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

*Jeremy Testa, Harry Wang, Breanna Maldonado, and David Forrest

Virginia Institute of Marine Science, William and Mary
Gloucester Point, VA 23062
Ph: 804-684-7215; Email: hvwang@vims.edu

**University of Maryland, Center for Environmental Science*
Chesapeake Bay Biological Laboratory
Ph: 410-326-7266; Email: jtesta@umces.edu

January 08, 2026

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?

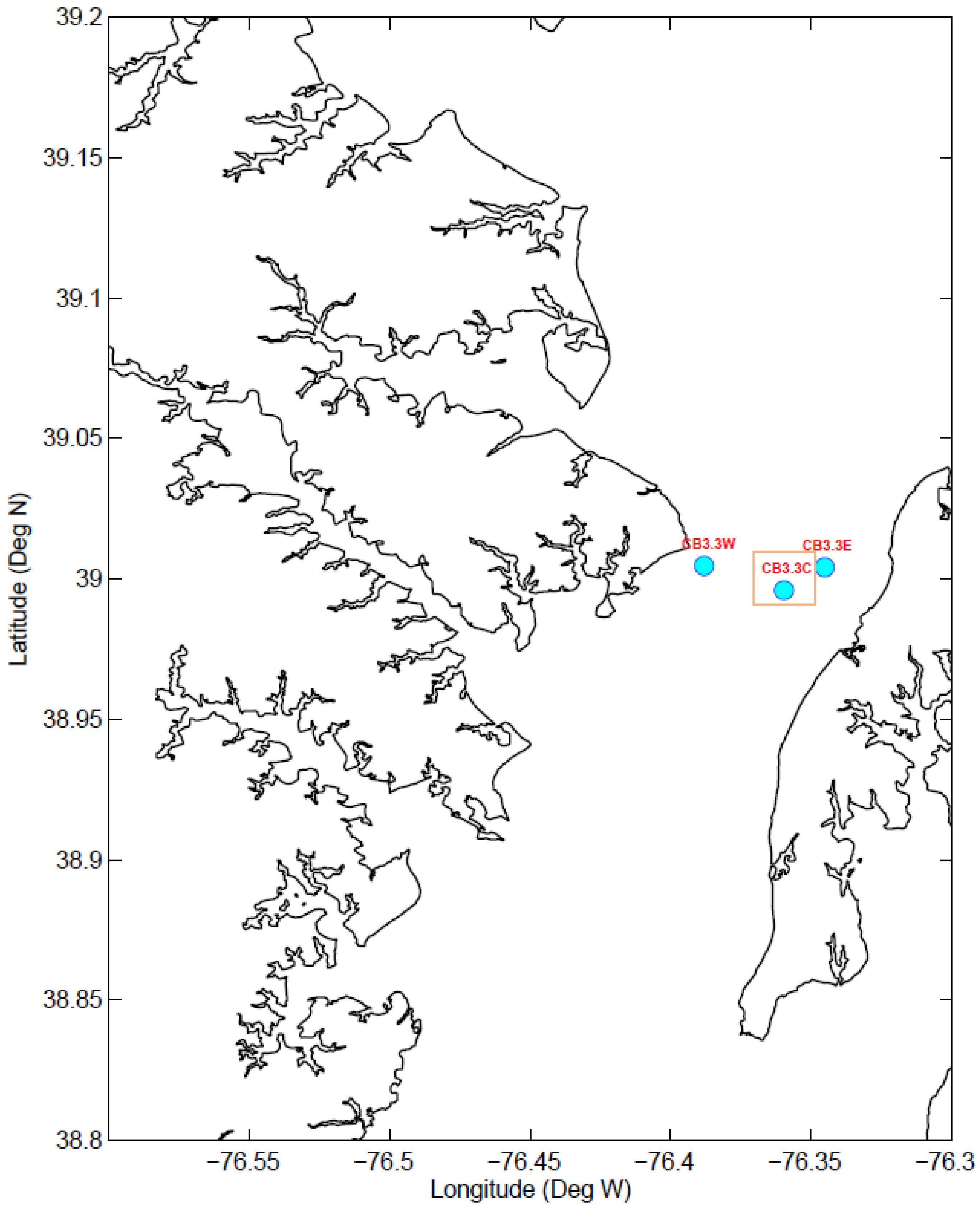
<u>CBP Monitoring program collects three relevant variables:</u>

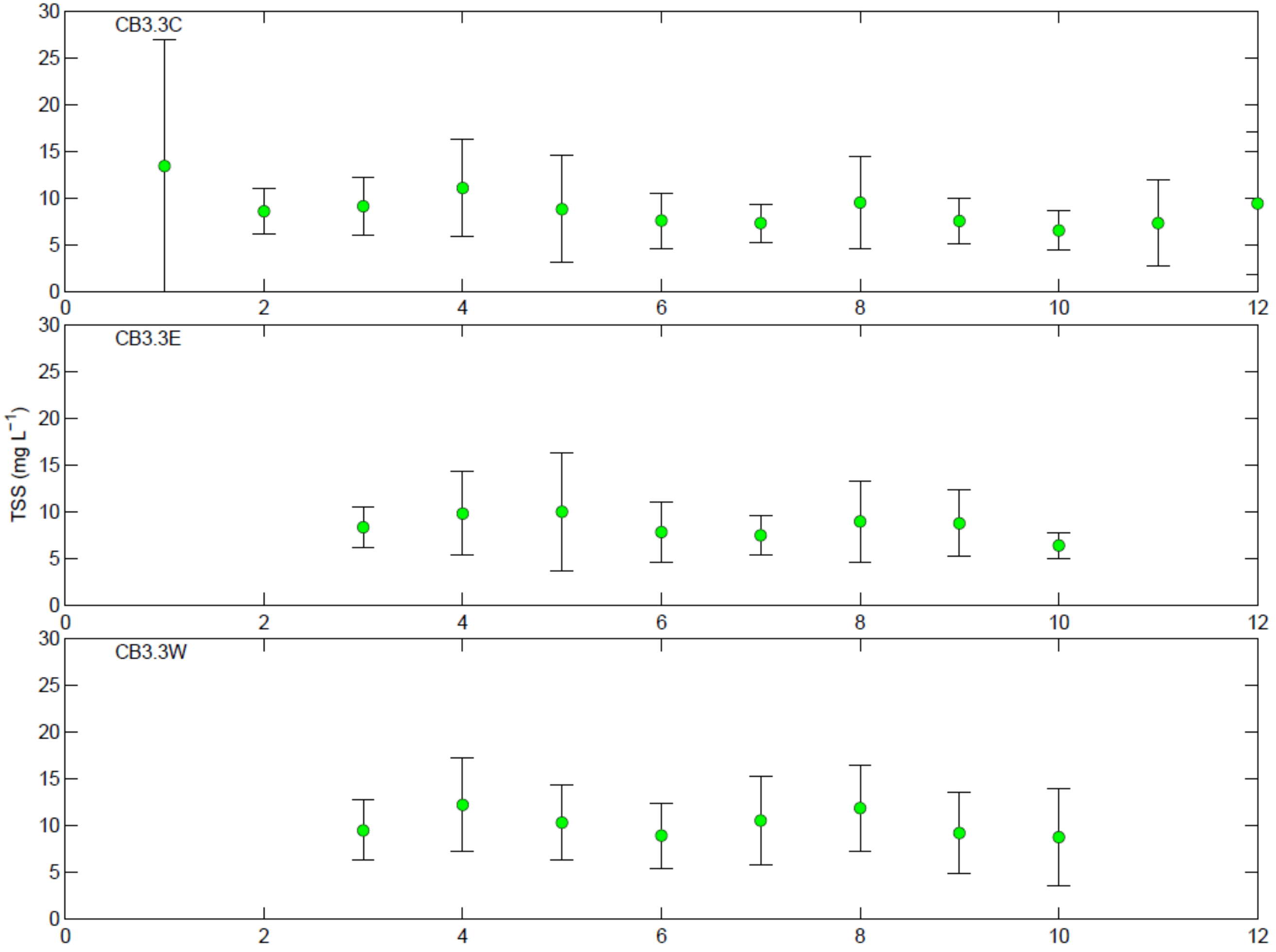
TSS = total suspended solids = inorganic plus organic material. Regularly measured
VSS = volatile suspended solids = solids that combust (organic) Rarely measured
PC = particulate carbon = concentration of particulate carbon (in CB, ~organic) Regularly measured

