Update on the Phase 7 Main Bay Model (MBM) with New Watershed Nutrient Loading (April, 2026)

VIMS team: Joseph Zhang, Jian Shen, Harry Wang, Marjy Friedrichs,

Zhengui Wang, Wenfan Wu, Pierre St-Laurent

CBPO: Richard Tian, Gopal Bhatt, Lew Linker et al.

UMCES team: Jeremy Testa

Advisor: Carl Cerco

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Outline

- ❑ **Incorporating new watershed model (WSM) loading into MBM workflow**
  - **New coupling method between WSM and MBM**
- ❑ **Assessment MBM simulation with new format of WSM inputs**
  - **Analysis on the new WSM nutrient loading (April, 2026 beta version)**
  - **Analysis of MBM results at RIM stations and embayments.**
  - **Comparison of MBM results between previous (June 2025) and new WSM loadings**
- ❑ **Summary and Future work**

Overview On Phase-7 MBM Status

- ❑ We have processed the new format of WSM nutrient loading and incorporated it into the MBM workflow.
- ❑ We performed the preliminary analysis on the new WSM nutrient loading.
- ❑ We conducted MBM calibration with new WSM loading. The results are generally comparable to old results with some difference.
- ❑ MBM results are overall satisfactory. However, we are continuing to improve the model skill, particularly regarding nutrient species (see Wenfan's talk about phosphorus improvement).

New Format of WSM nutrient loading (April, 2026)

- MBM team received new format of WSM loading in April, 2026 (Thank Gopal).
- The new format is based on stream networks, while the old format is based on watershed segments.
- WSM loading includes Terminal loads and Tidal loads.

Database

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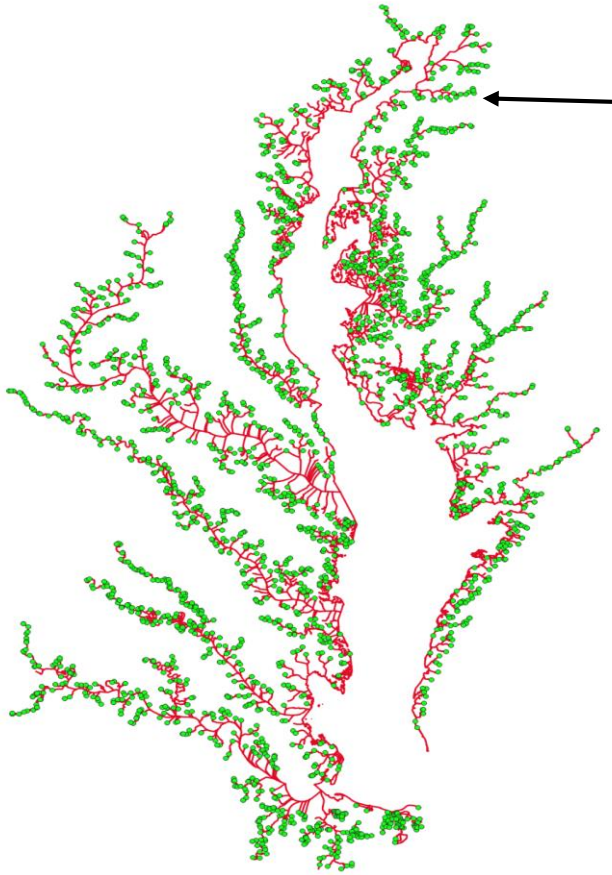
New Format of WSM loadings



