The 3rd Quarterly Progress review on the Patapsco/Back MTM Program

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Outline:

I. Non-point source loading from hybrid phase 6 and 7

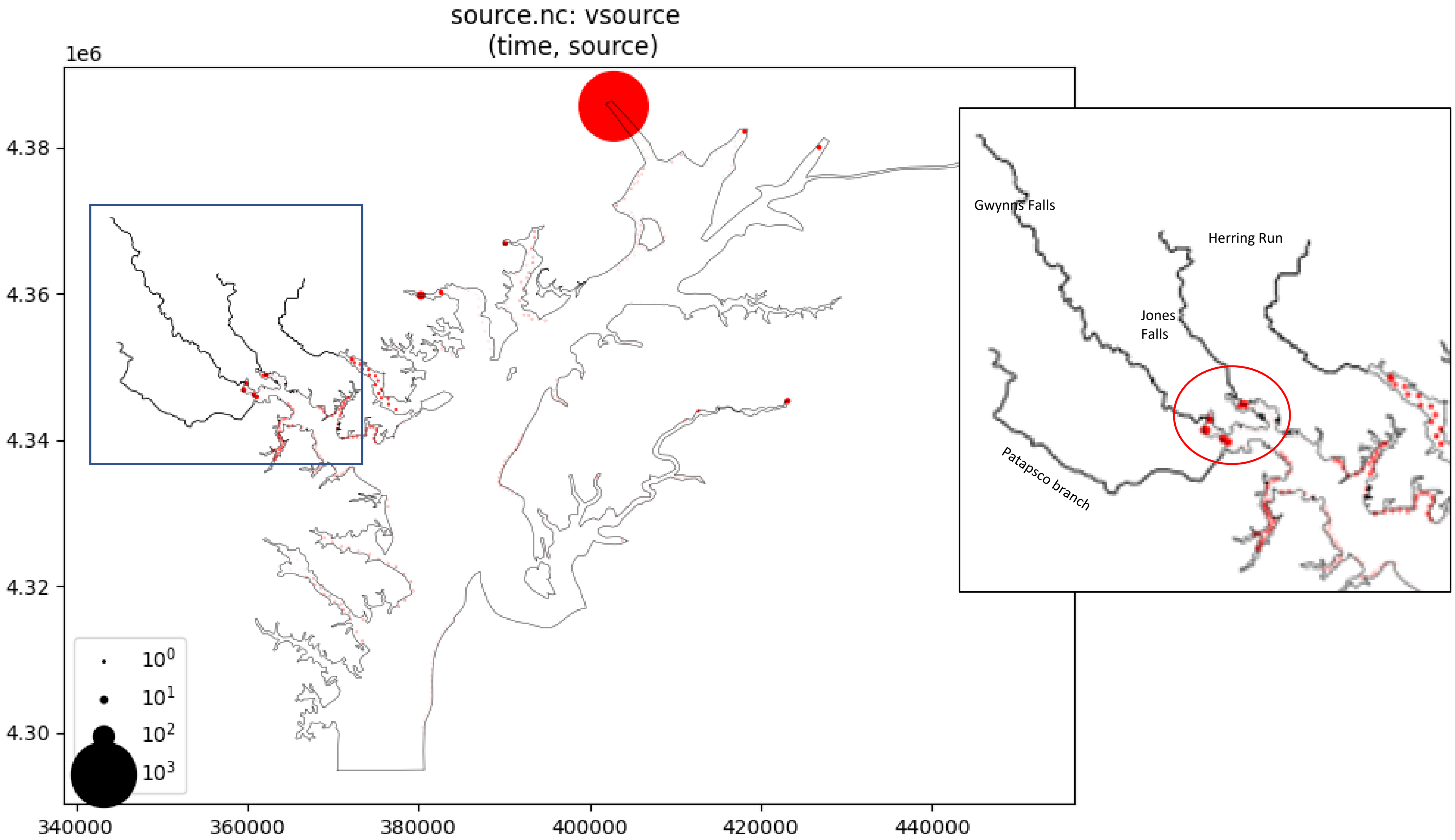
II. Water quality simulation for 10-year: 1991-2000 (off-line approach)

III. Specific issues and those local to the Patpsco/Back River MTM

IV. Summary

I. Characterization of Phase6/7 Hybrid Non-point Source Loading

Non-point source flow



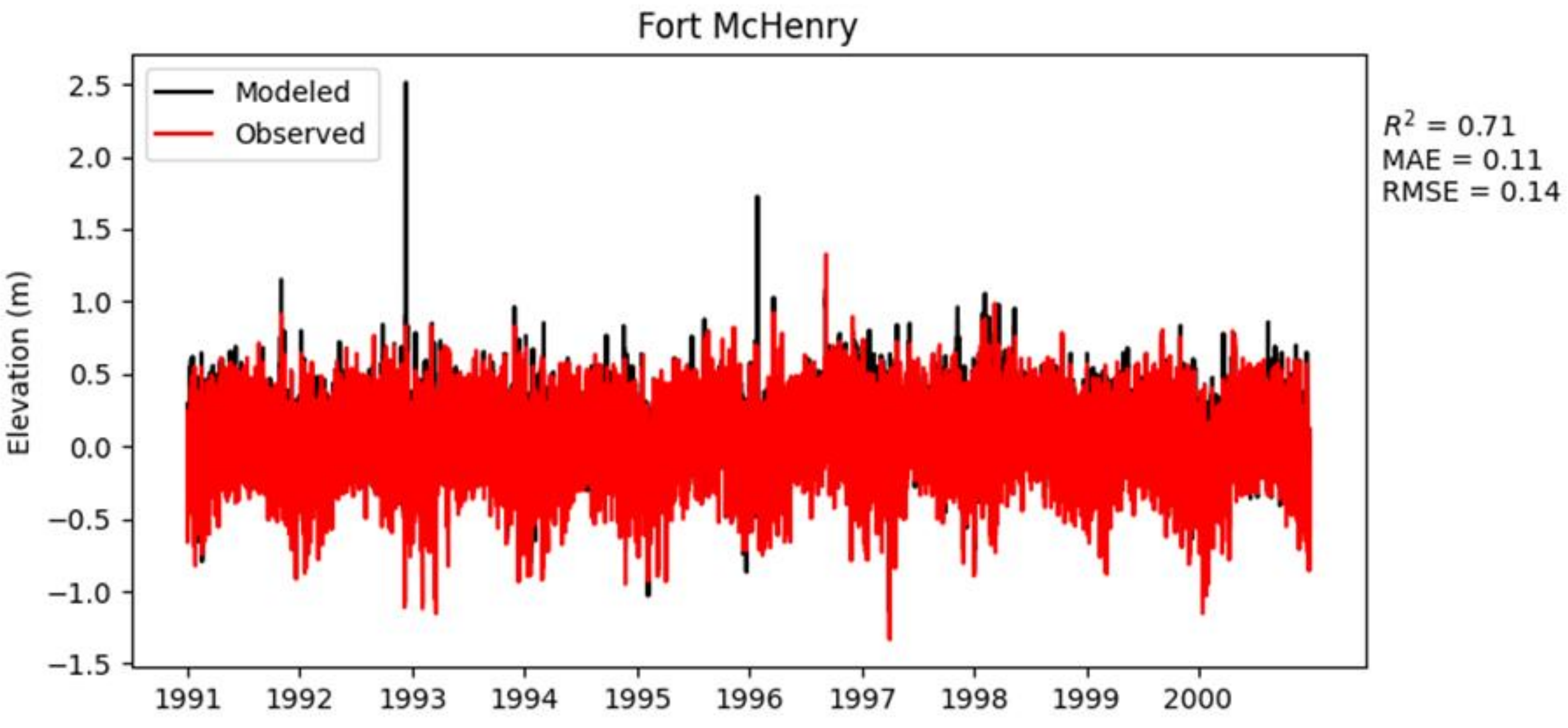
Non-point sources for water quality variables

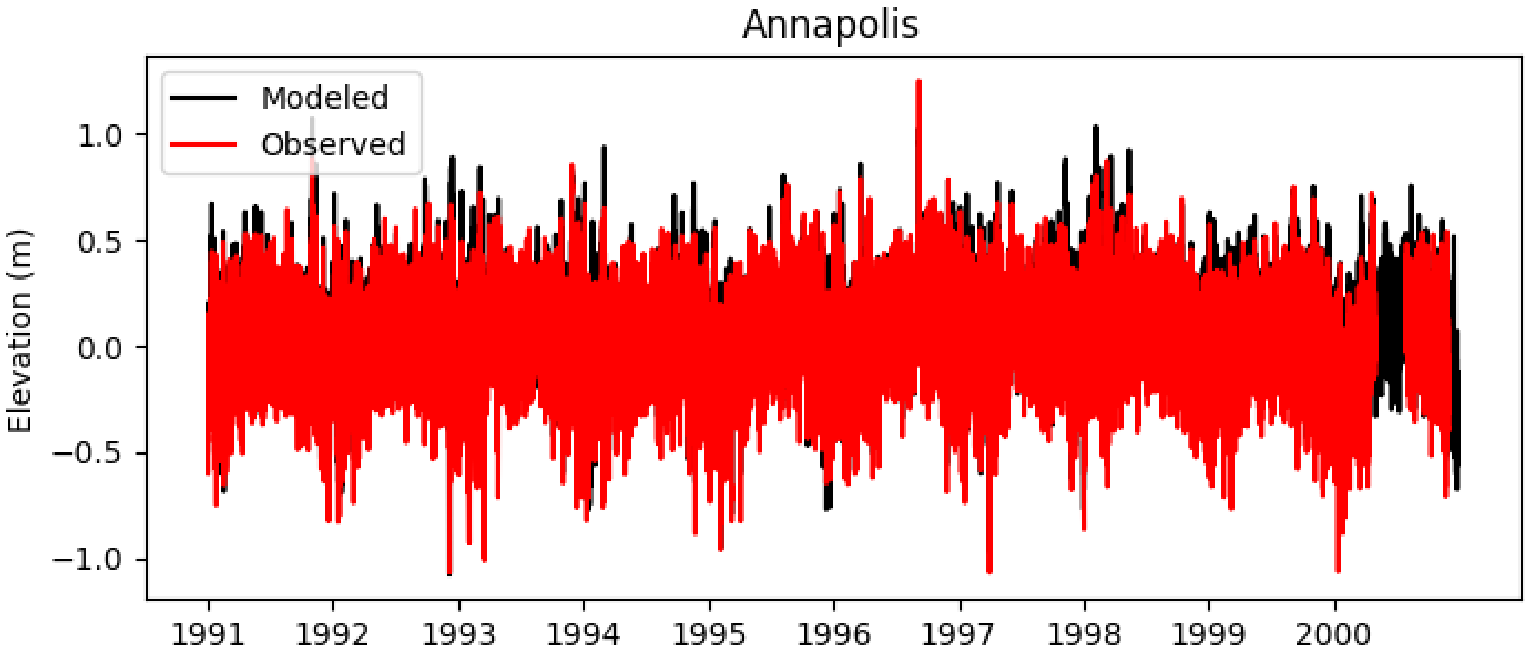
Msource specify concentration for 23 variables within the source.nc input file. They are:

1. Temperature
2. Salinity
3. PB1 (Diatom)
4. PB2 (Green Algae)
5. PB3 (Cyanobacteria)
6. RPOC (Refractory Particulate Organic Carbon)
7. LPOC (Labile Particulate Organic Carbon)
8. DOC (Dissolved Organic Carbon)
9. RPON (Refractory Particulate Organic Nitrogen)
10. LPON (Labile Particulate Organic Nitrogen)
11. DON (Dissolved Organic Nitrogen)
12. NH4 (Ammonium Nitrogen)
13. NO3 (Nitrate Nitrogen)
14. RPOP (Refractory Particulate Organic Phosphorus)
15. LPOP (Labile Particulate Organic Phosphorus)
16. DOP (Dissolved Organic Phosphorus)
17. PO4 (Total Phosphate)
18. COD (Chemical Oxygen Demand)
19. DOX (Dissolved Oxygen)
20. SRPOC (Slow Refractory Particulate Organic Carbon)
21. SRPON (Slow Refractory Particulate Organic Nitrogen)
22. SRPOP (Slow Refractory Particulate Organic Phosphorus)
23. PIP (Particulate Inorganic Phosphate)