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

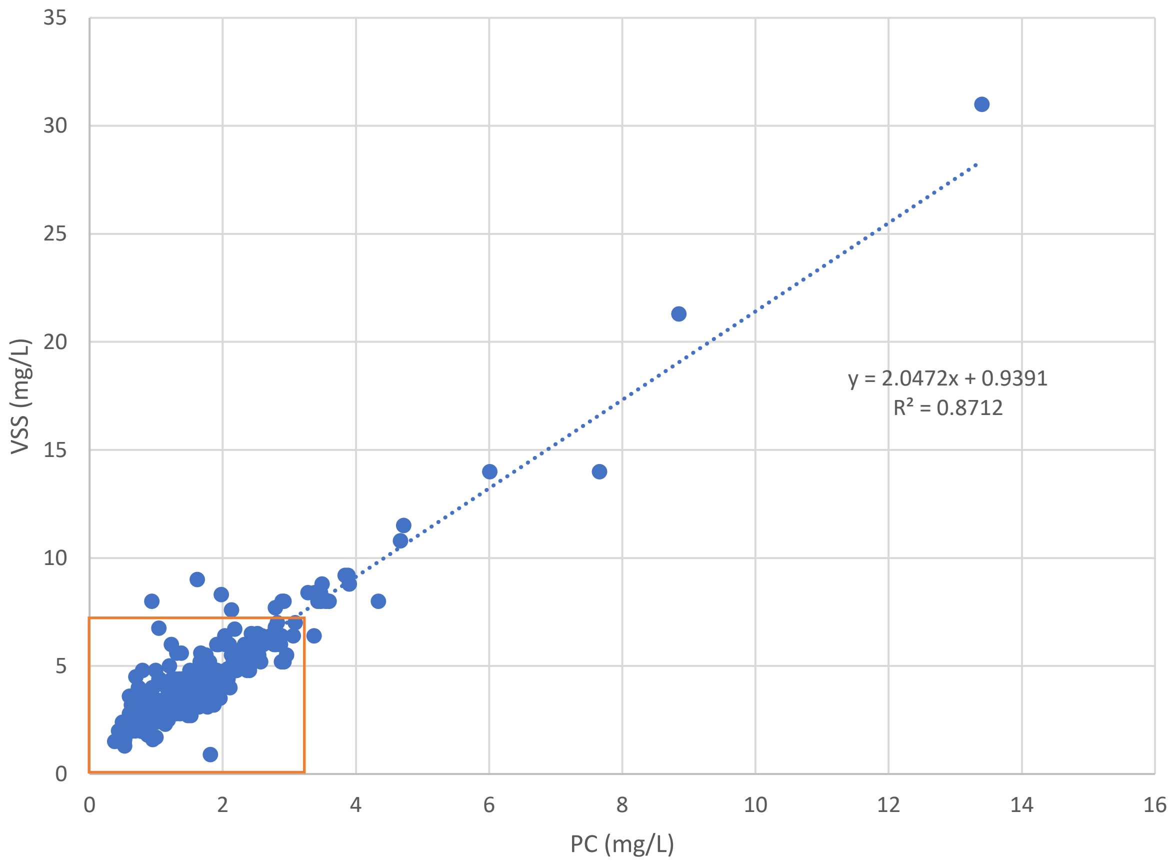
ISS = TSS – VSS

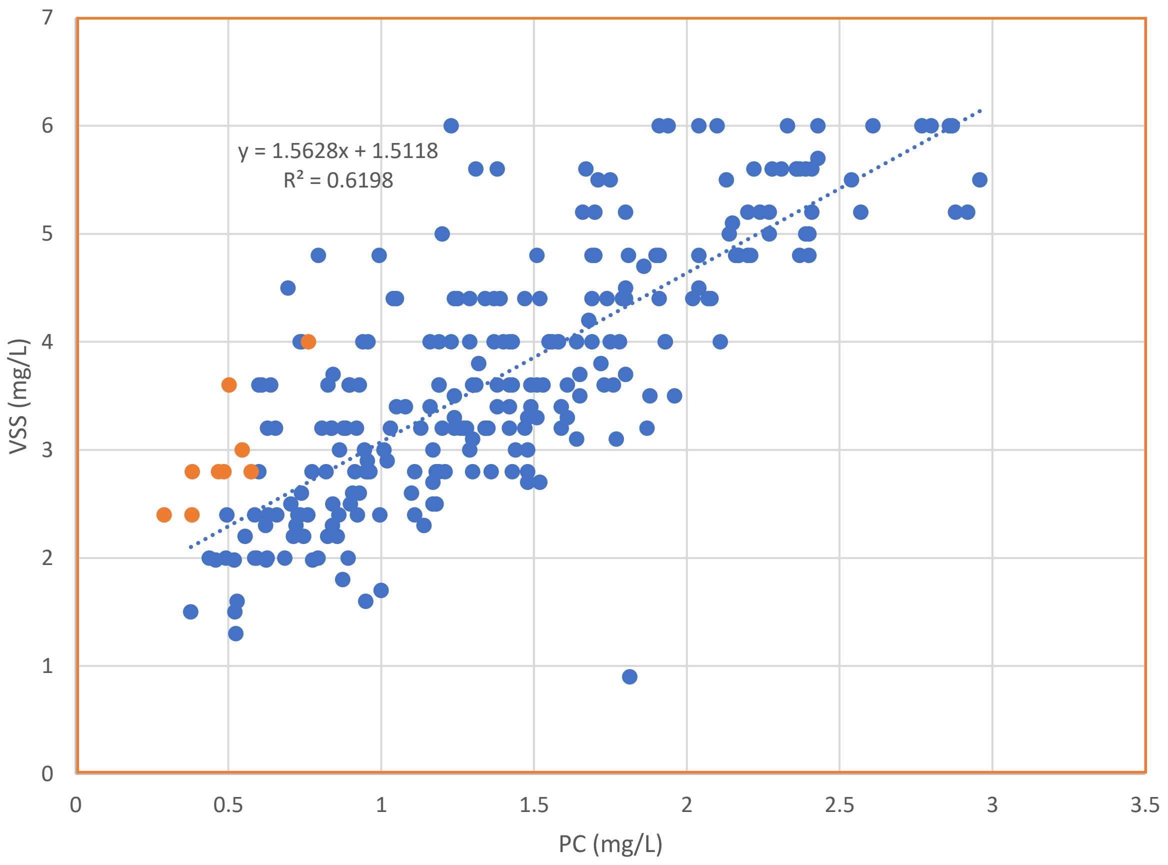
Relevant TSS, PC and VSS Data





Estimating VSS from PC at CB3.3C

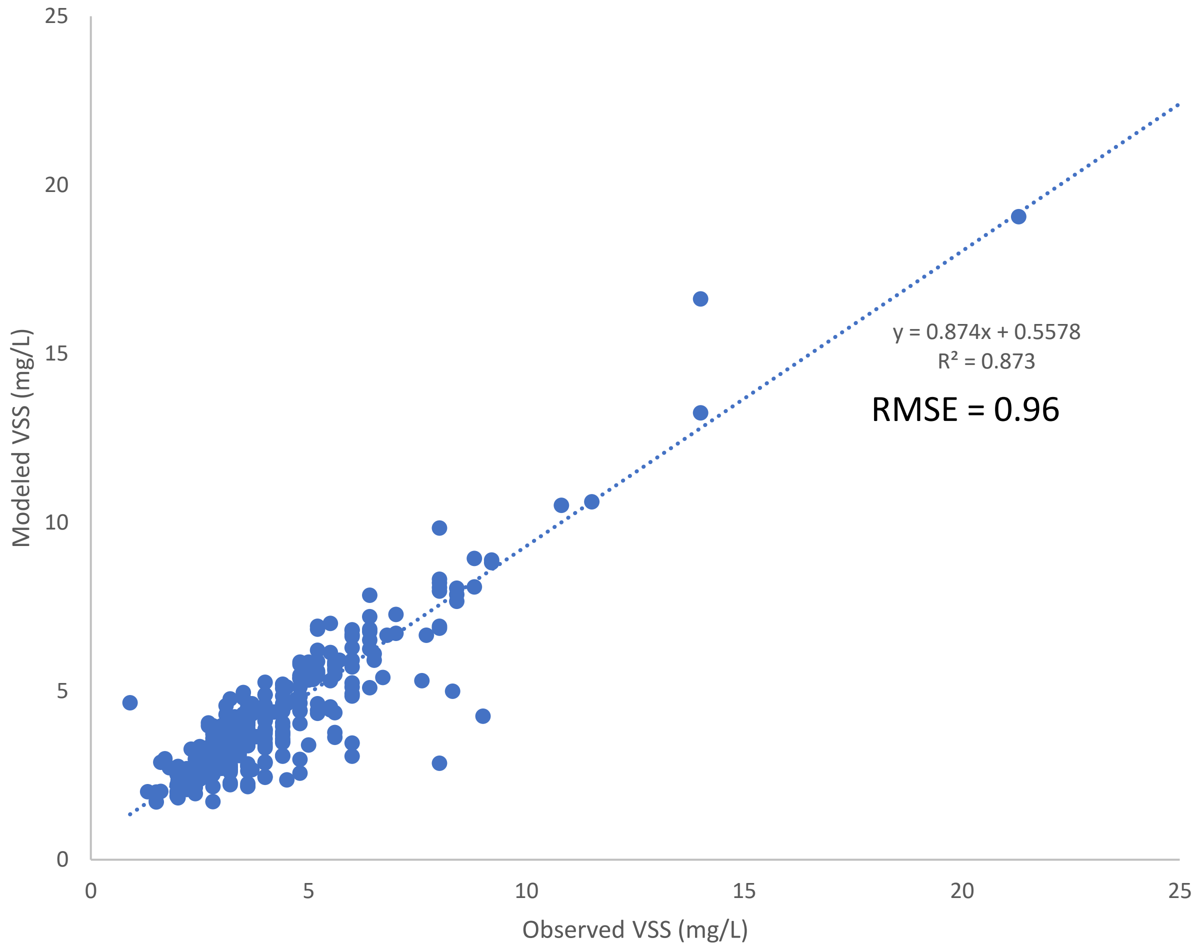


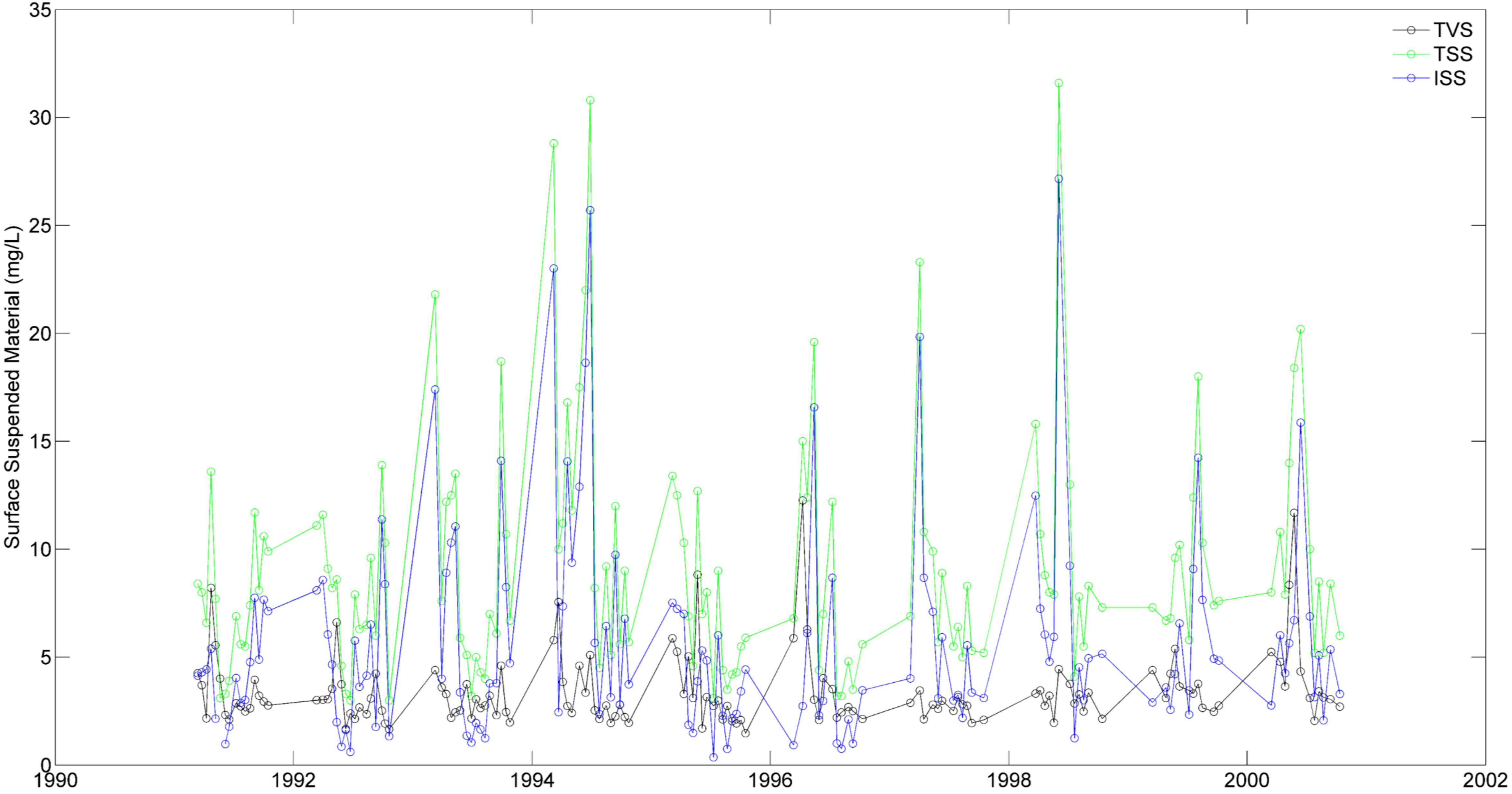


Paired TSS, VSS, and PC measurements made from 1998 to 2020 at CB3.3C in the surface layer, and on September 17, 2018 at all depths. VSS is about 40% carbon.

Model for VSS

- Model skill largely relies on strong correlation between PC and VSS
- PC-based model can ‘predict’ VSS at any location
- $ISS_{est} = TSS_{obs} - VSS_{est}$





Surface Suspended Material (mg/L)
35
30
25
20
15
10
5
0
1990
1992
1994
1996
1998
2000
2002
TVS
TSS
ISS

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. Herea 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 Patapasco 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

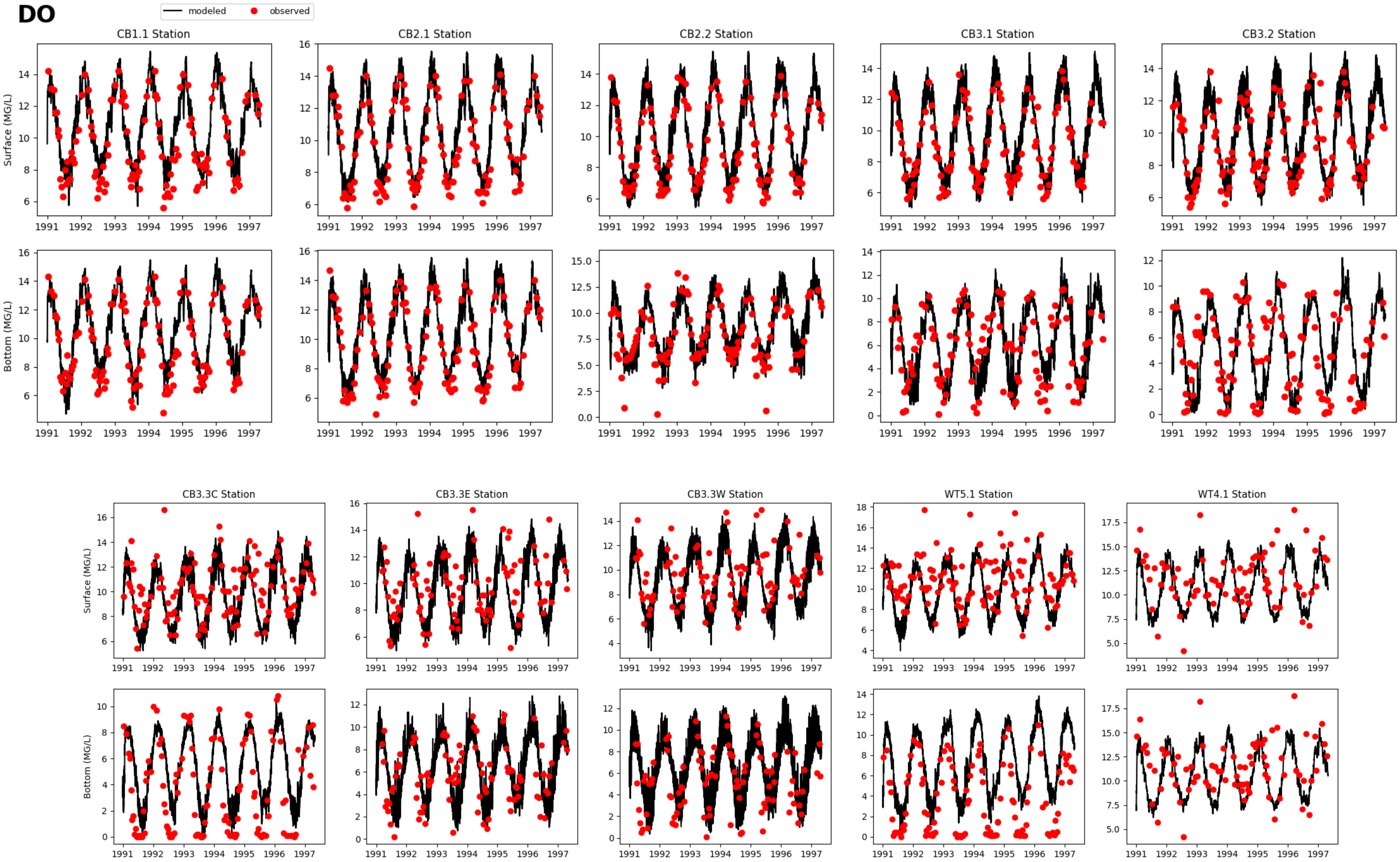
Due to continuous input of fine particulates and organic matter from the Back River WWTP and low-energy hydrodynamic conditions, Back River is dominated by very fine, organic sediment, in contrast to many estuarine systems with higher sand content. It favors fine sediment accumulation, enhanced floc 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.

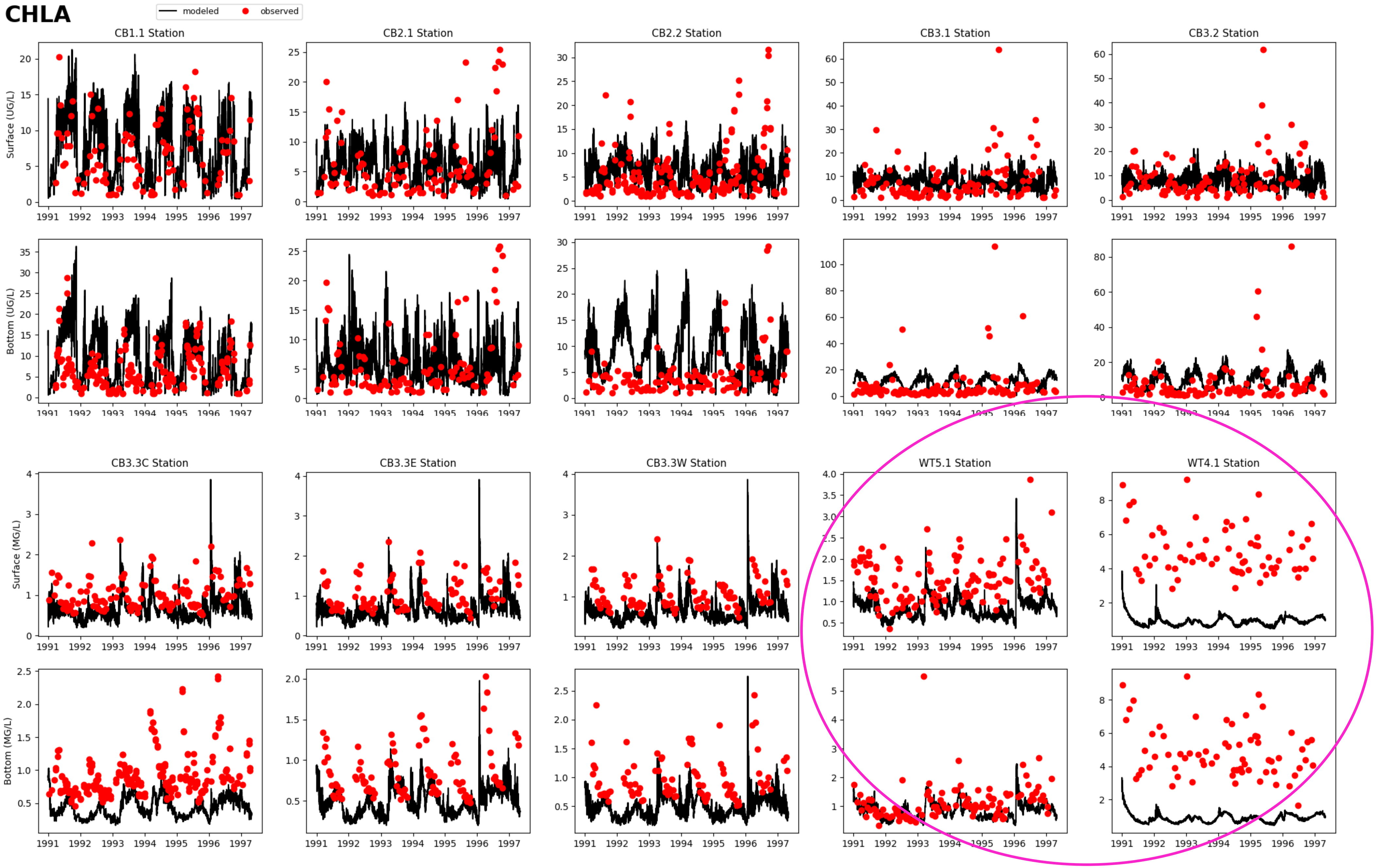
II. Calibration 1 – Under-calibration TSS in Patapsco/Back River

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.

