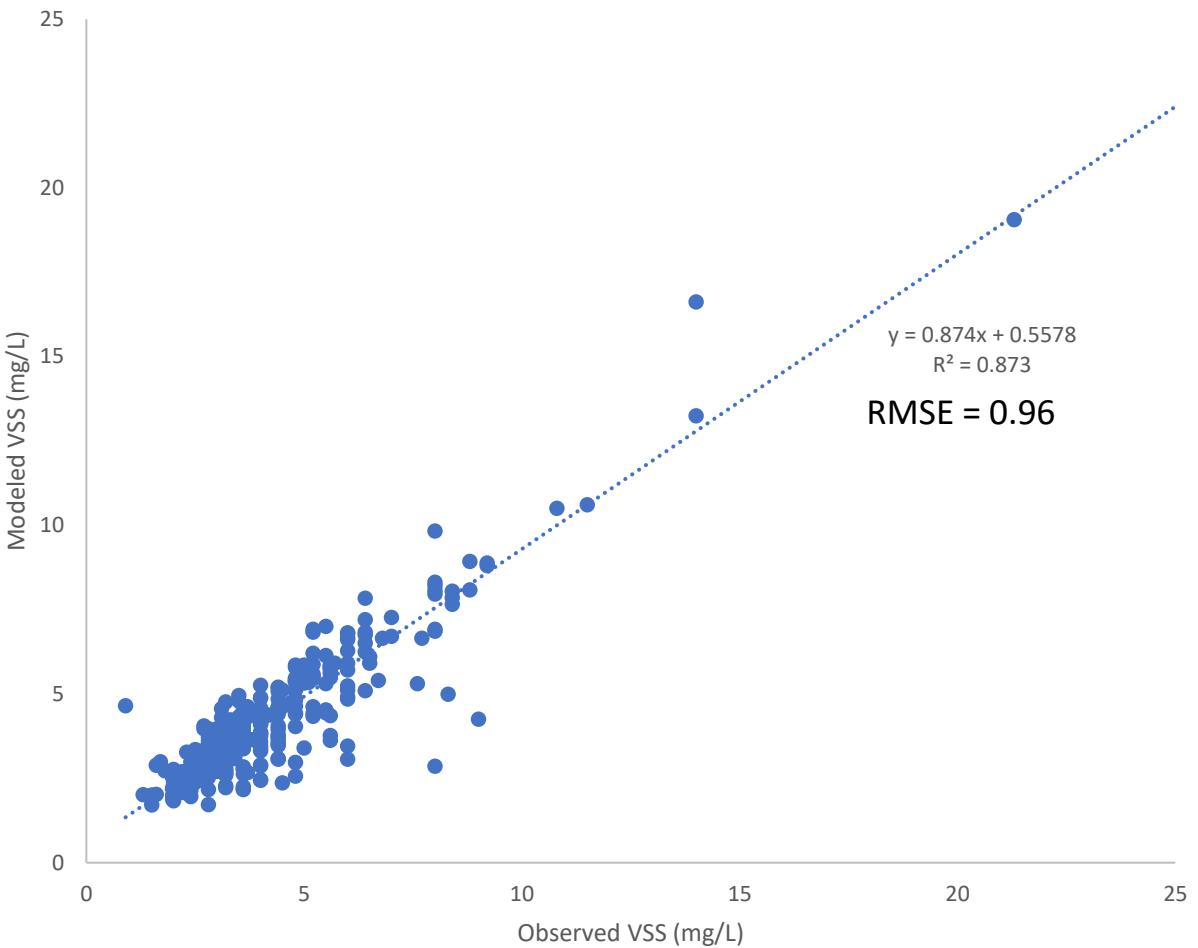
Estimating VSS from PC at CB3.3C

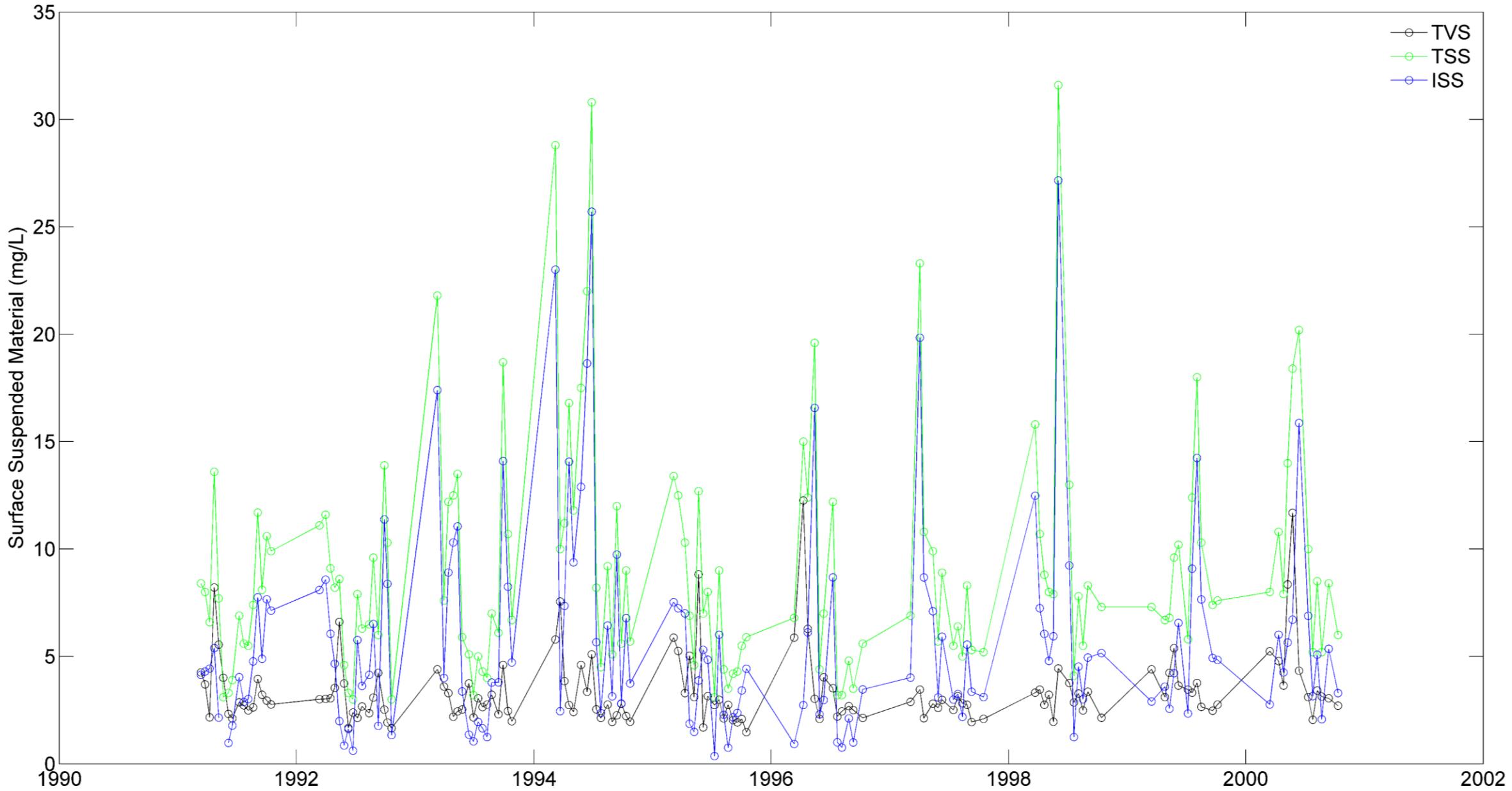


Paired TSS, VSS, and PC measurements made from 1998 to 2020 at CB3.3C in the surface layer, and on September 17, 2018 at all depths. VSS is about 40% carbon.

Model for VSS

- Model skill largely relies on strong correlation between PC and VSS
- PC-based model can 'predict' VSS at any location
- $\text{ISS}_{\text{est}} = \text{TSS}_{\text{obs}} - \text{VSS}_{\text{est}}$





Why is iterative calibration so important for MTM Patapsco/Back River calibration?

Although the modeling domain of MTM overlaps that of MBM, we were not able to obtain adequate TSS comparison inside Patapsco River/Back River by just mimicking parameter specified by MBM in Patapsco/Back River. Here are the distinct sediment characteristics of Patapsco/Back River differs from the main stem Upper Bay.

Patapsco River

“The Patapsco River forms the main portion of Baltimore Harbor, where Patapsco and Back River WWTP effluent inputs coincide with intense ship traffic—the sediment system has several distinctive characteristics that are important for interpretation and modeling. Sediments in Baltimore Harbor (Patapsco River) are dominated by fine, cohesive, organic-rich material influenced by WWTP effluent inputs and persistent ship-induced resuspension, resulting in a weakly consolidated, highly erodible bed and elevated background turbidity. Fine, cohesive inorganic particles (ISS) and organic matter (VSS) are continuously supplied by upstream watershed inputs and effluent discharges from the Patapsco/Back River Wastewater Treatment Plant (WWTP). In the water column, inorganic and organic particles interact through flocculation to form organic–mineral aggregates that govern effective settling velocities and light attenuation. Frequent ship traffic generates propeller wash and vessel-induced turbulence, enhancing resuspension of fine, weakly consolidated bottom sediments and maintaining elevated background TSS concentrations even under low-flow conditions. Repeated resuspension inhibits bed consolidation, resulting in a highly erodible sediment layer characterized by low critical shear stress for erosion. Deposited organic-rich sediments contribute to sediment oxygen demand and nutrient recycling, linking sediment dynamics to water quality processes.

Back River

Due to continuous input of fine particulates and organic matter from the Back River WWTP and low-energy hydrodynamic conditions, Back River is dominated by very fine, organic sediment, in contrast to many estuarine systems with higher sand content. It favors fine sediment accumulation, enhanced floc formation driven by elevated organic content, and wastewater-derived polymers. As a result, suspended sediment is primarily composed of fine, cohesive particles, organic-rich flocs dominate the VSS fraction, while ISS is largely fine-grained mineral sediment. The sediment behavior obviously deviates from classical non-cohesive (sand-based) transport assumptions.

II. Calibration 1 – Under-calibration TSS in Patapsco/Back River

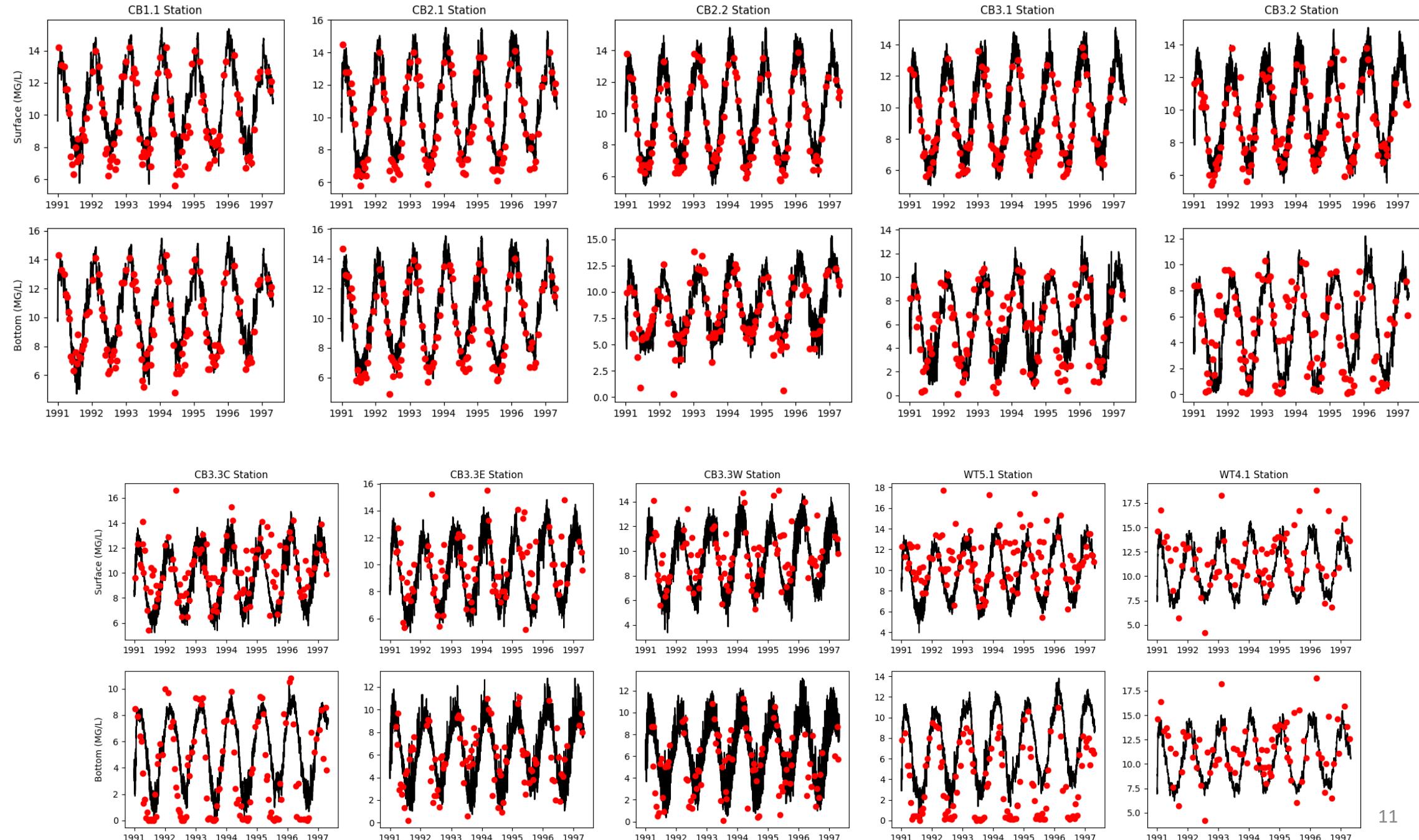
Critical shear stress is NOT a spatial-varying variable, rather it depends on sediment classes (see table). The sediment bed fraction (classes) in each grid cell, on the other hand, can be specified differently in different regions.