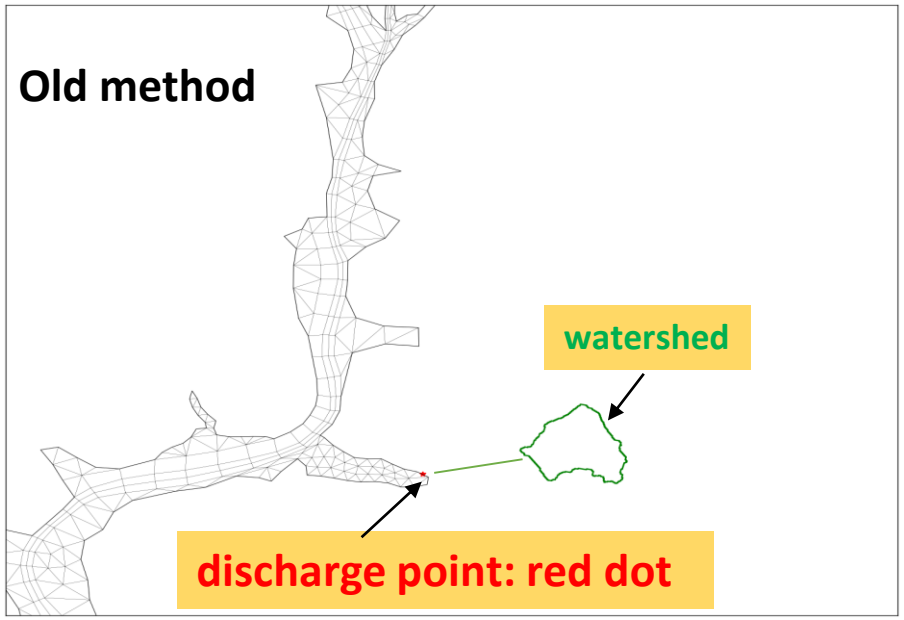
green dots represent the terminal flow

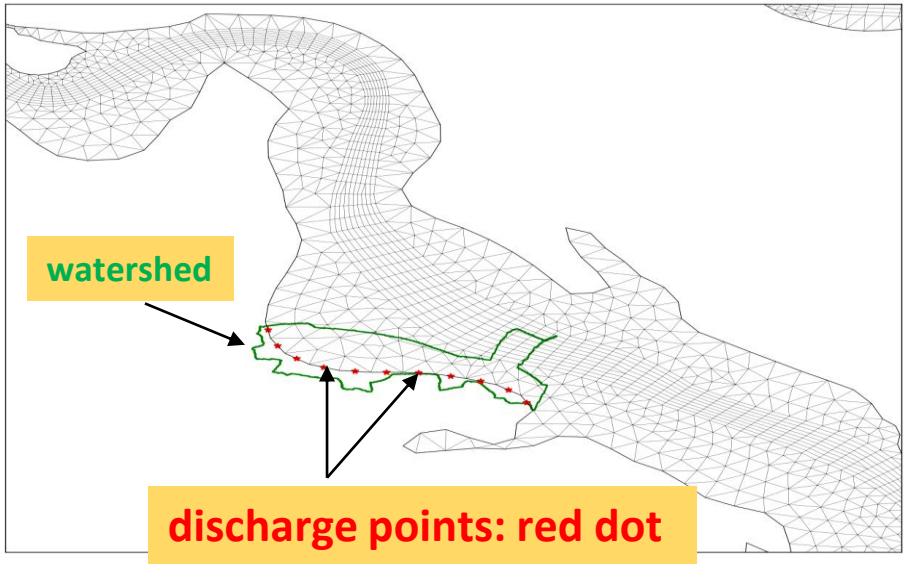
Mean Terminal Flow: 2235.9 m^3/s

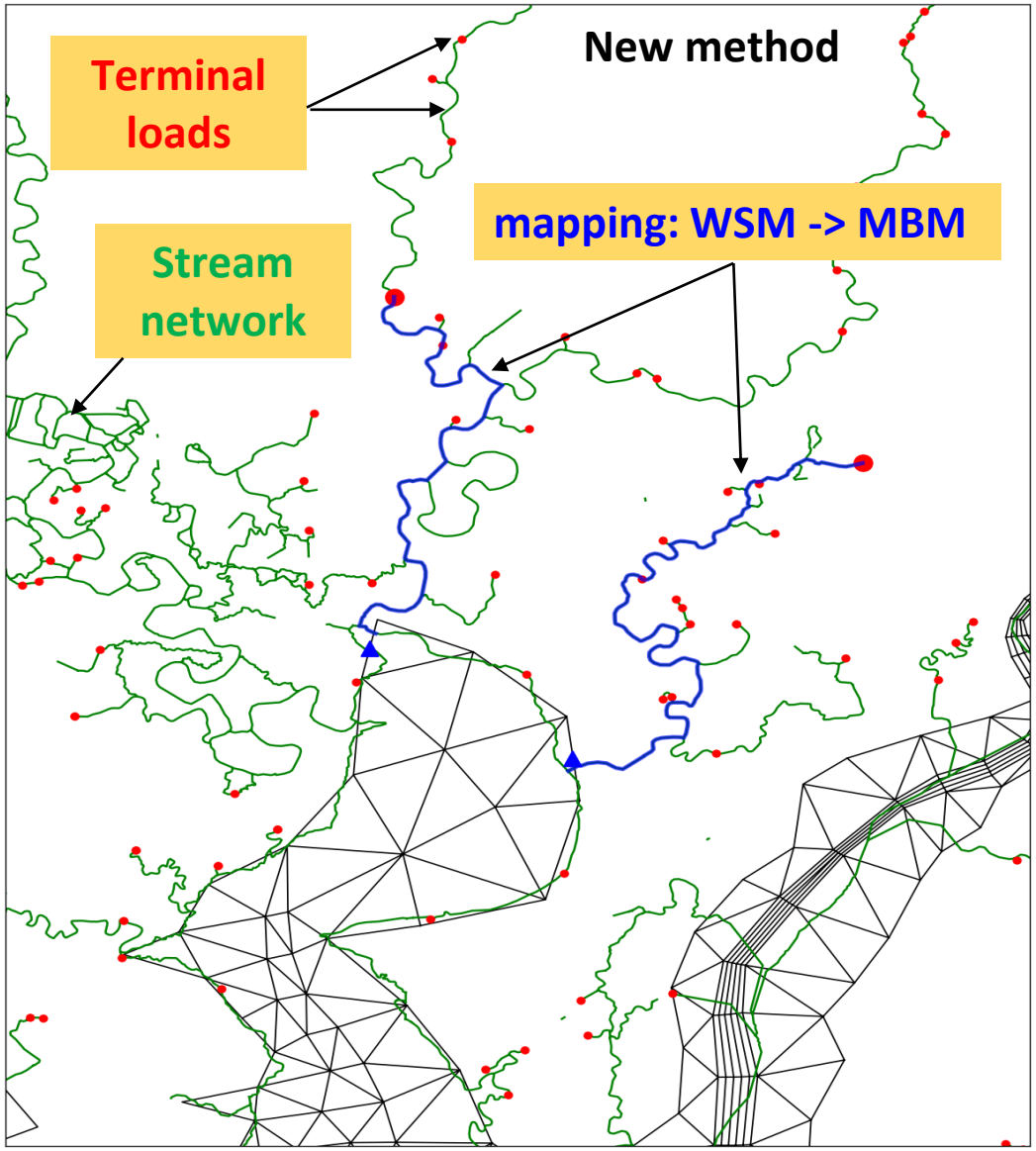
Mean Tidal Flow: 116.6 m^3/s

Coupling between Watershed Model (WSM) and MBM in redistributing WSM loads

- The discharge points in old method are computed based on one MBM grid, while the new method dynamically compute them.
- The new method has fewer discharge points, but is more accurate and efficient.