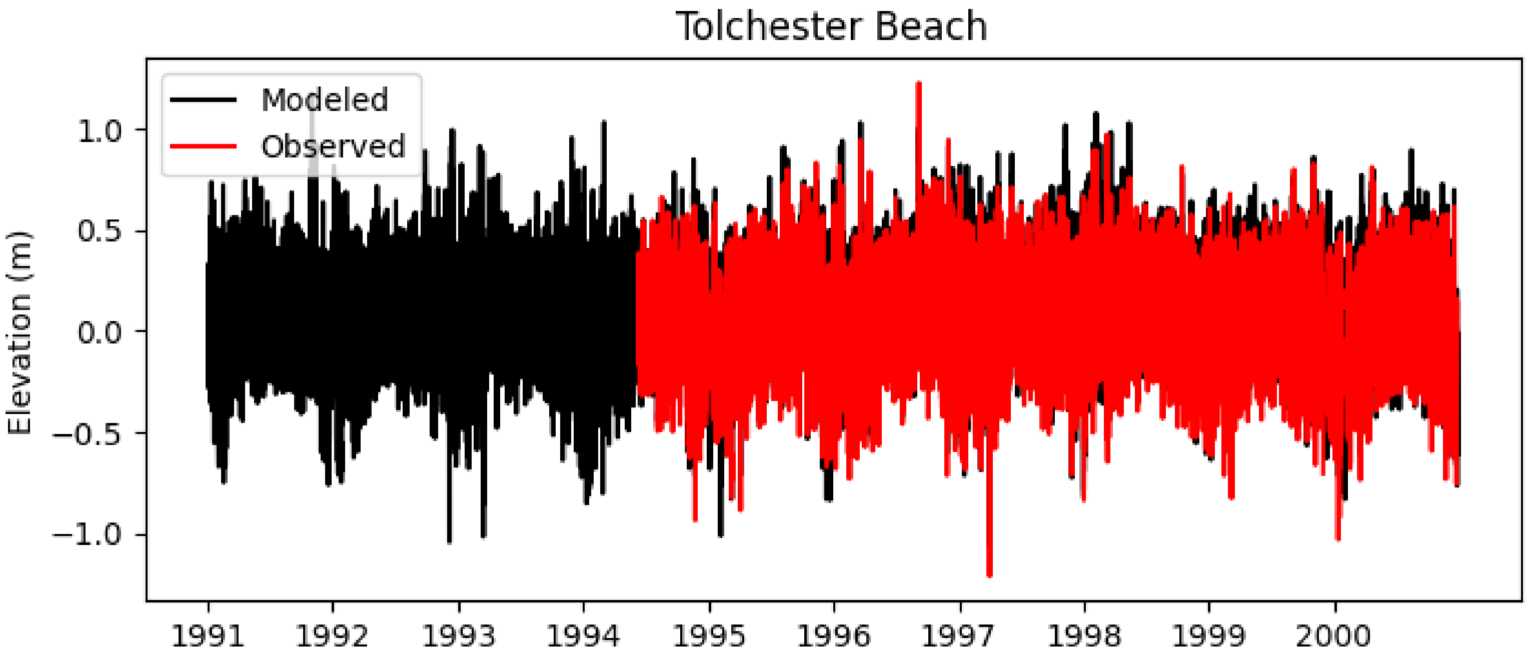
II. Water quality simulation for 10-year: 1991-2000 (off-line approach)

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



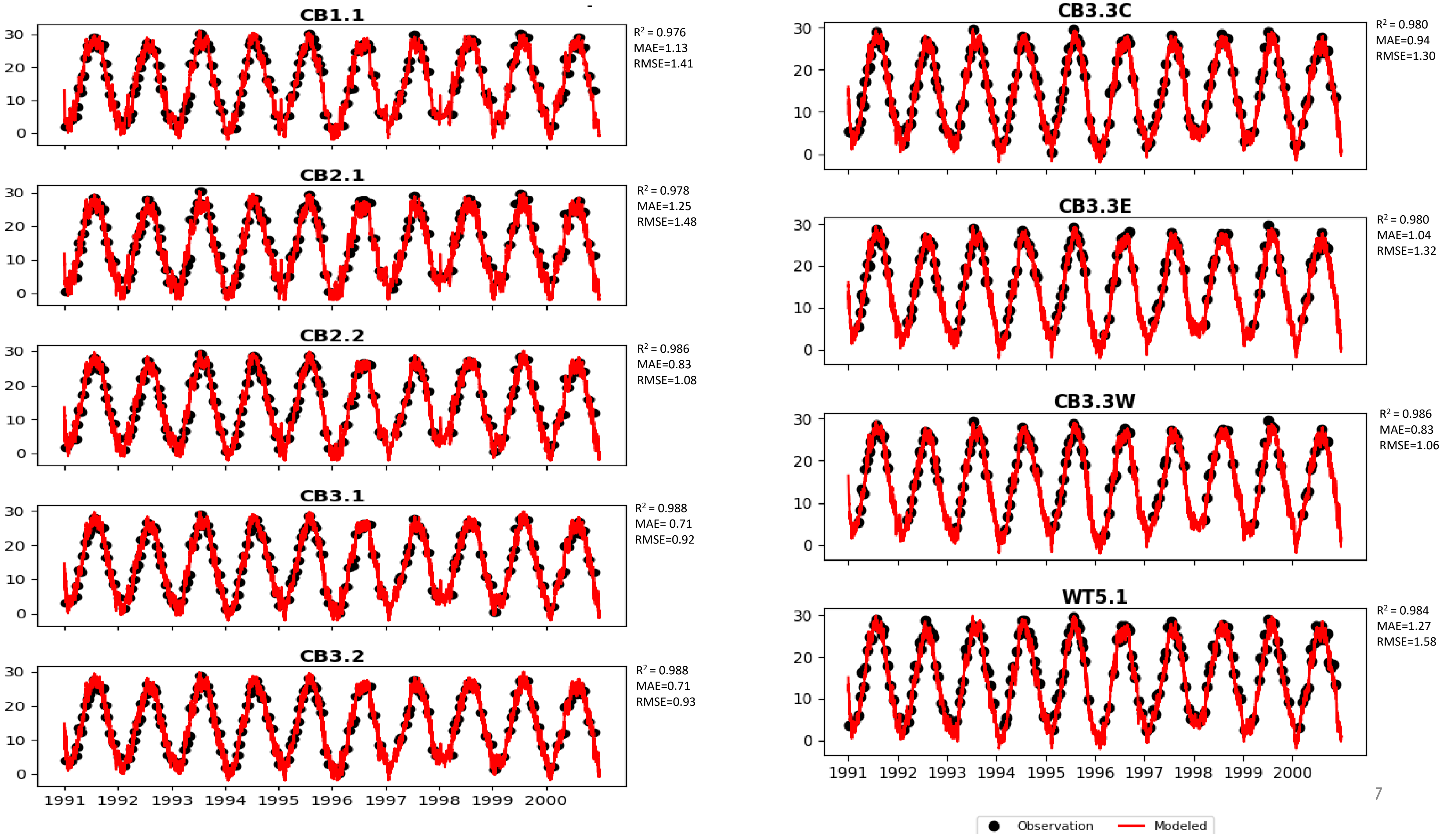


R^2 = 0.79
MAE = 0.09
RMSE = 0.12

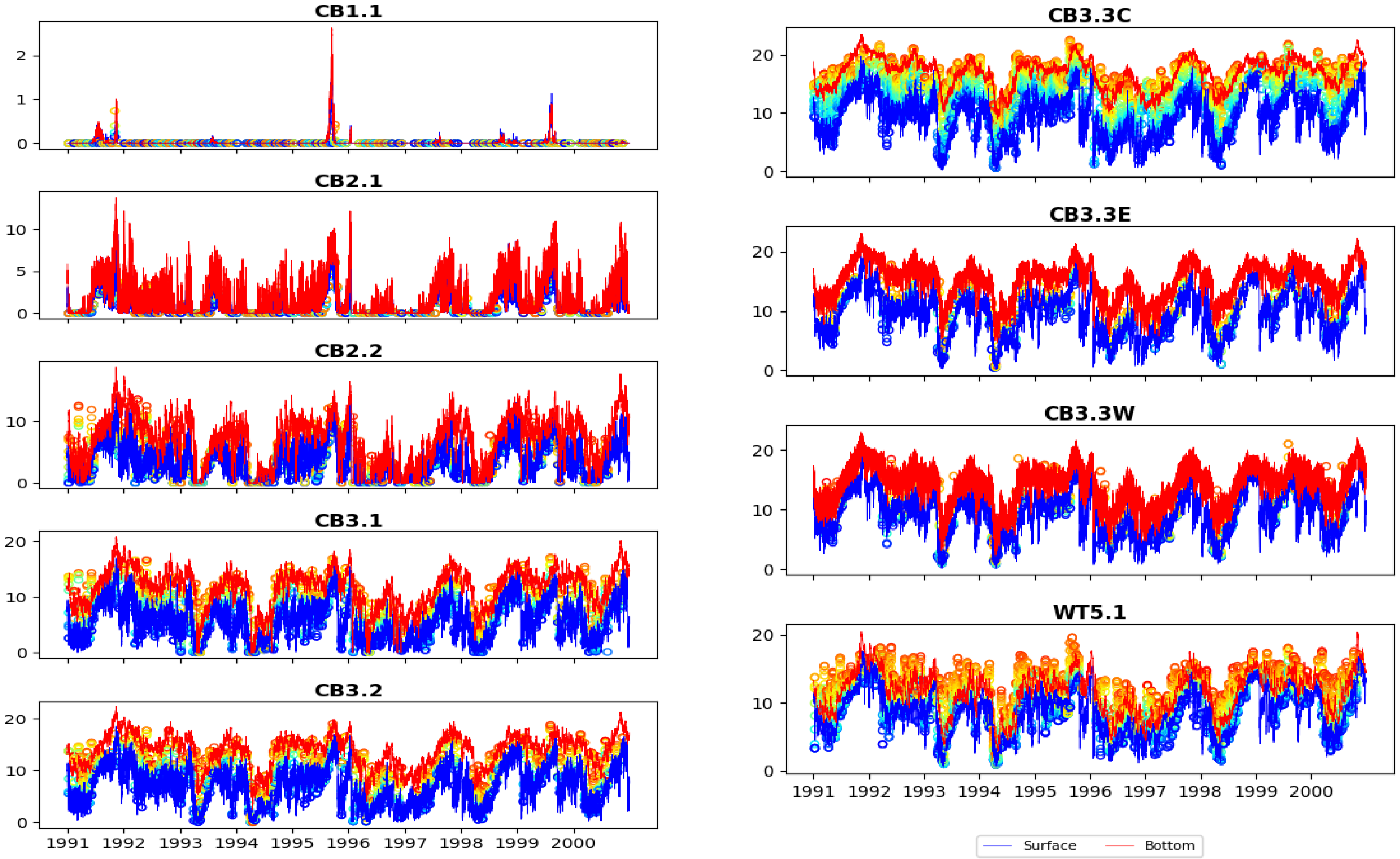


R^2 = 0.81
MAE = 0.09
RMSE = 0.12

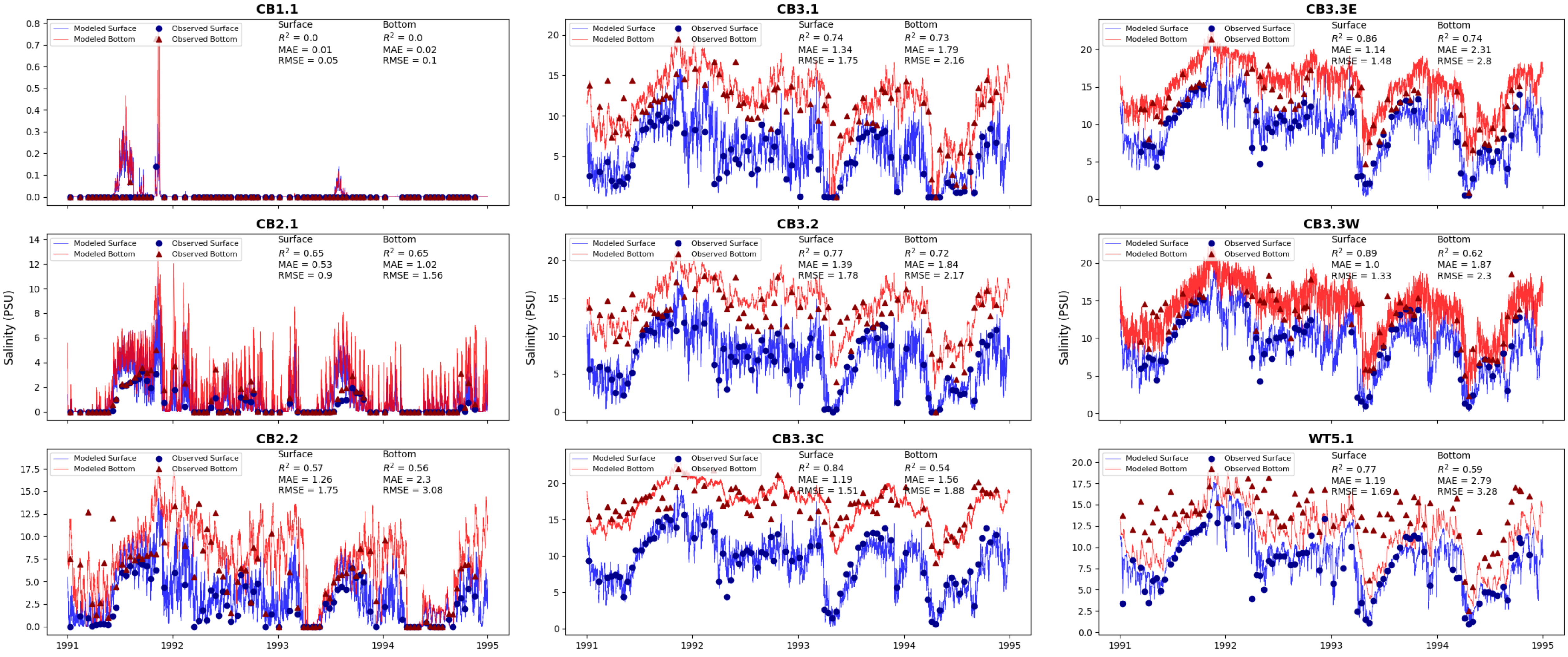
Elevation, **Temperature**, Salinity, DO, ChlA, TN, TP, TSS