Sed. classes	Grain diameter (mm)	Particle settling velocity (mm/s)	Critical shear stress for erosion (pa)
Class 1	0.003	0.012	0.03
Class 2	0.003	0.03	0.03
Silt	0.003	0.1	0.03
Sand	0.3	1.0	20

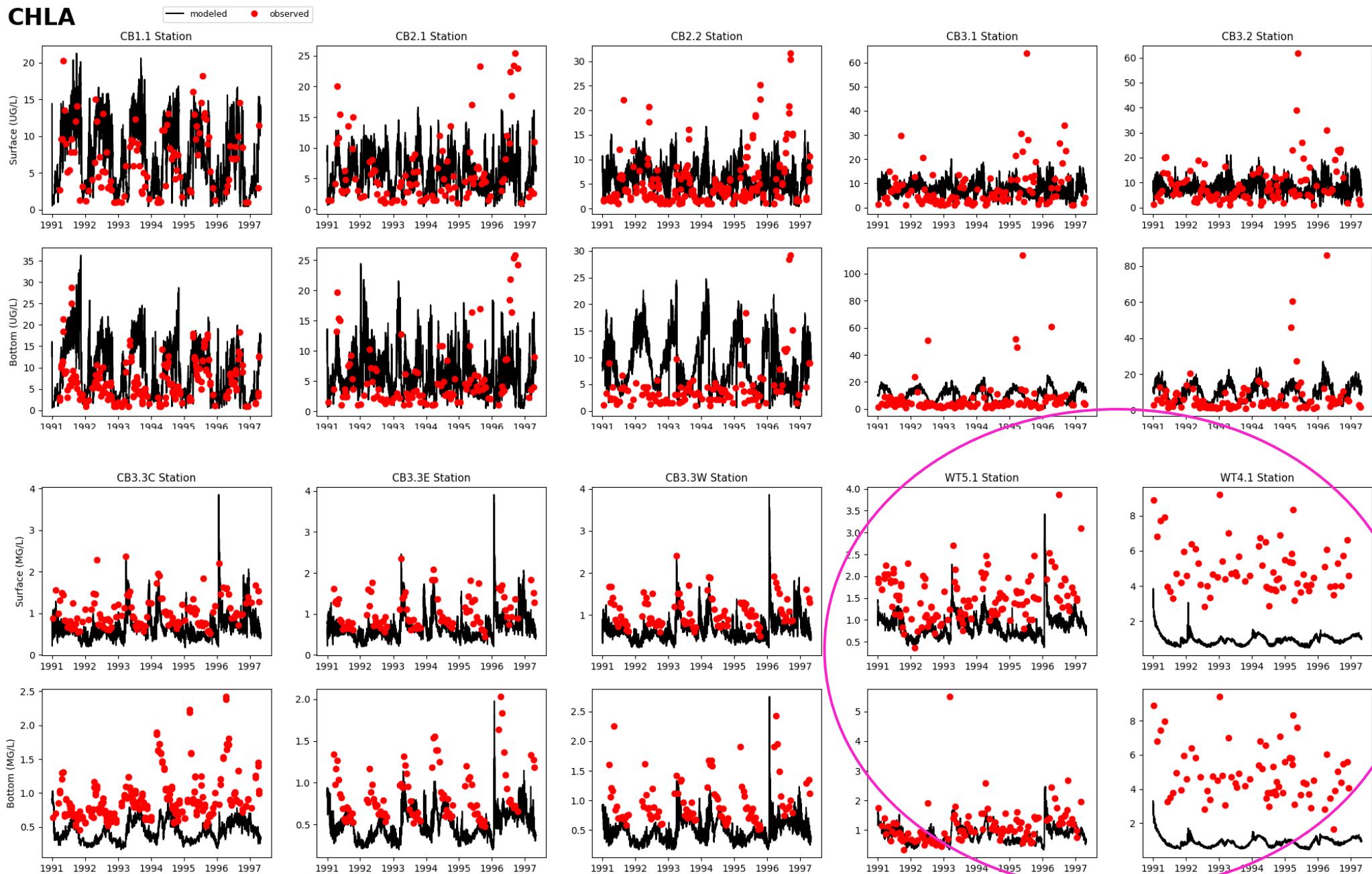
Sediment bed fraction / Region applied	Baltimore Harbor (channel)	Baltimore Harbor (shoal)	Back River	Rest of Upper Chesapeake Bay
Class 1	80%	30%	30%	(follow MBM specification)
Class 2	10%	30%	30%	
Silt	5%	35%	35%	
sand	5%	5%	5%	

DO

— modeled ● observed

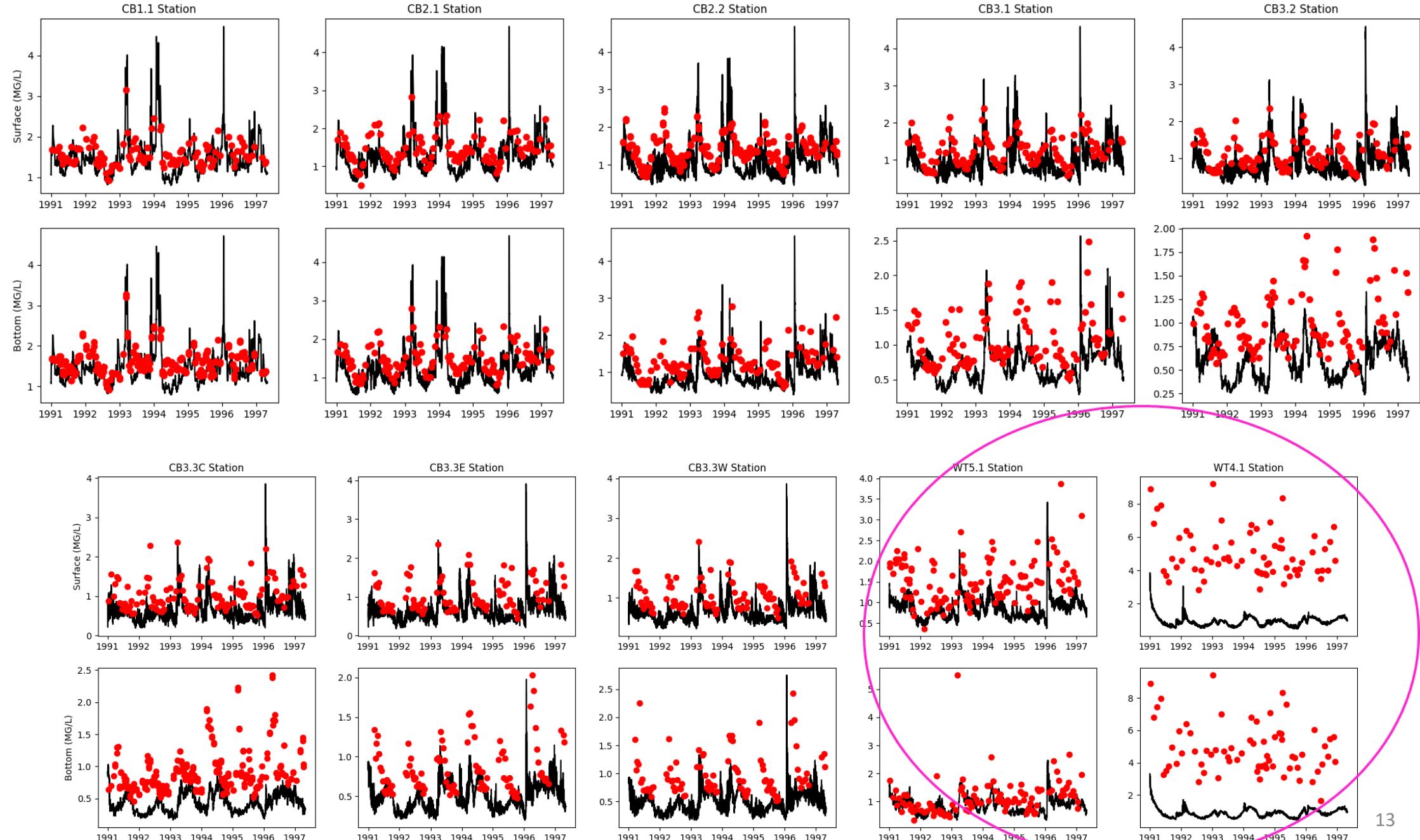


CHLA



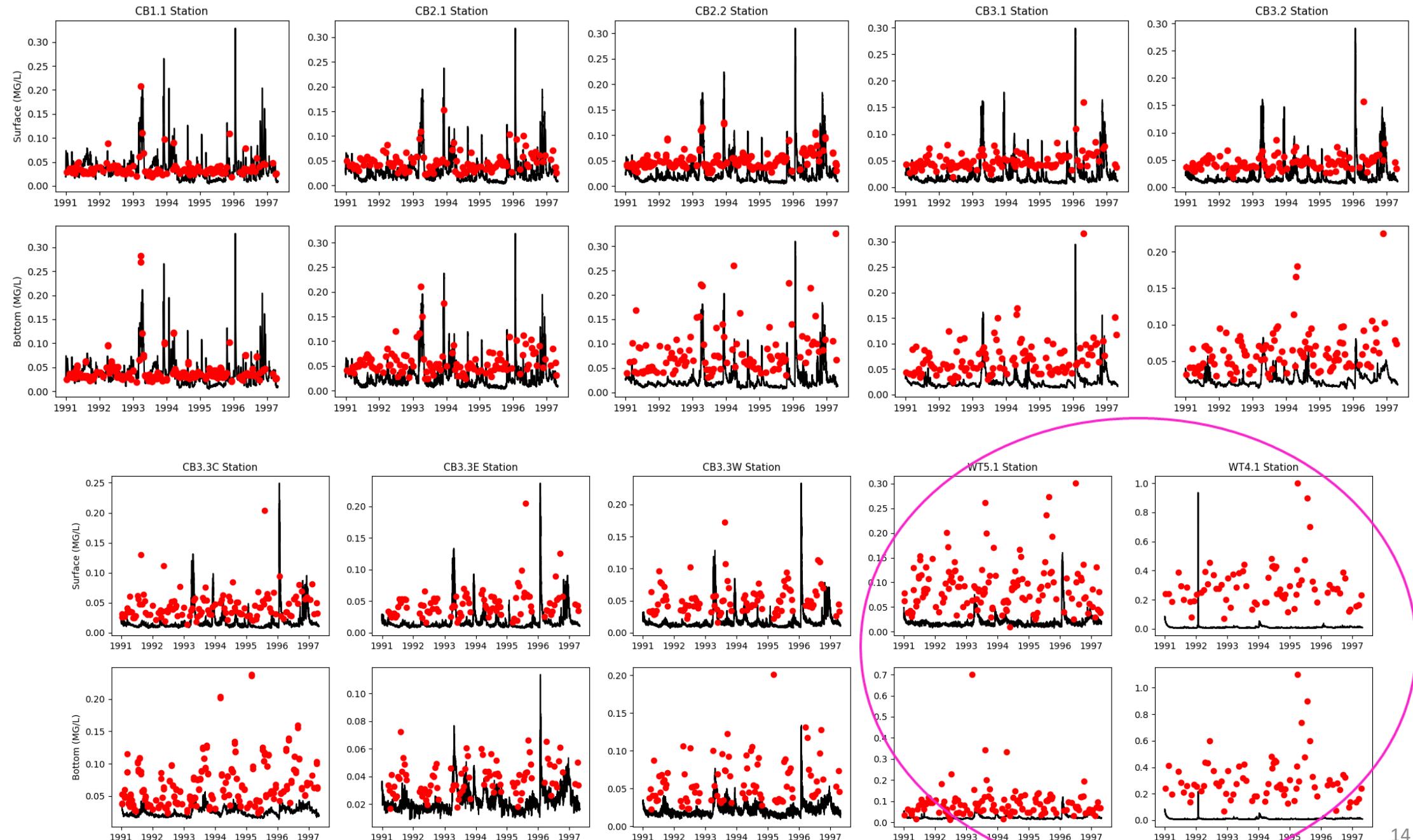
TN

— modeled ● observed



TP

— modeled ● observed



III. Calibration 2 – Over-calibration TSS in Patapsco/Back River

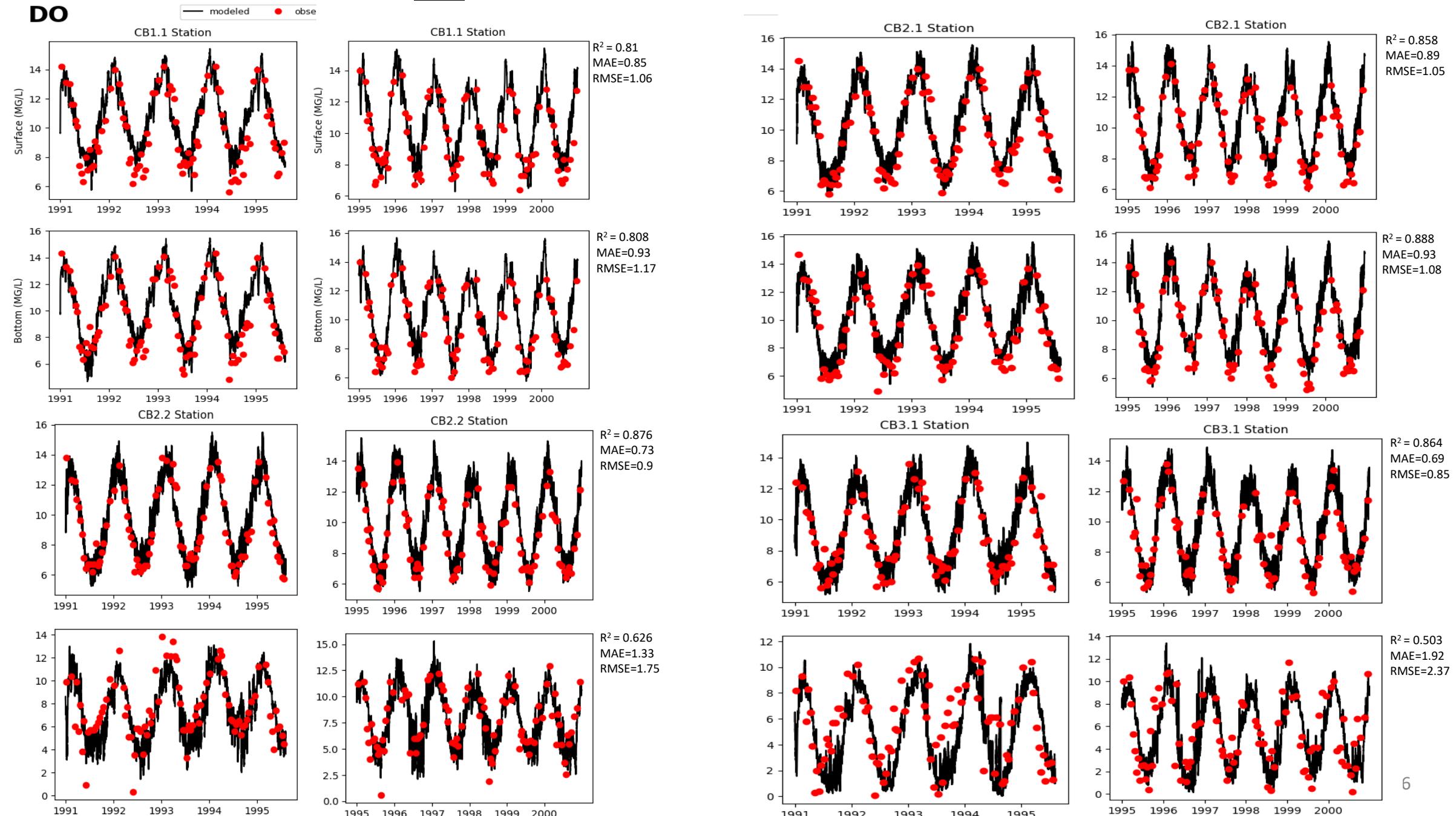
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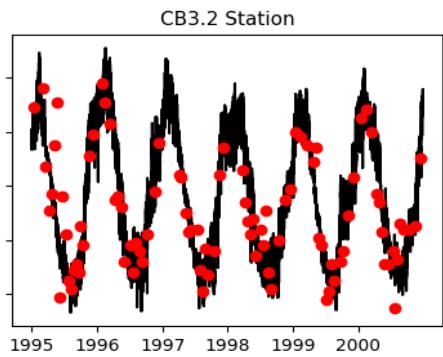
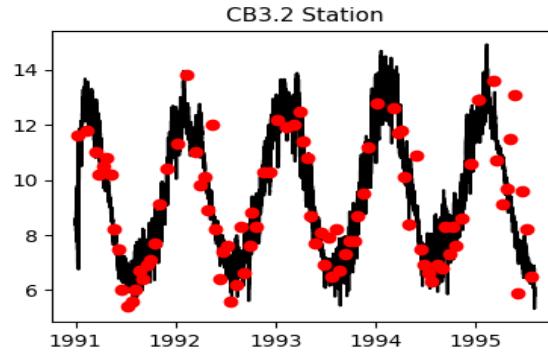
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Class 2	10%	15%	15%	
Silt	5%	15%	5%	
sand	5%	0%	0%	