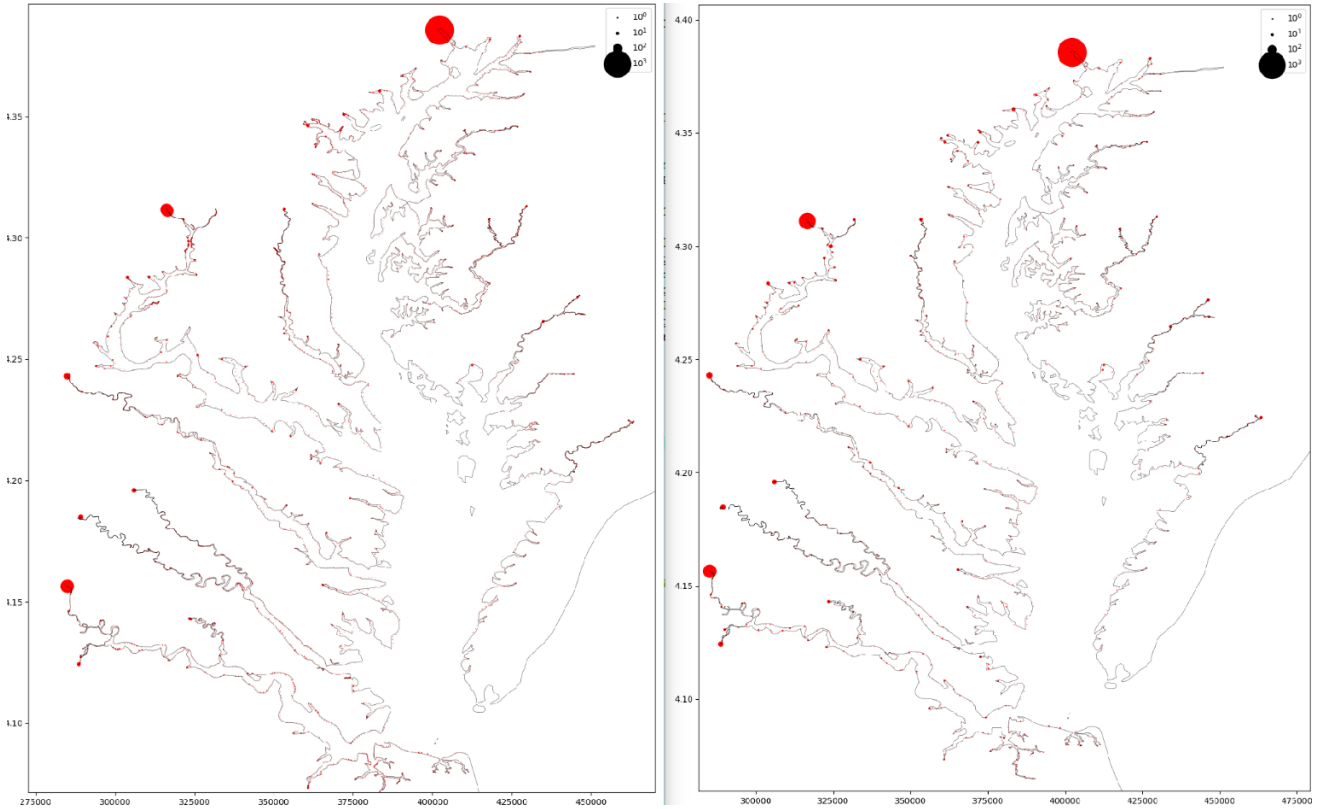




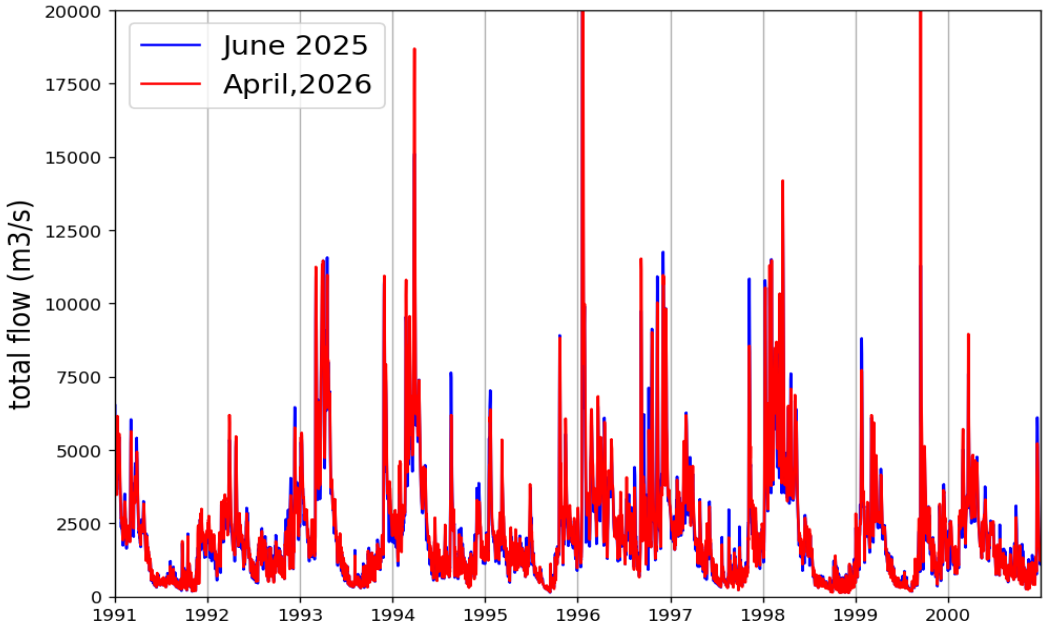
Flow Comparison: Distribution in MBM

Old WSM Loading (June 2025)

New WSM Loading (April 2026)



Total flow from 1991 to 2000