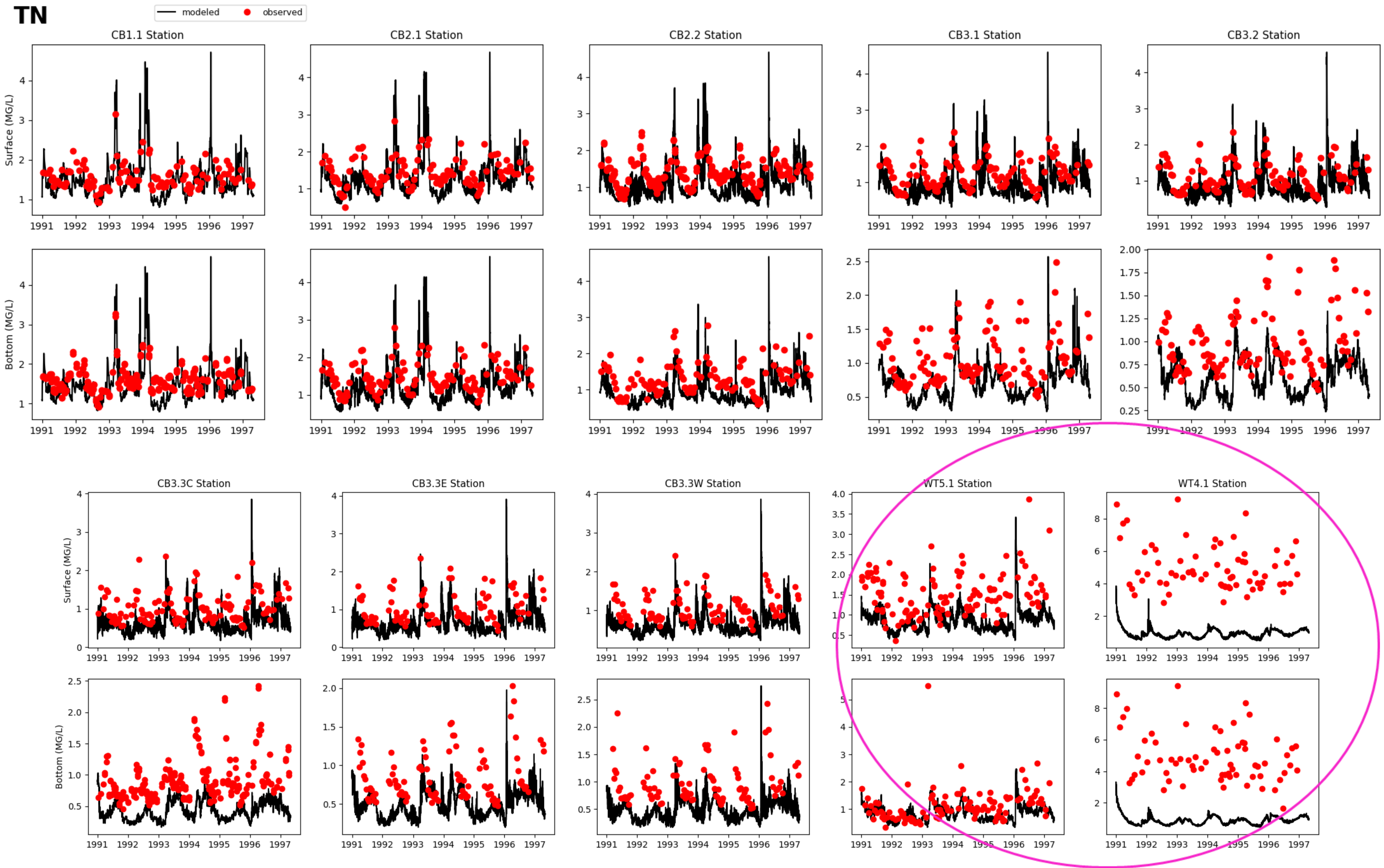
Sed. classes	**Grain diameter (mm)**	**Particle settling velocity (mm/s)**	**Critical shear stress for erosion (pa)**
Class 1	0.003	0.012	0.03
Class 2	0.003	0.03	0.03
Silt	0.003	0.1	0.03
Send	0.3	1.0	20

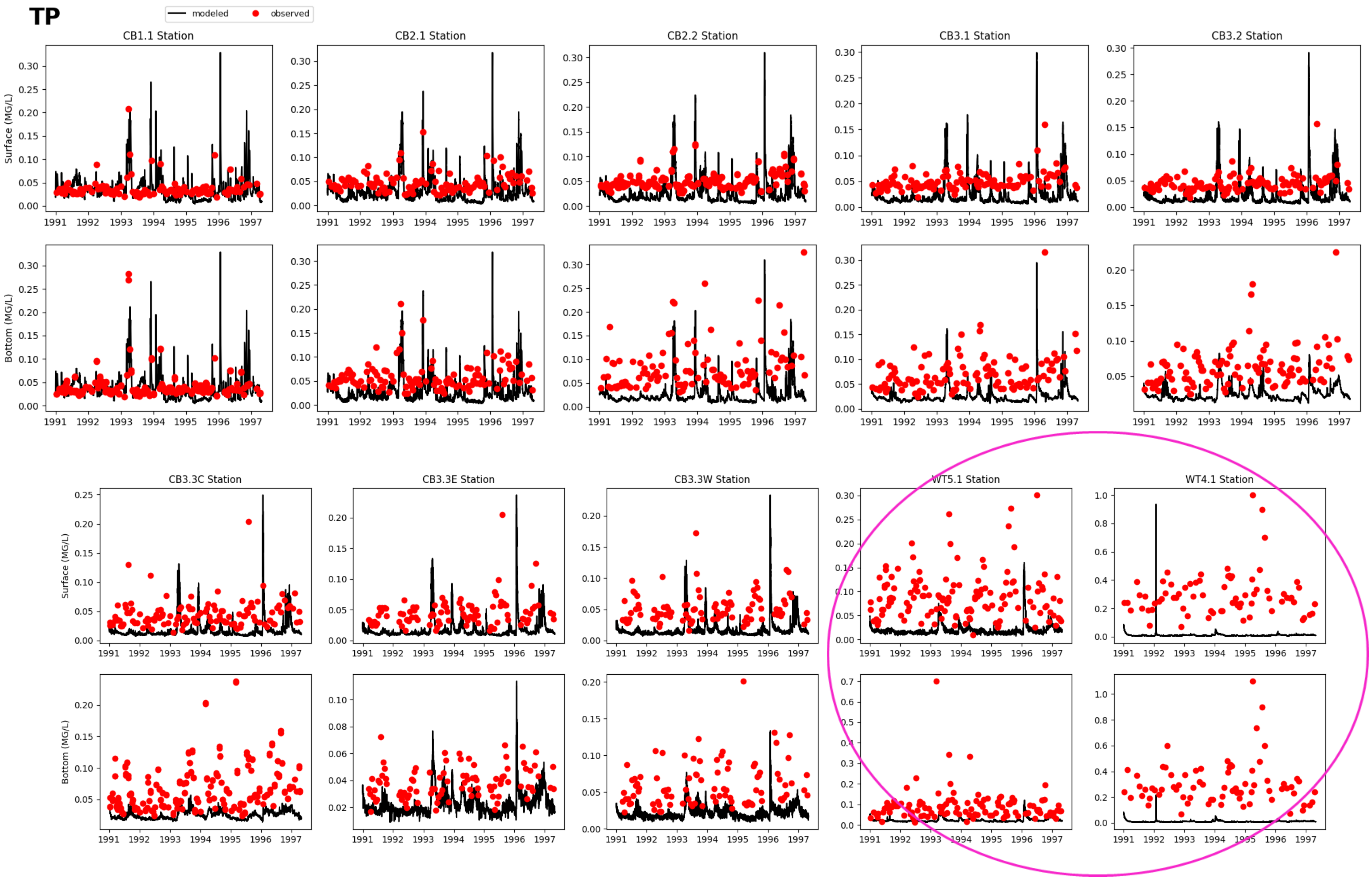
Sediment bed fraction / Region applied	Baltimore Harbor (channel)	Baltimore Harbor (shoal)	Back River	Rest of Upper Chesapeake Bay
Class 1	80%	30%	30%	(follow MBM specification)
Class 2	10%	30%	30%	
Silt	5%	35%	35%	
sand	5%	5%	5%	


DO
modeled
observed
CB1.1 Station
CB2.1 Station
CB2.2 Station
CB3.1 Station
CB3.2 Station
Surface (MG/L)
Bottom (MG/L)
CB3.3C Station
CB3.3E Station
CB3.3W Station
WT5.1 Station
WT4.1 Station
1991 1992 1993 1994 1995 1996 1997



CHLA
modeled
observed
CB1.1 Station
CB2.1 Station
CB2.2 Station
CB3.1 Station
CB3.2 Station
Surface (UG/L)
Bottom (UG/L)
CB3.3C Station
CB3.3E Station
CB3.3W Station
WT5.1 Station
WT4.1 Station
Surface (MG/L)
Bottom (MG/L)
1991
1992
1993
1994
1995
1996
1997


TN
modeled
observed
CB1.1 Station
CB2.1 Station
CB2.2 Station
CB3.1 Station
CB3.2 Station
CB3.3C Station
CB3.3E Station
CB3.3W Station
WT5.1 Station
WT4.1 Station
Surface (MG/L)
Bottom (MG/L)
1991
1992
1993
1994
1995
1996
1997



TP
modeled
observed
CB1.1 Station
CB2.1 Station
CB2.2 Station
CB3.1 Station
CB3.2 Station
CB3.3C Station
CB3.3E Station
CB3.3W Station
WT5.1 Station
WT4.1 Station
Surface (MG/L)
Bottom (MG/L)

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

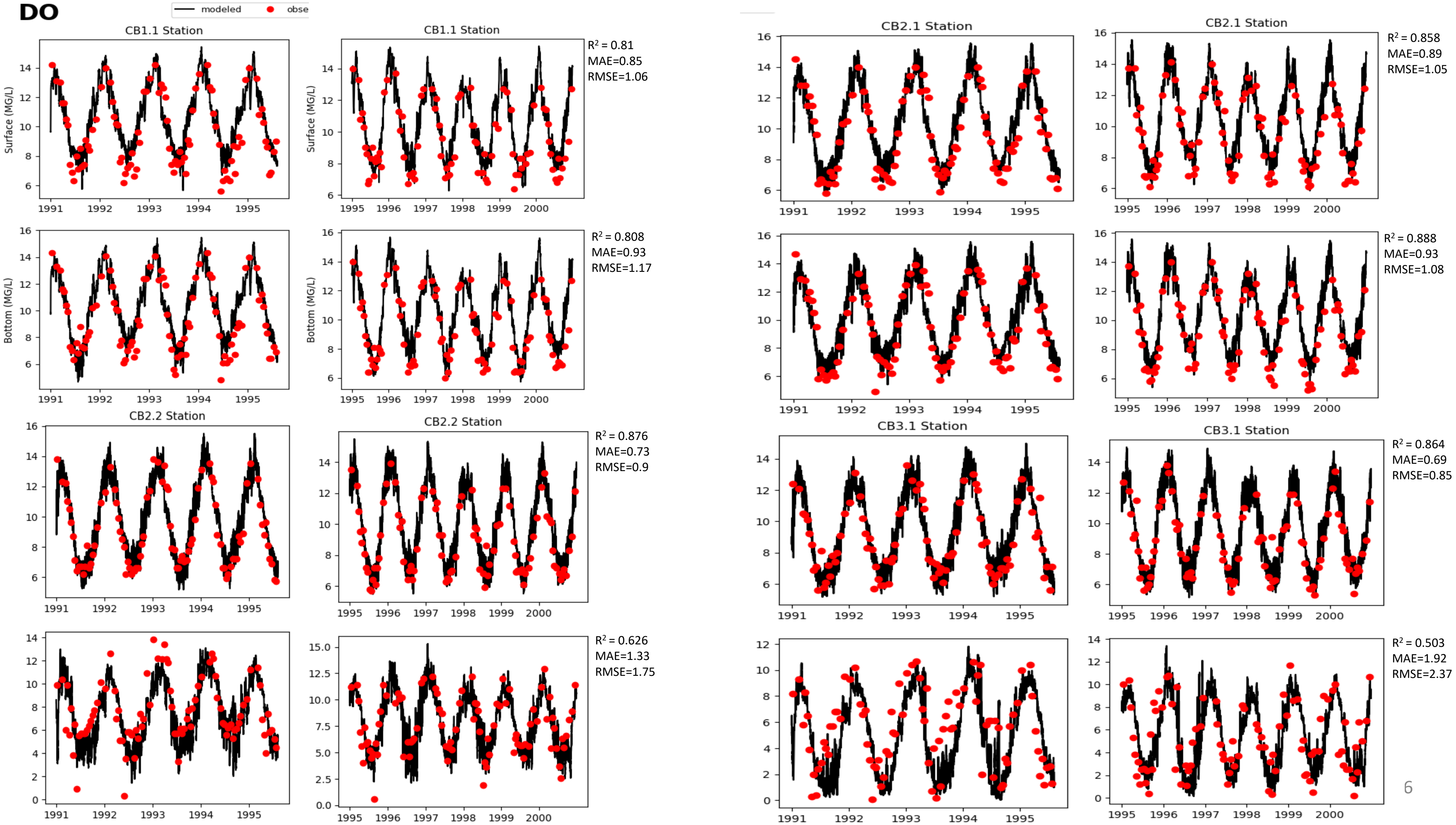
Critical shear stress is NOT a spatial-varying variable, rather it depends on sediment classes (see table). The sediment bed fraction (classes) in each grid cell, on the other hand, can be specified differently in different regions.