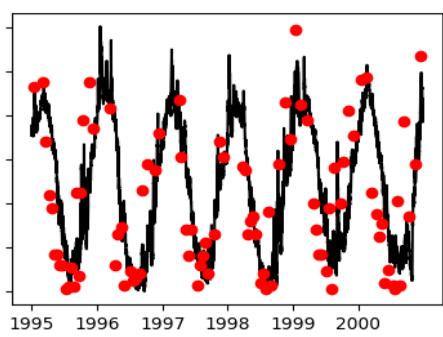
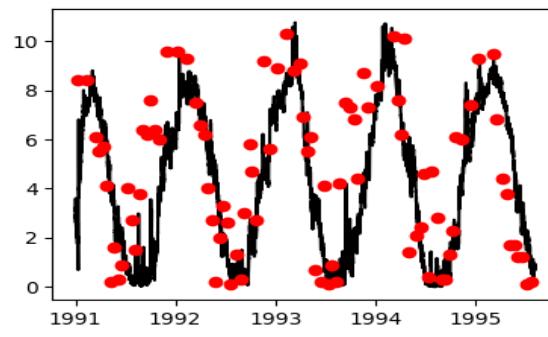
Elevation, Temperature, Salinity, DO, ChlA, TN, TP, TSS

DO

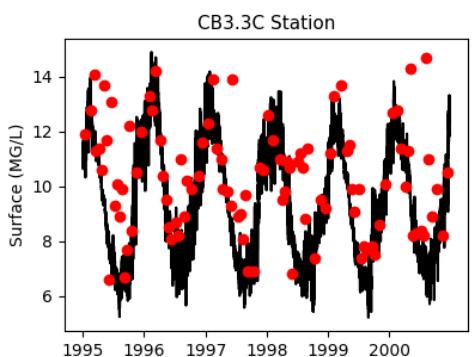
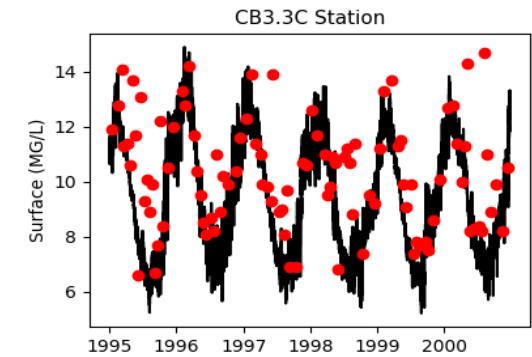




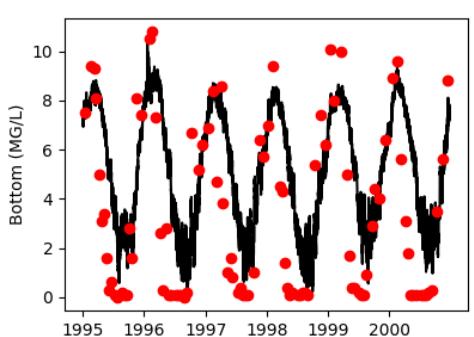
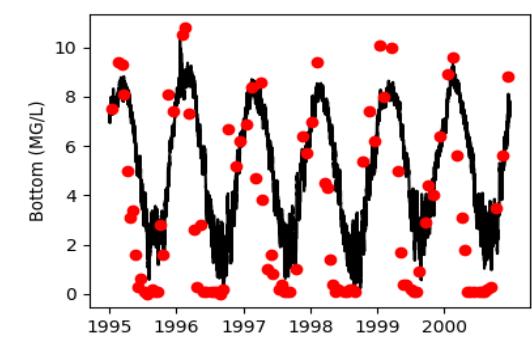
$R^2 = 0.754$
 $MAE = 0.82$
 $RMSE = 1.06$



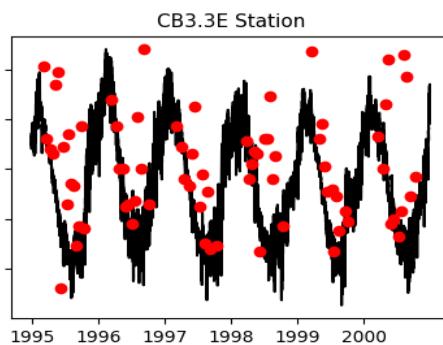
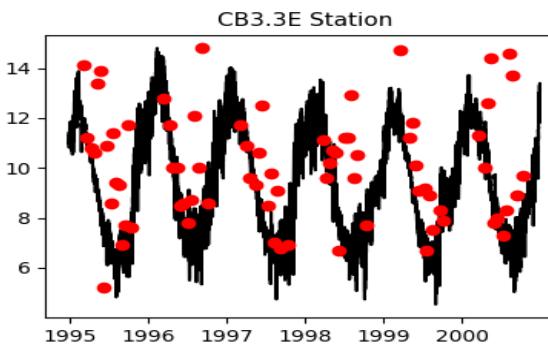
$R^2 = 0.385$
 $MAE = 2.08$
 $RMSE = 2.63$



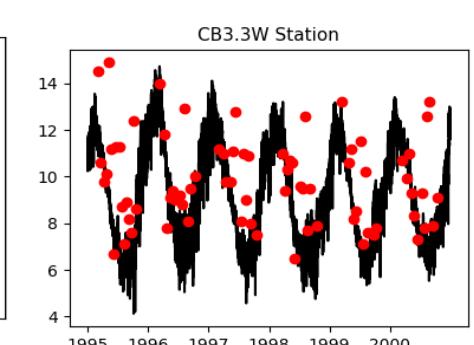
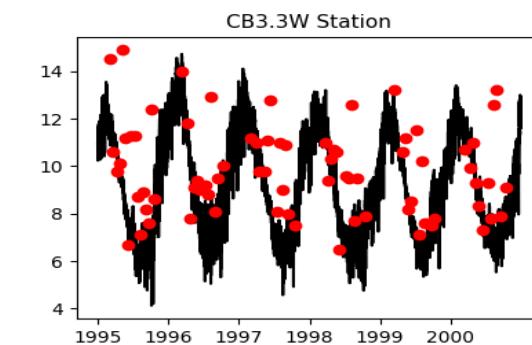
$R^2 = 436$
 $MAE = 1.39$
 $RMSE = 1.93$



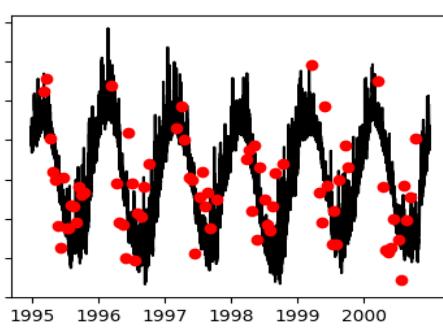
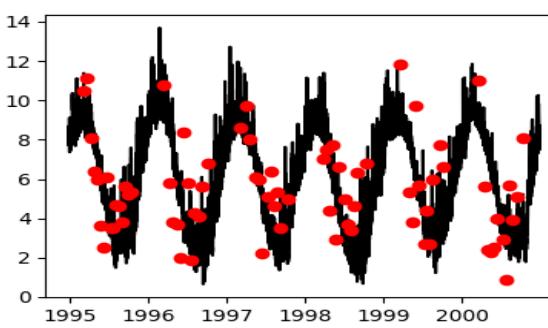
$R^2 = 0.439$
 $MAE = 2.39$
 $RMSE = 2.91$



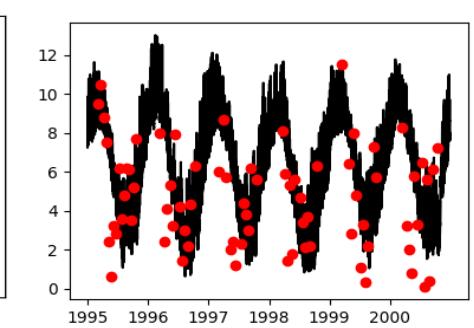
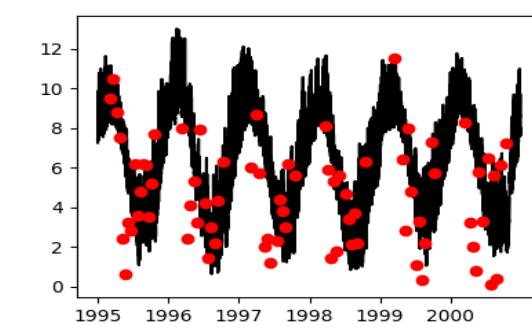
$R^2 = 0.976$
 $MAE = 1.13$
 $RMSE = 1.41$



$R^2 = 0.321$
 $MAE = 1.59$
 $RMSE = 2.16$



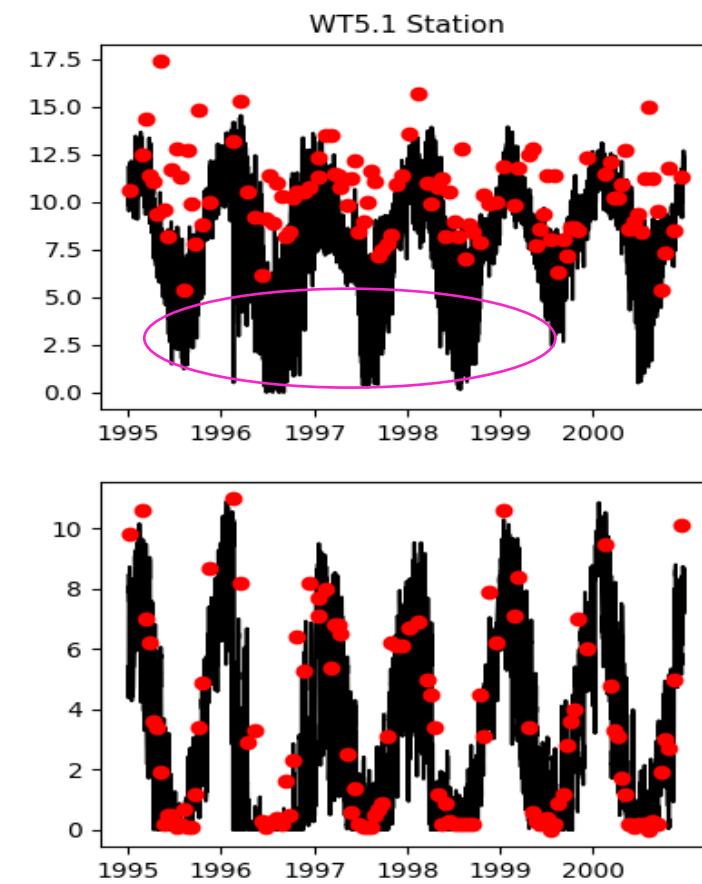
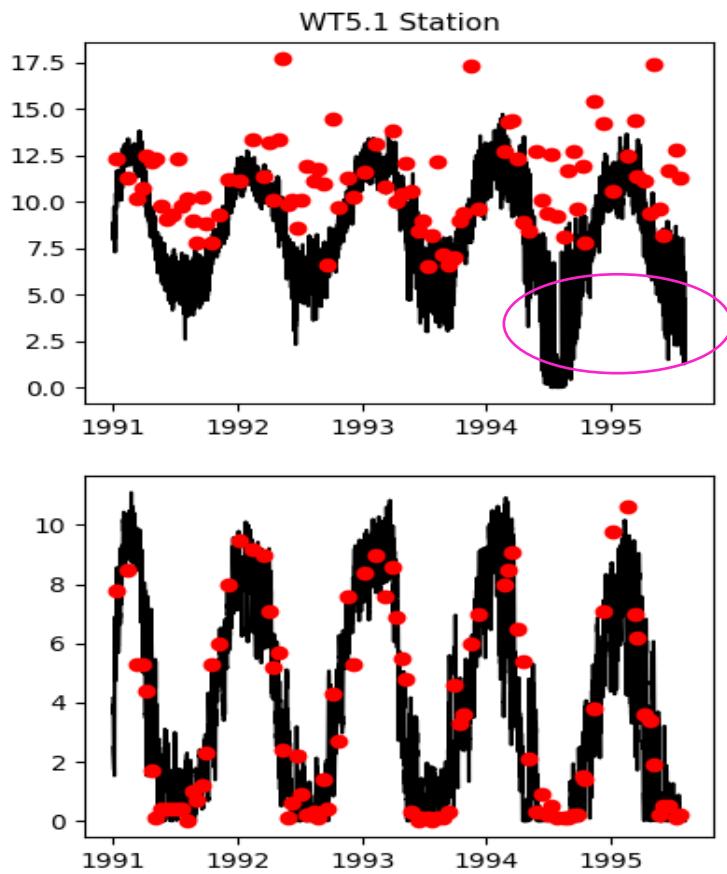
$R^2 = 0.976$
 $MAE = 1.13$
 $RMSE = 1.41$