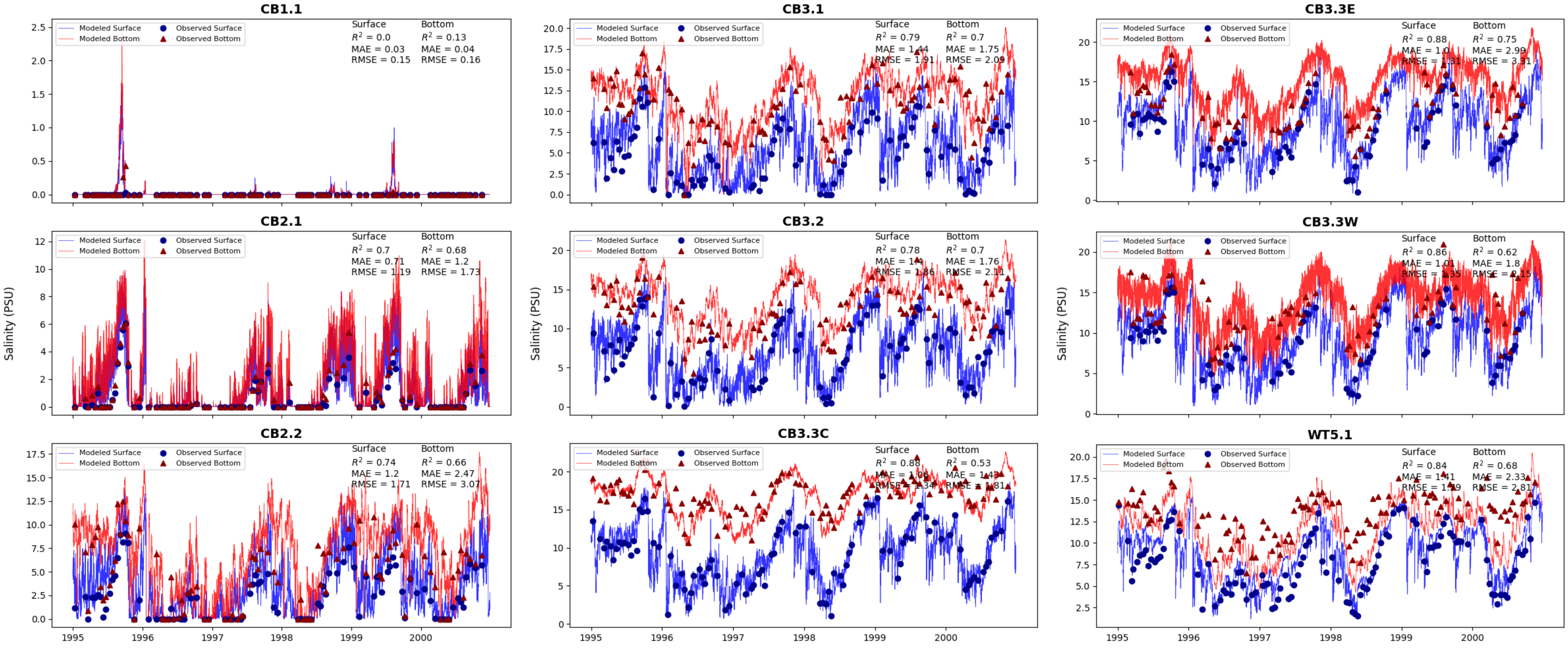
Elevation, Temperature, **Salinity**, DO, ChlA, TN, TP, TSS