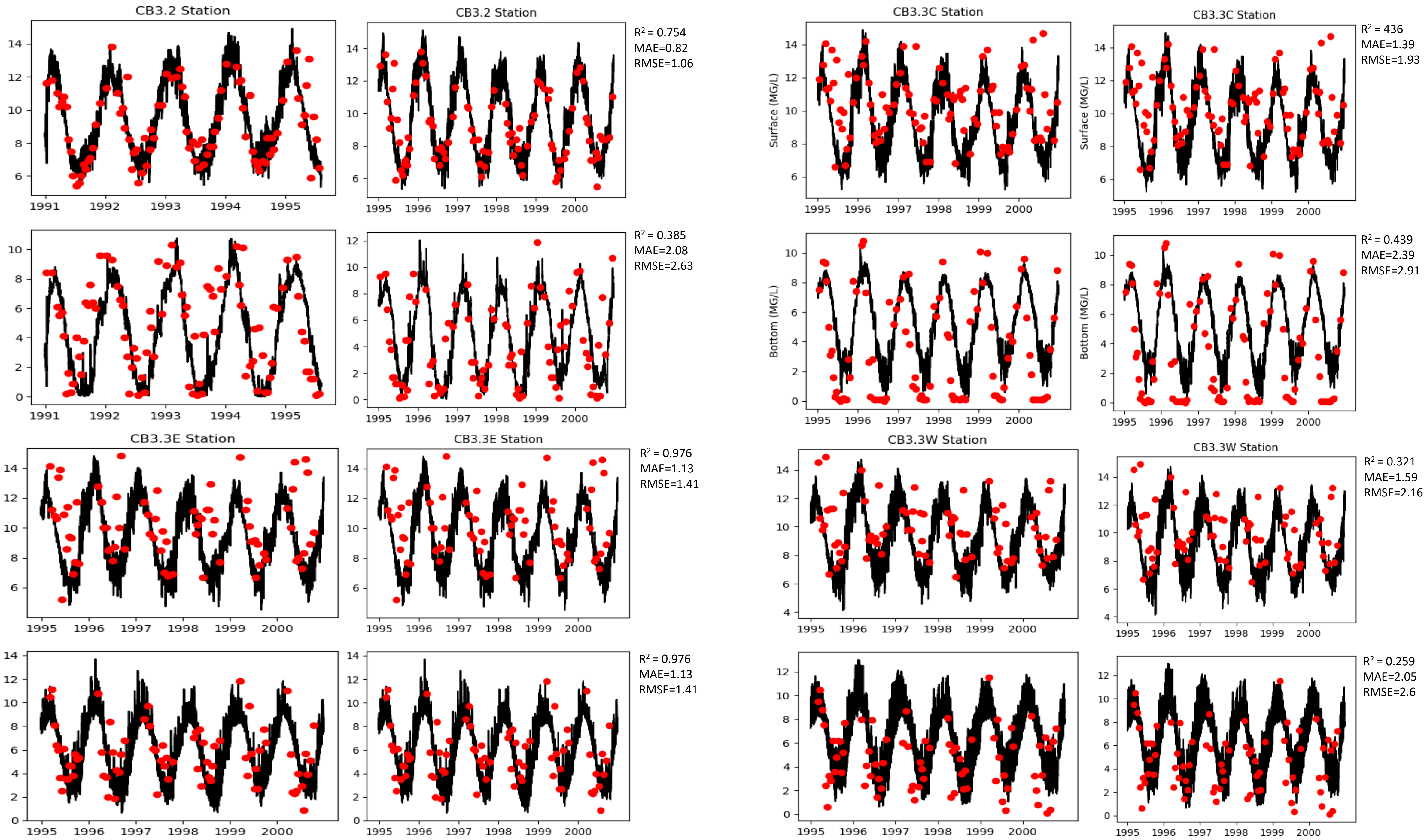
Sed. classes	**Grain diameter (mm)**	**Particle settling velocity (mm/s)**	**Critical shear stress for erosion (pa)**
Class 1	0.003	0.010	0.010
Class 2	0.003	0.03	0.02
Silt	0.003	0.1	0.03
Send	0.3	1.0	20

Sediment bed fraction / Region applied	Baltimore Harbor (channel)	Baltimore Harbor (shoal)	Back River	Rest of Upper Chesapeake Bay
Class 1	80%	80%	80%	(follow MBM specification)
Class 2	10%	15%	15%	
Silt	5%	15%	5%	
sand	5%	0%	0%	

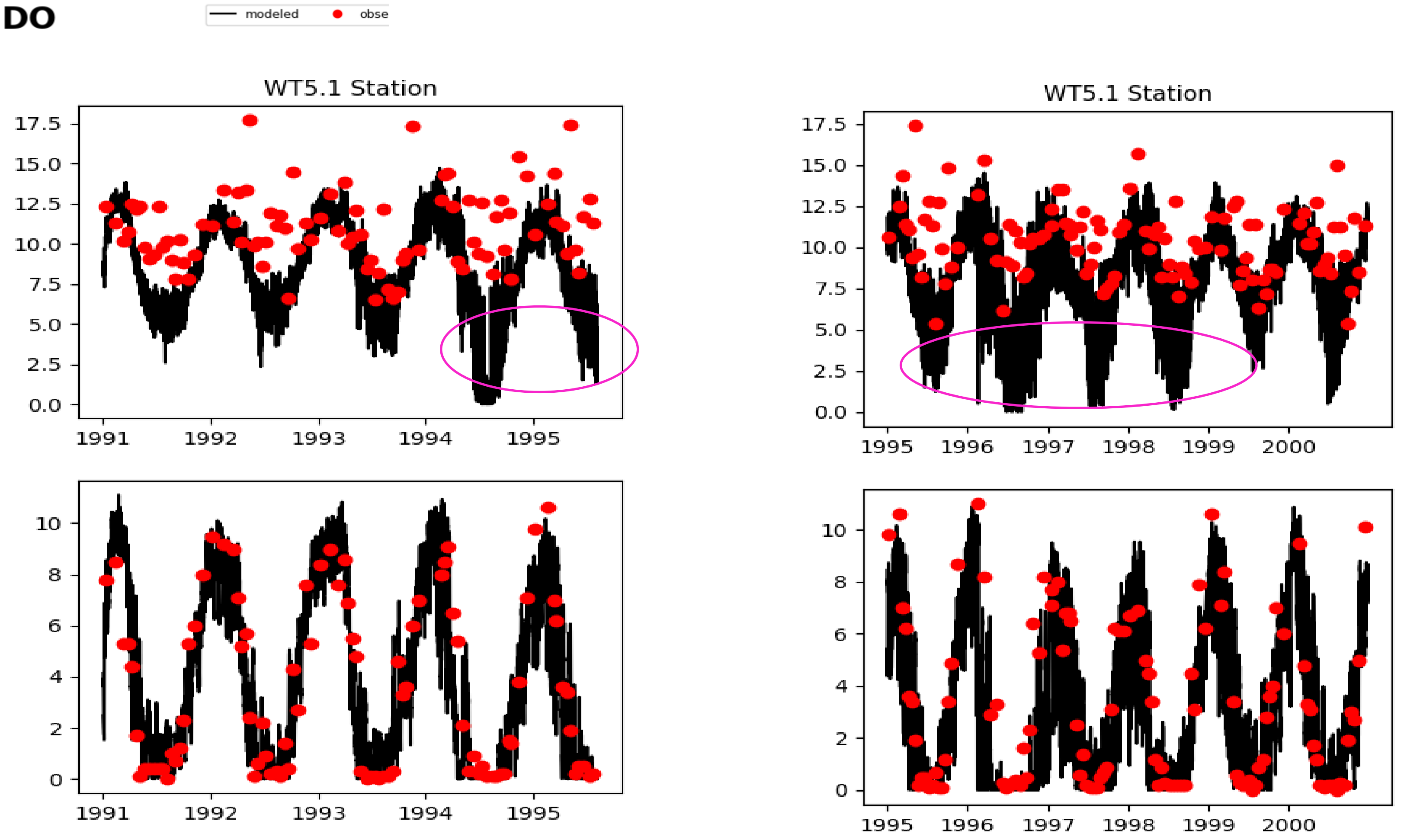
Elevation, Temperature, Salinity, **DO**, ChlA, TN, TP, TSS

DO

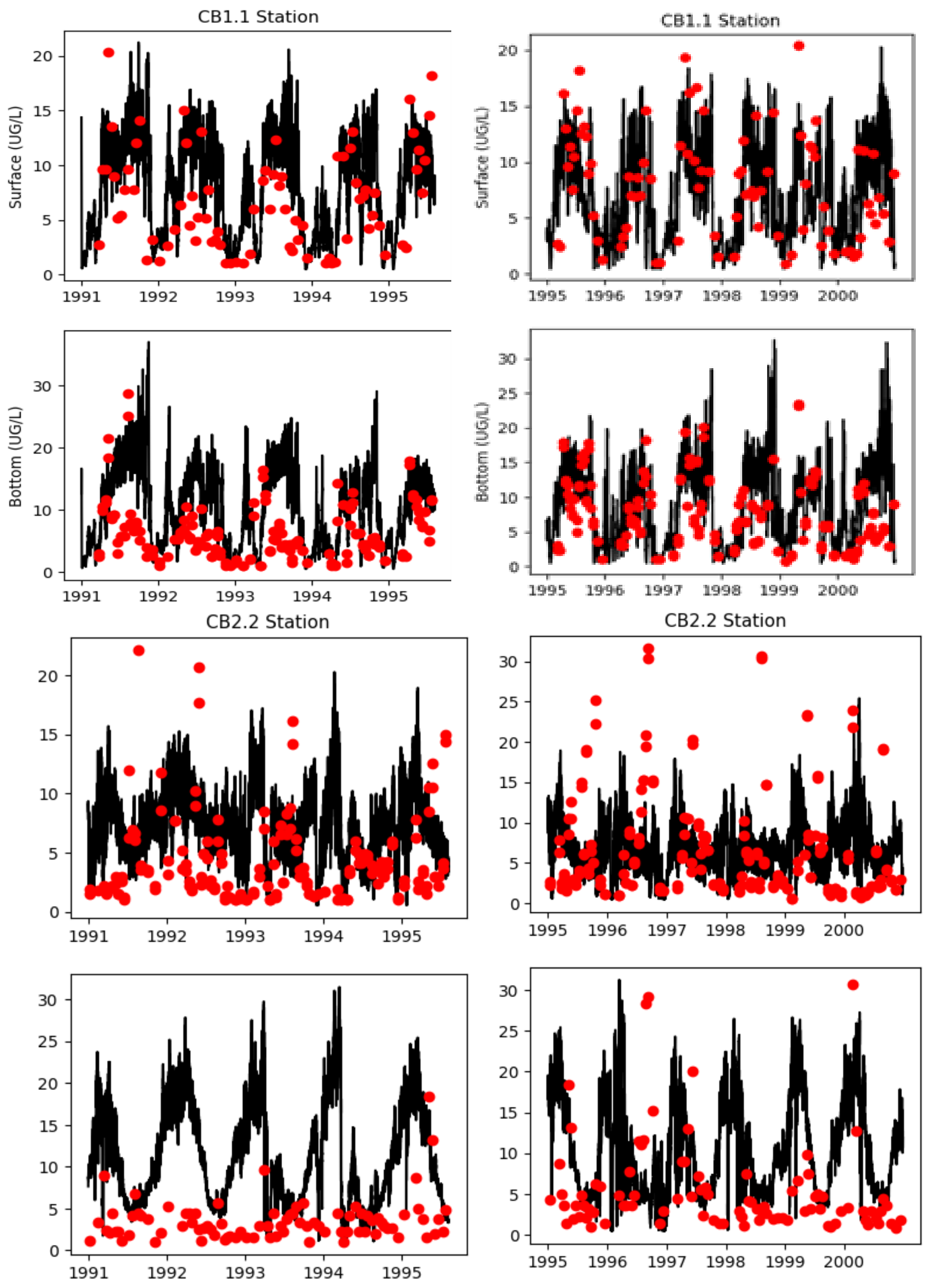



CB3.2 Station
CB3.2 Station
R² = 0.754
MAE=0.82
RMSE=1.06
R² = 0.385
MAE=2.08
RMSE=2.63
CB3.3C Station
CB3.3C Station
Surface (MG/L)
R² = 436
MAE=1.39
RMSE=1.93
Bottom (MG/L)
R² = 0.439
MAE=2.39
RMSE=2.91
CB3.3E Station
CB3.3E Station
R² = 0.976
MAE=1.13
RMSE=1.41
R² = 0.976
MAE=1.13
RMSE=1.41
CB3.3W Station
CB3.3W Station
R² = 0.321
MAE=1.59
RMSE=2.16
R² = 0.259
MAE=2.05
RMSE=2.6