$R^2 = 0.259$
 $MAE = 2.05$
 $RMSE = 2.6$

DO

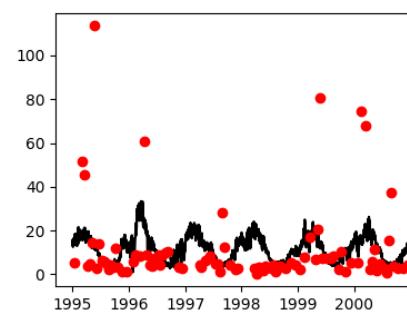
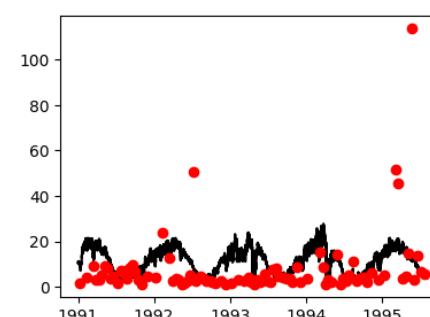
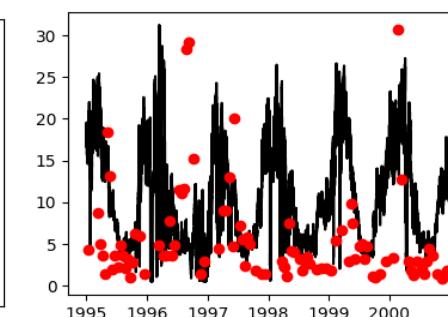
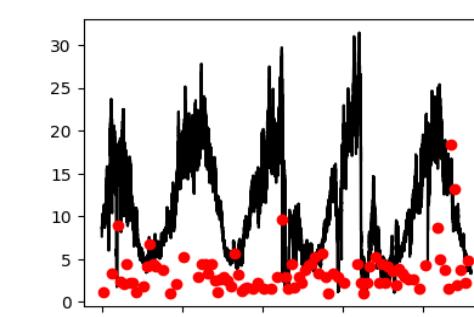
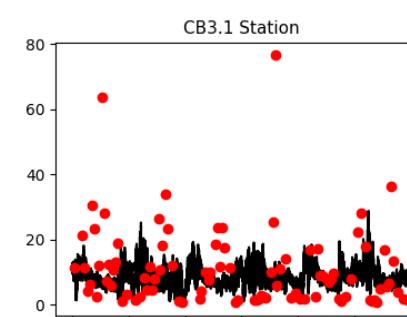
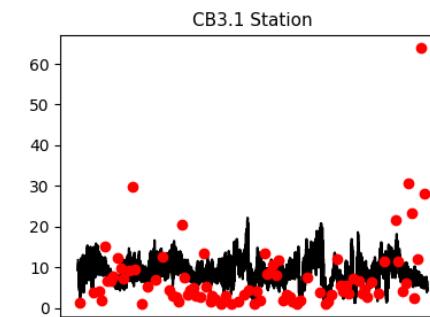
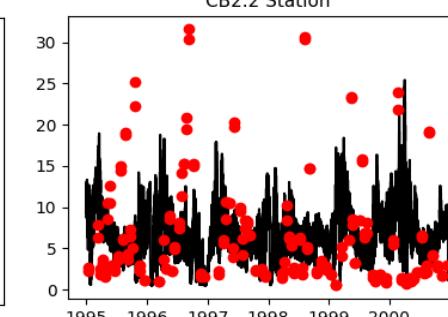
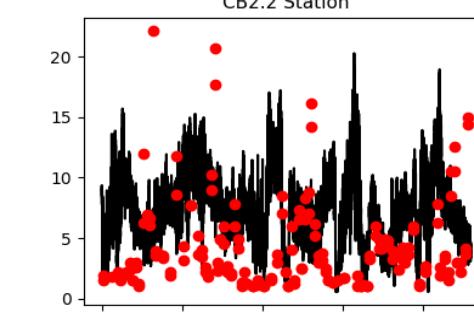
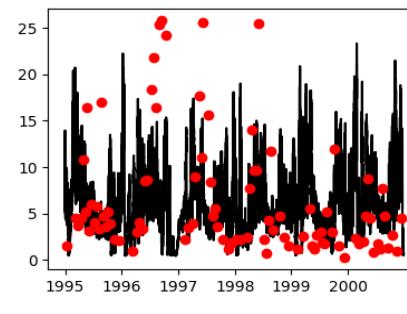
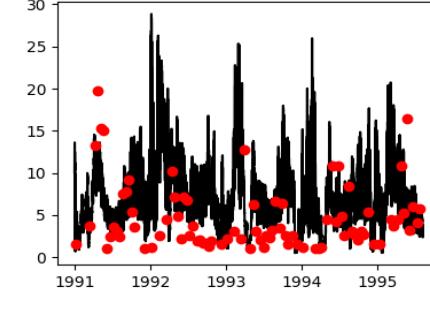
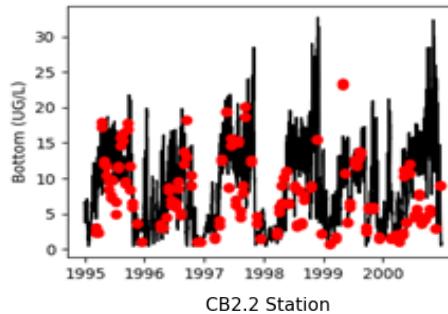
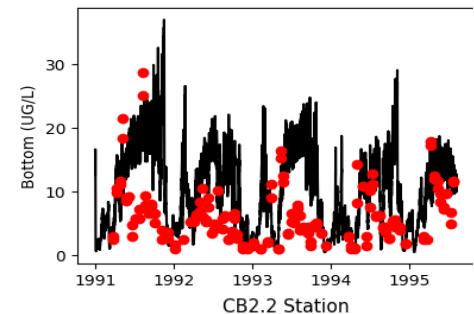
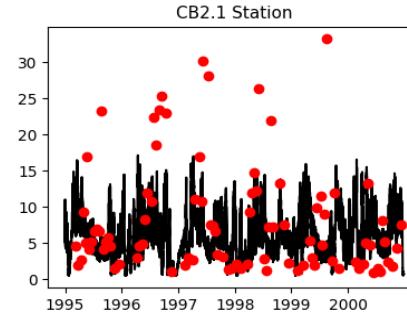
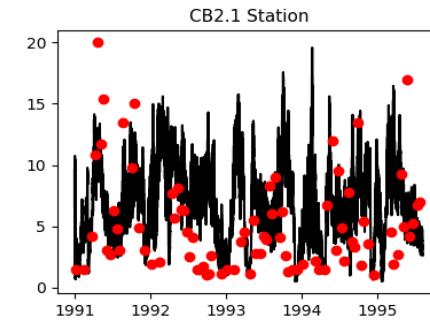
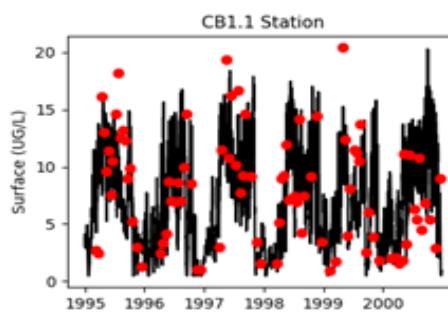
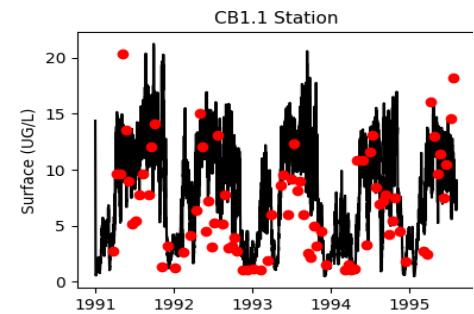
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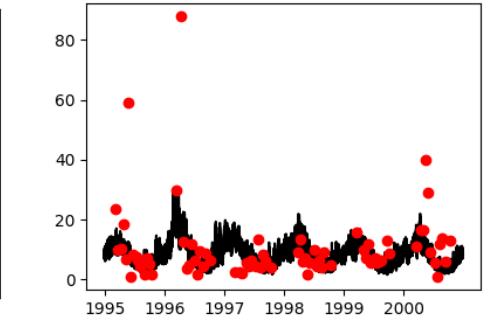
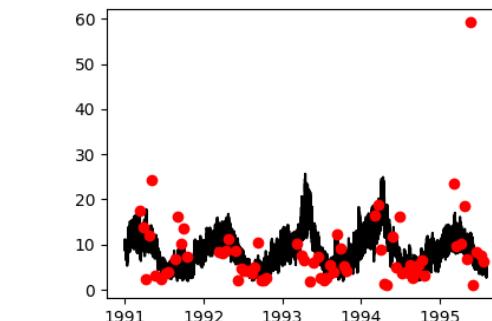
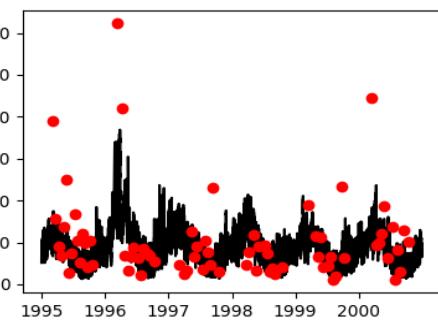
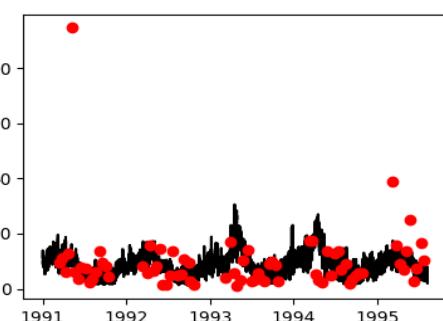
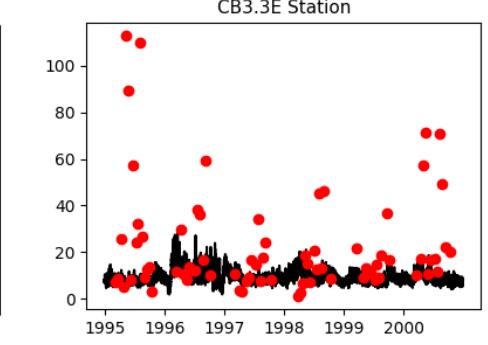
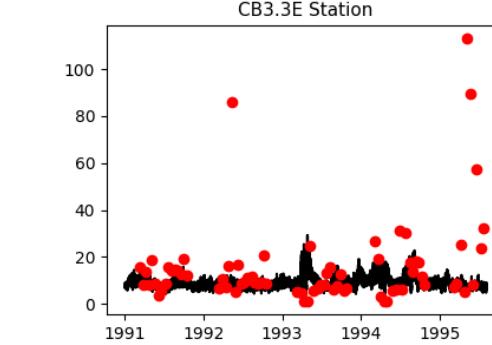
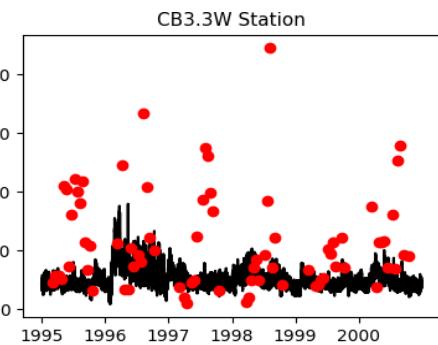
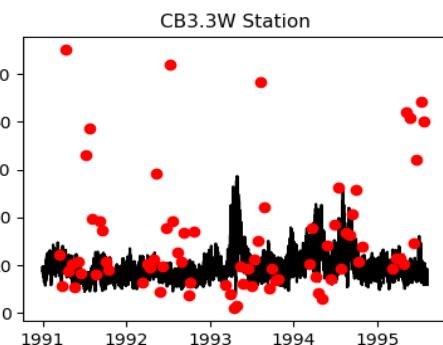
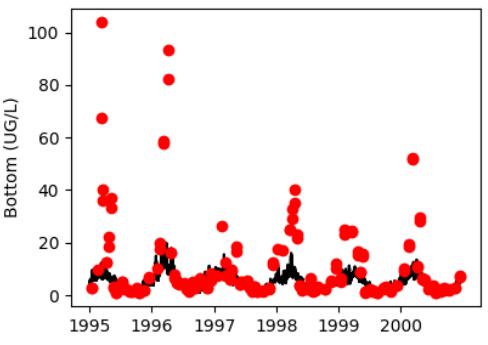
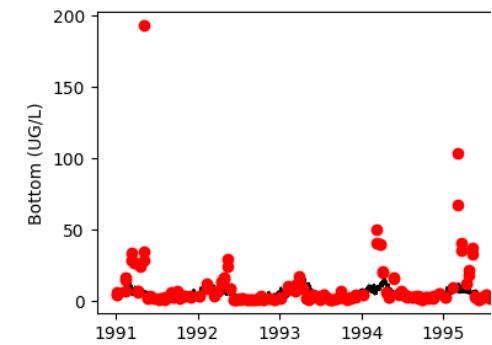
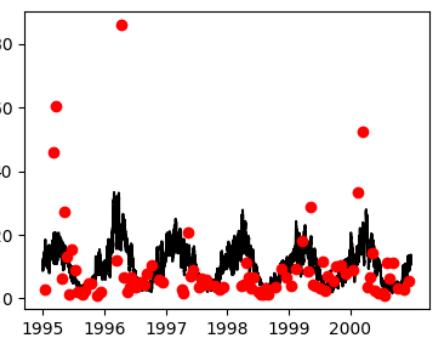
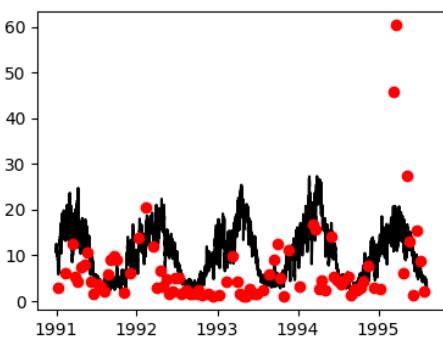
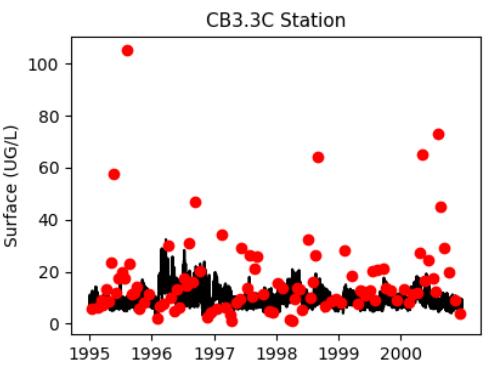
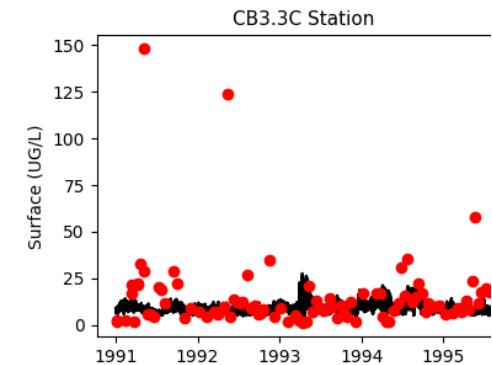
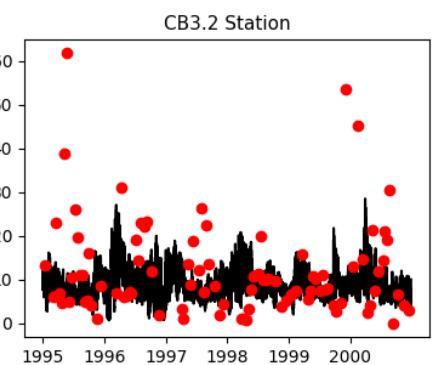
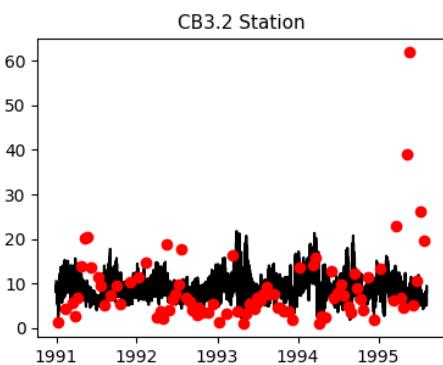


Elevation, Temperature, Salinity, DO, **ChlA**, TN, TP, TSS

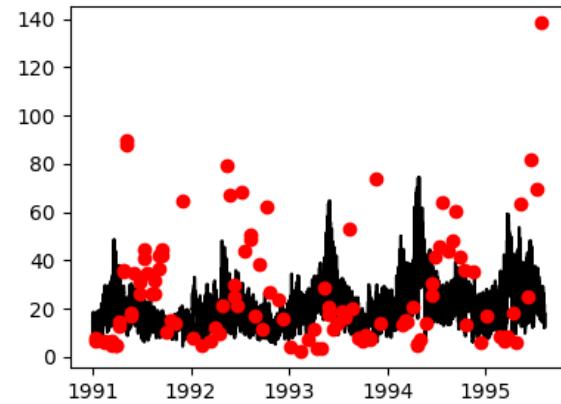
CHLA

— modeled ● observed

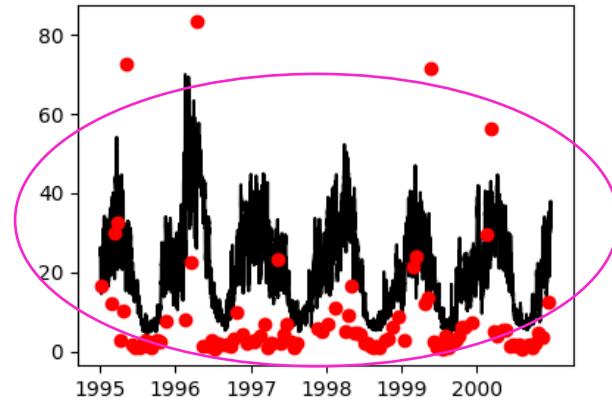
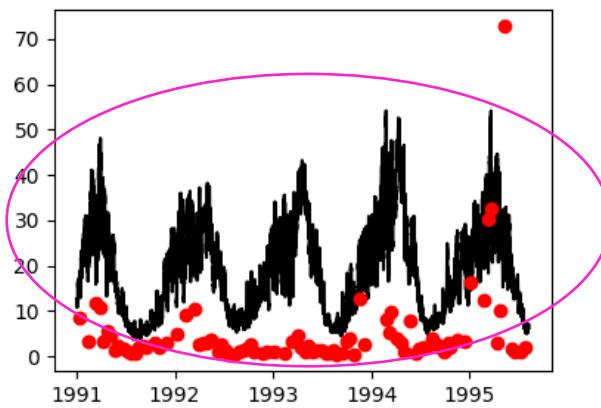
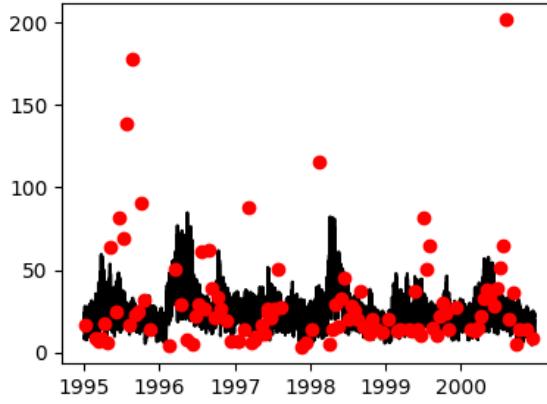