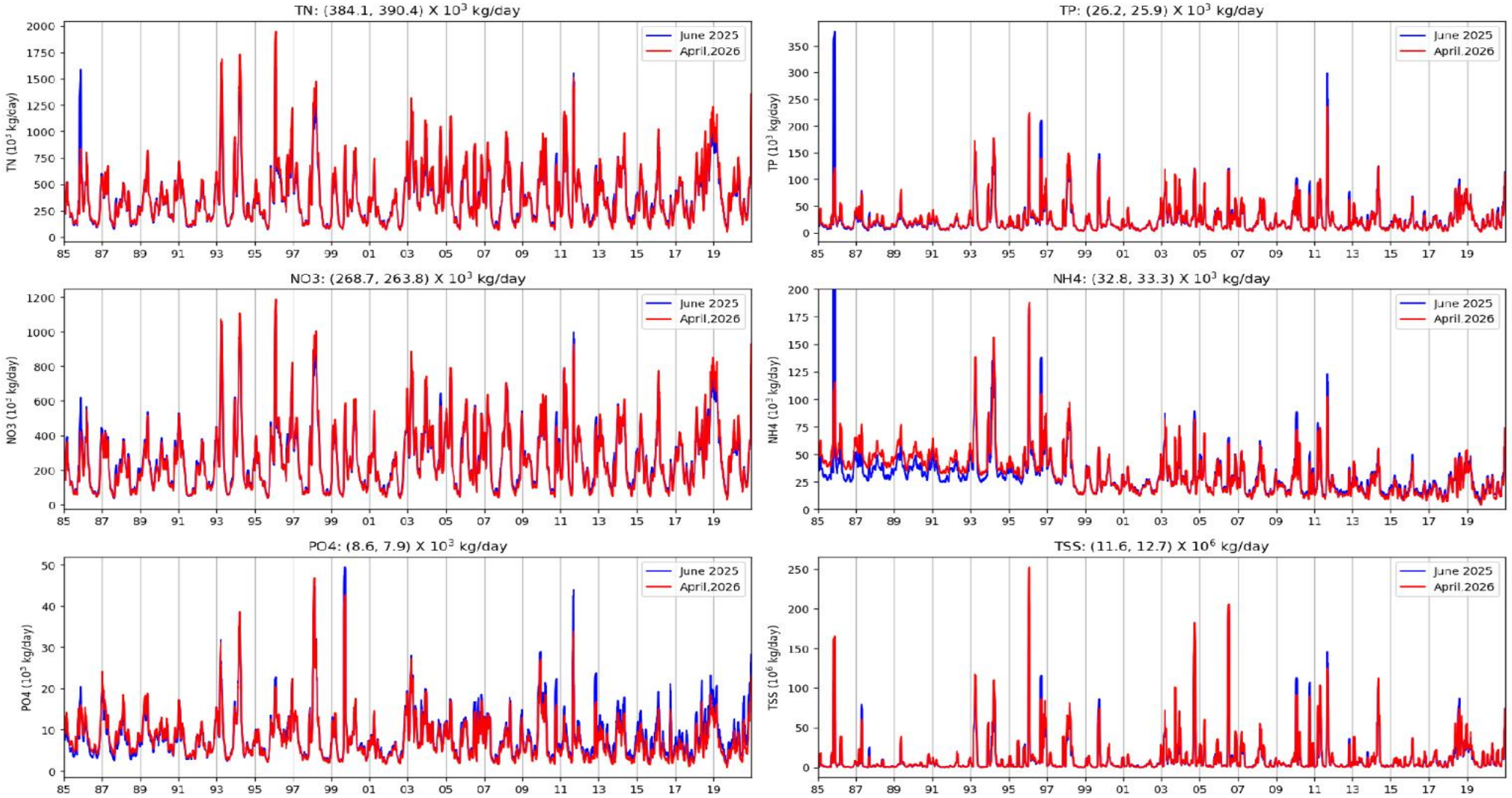
- Overall, the mean flow distribution are very similar between old and new WSM loadings.
- There are 9235 discharge points for WSM_Jun2025, while there are only 2852 discharge points for WSM_Apr2026.