DO

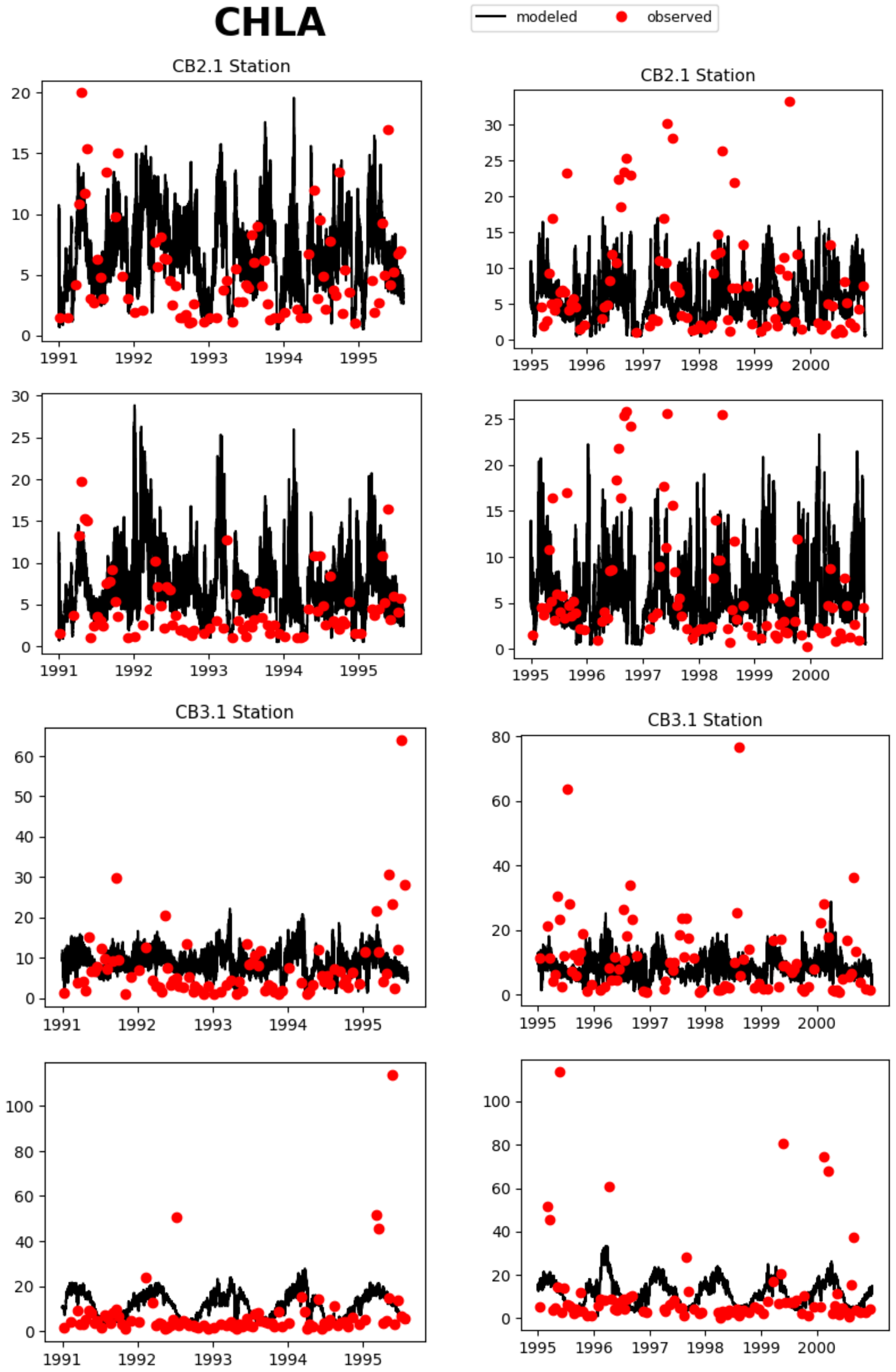


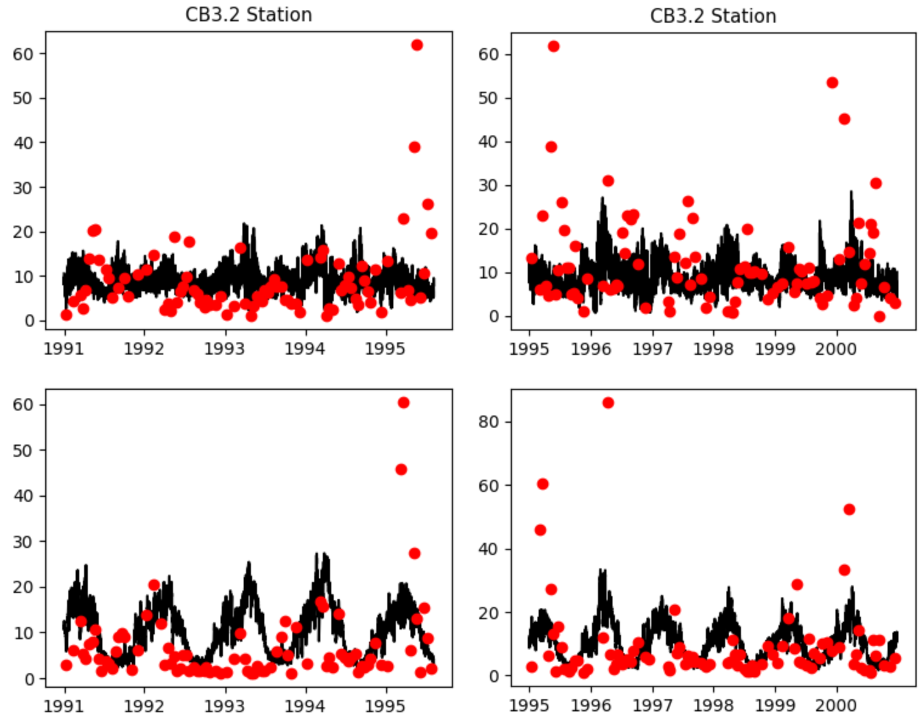
Elevation, Temperature, Salinity, DO, **ChlA**, TN, TP, TSS

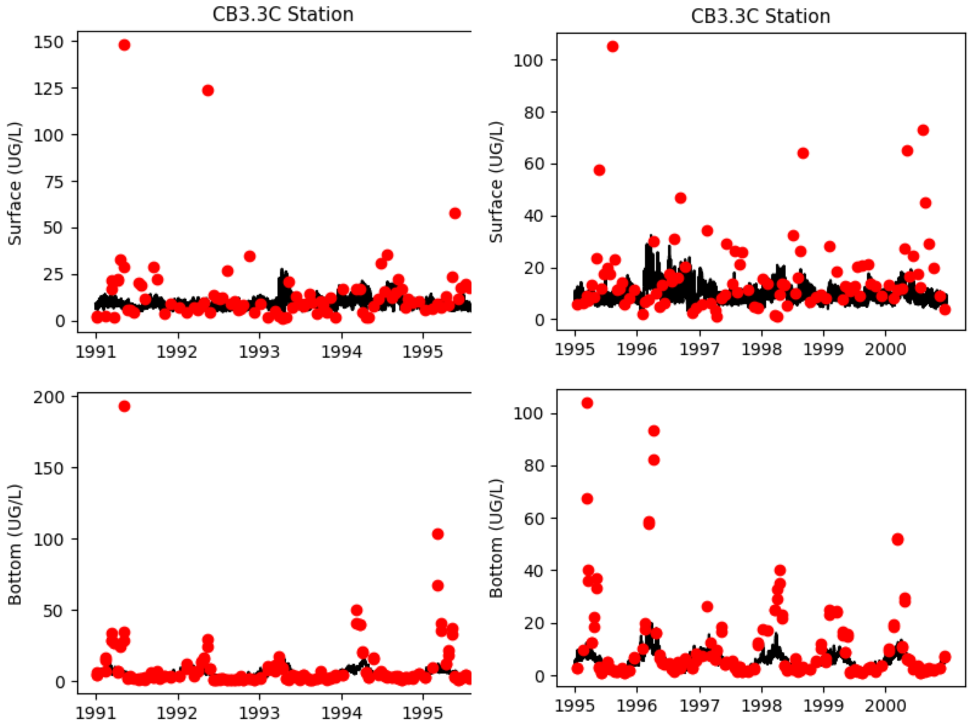


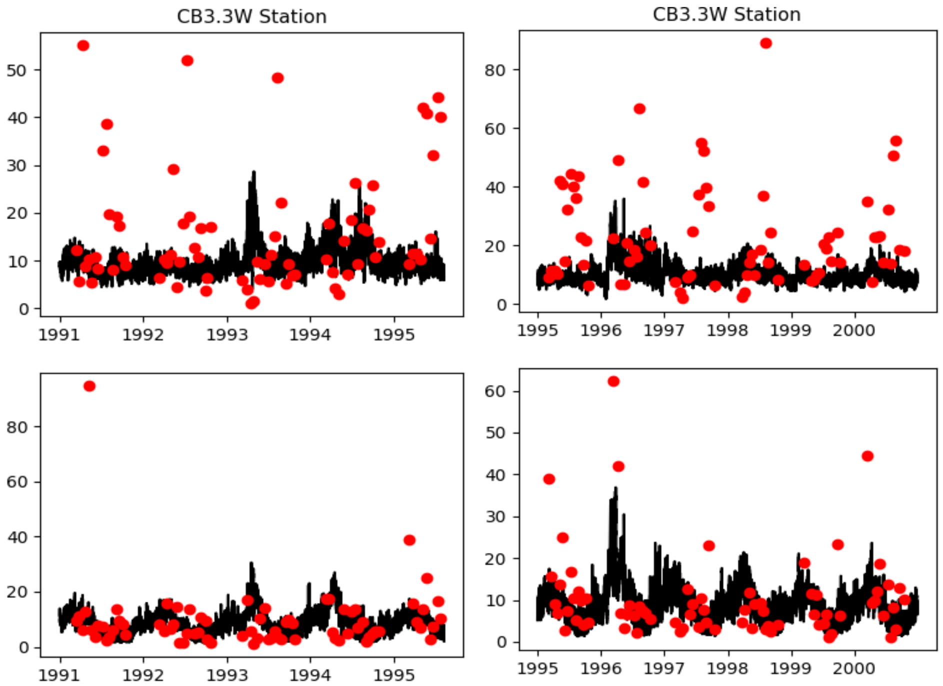
1

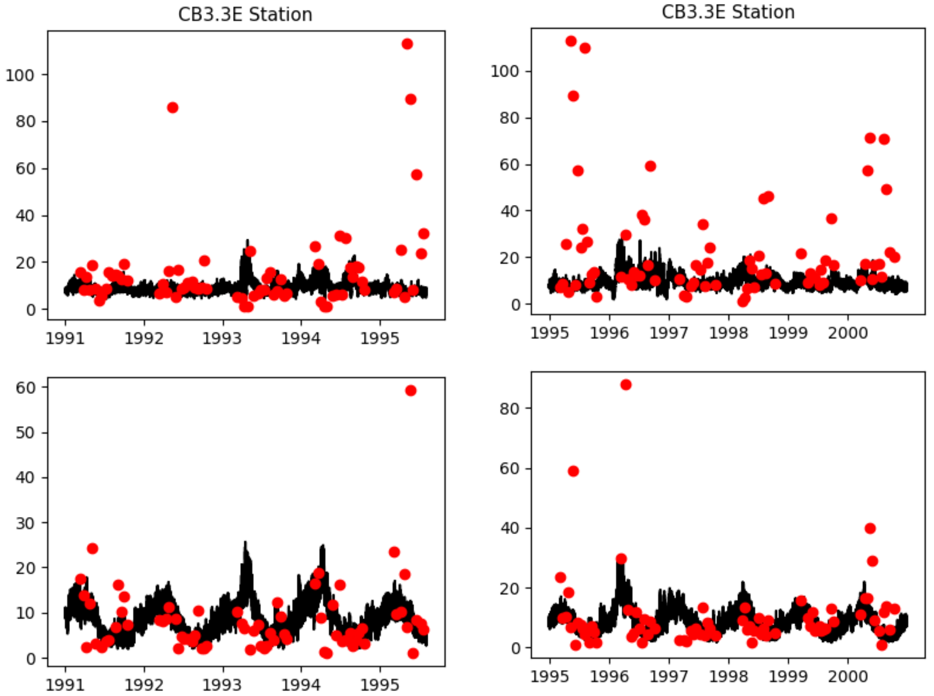
CHLA

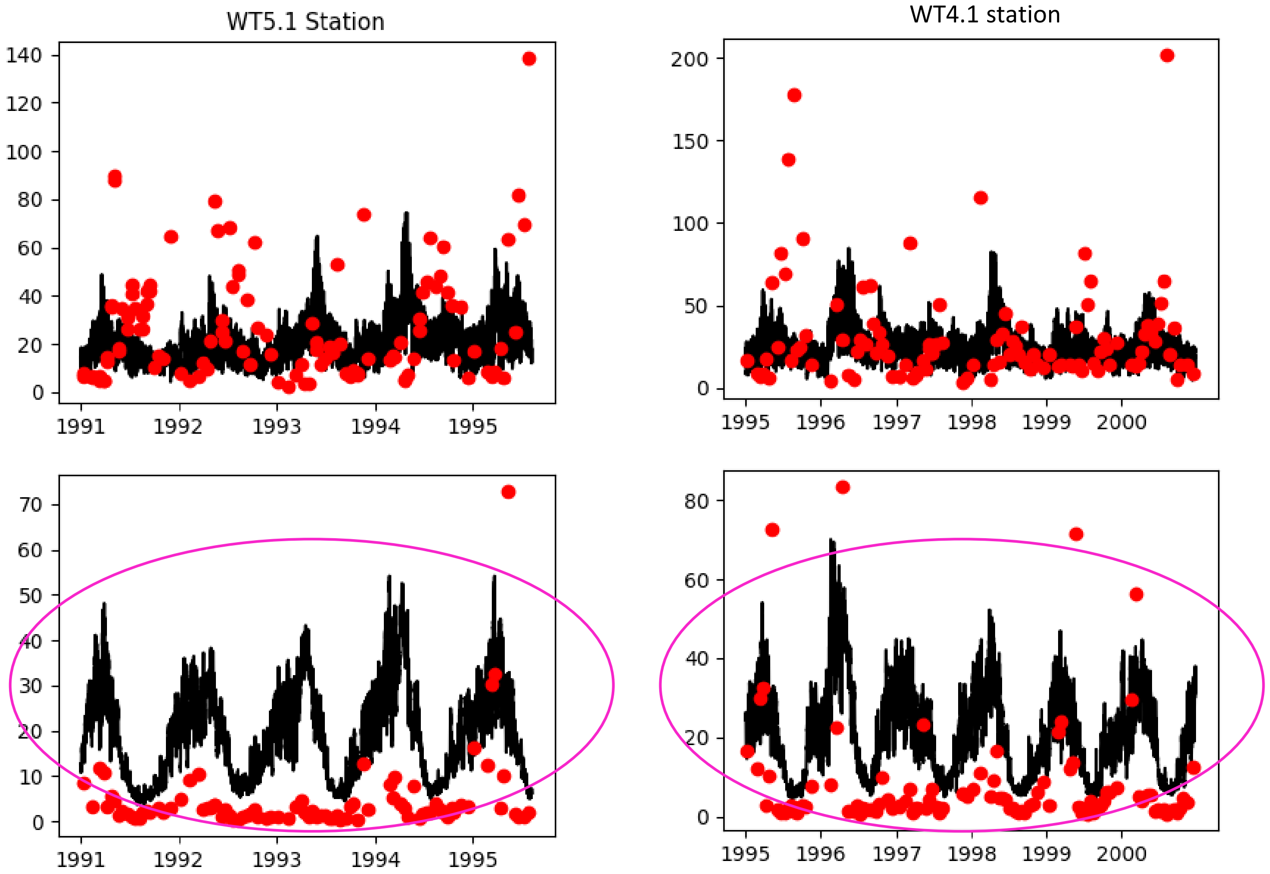



CB3.2 Station
CB3.2 Station

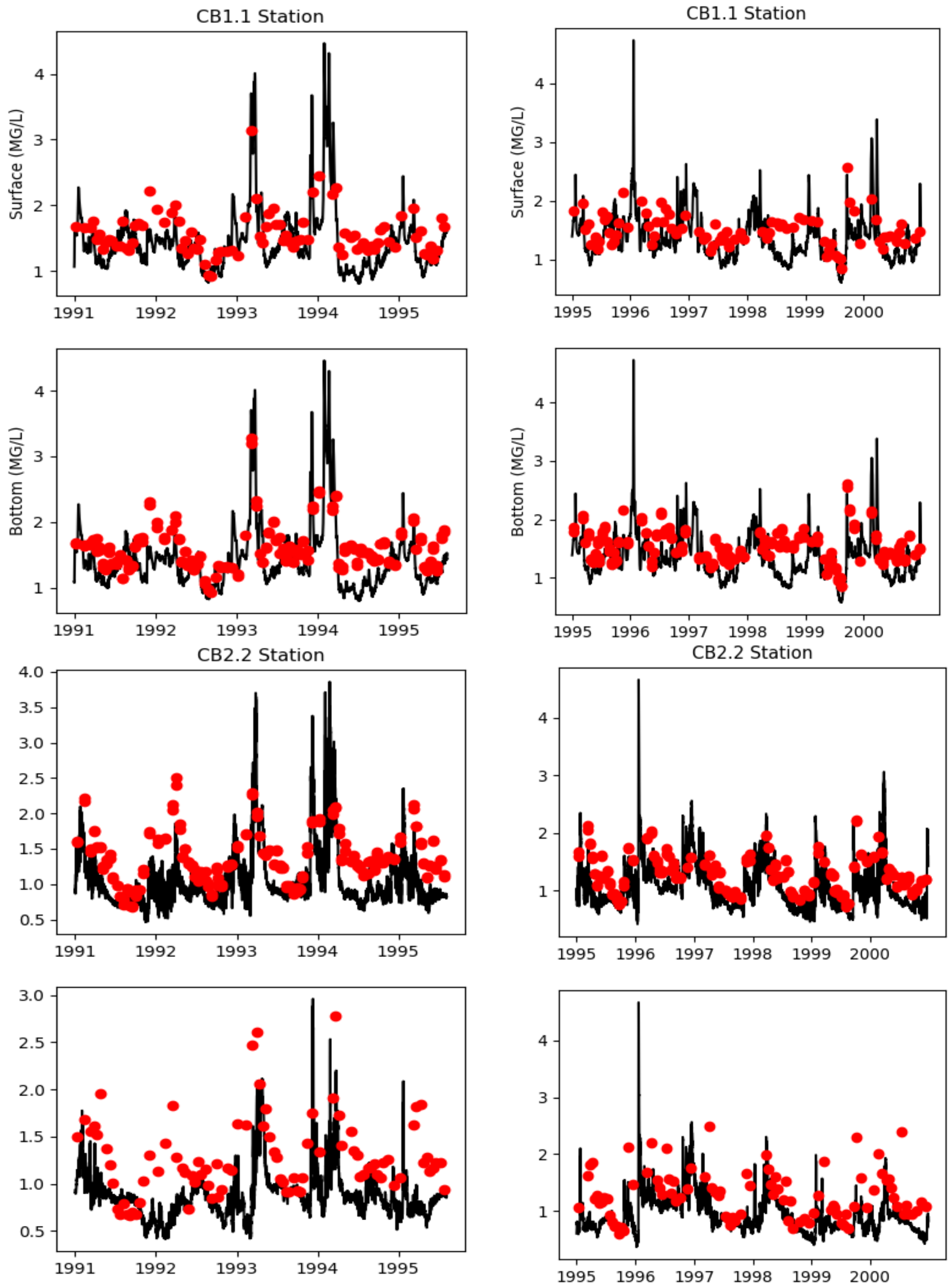

CB3.3C Station
CB3.3C Station
Surface (UG/L)
Surface (UG/L)
Bottom (UG/L)
Bottom (UG/L)