WT5.1 Station



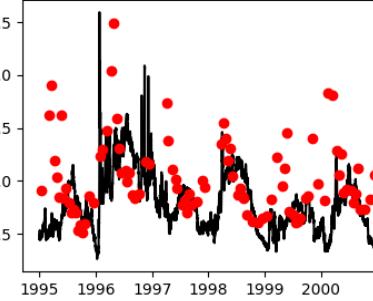
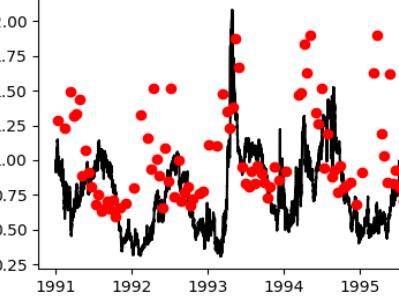
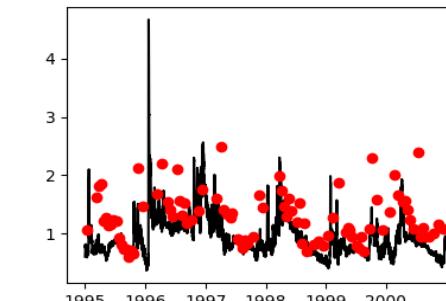
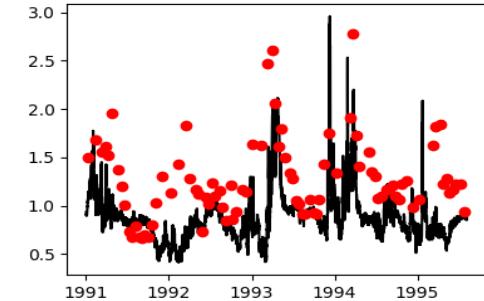
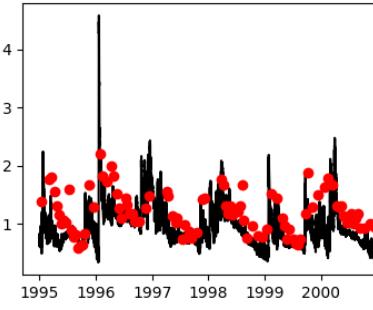
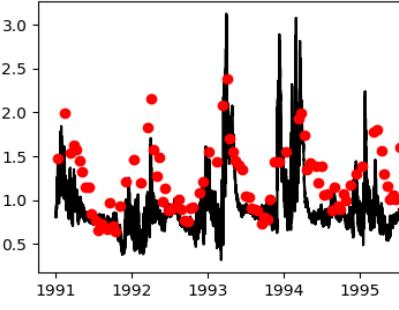
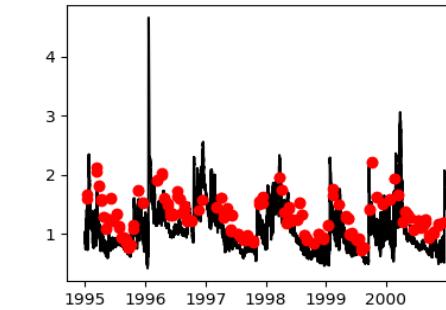
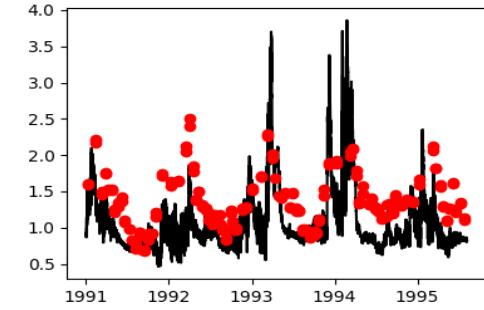
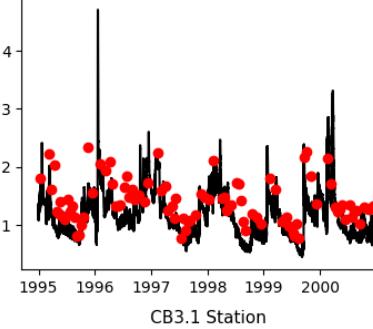
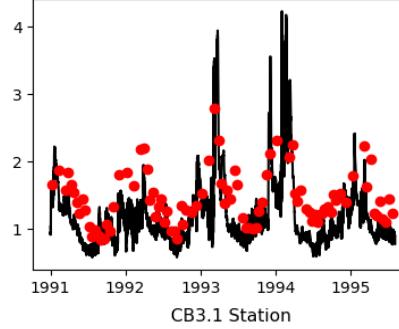
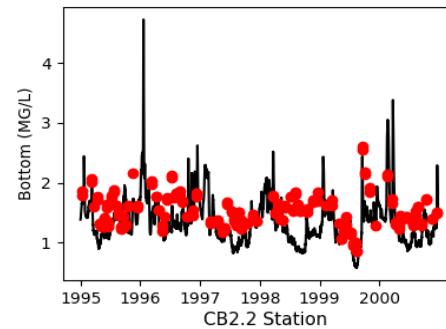
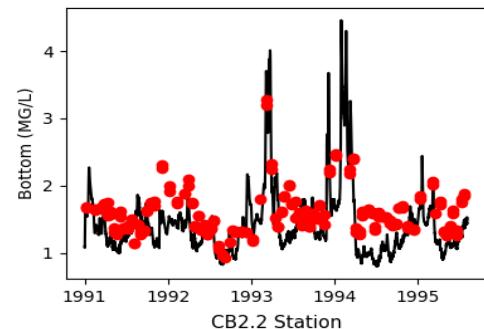
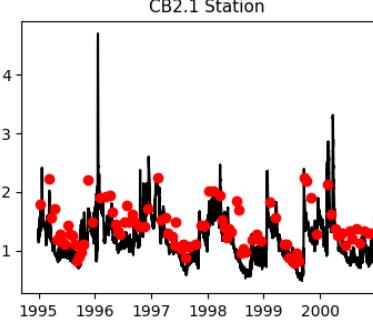
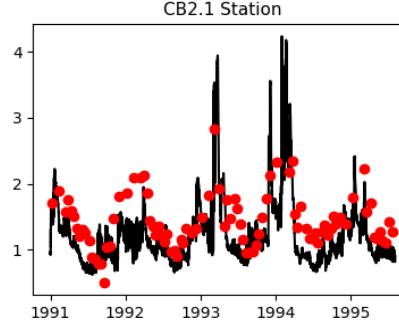
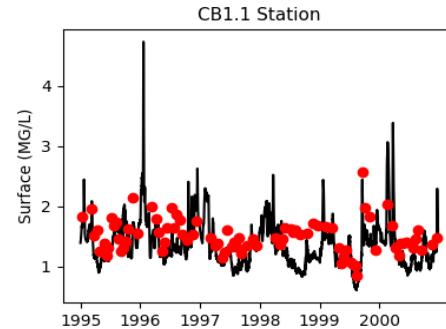
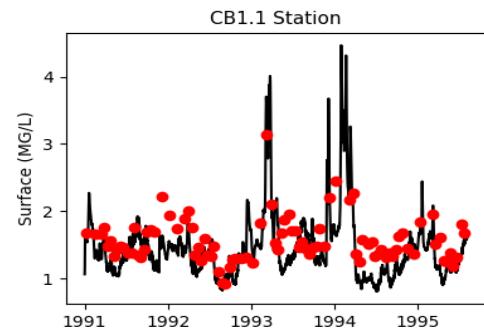
WT4.1 station

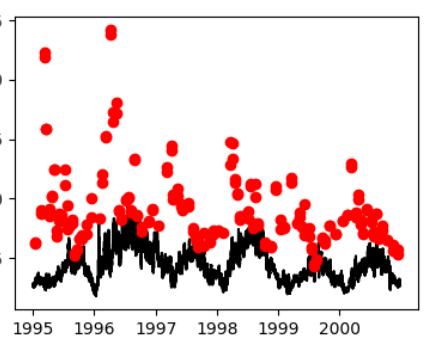
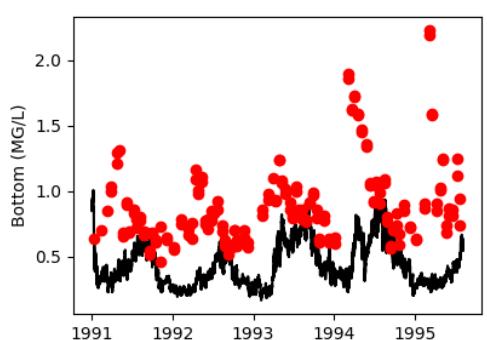
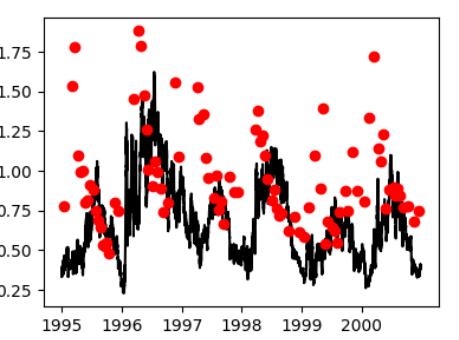
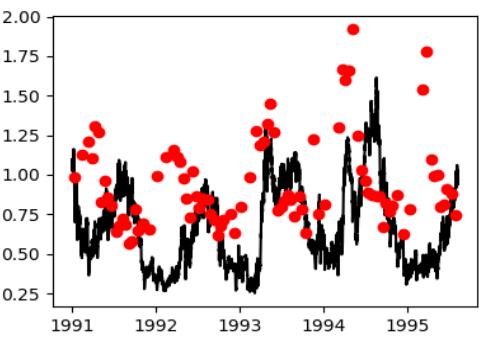
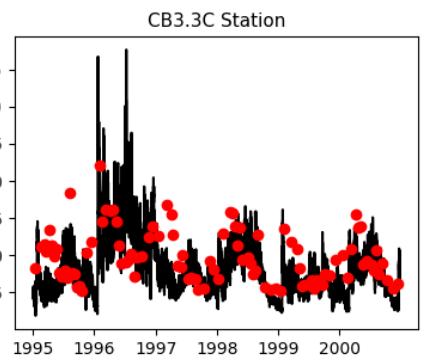
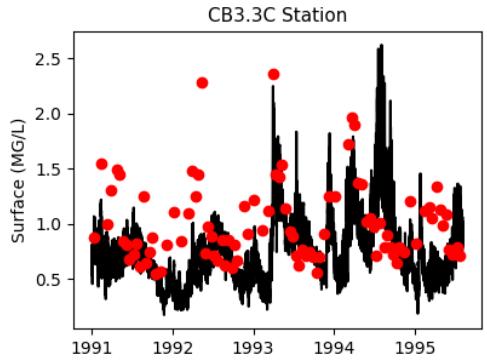
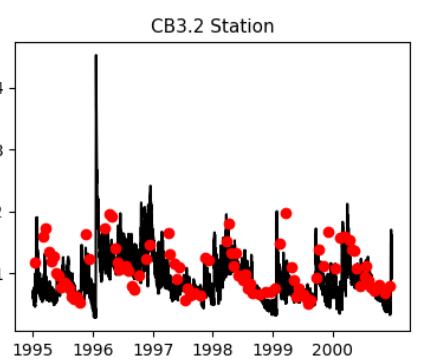
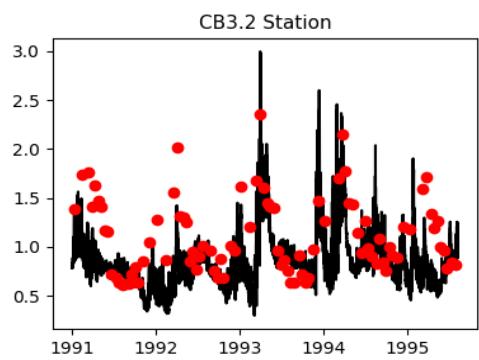


Elevation, Temperature, Salinity, DO, ChlA, **TN**, TP, TSS

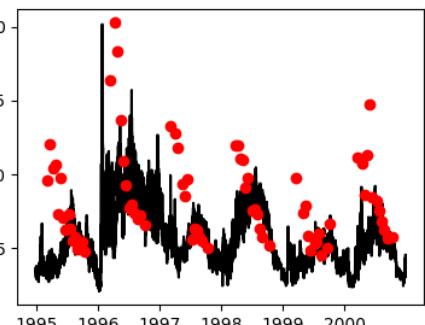
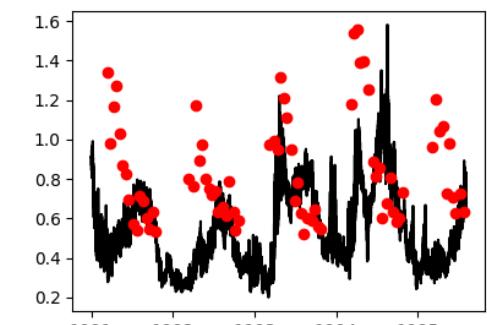
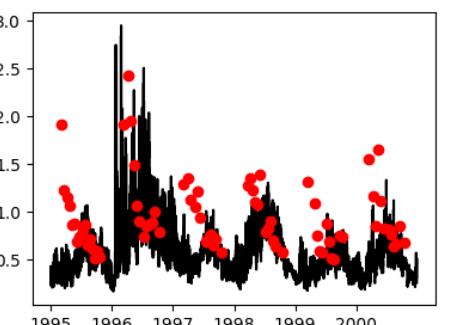
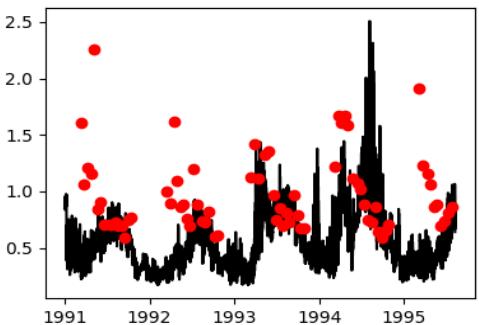
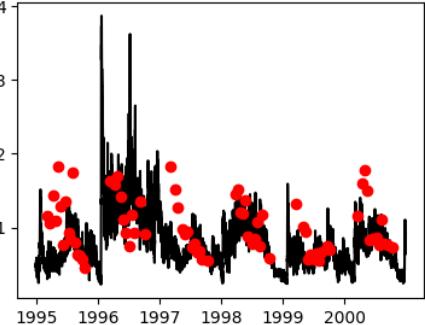
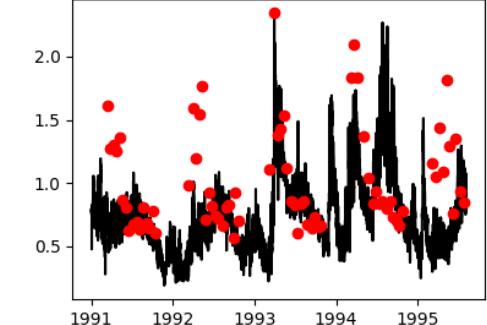
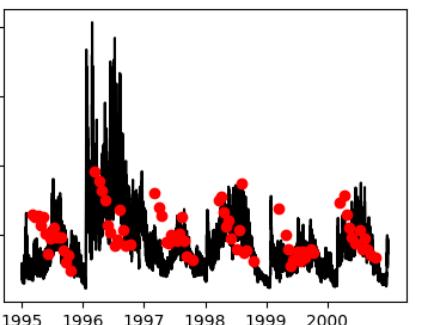
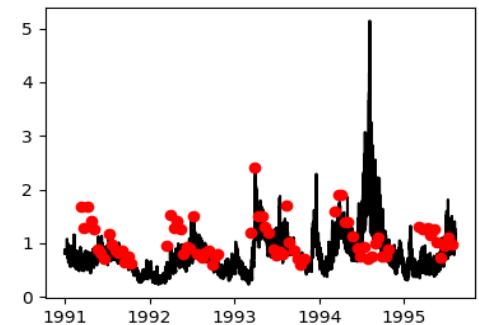
TN