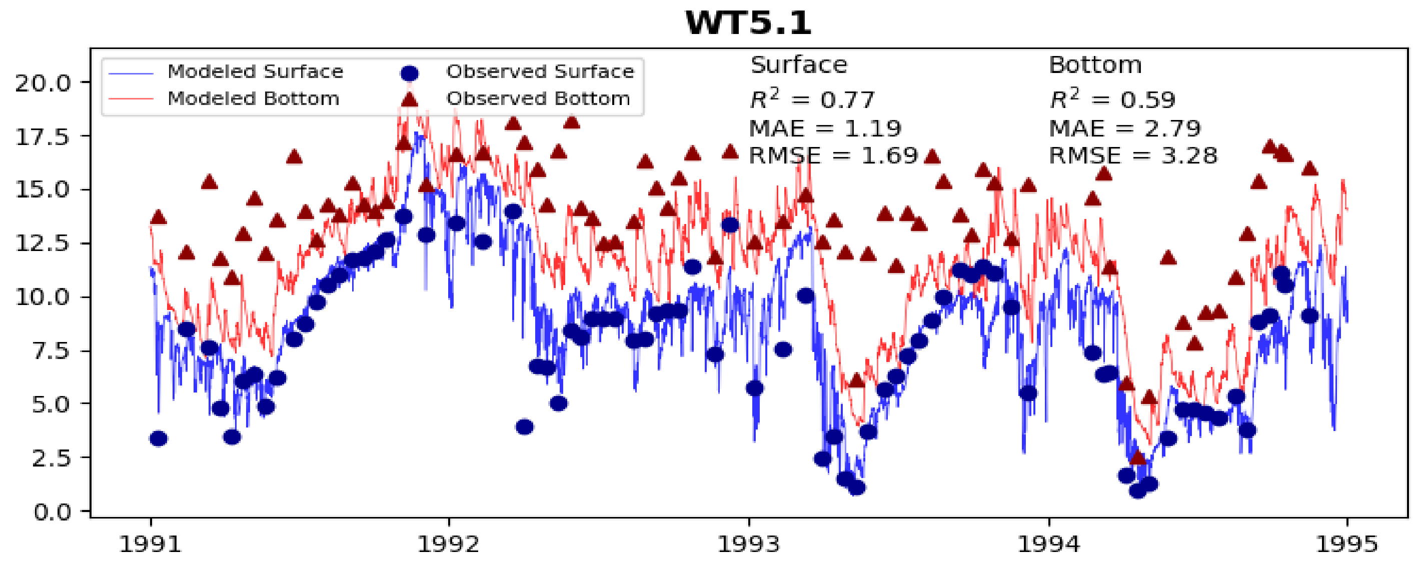


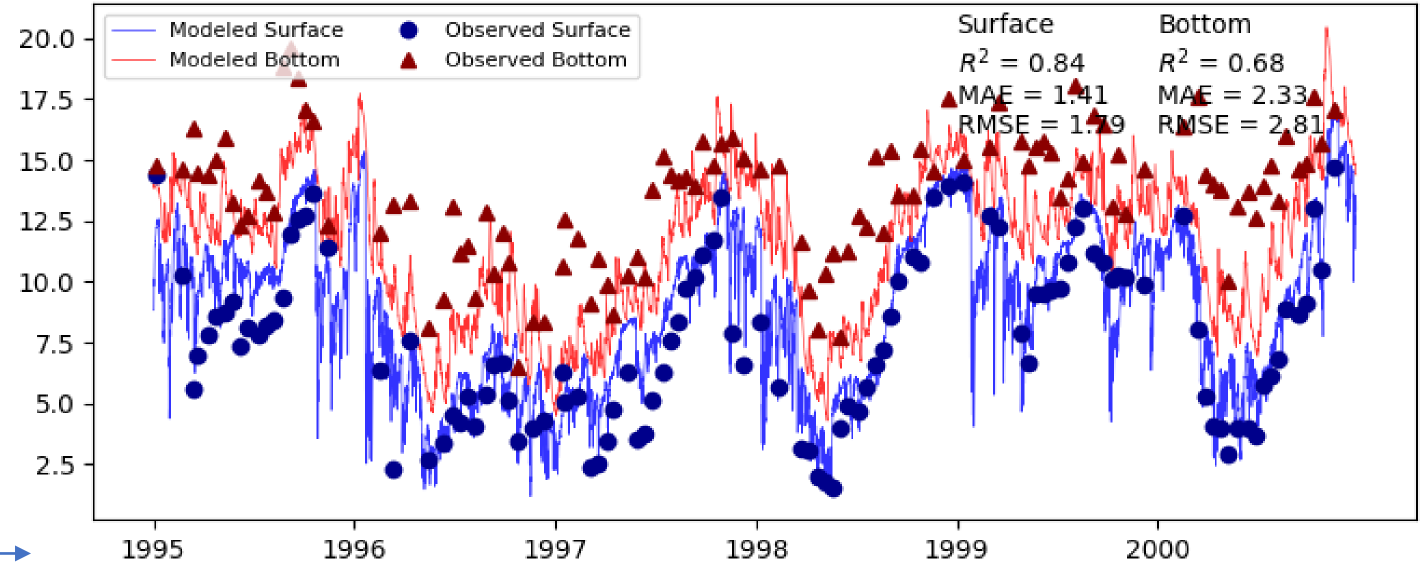
Statistics for 1991-1995



Statistics for 1995-2000

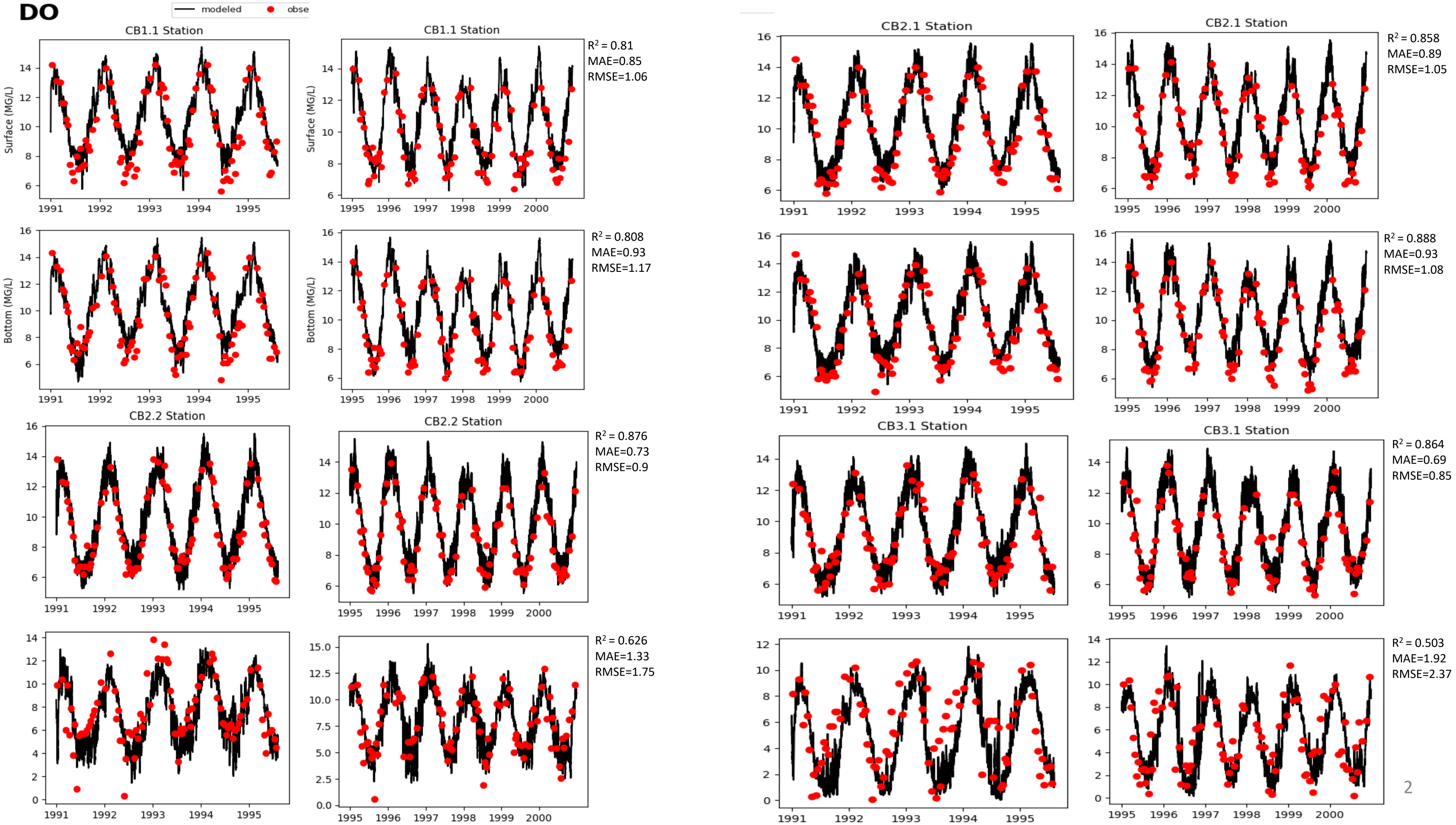


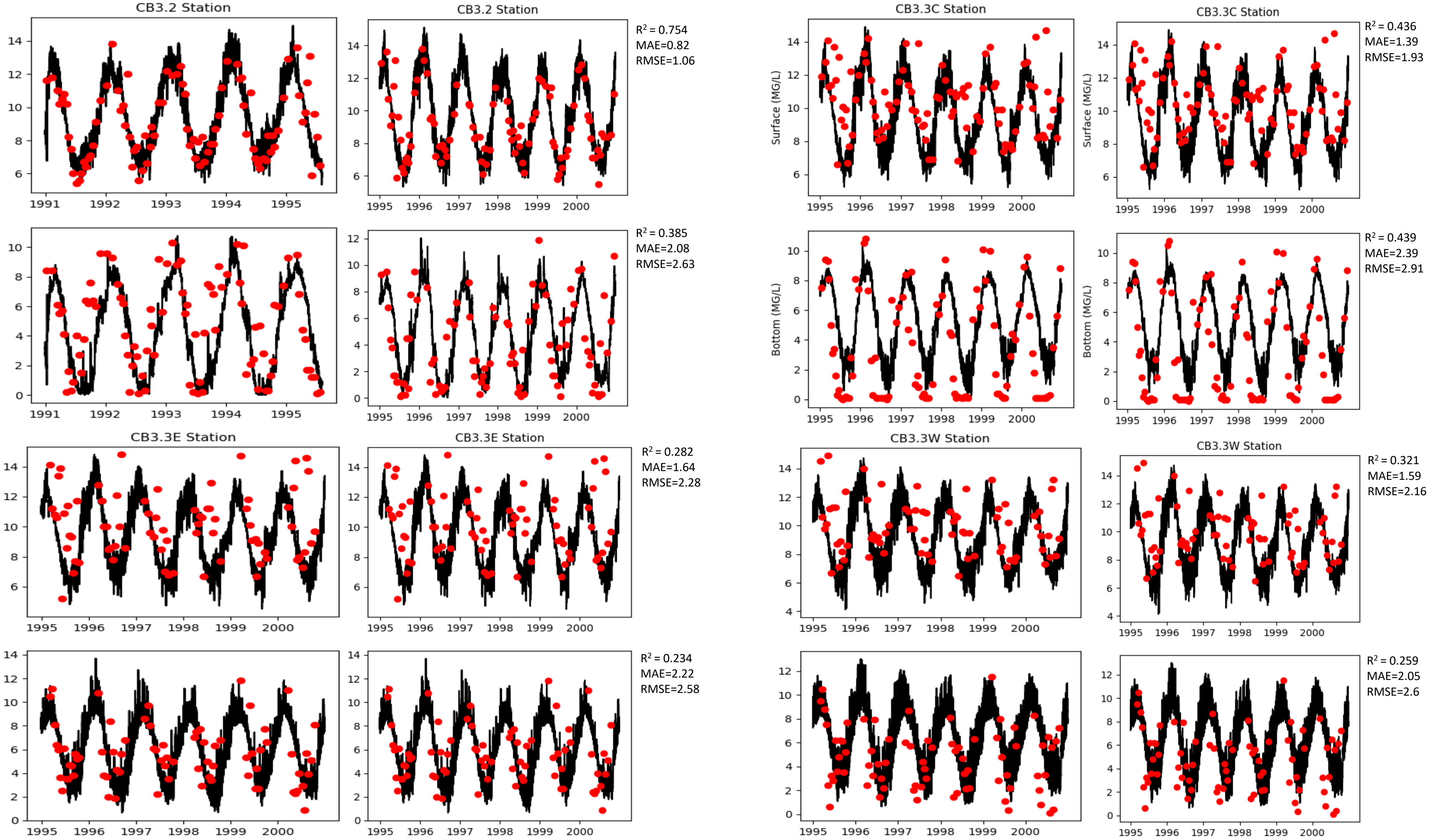




The surface salinity skill in general is better than the bottom

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



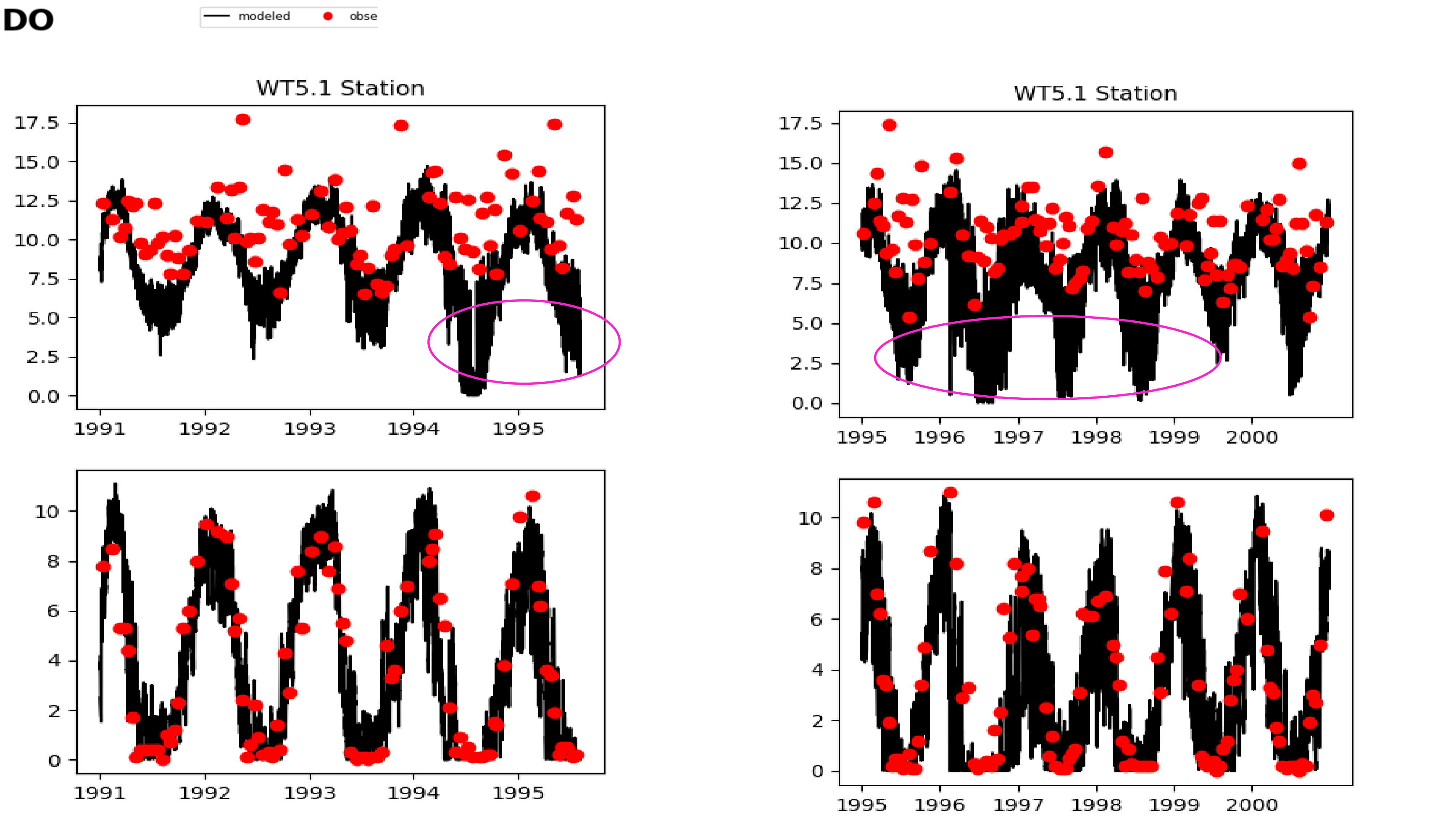


CB3.2 Station
CB3.2 Station
R² = 0.754
MAE=0.82
RMSE=1.06
R² = 0.385
MAE=2.08
RMSE=2.63
CB3.3C Station
CB3.3C Station
Surface (MG/L)
R² = 0.436
MAE=1.39
RMSE=1.93
Bottom (MG/L)
R² = 0.439
MAE=2.39
RMSE=2.91
CB3.3E Station
CB3.3E Station
R² = 0.282
MAE=1.64
RMSE=2.28
R² = 0.234
MAE=2.22
RMSE=2.58
CB3.3W Station
CB3.3W Station
R² = 0.321
MAE=1.59
RMSE=2.16
R² = 0.259
MAE=2.05
RMSE=2.6