CB3.3W Station
CB3.3W Station

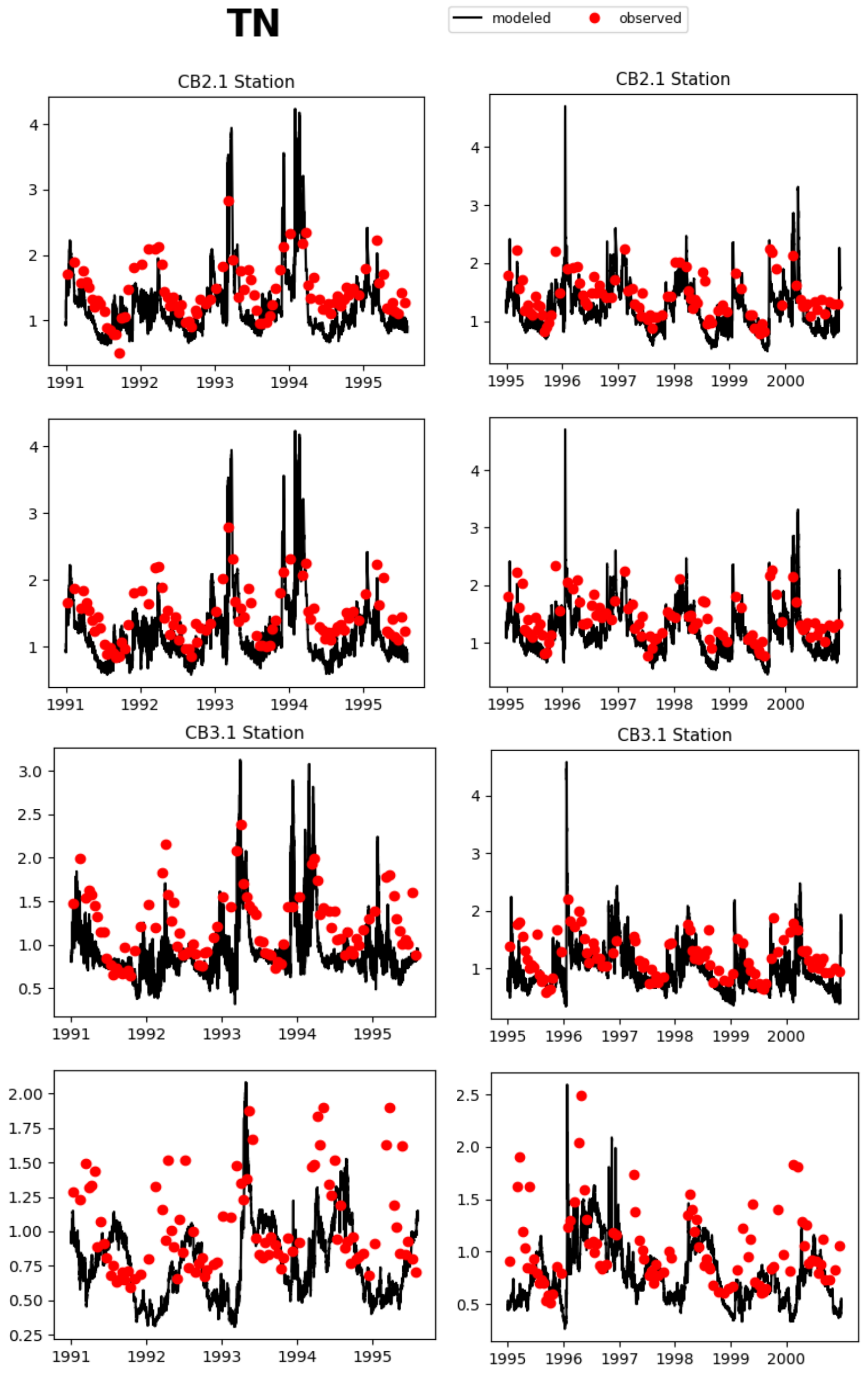

CB3.3E Station
CB3.3E Station

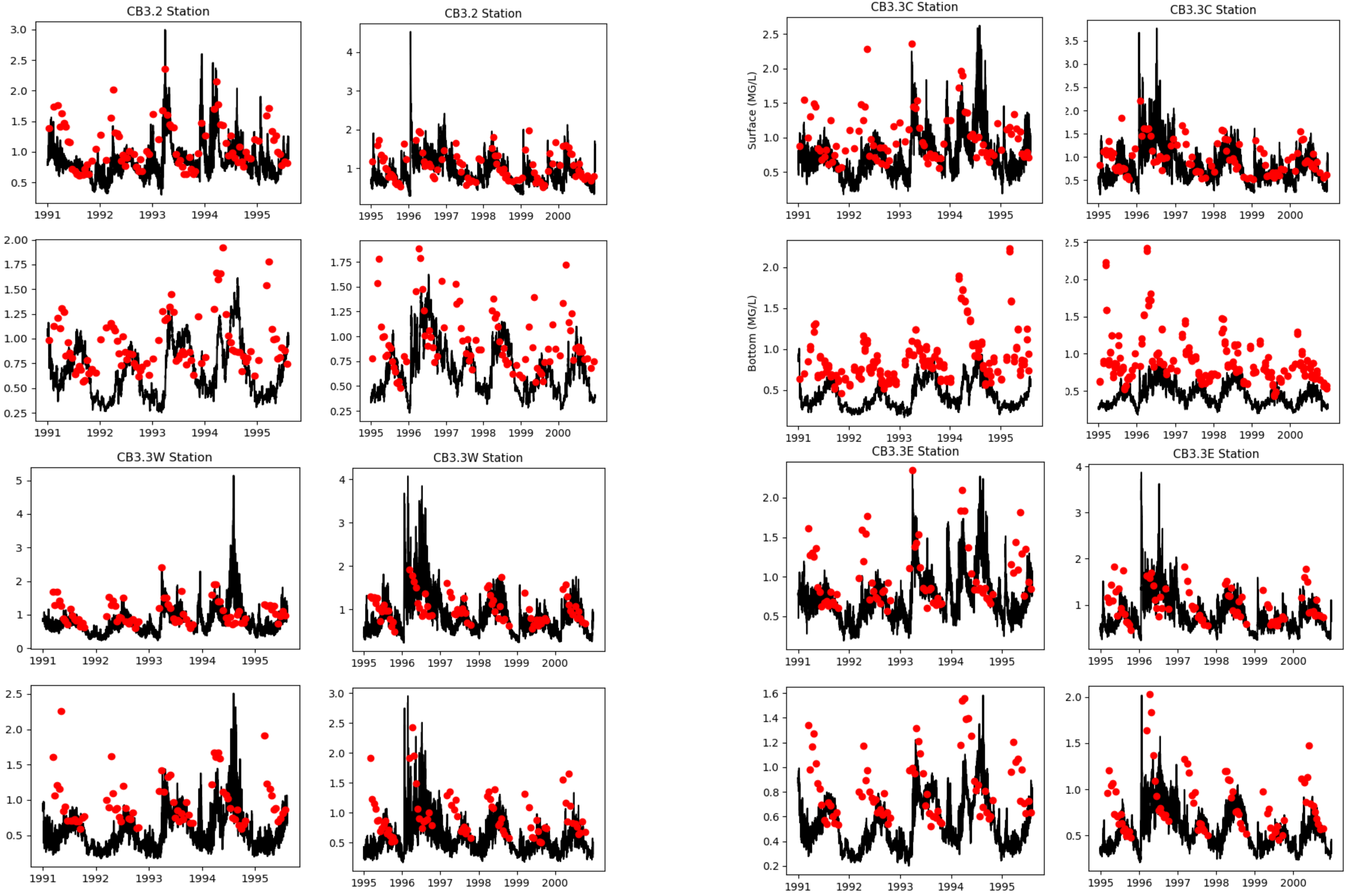

WT5.1 Station
WT4.1 station
140
120
100
80
60
40
20
0
1991
1992
1993
1994
1995
200
150
100
50
0
1995
1996
1997
1998
1999
2000
70
60
50
40
30
20
10
0
1991
1992
1993
1994
1995
80
60
40
20
0
1995
1996
1997
1998
1999
2000

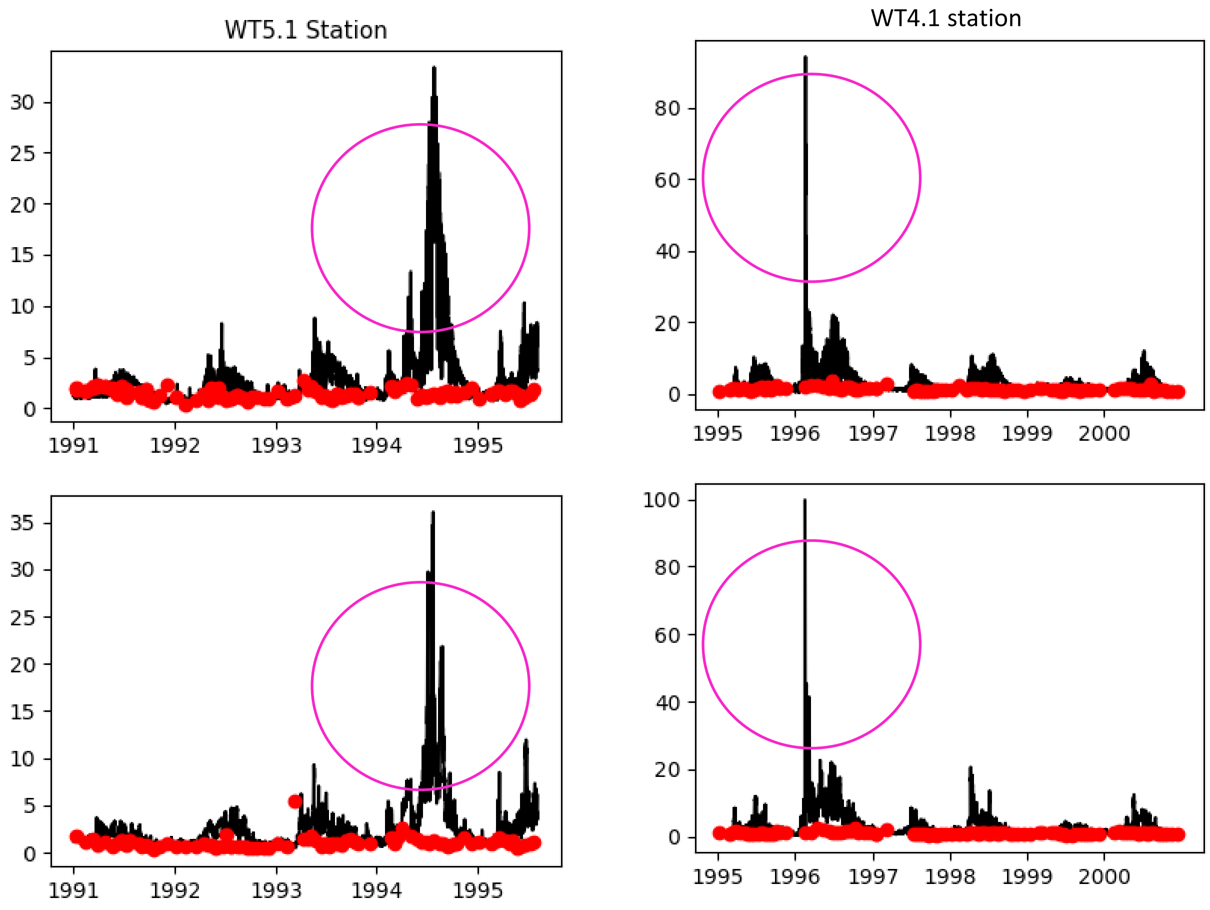
Elevation, Temperature, Salinity, DO, ChlA, **TN,** TP, TSS