- Mean Flow (June 2025): 2248.7 m^3/s
- Mean Flow (April 2026): 2307.9 m^3/s

WSM loading comparison: WSM_Jun2025 vs. WSM_Apr2026

- On AVERAGE, old and new WSM nutrient loads are very close.
- Loads of TN, NH4 and TSS are slightly higher in WSM_Apr2026 than WSM_Jun2025, while TP, NO3 and PO4 are lower.

The 1st/2nd number is the average load for old/new WSM versions



WSM loading comparison at RIM station: WSM_Jun2025 vs. WSM_Apr2026

- Overall, the nutrient concentrations of old and new WSM loadings are similar when compared with RIM observations.
- However, some stations show worse model skills for nitrogen concentrations. This influenced MBM skills

Comparison to nearfield RIM Obs.

RMSE(RIM)	Station	NH4	NO3	PO4	TN	TP	TSS
Susquehanna	SL9_2720_0001	(0.0575, 0.0555)	(0.5287, 0.4973)	(0.0174, 0.0174)	(0.9003, 0.9000)	(0.0485, 0.0473)	(166.0819, 166.6446)
Patuxent	XU3_4650_0001	(0.1409, 0.1391)	(0.6006, 0.5651)	(0.0323, 0.0328)	(0.7022, 0.6736)	(0.1338, 0.1187)	(88.0396, 73.9501)
Potomac	PM7_4820_0001	(0.0793, 0.0978)	(0.7160, 0.7794)	(0.0226, 0.0270)	(0.6105, 0.7335)	(0.1856, 0.1677)	(112.5892, 120.6860)
Rappahannock	RU5_6030_0001	(0.0695, 0.0430)	(0.3222, 0.3477)	(0.0119, 0.0126)	(0.6651, 0.6650)	(0.2220, 0.2081)	(219.0315, 214.7200)
James	JL7_7100_7030	(0.0461, 0.0326)	(0.1580, 0.1650)	(0.0367, 0.0362)	(0.4558, 0.4445)	(0.1788, 0.1677)	(149.9177, 150.9523)
Choptank	EM2_3980_0001	(0.0561, 0.0567)	(0.3911, 0.5509)	(0.0237, 0.0253)	(0.3489, 0.3919)	(0.0797, 0.0820)	(17.4920, 15.6242)
Mattaponi	YM4_6620_0003	(0.0350, 0.0328)	(0.1213, 0.1475)	(0.0191, 0.0154)	(0.2287, 0.2312)	(0.0480, 0.0466)	(16.3005, 16.1084)
Pamunkey	YP4_6720_6750	(0.0604, 0.0512)	(0.1880, 0.1915)	(0.0373, 0.0350)	(0.3595, 0.3458)	(0.0951, 0.0850)	(64.0046, 61.6652)
Appomattox	JA5_7480_0001	(0.0434, 0.0430)	(0.1571, 0.1527)	(0.0113, 0.0124)	(0.2512, 0.2438)	(0.1007, 0.1012)	(13.4362, 12.5985)