DO

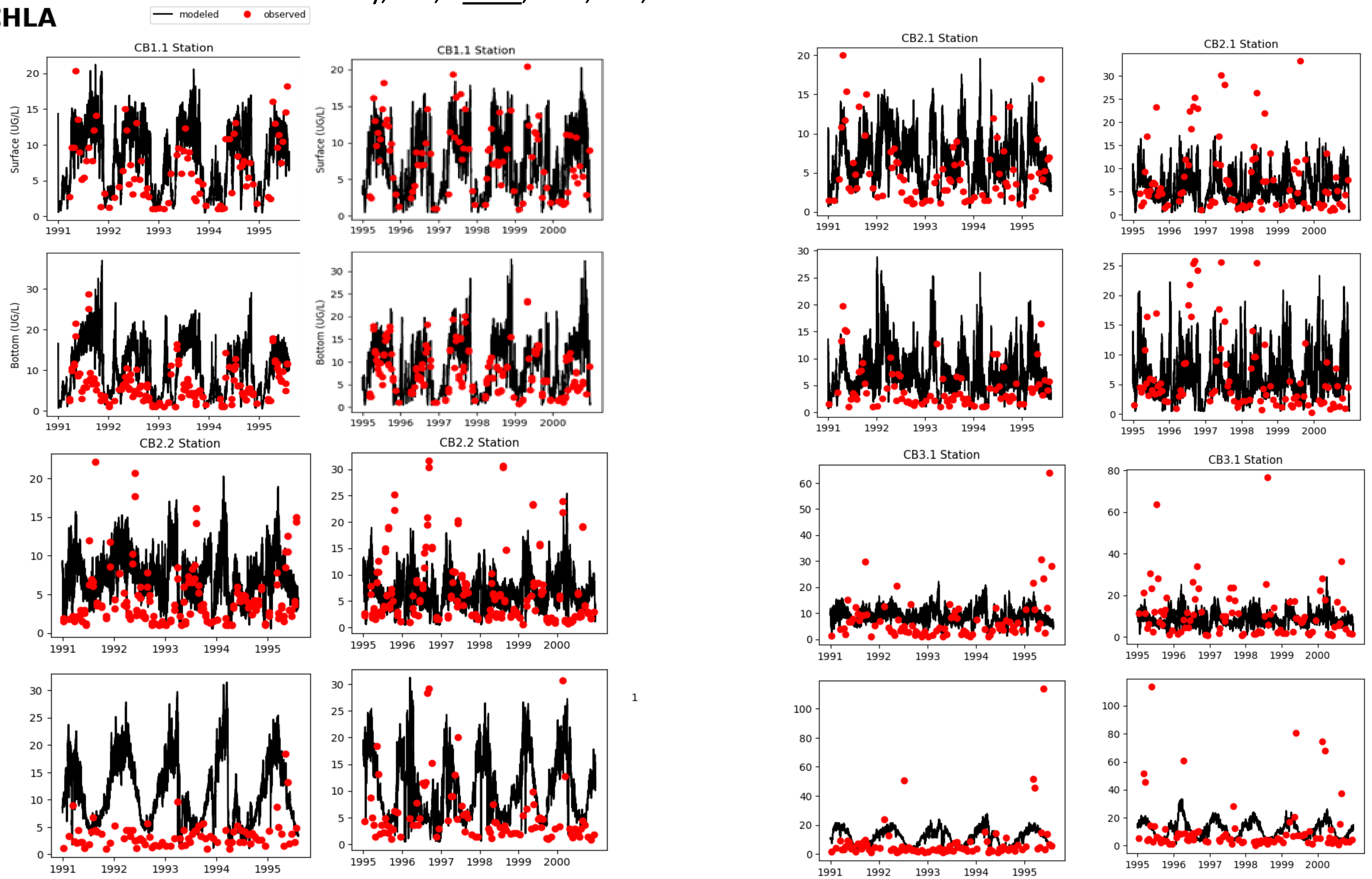
surface →

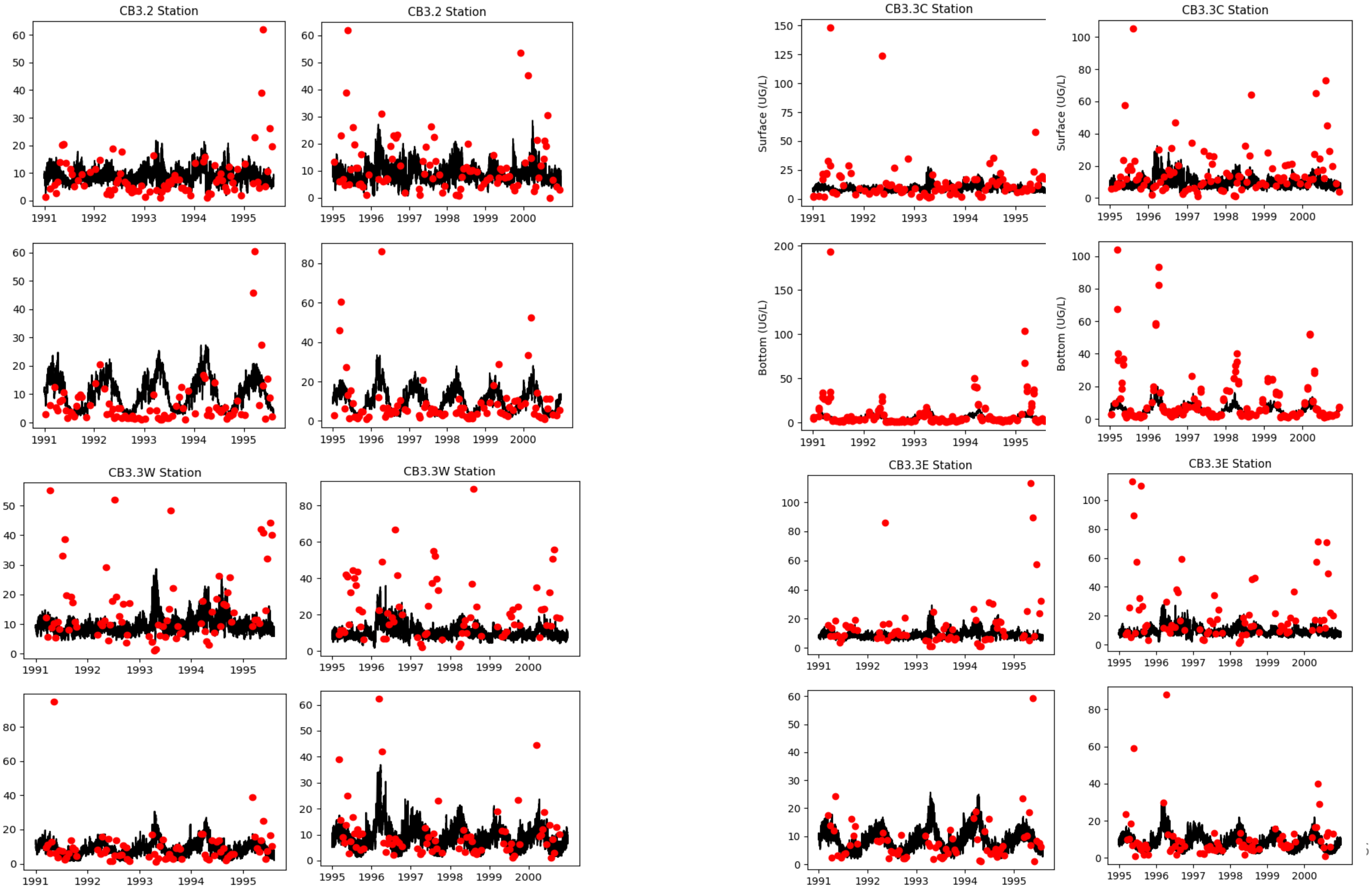
Bottom →



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

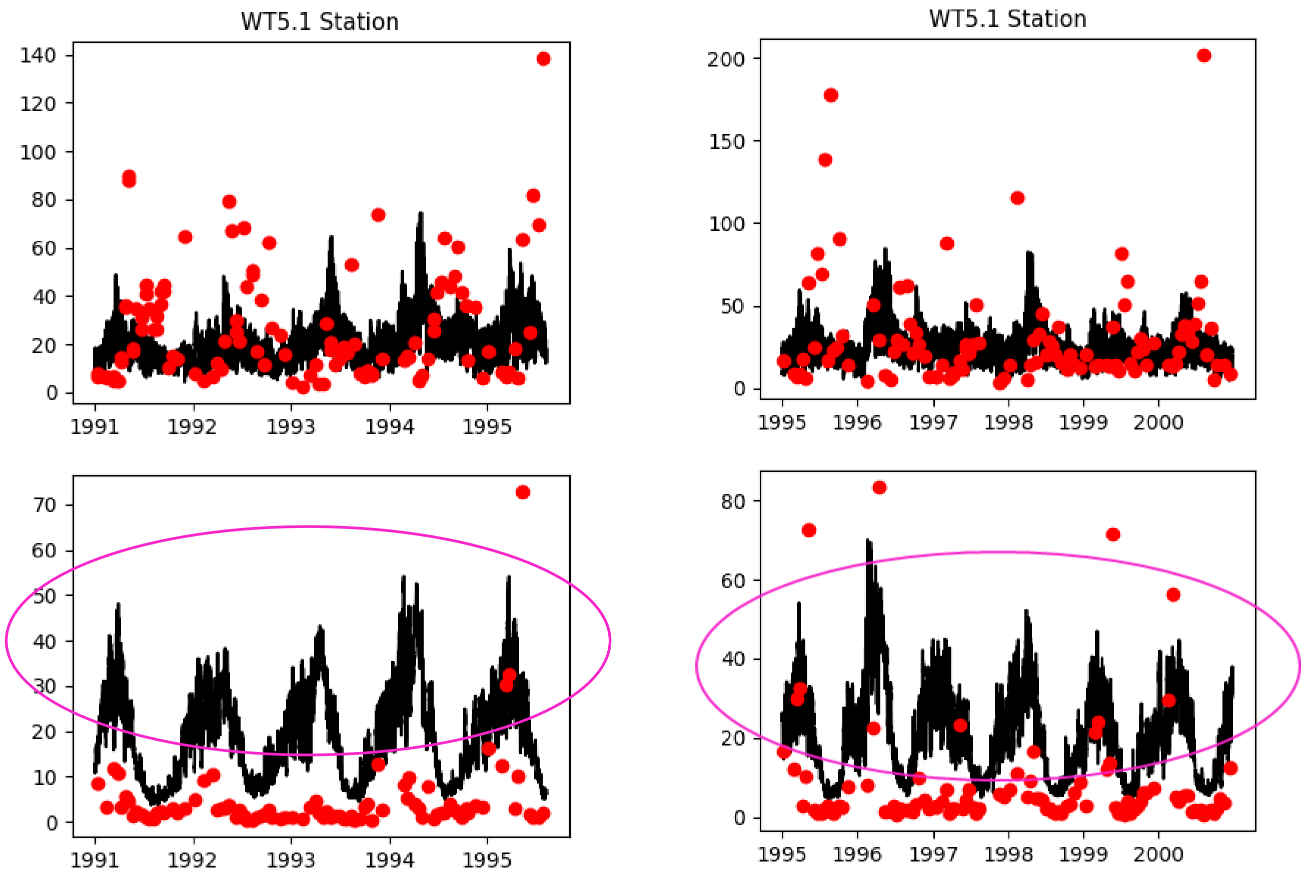
CHLA




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

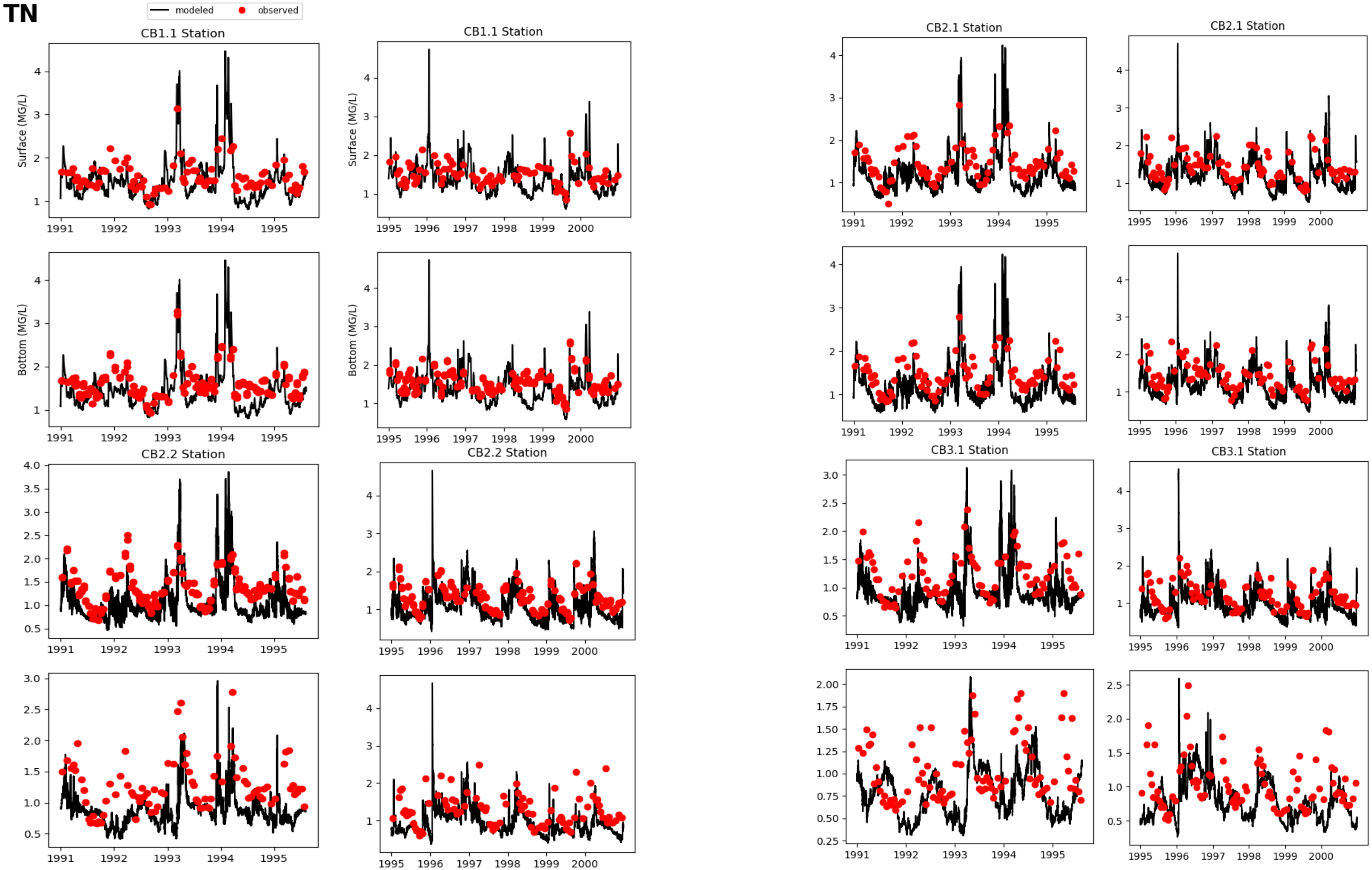
surface

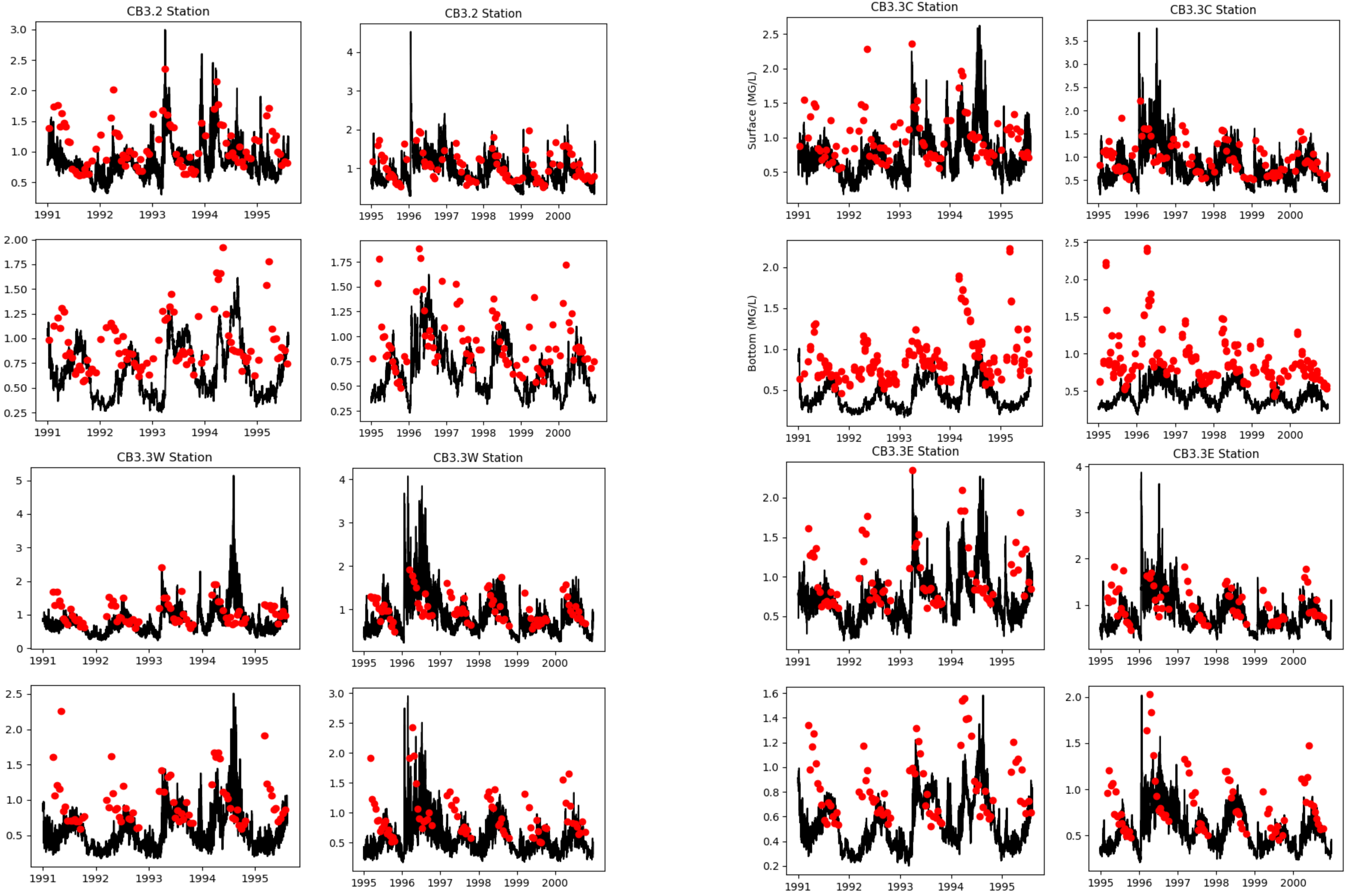
Bottom



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

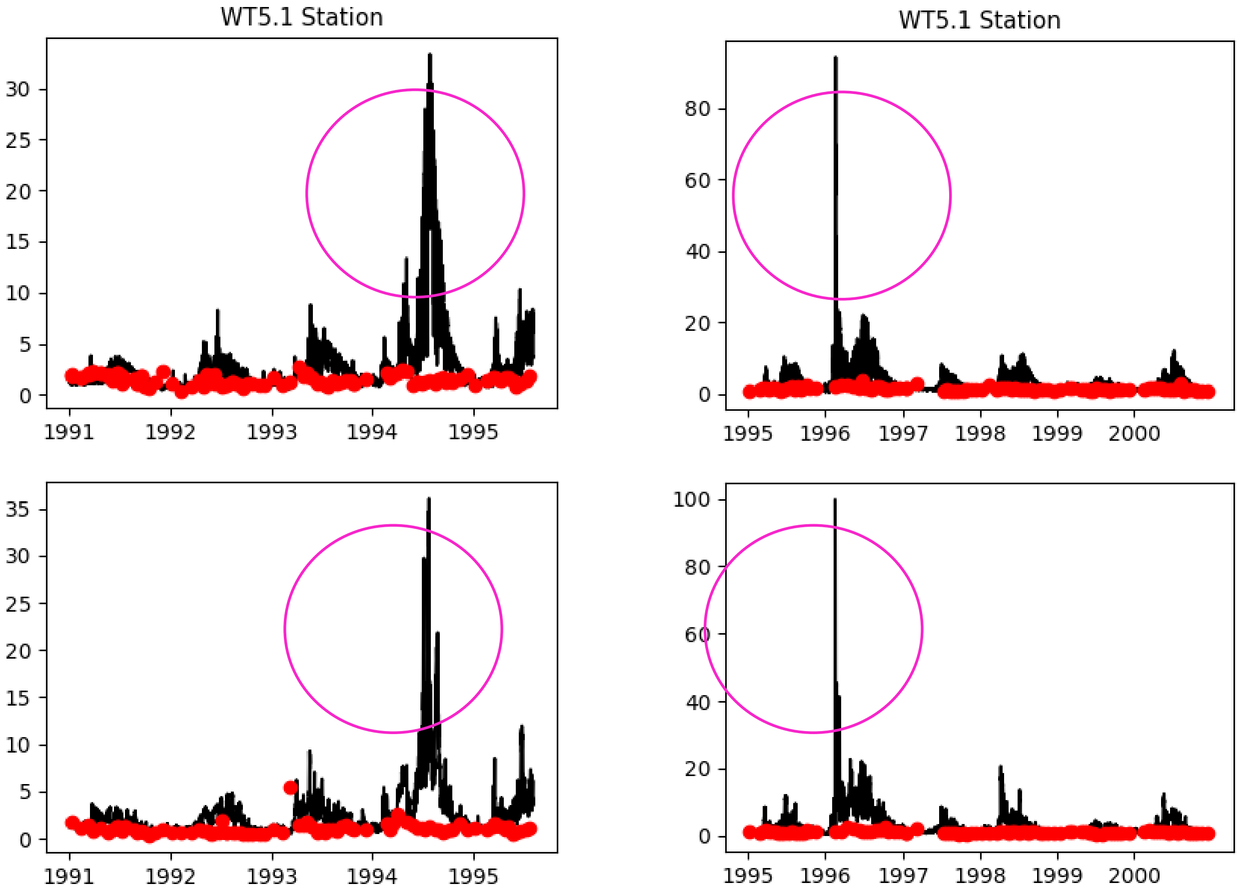
TN




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

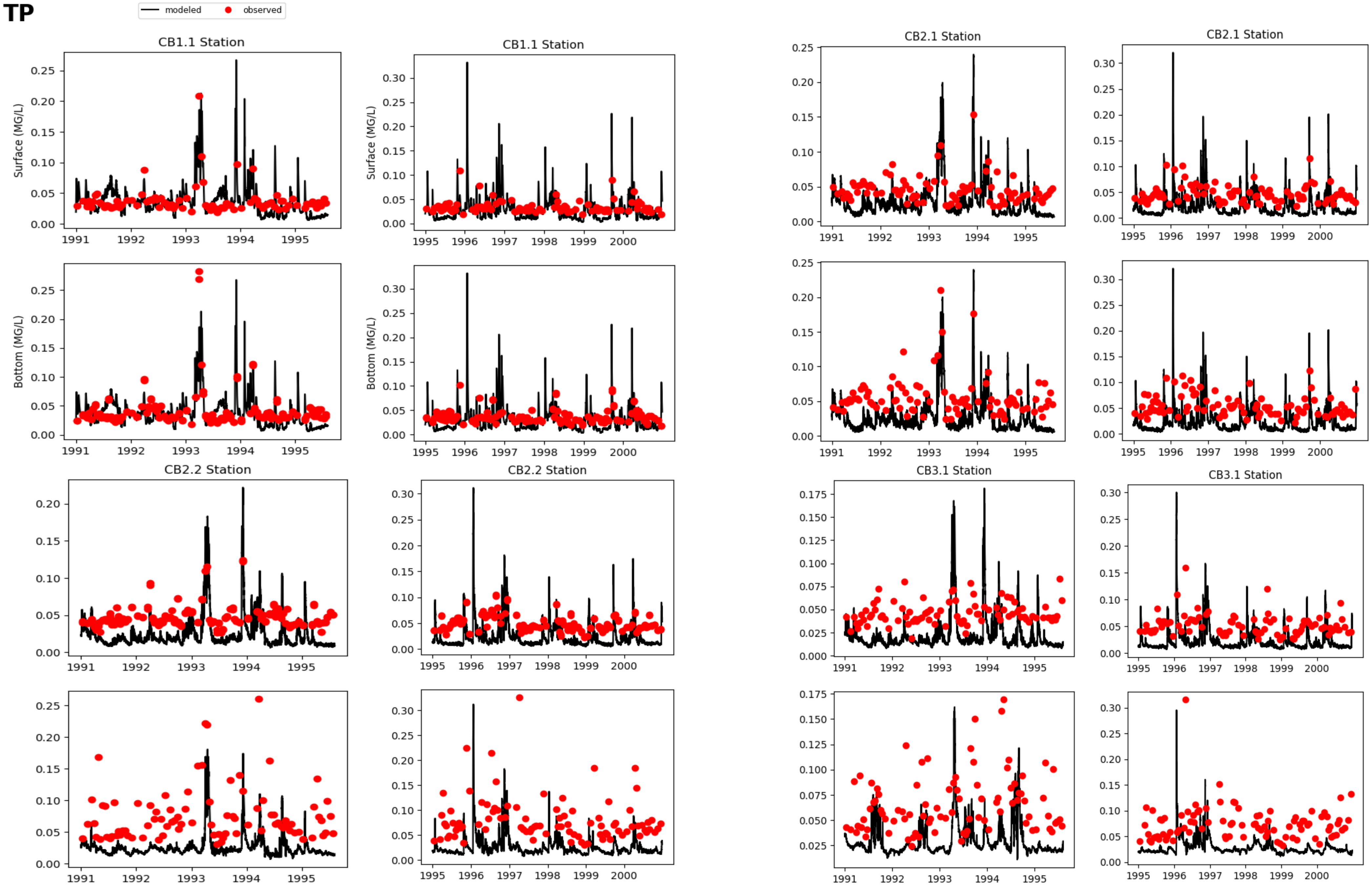
surface →

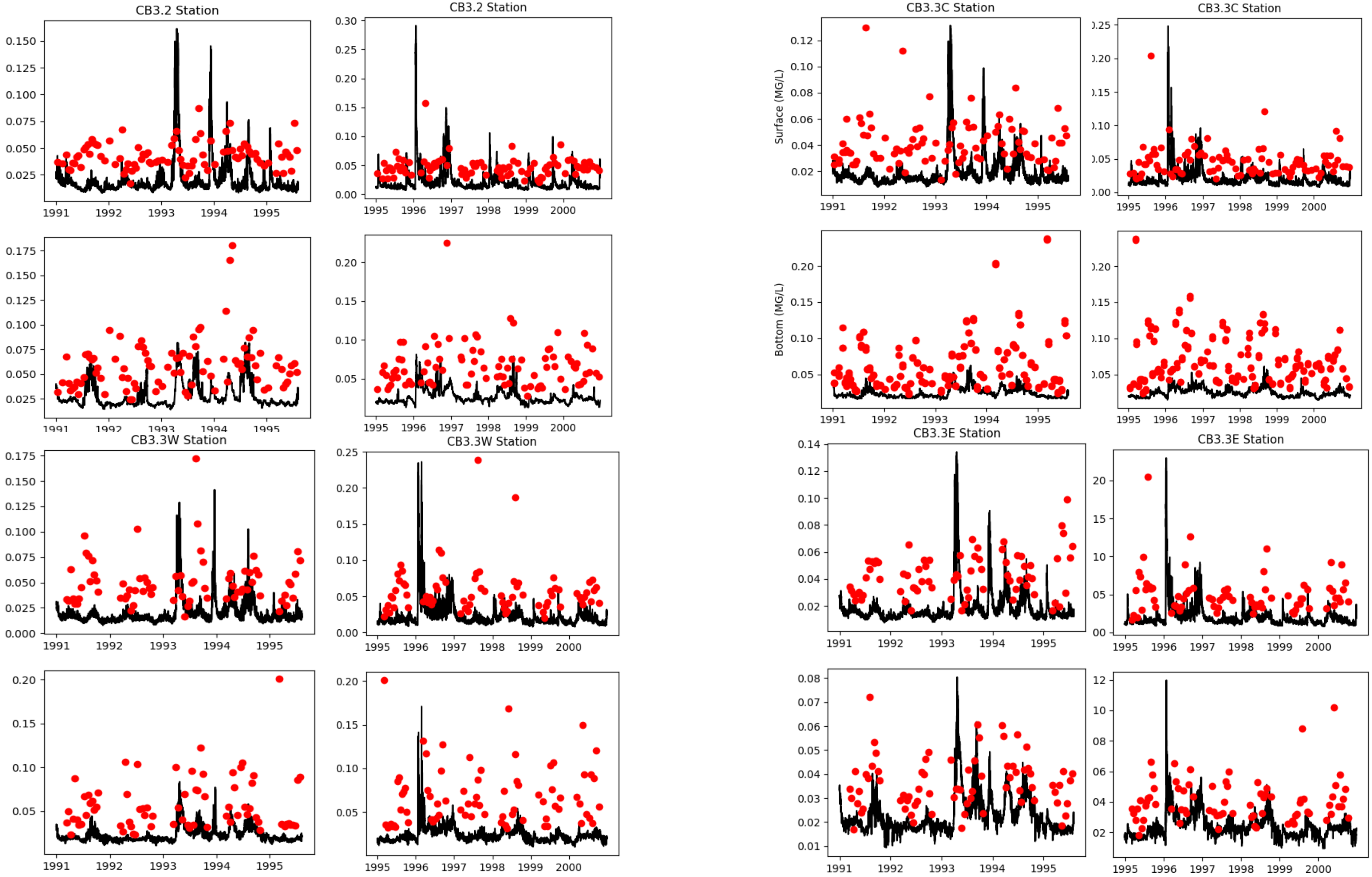
Bottom →



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

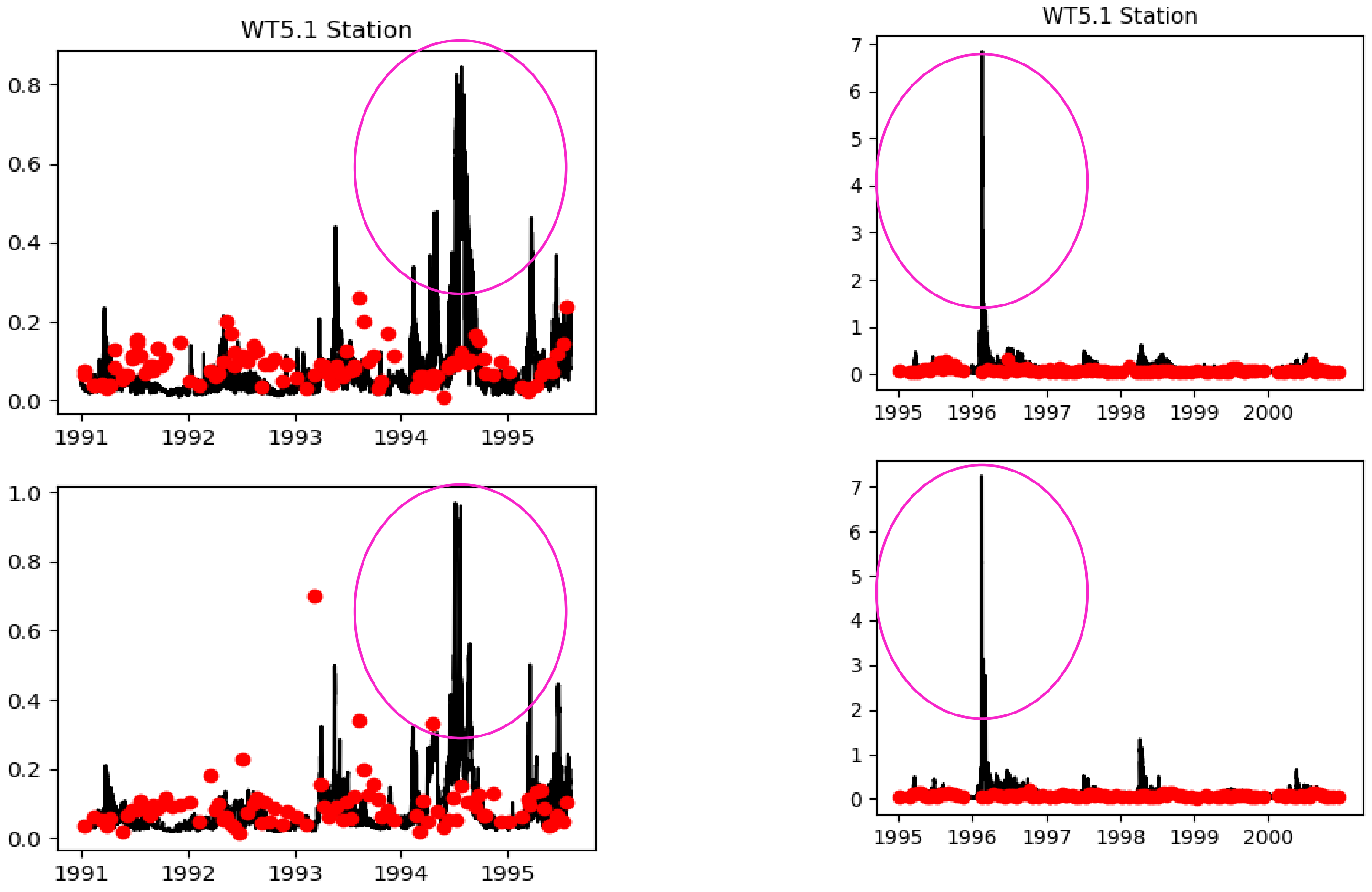
TP