TN



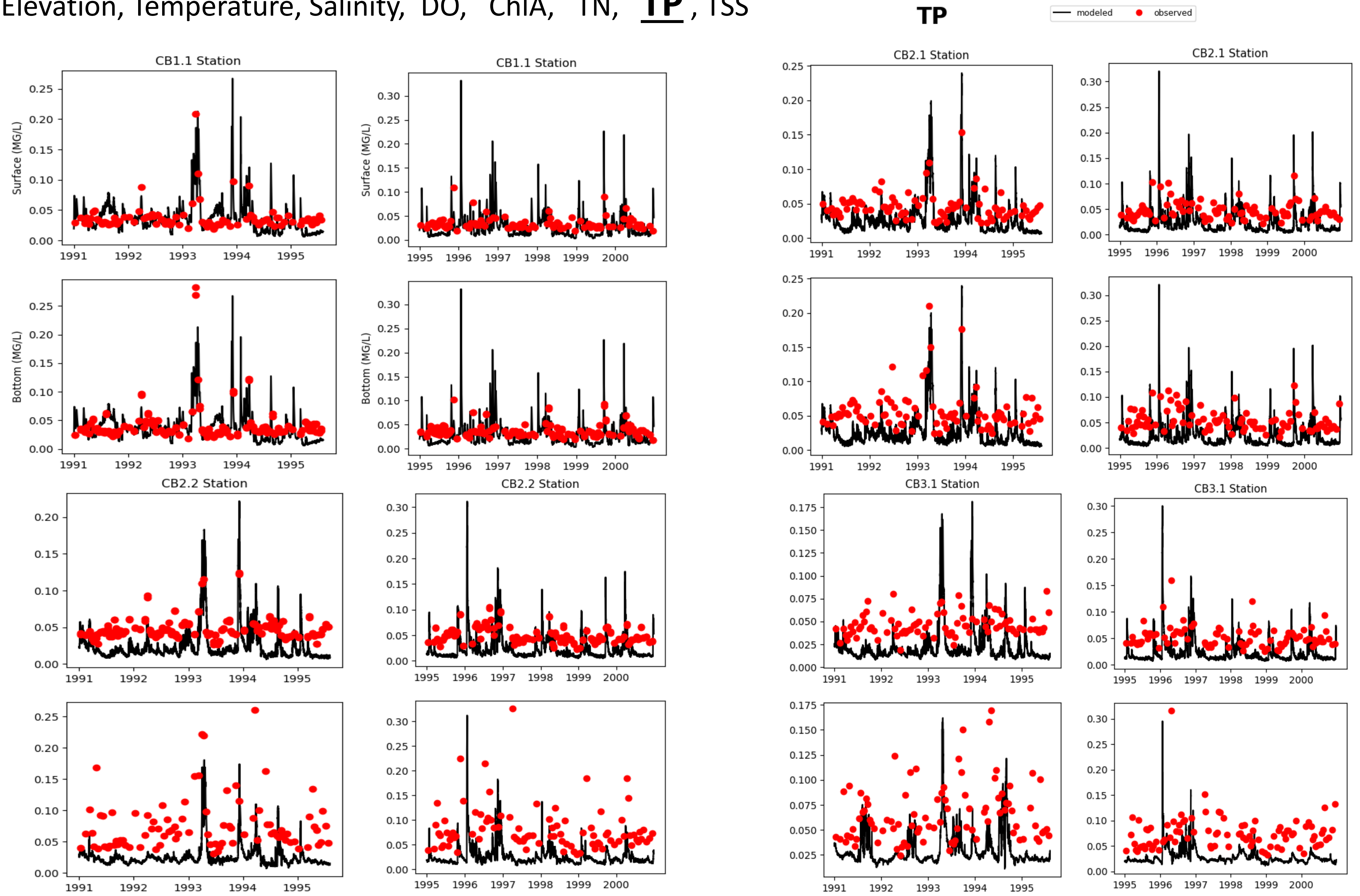

CB3.2 Station
CB3.2 Station
CB3.3C Station
CB3.3C Station
Surface (MG/L)
Bottom (MG/L)
CB3.3W Station
CB3.3W Station
CB3.3E Station
CB3.3E Station

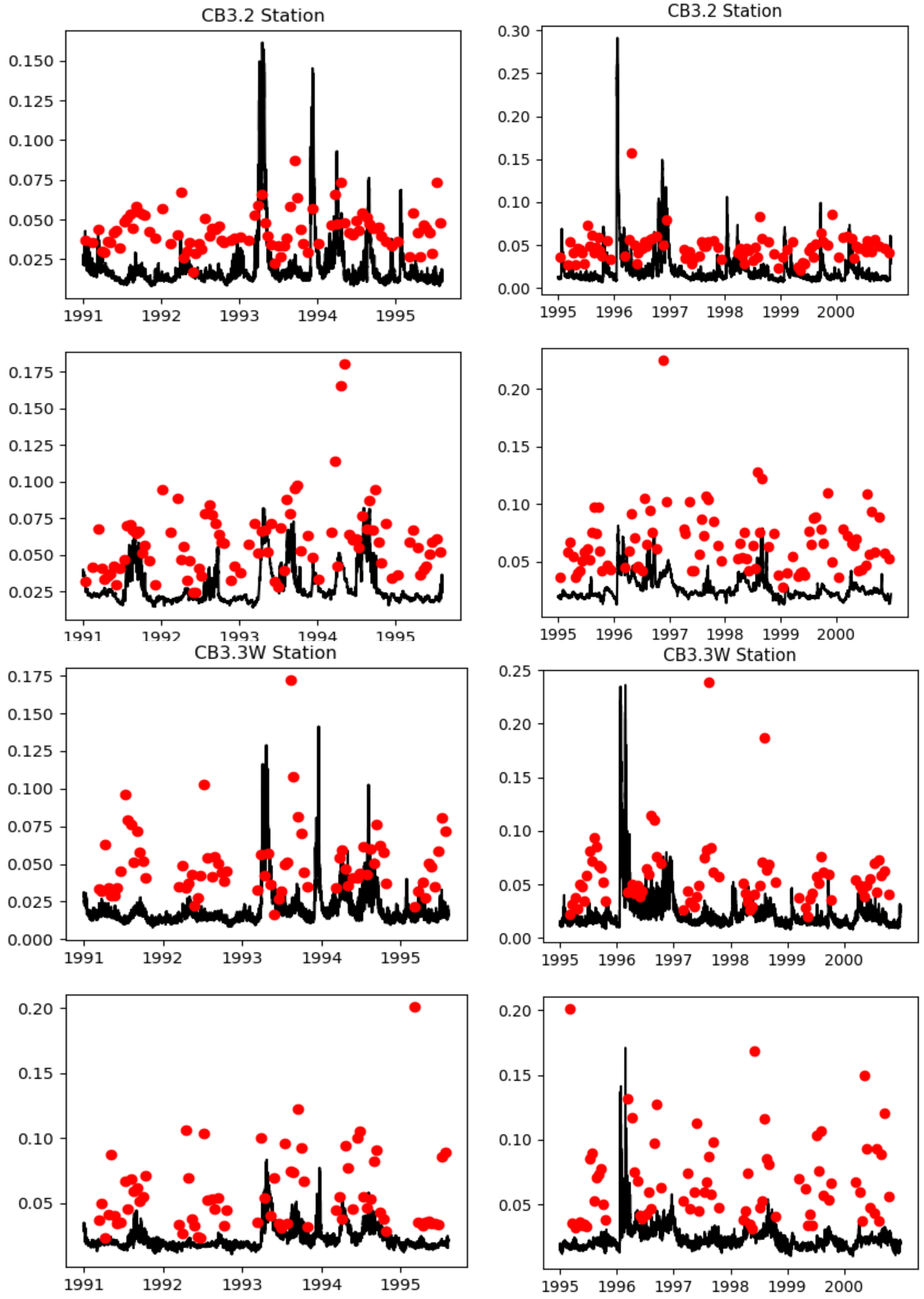


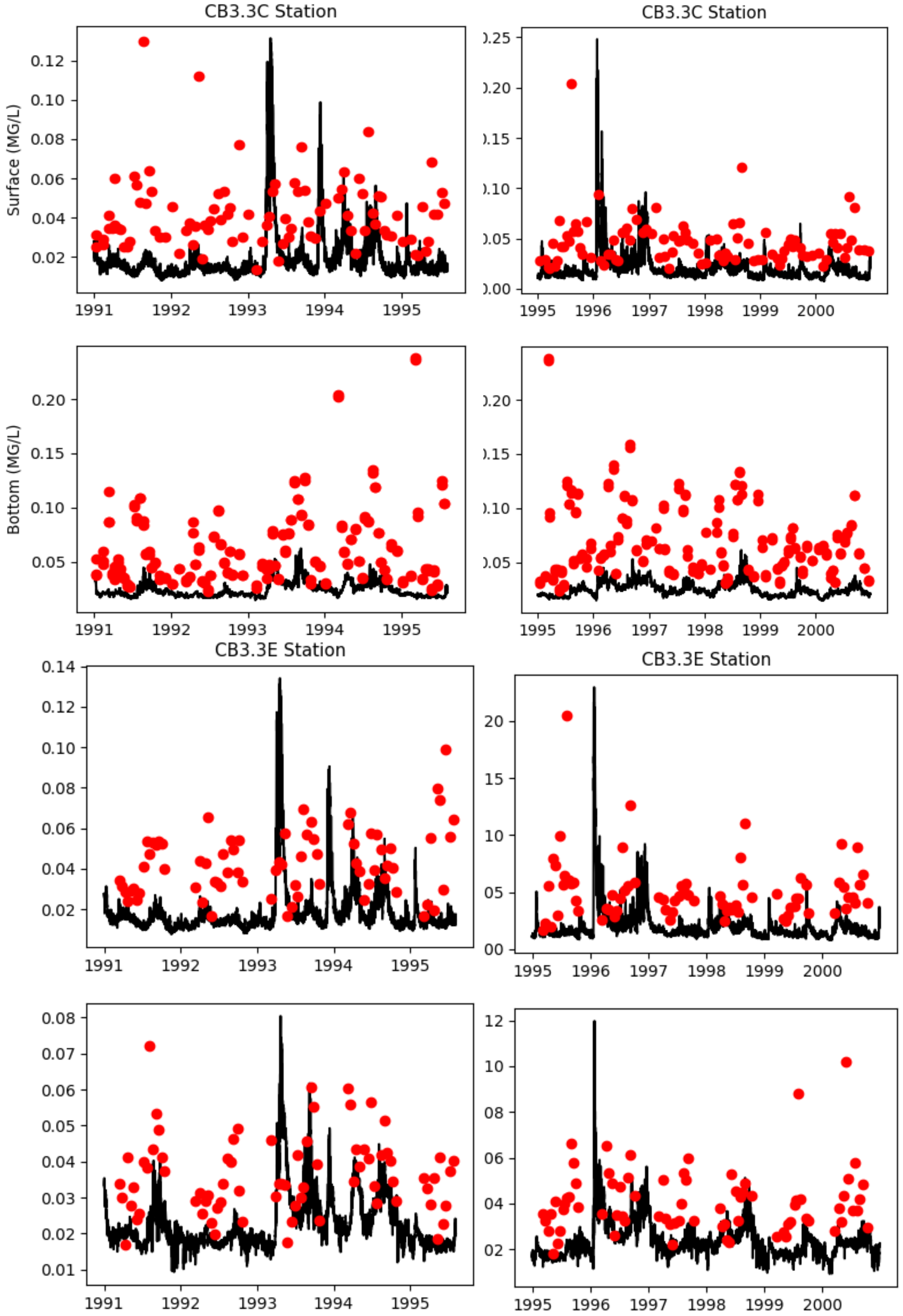
WT5.1 Station
WT4.1 station
30
25
20
15
10
5
0
1991
1992
1993
1994
1995
80
60
40
20
0
1995
1996
1997
1998
1999
2000
35
30
25
20
15
10
5
0
1991
1992
1993
1994
1995
100
80
60
40
20
0
1995
1996
1997
1998
1999
2000

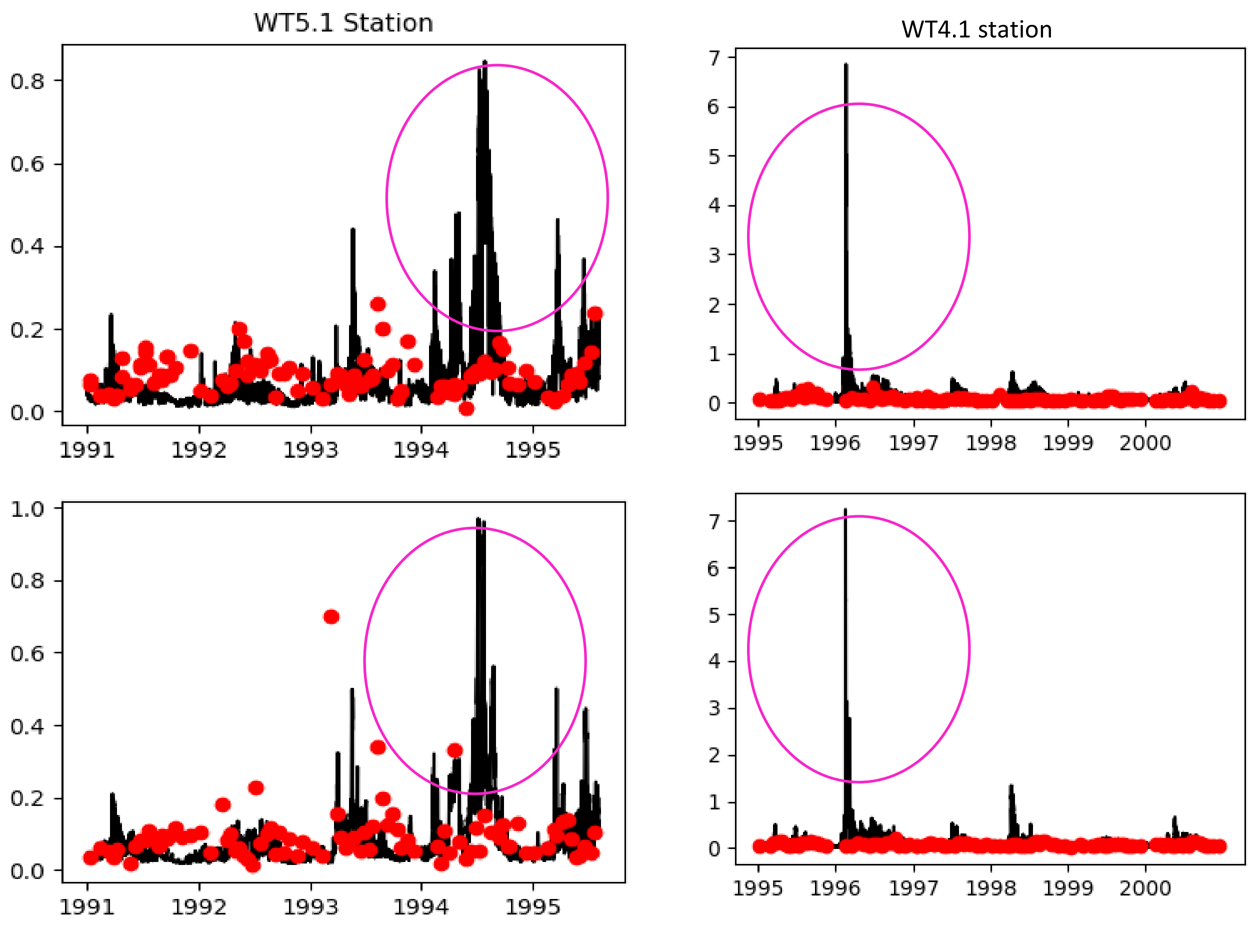
Elevation, Temperature, Salinity, DO, ChlA, TN, **TP**, TSS

TP




CB3.2 Station
CB3.2 Station
CB3.3W Station
CB3.3W Station


CB3.3C Station
CB3.3C Station
Surface (MG/L)
Bottom (MG/L)
CB3.3E Station
CB3.3E Station