Worse

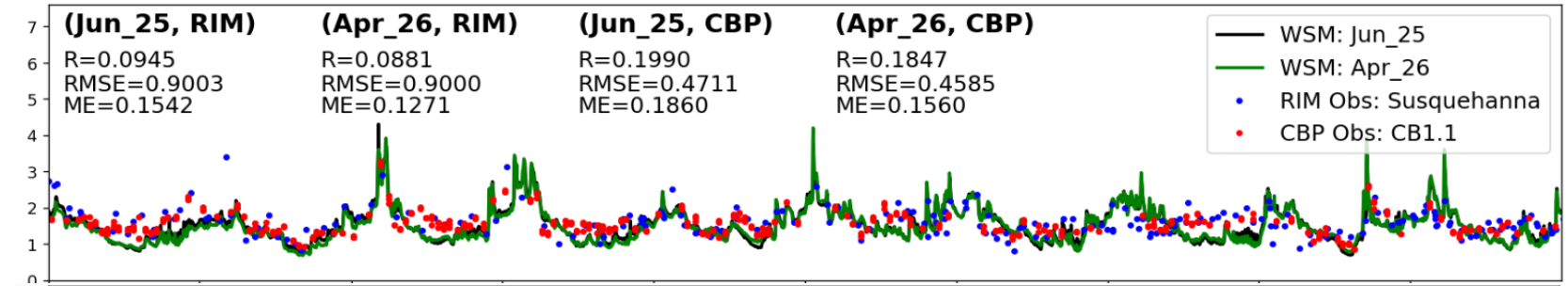
Close

Better

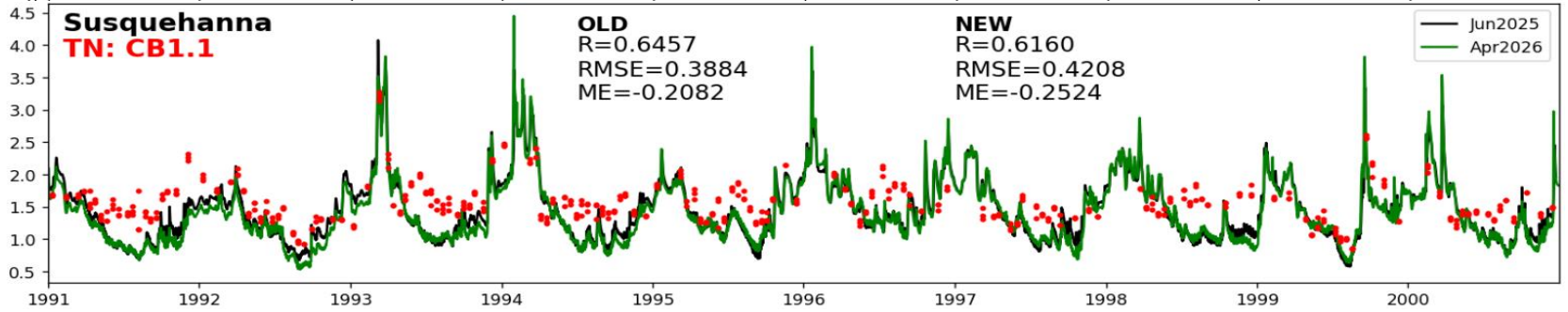
In brackets, the 1st number is June 2025 error, and 2nd number is April 2026 error.