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

surface →

Bottom →



III. Specific issues and those local to the Patpsco/Back River MTM

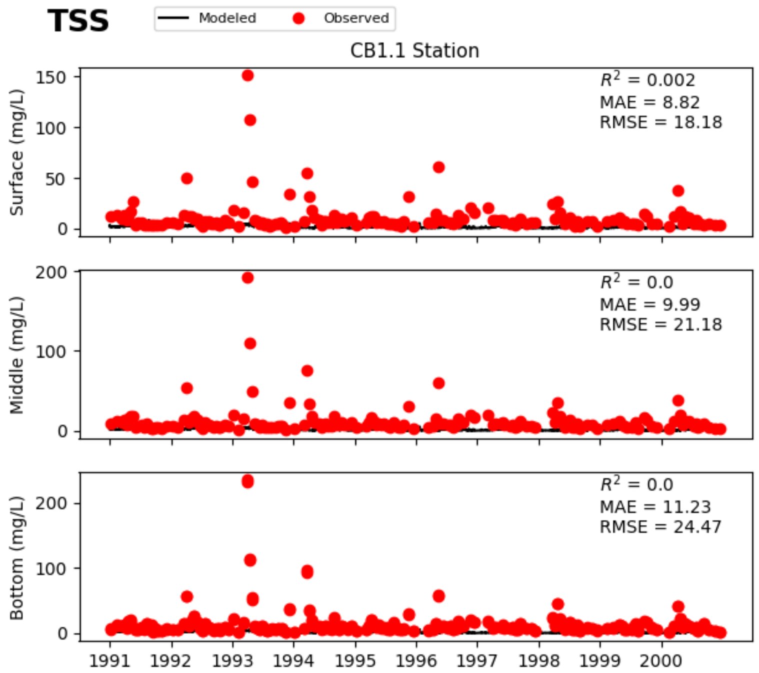
Elevation, Temperature, Salinity, DO, ChlA, TN, TP, **TSS**

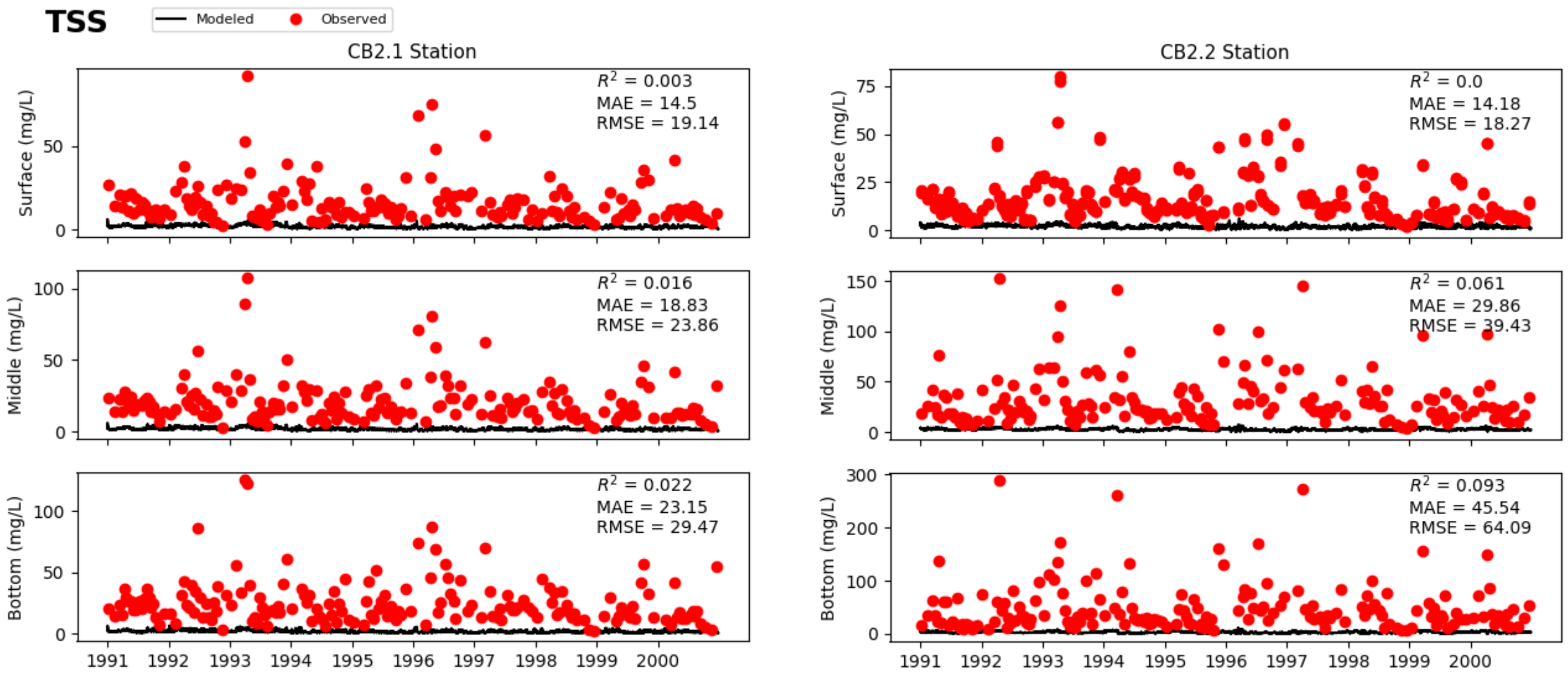
Methodology:

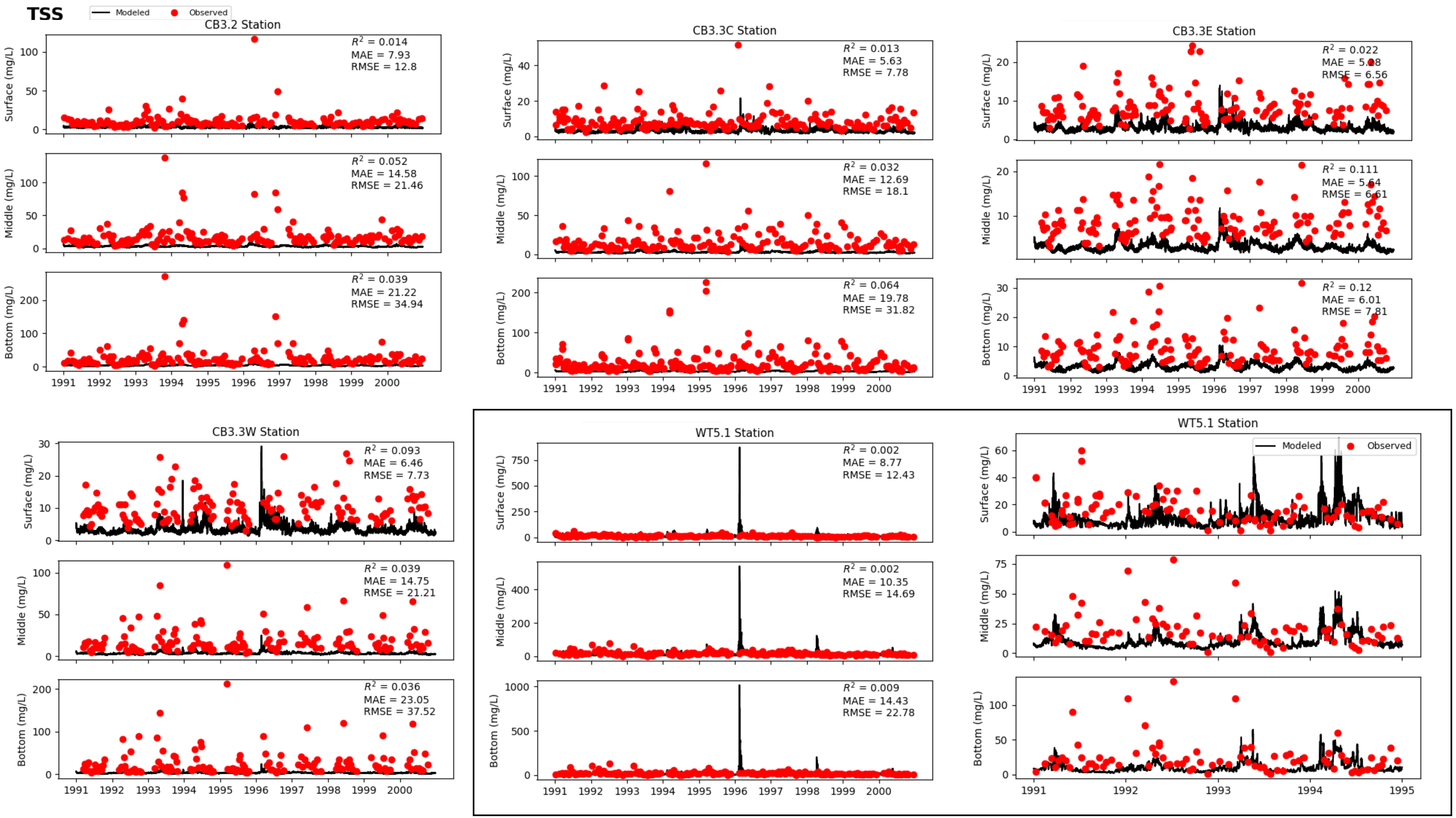
TSS = ISS + 2.5*(B1+B2+B3+LPOC+RPOC+G3OC) (recommended)

Where, TSS = total suspended solids (g/m)
ISS = fixed solids (g/m3)
B1,B2,B3 =algal biomass (g C / m3)
LPOC,RPOC, G3OC = model particulate carbon variables (g C / m3)

TSS is the one variable which is currently systematically under-predicted







TSS
Modeled
Observed
CB3.2 Station
R² = 0.014
MAE = 7.93
RMSE = 12.8
R² = 0.052
MAE = 14.58
RMSE = 21.46
R² = 0.039
MAE = 21.22
RMSE = 34.94
CB3.3C Station
R² = 0.013
MAE = 5.63
RMSE = 7.78
R² = 0.032
MAE = 12.69
RMSE = 18.1
R² = 0.064
MAE = 19.78
RMSE = 31.82
CB3.3E Station
R² = 0.022
MAE = 5.28
RMSE = 6.56
R² = 0.111
MAE = 5.64
RMSE = 6.61
R² = 0.12
MAE = 6.01
RMSE = 7.81
CB3.3W Station
R² = 0.093
MAE = 6.46
RMSE = 7.73
R² = 0.039
MAE = 14.75
RMSE = 21.21
R² = 0.036
MAE = 23.05
RMSE = 37.52
WT5.1 Station
R² = 0.002
MAE = 8.77
RMSE = 12.43
R² = 0.002
MAE = 10.35
RMSE = 14.69
R² = 0.009
MAE = 14.43
RMSE = 22.78
WT5.1 Station
Modeled
Observed
Surface (mg/L)
Middle (mg/L)
Bottom (mg/L)
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000

Importnace of flocculation of cohesive sediments in Baltimore Harbor

The reason Baltimore Harbor is prone to sediment flocculation:

(1) High clay concentration in the water column (source from Susquehanna River and due to frequent ship-induced resuspension)
(2) Flocculation enhanced by EPS (extracellular polymetric substance) or biological ‘slime’ (see Inner Harbor biofilm by National Aquarium biofilm program)
(3) Low turbulent shear in the water column (due to stratification setup by Susquehanna discharge and salt intrusion)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Sediment resuspension characteristics in Baltimore Harbor, Maryland

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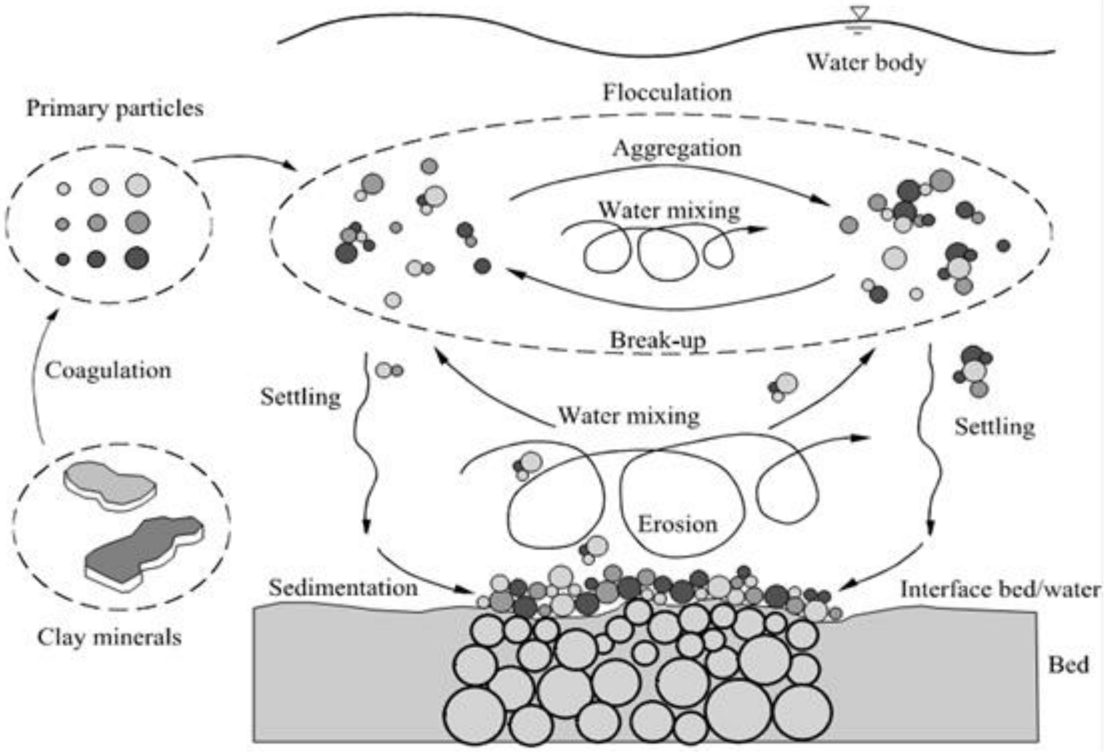
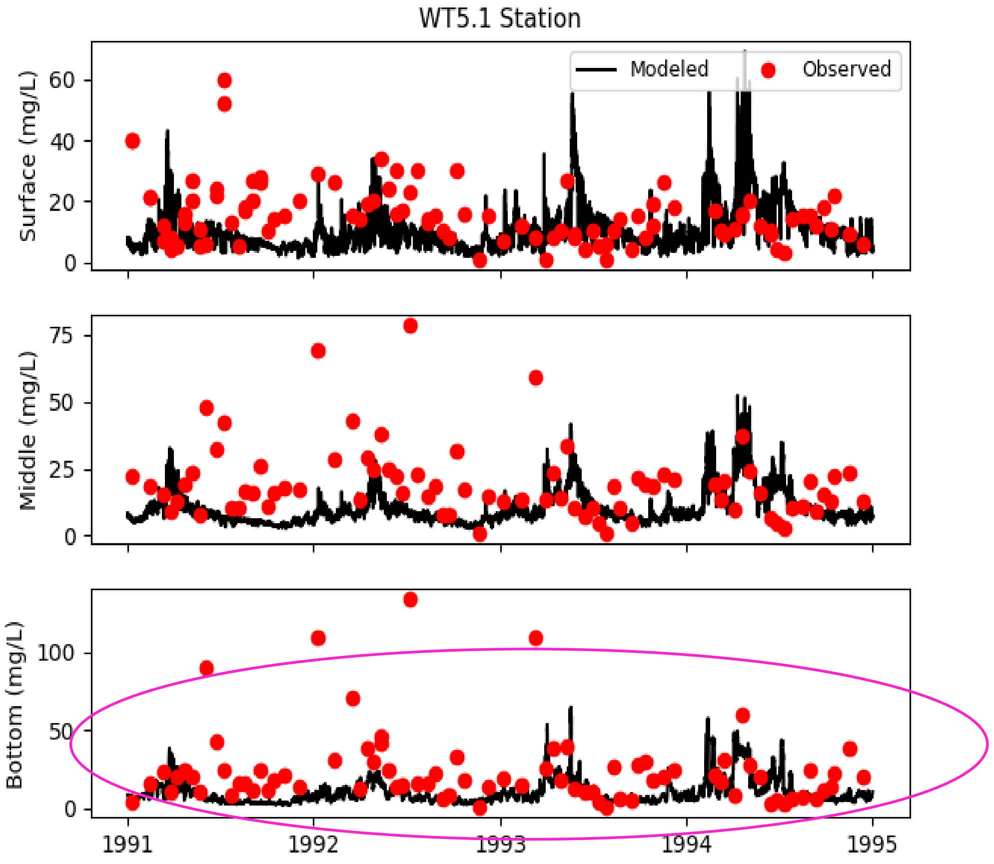
Abstract

Critical bed shear stress for sediment resuspension and sediment erosion rate were measured in-situ at sites from inner to outer Baltimore Harbor using the VIMS Sea Carousel. Clay mineral contents and biological conditions were almost the same at the four study sites. The experimental results indicated that the erosion rate increased from the outer harbor toward the inner harbor with a maximum difference of about 10 times at an excess bed shear stress of 0.1 Pa. The measured critical bed shear stress strongly depended on the existence of a fluff layer. It was approximately 0.05 Pa if a fluff layer existed, and increases to about 0.1 Pa in the absence of a fluff layer. © 1998 Elsevier Science

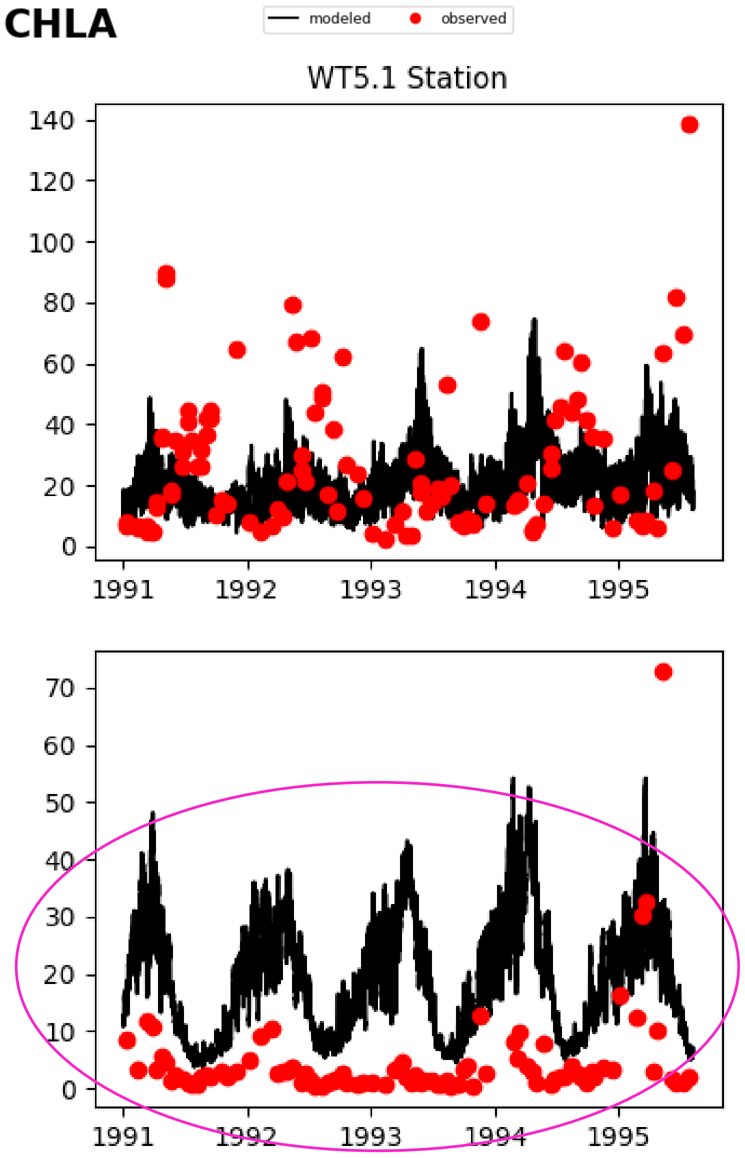


TSS



Related to fluff – layer-induced low critical shear stress

CHLA



Related to flocculation-induced larger settling velocity

(see next slide)

Current formula used (recommend):

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

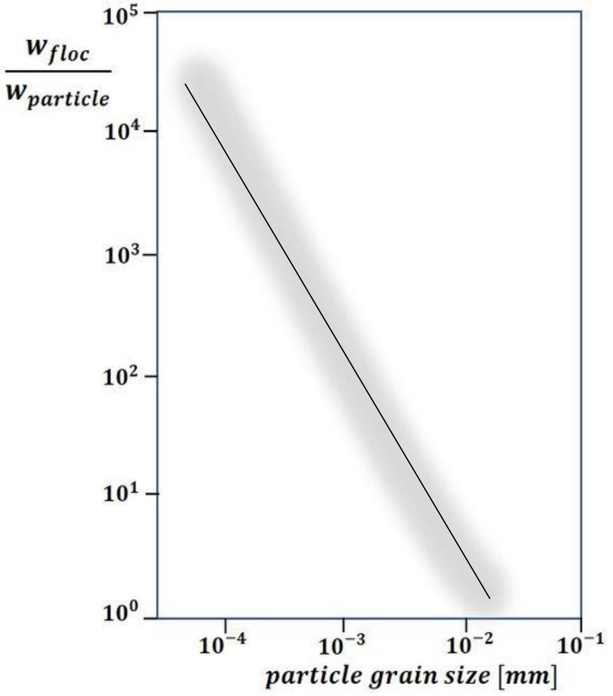
Settling velocity formulas

Using a special camera, Van Leussen (1994[16]) observed vertical particle motions in the Ems-Dollard estuary during different tidal phases. From these observations he deduced that the settling velocity of these particles critically depended on two variables: the volume concentration ϕ of the particles and the degree of turbulence, characterized by the turbulent velocity shear rate G. He proposed for the dependence of the settling velocity on these variables the formula

$$w_s = w_{sh}(G)\left(\frac{\phi}{\phi_h}\right)^n, \quad w_{sh}(G) = w_{s0}\frac{1+\lambda_a G}{1+\lambda_b G^2}. \qquad (1)$$

The velocity shear rate with dimension $[s^{-1}]$ is given by $G = \sqrt{\frac{\epsilon}{\nu}} = \sqrt{\frac{\tau}{\rho\nu}\frac{dU}{dz}}$. (2)

Symbols designate: $\epsilon =$ energy dissipation rate per unit mass, $\tau =$ shear stress, $\nu =$ kinematic viscosity, $\rho =$ water density, $U(z) =$ the current velocity as a function of depth z. The volume fraction at the onset of hindered settling is ϕ_h and $w_{sh}(G)$ is the maximum settling velocity for this volume fraction. The constants w_{s0}, ϕ_h, n, λ_a, λ_b are supposed to be independent of G but depend, inter alia, on local sediment characteristics and must be determined experimentally. For Ems-Dollard mud, Van Leussen found $\lambda_a \approx 0.3$, $\lambda_b \approx 0.09$. Values of the exponent n widely varied between 0.6 and 3.



Reference:

Van Leussen, W. 1994. Estuarine macroflocs and their role in fine-grained sediment transport. PhD thesis Utrecht University

IV. Summary

1. Coupled hydrodynamic, sediment transport, wind wave, water column water quality, and sediment flux models in offline mode were implemented in Patapsco/Back River MTM. The 10-year results (1991-2000) were presented. Non-point source loading used is adopted from the CBP watershed hybrid phase 6 and 7 outputs.

2. Hydrodynamic variables: water level, temperature, and salinity were well-captured compared with observations. Water quality variables: DO, Chlorophyll-a, TN and TP are within a reasonable range of observation of 10 year period and likely can be further improved.

3. The one variable that is systematically under-predicted is TSS. The TSS concentration consisted of fixed solids (inorganic sediment) and volatile solids (organic sediment). The clay component of the fixed solids is known to interact with the biological EPS (extracellular polymetric substance) resulted cohesive sediments whose settling velocity can be many times larger than the non-cohesive sediment that is presently used.

4. The flocculated cohesive sediment is believed to occur in Baltimore Harbor, evidenced by the fluff layer and low critical shear stress measured. In other parts of the Bay, SAV beds distribution also affect TSS . The calibration and validation of TSS needs special attention in future work.