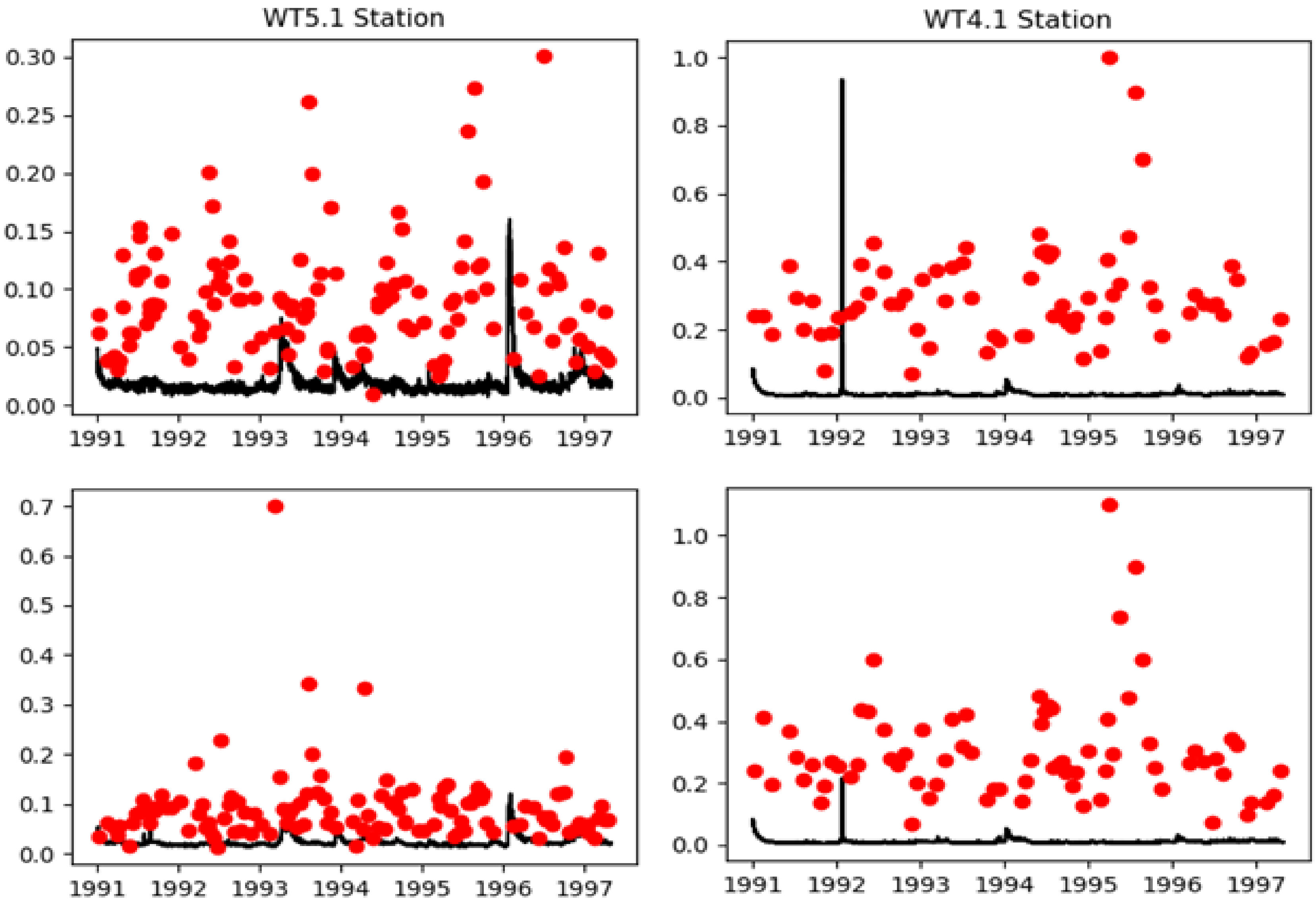

WT5.1 Station
WT4.1 station
0.0 0.2 0.4 0.6 0.8
1991 1992 1993 1994 1995
0 1 2 3 4 5 6 7
1995 1996 1997 1998 1999 2000
0.0 0.2 0.4 0.6 0.8 1.0
1991 1992 1993 1994 1995
0 1 2 3 4 5 6 7
1995 1996 1997 1998 1999 2000

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

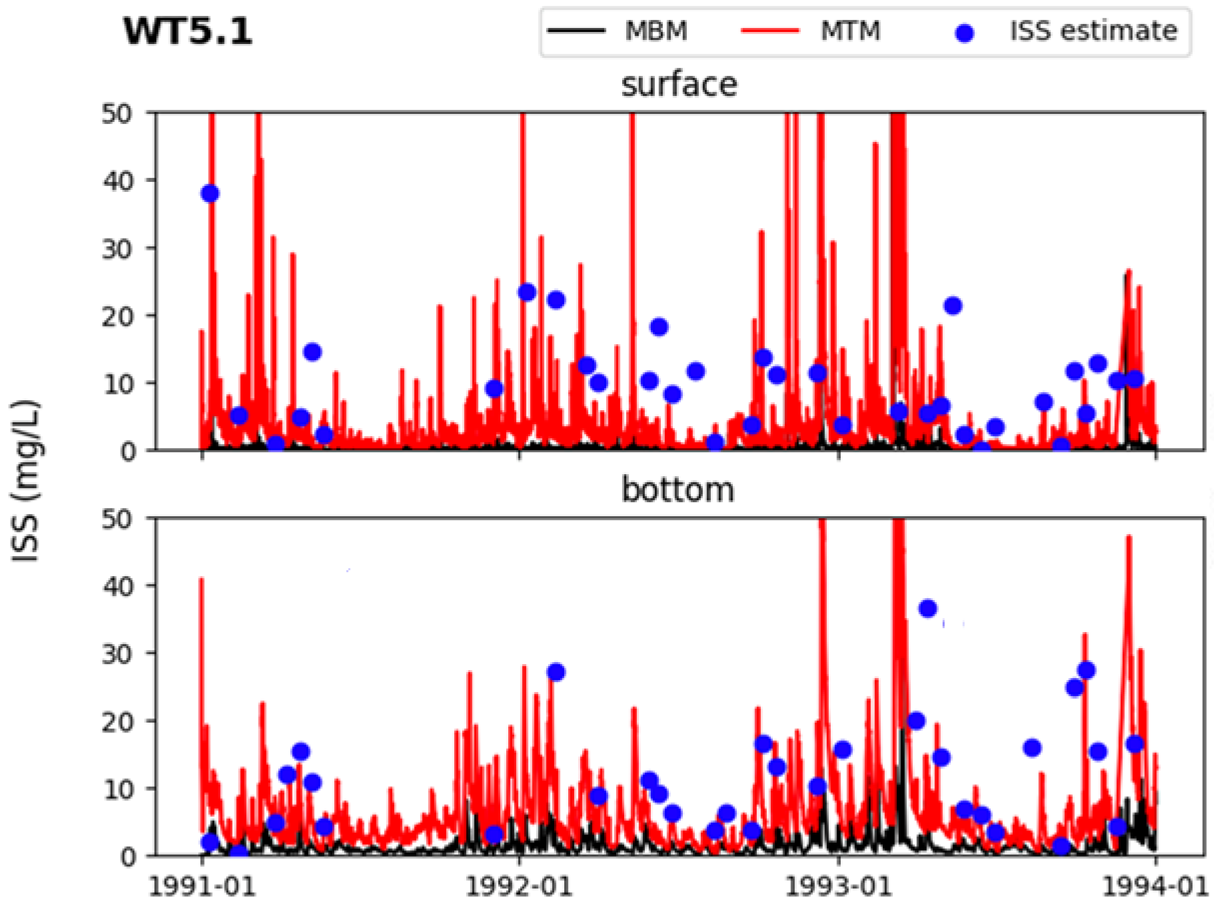
Sed. classes	**Grain diameter (mm)**	**Particle settling velocity (mm/s)**	**Critical shear stress for erosion (pa)**
Class 1	0.003	0.010	0.010
Class 2	0.003	0.03	0.02
Silt	0.003	0.1	0.03
Send	0.3	1.0	20

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



surface:

MBM RUN11fb ISS mean: 0.449, max: 69.731

MTM RUN04c ISS mean: 3.699, max: 1177.607

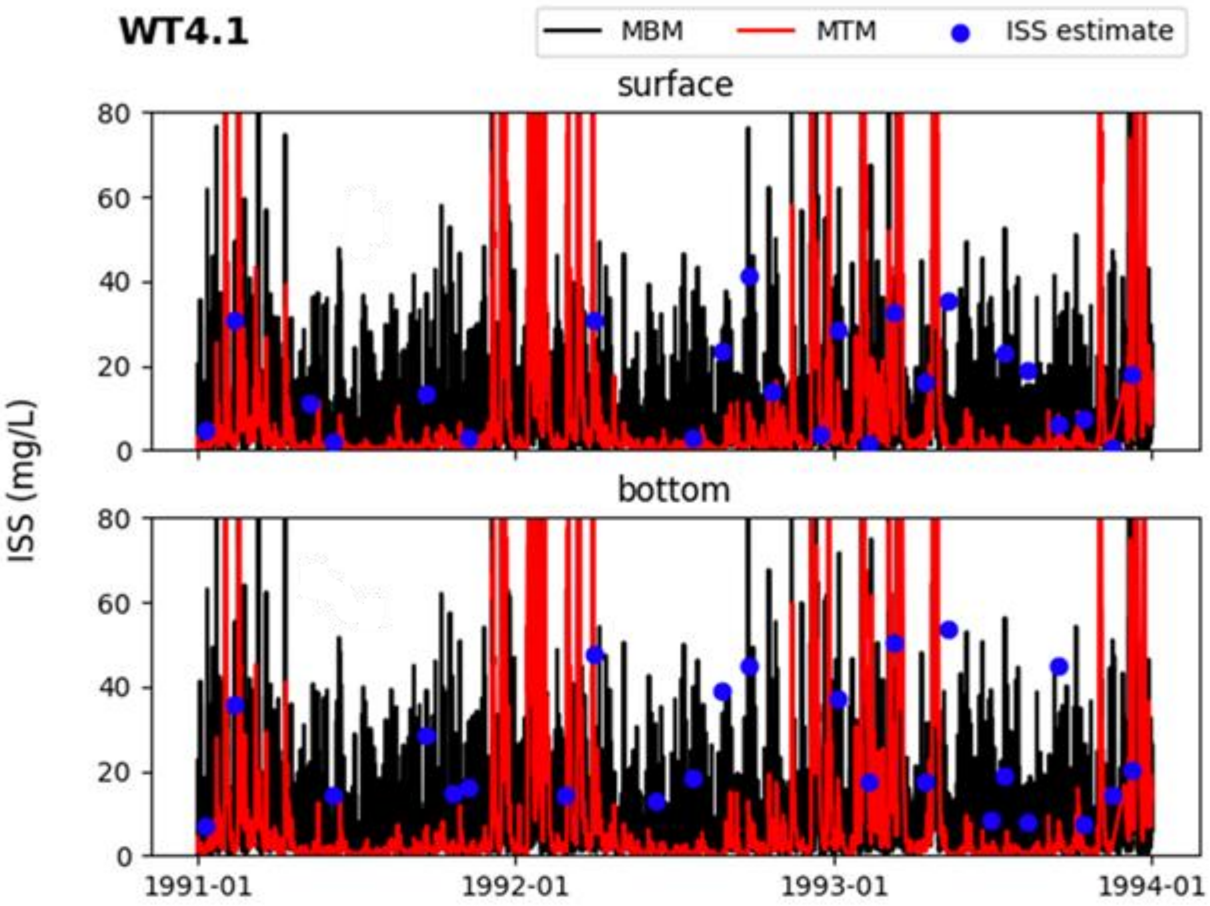
Obs ISS est. mean: 10.116, max: 38.14

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



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:

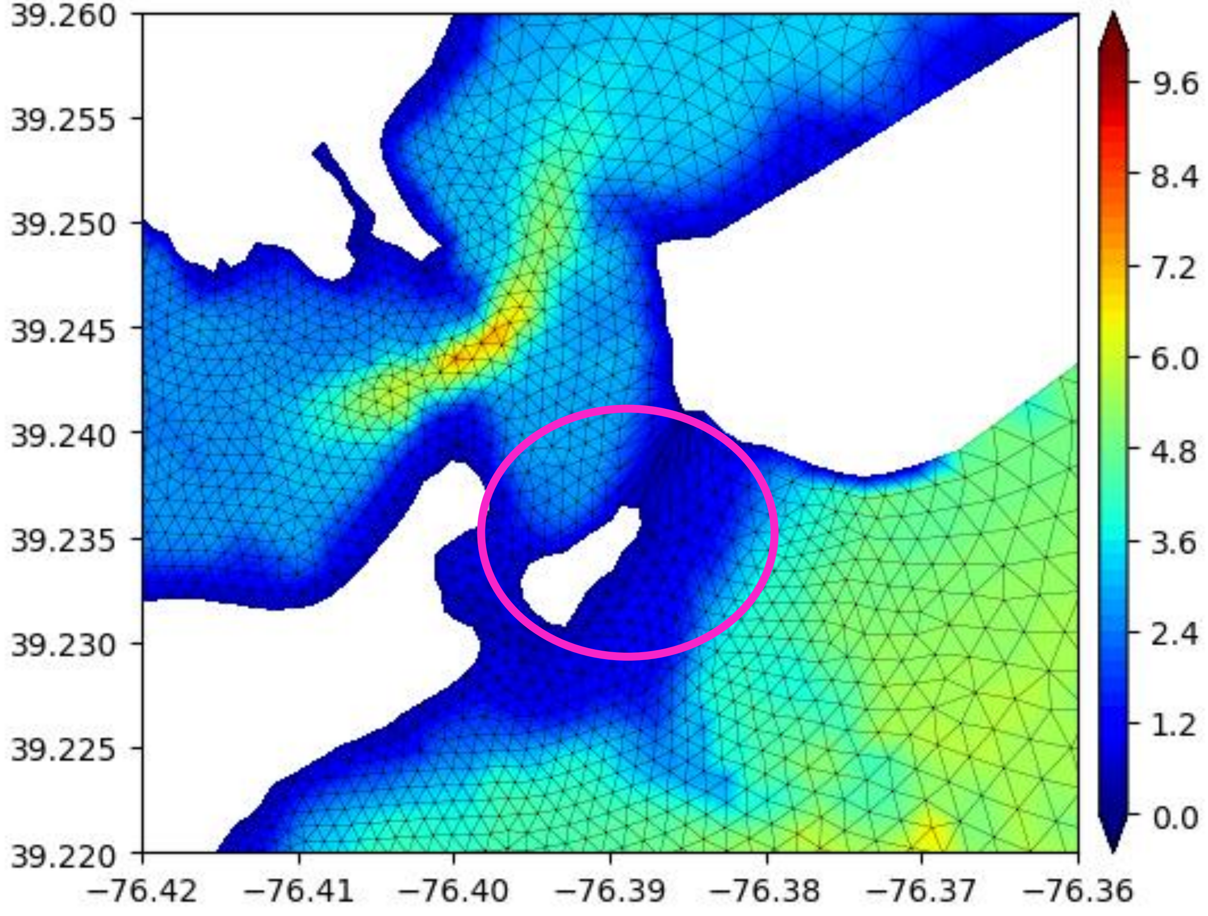
MBM RUN11fb ISS mean: 10.813, max: 653.472

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.

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.