— modeled ● observed

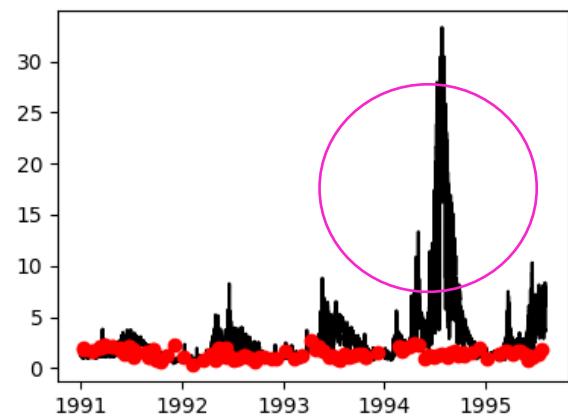




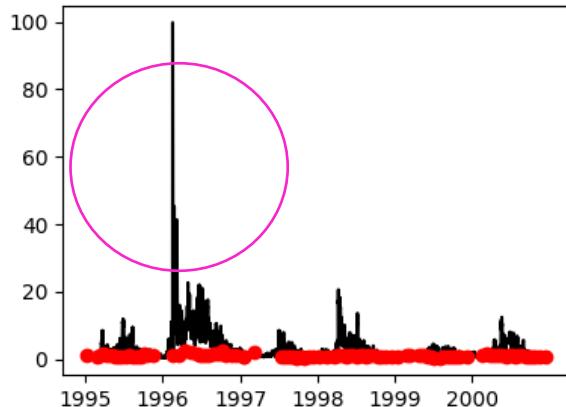
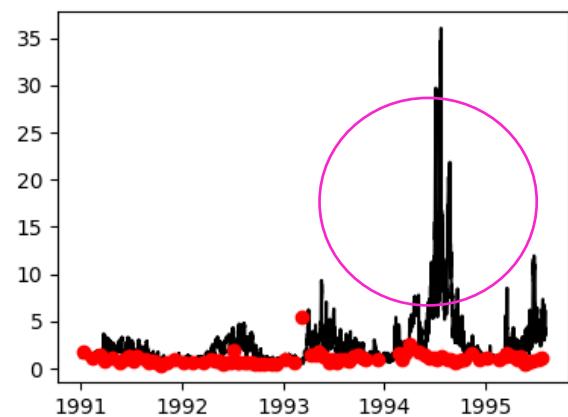
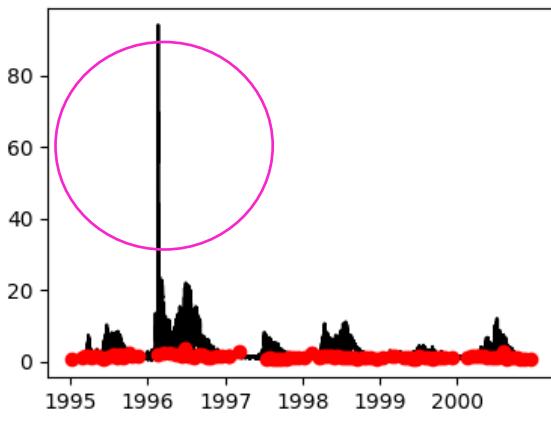
CB3.3W Station



WT5.1 Station



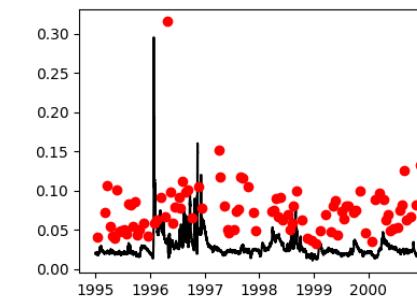
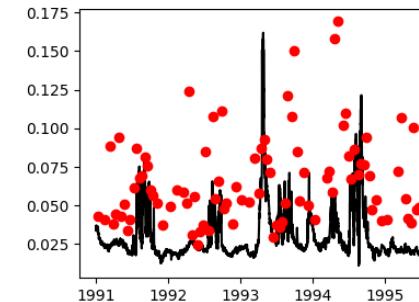
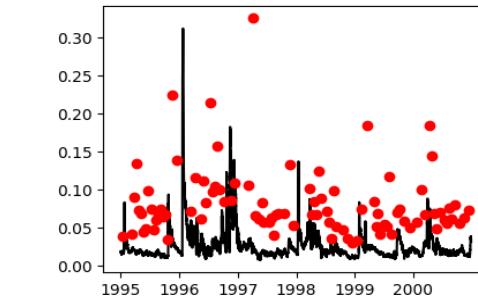
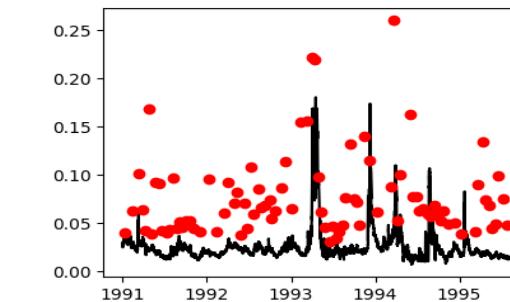
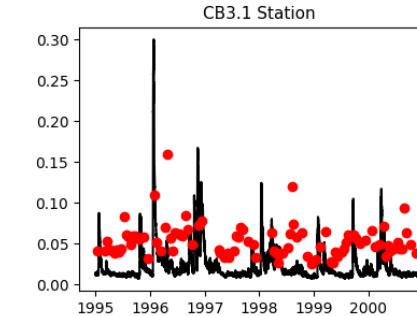
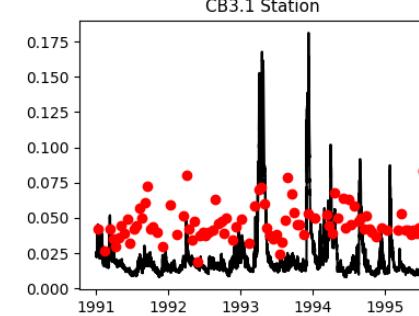
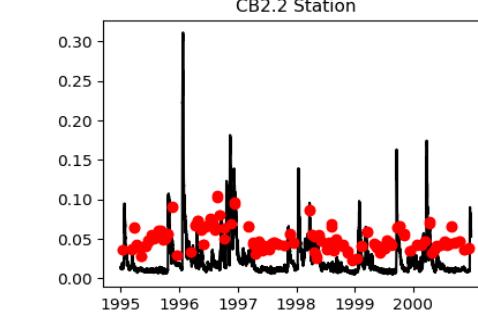
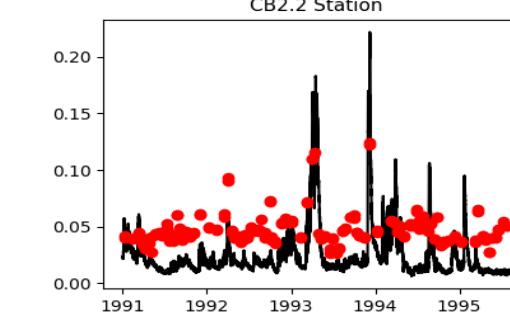
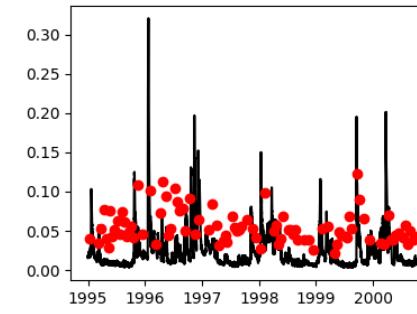
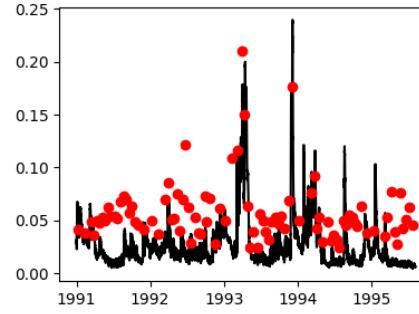
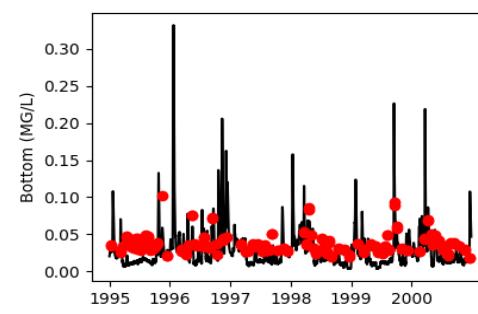
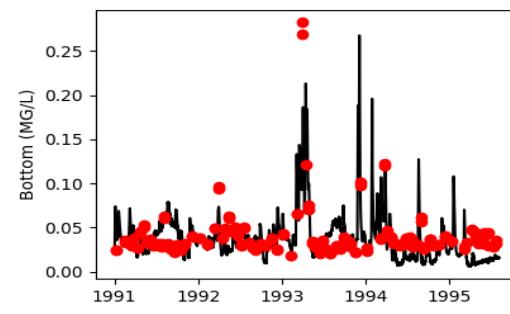
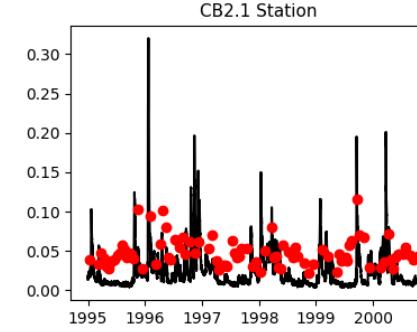
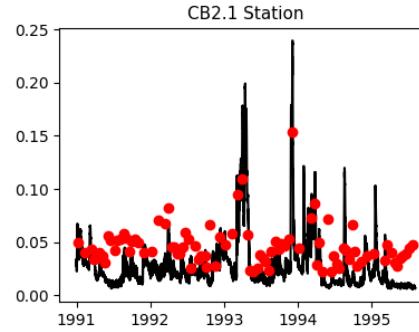
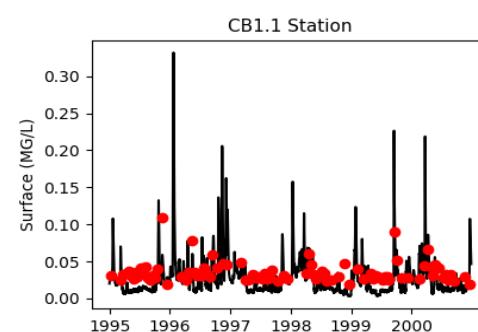
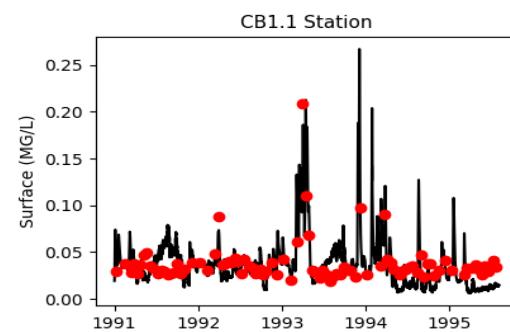
WT4.1 station

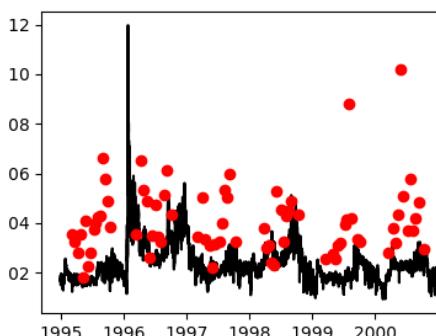
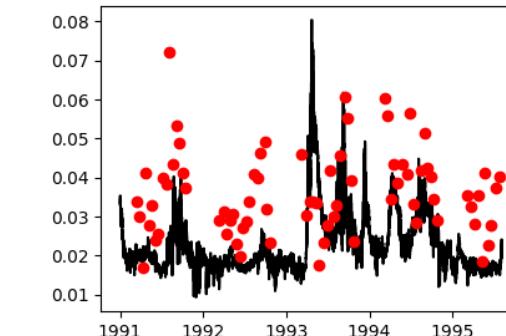
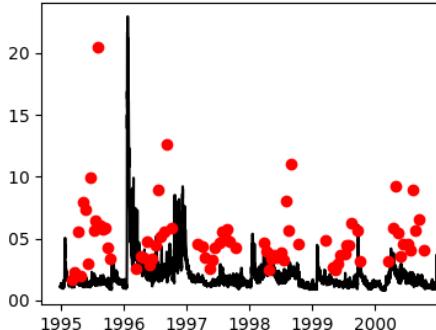
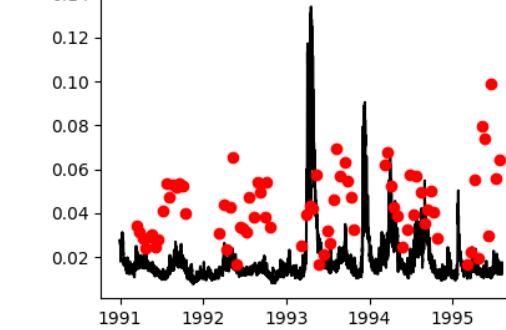
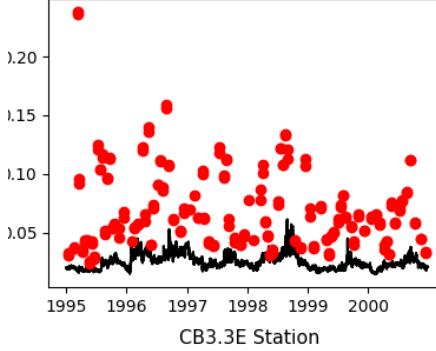
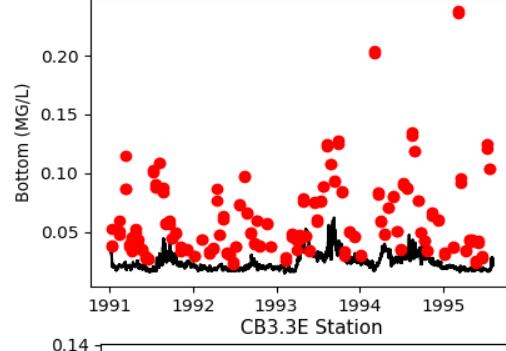
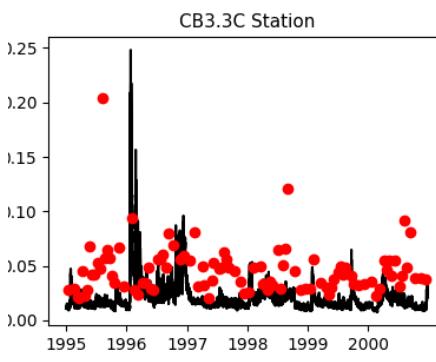
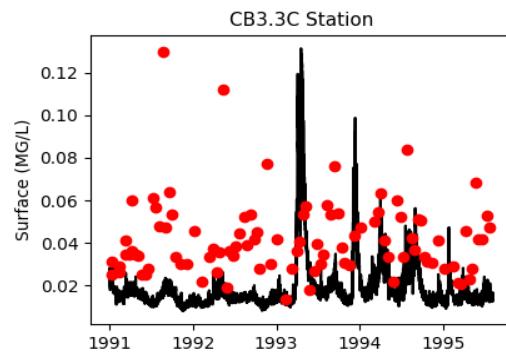
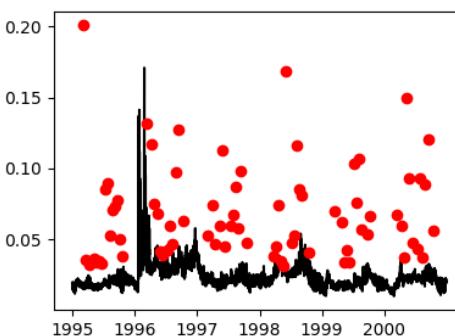
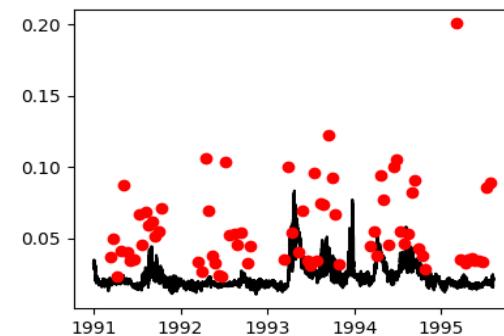
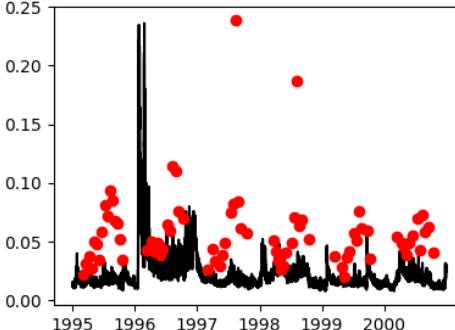
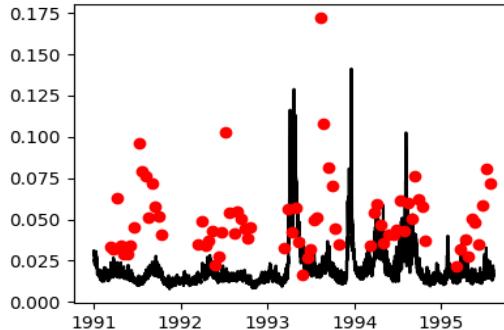
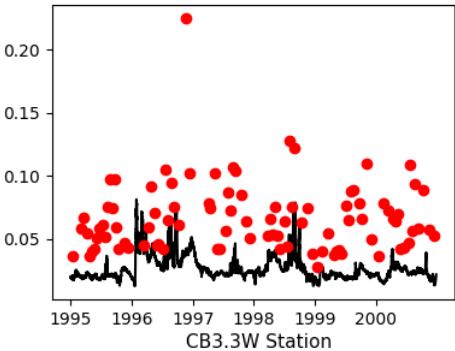
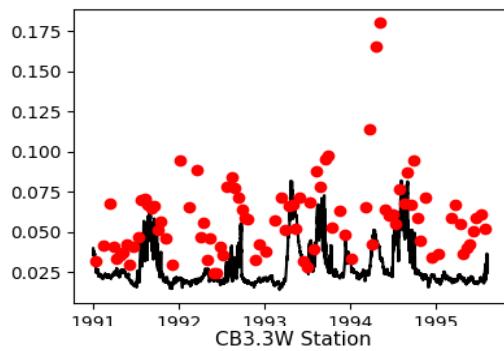
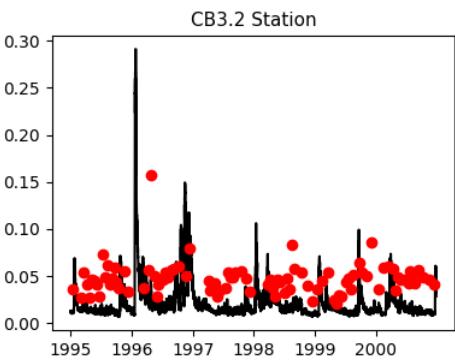
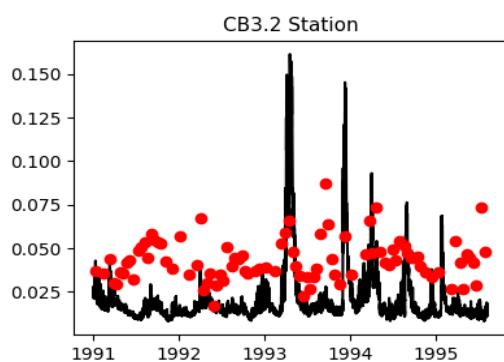


Elevation, Temperature, Salinity, DO, ChlA, TN, TP, TSS

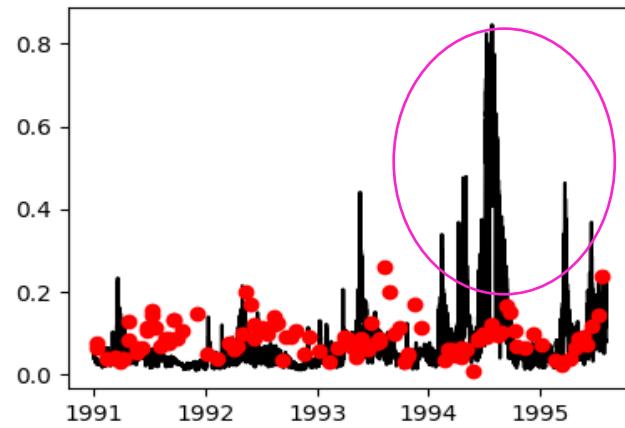
TP

— modeled ● observed

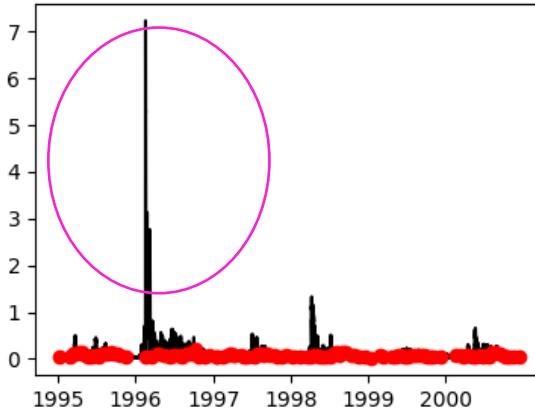
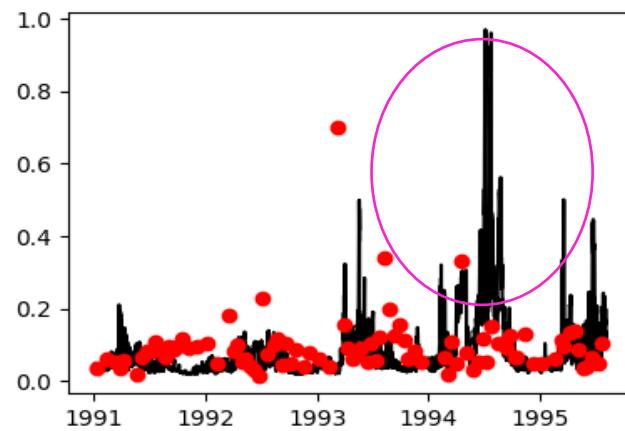
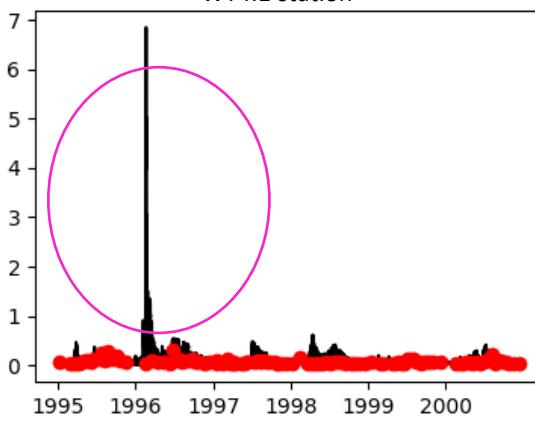




WT5.1 Station



WT4.1 station

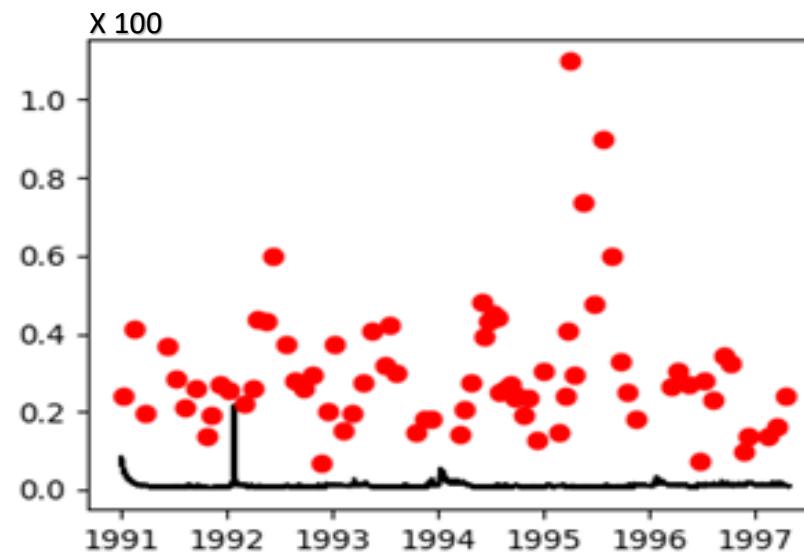
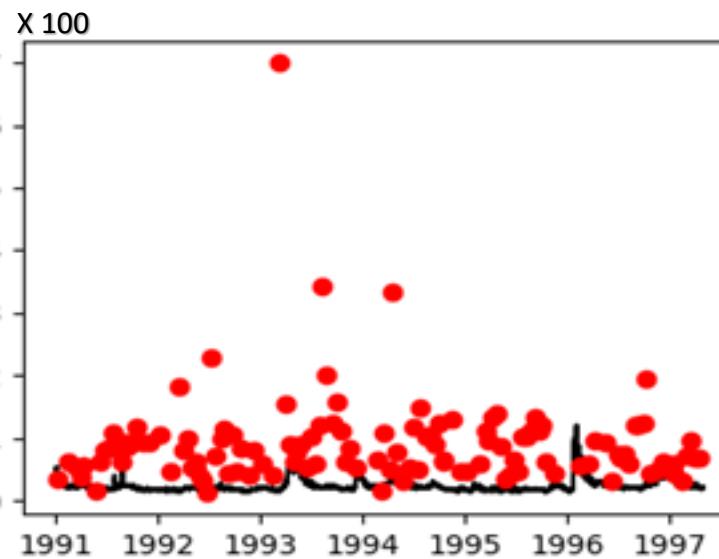
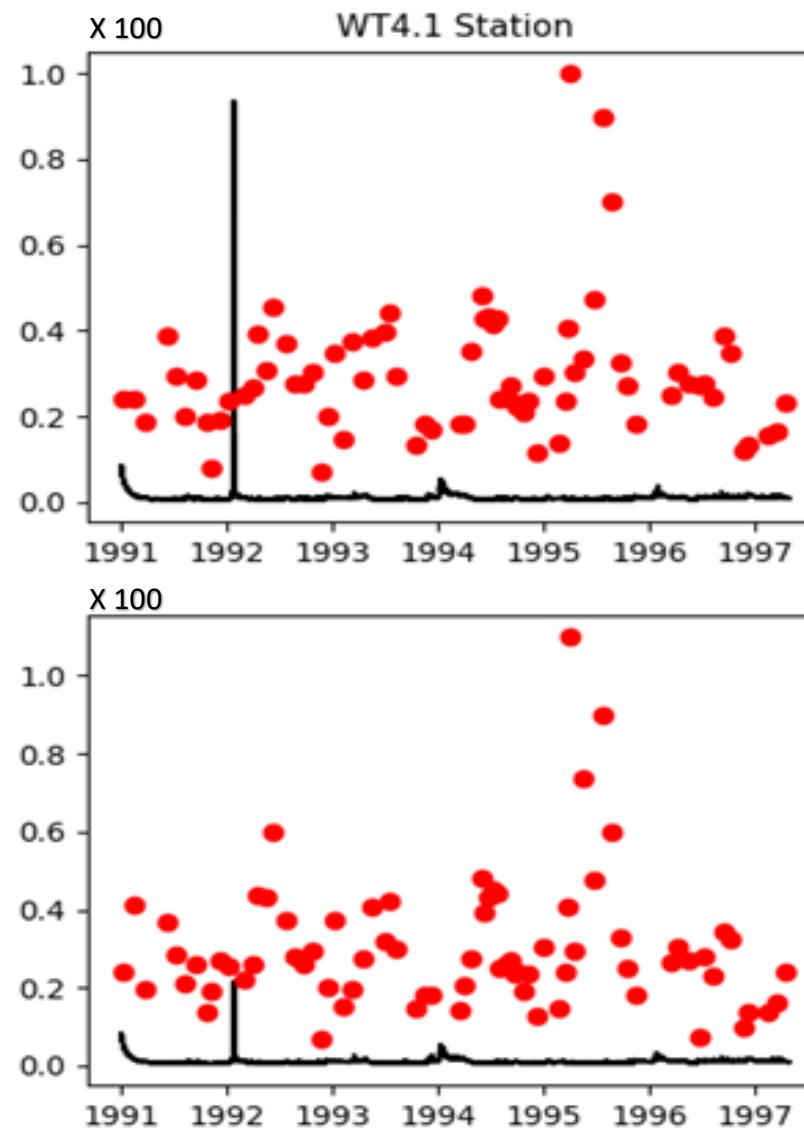
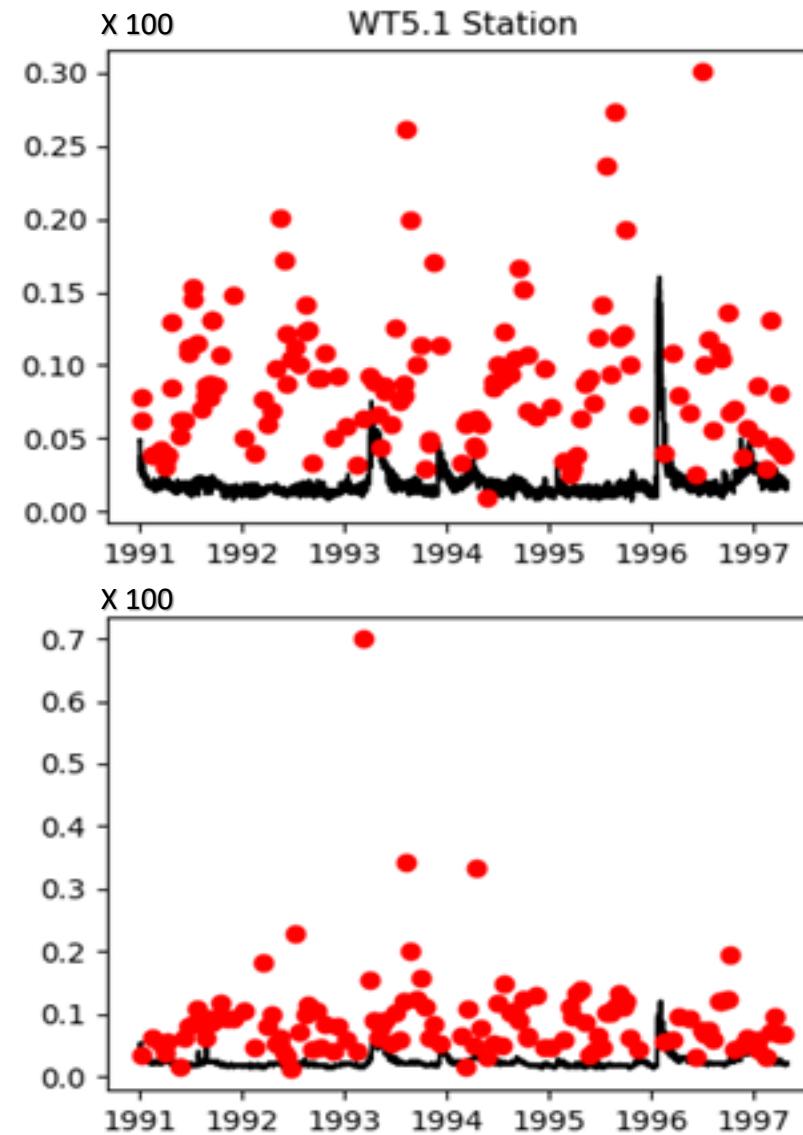


IV. Iterative calibration using ISS and VSS for TSS calibration

Critical shear stress is NOT a spatial-varying variable, rather it depends on sediment classes (see table). The sediment bed fraction (classes) in each grid cell, on the other hand, can be specified differently in different regions

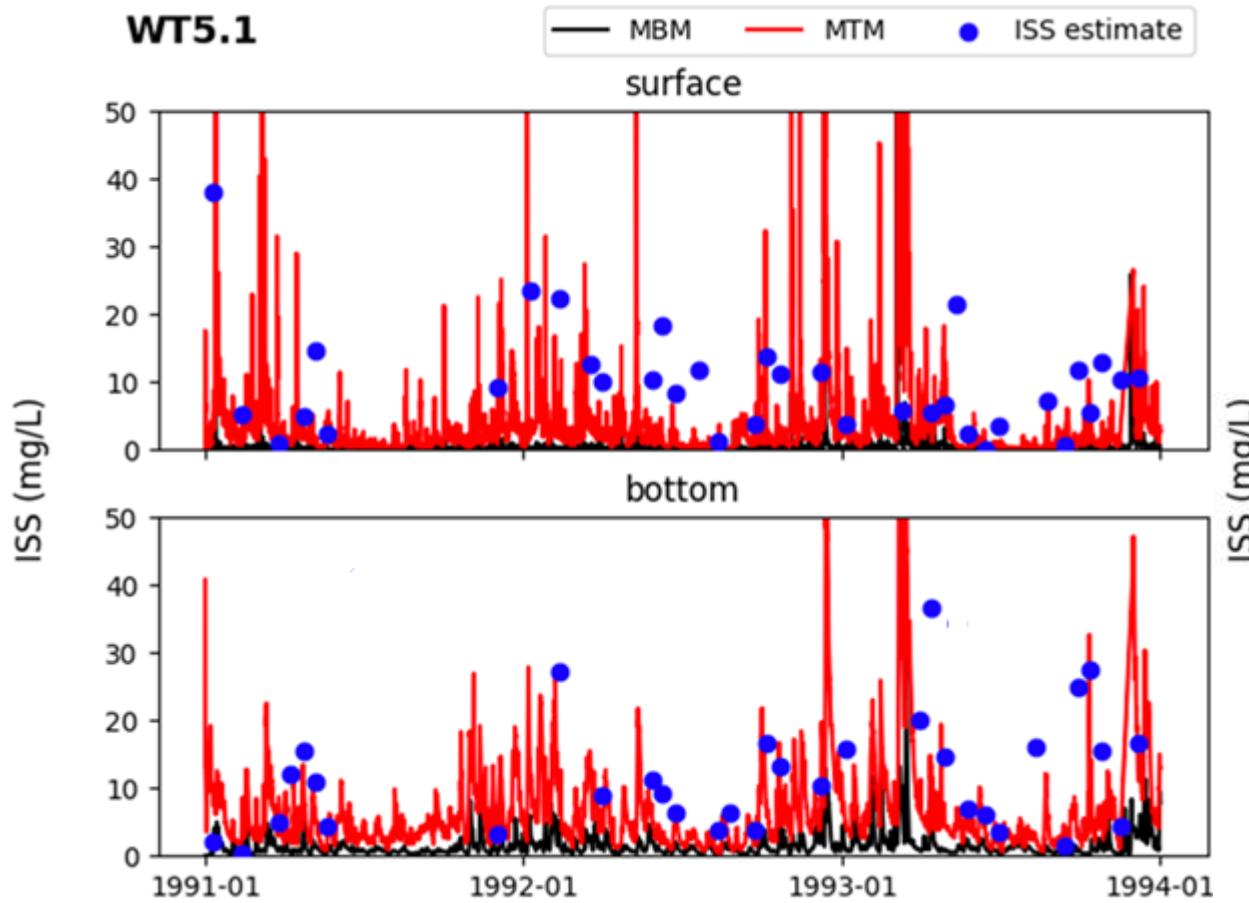
Sed. classes	Grain diameter (mm)	Particle settling velocity (mm/s)	Critical shear stress for erosion (pa)
Class 1	0.003	0.010	0.010
Class 2	0.003	0.03	0.02
Silt	0.003	0.1	0.03
Sand	0.3	1.0	20

Sediment bed fraction / Region applied	Baltimore Harbor (channel)	Baltimore Harbor (shoal)	Back River	Rest of Upper Chesapeake Bay
Class 1	80%	40%	40%	(follow MBM specification)
Class 2	10%	25%	25%	
Silt	5%	30%	30%	
sand	5%	5%	5%	



The formula used:

Sed. Class	Grain Diameter (mm)	Particle Settling Vel. (mm/s)	Critical Shear Stress for Erosion (Pa)
Class 1: Clay	0.003	0.012	0.03
Class 2: Clay	0.003	0.03	0.03
Class 3: Silt	0.03	0.1	0.03
Class 4: Sand	0.3	1.0	20

WT5.1**surface:**

MBM RUN11fb ISS mean: 0.449, max: 69.731

MTM RUN04c ISS mean: 3.699, max: 1177.607

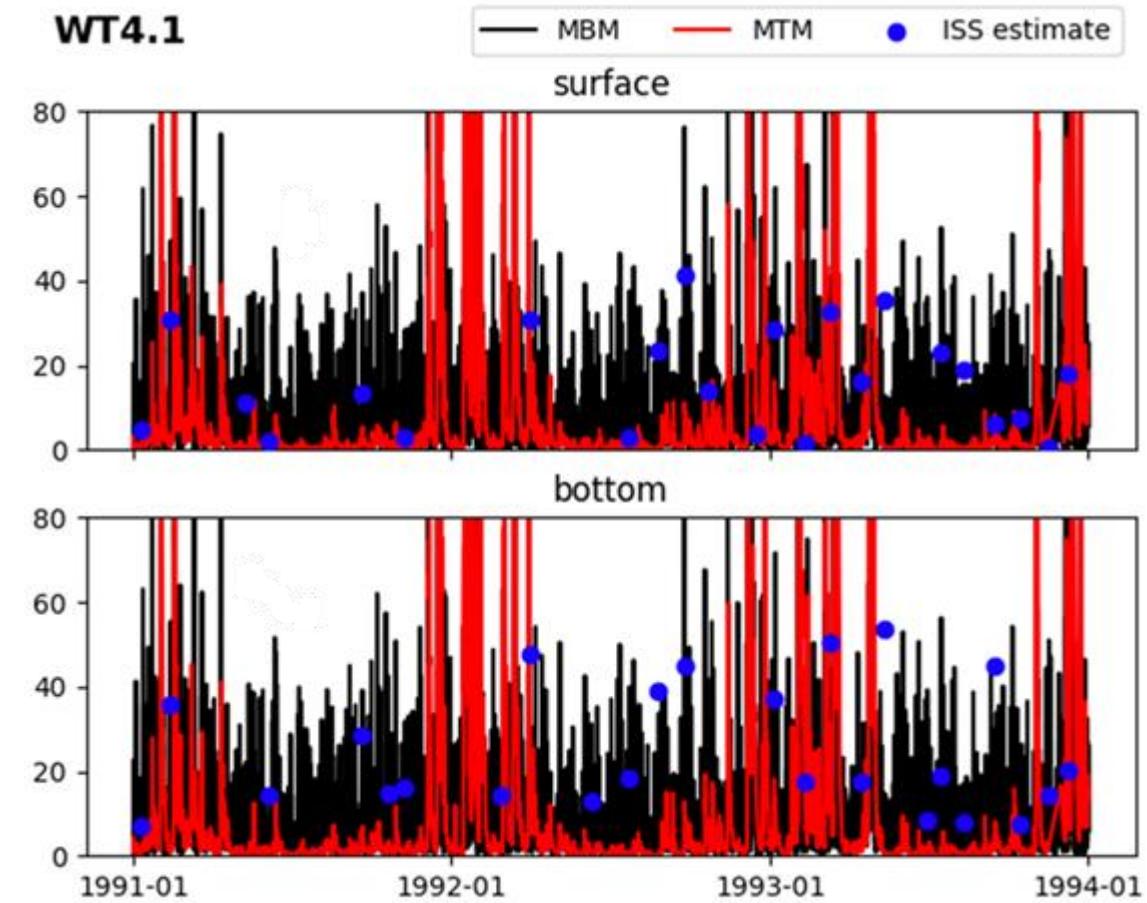
Obs ISS est. mean: 10.116, max: 38.14

bottom:

MBM RUN11fb ISS mean: 1.564, max: 40.449

MTM RUN04c ISS mean: 6.547, max: 83.342

Obs ISS est. mean: 19.428, max: 107.792

WT4.1**surface:**

MBM RUN11fb ISS mean: 8.524, max: 595.343

MTM RUN04c ISS mean: 9.098, max: 772.305

Obs ISS est. mean: 17.588, max: 53.48

bottom:

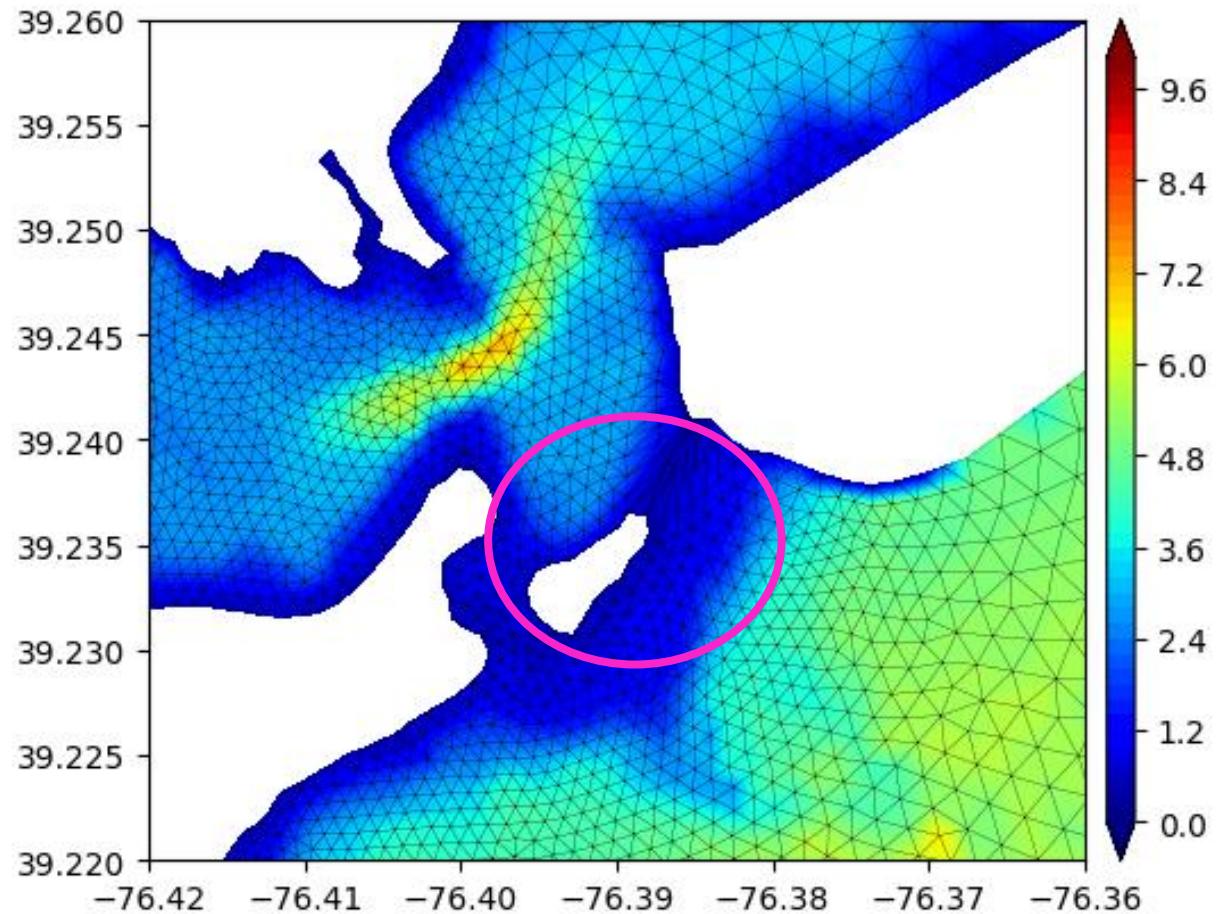
MBM RUN11fb ISS mean: 10.813, max: 653.472

MTM RUN04c ISS mean: 10.784, max: 435.175

Obs ISS est. mean: 27.506, max: 66.121

RUN04ca ISS Results

- RUN04c, with our adjusted hgrid and vgrid (almost no spit at Hart Miller Island)





Computer shut down for cooling system
maintenance !!

We do not have time to run full water quality
model this time, but will next time with upgrade
to Phase 7.

V. Summary

1. A methodology was developed enabling estimation of Inorganic Suspended Solids (ISS) from monitoring data. This is critical in that it allows the calibration of TSS to be transformed into a linear, sequential process, substantially reducing calibration time and effort, especially for the complex sediment environment such as Patapsco/Back Rivers in MTM, which requires iterative calibration.
2. Example of under-calibration of TSS was presented. It takes two weeks to run physical model (in a queue), save the results, and use it to drive water quality model (wait for another queue) to finally obtain the results, a laborious procedure.
3. Example of over-calibration of TSS was presented. In comparison with the under-calibration case, it demonstrates that TSS links hydrodynamics, sediment transport, and the biogeochemistry of the benthic sediment and pelagic processes. It influences water column's light and, as a results, modeling of oxygen, TN, and TP results were all affected.
4. By decoupling ISS and VSS, the inherently nonlinear calibration, previously complicated by parameter interactions, can be restructured into a straightforward, linear sequence. This strategy significantly accelerates calibration while minimizing effort, offering a practical solution for challenging sediment environments. It should enhance our ability for further calibration of MTM Patapsco/Back Rivers hydro/WQ model, in which phase 7 watershed loading will be used.