Assessment on the WSM loading: Susquehanna River

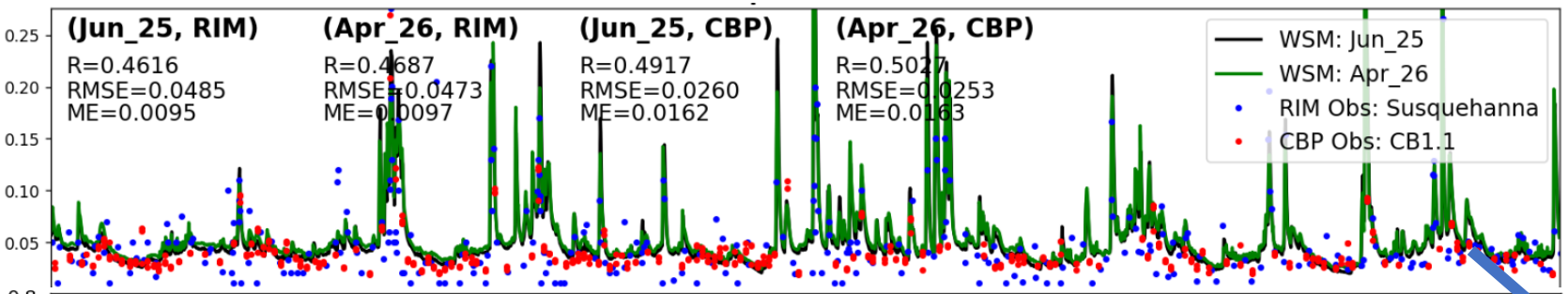
TN: WSM



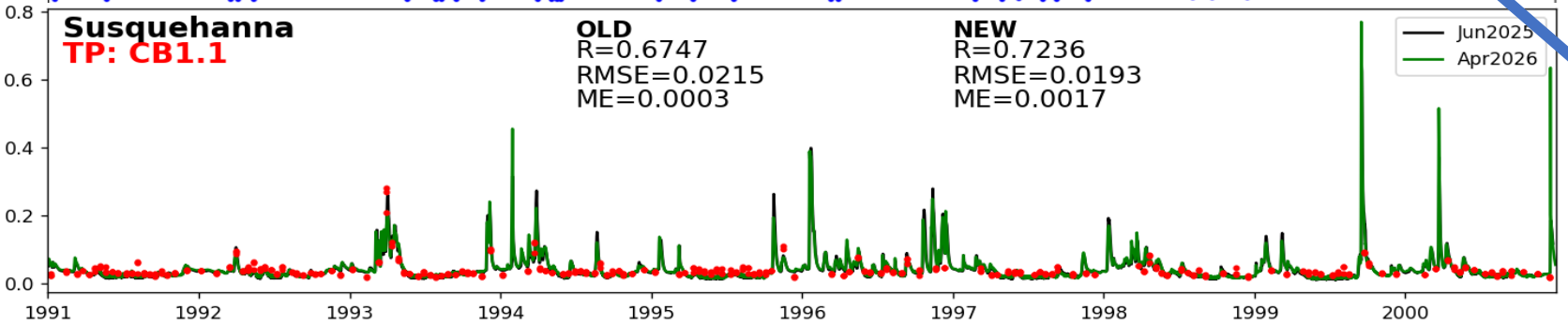
TN: MBM

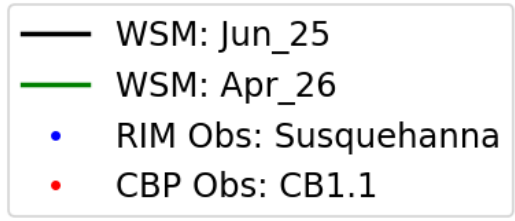


TP: WSM



TP: MBM



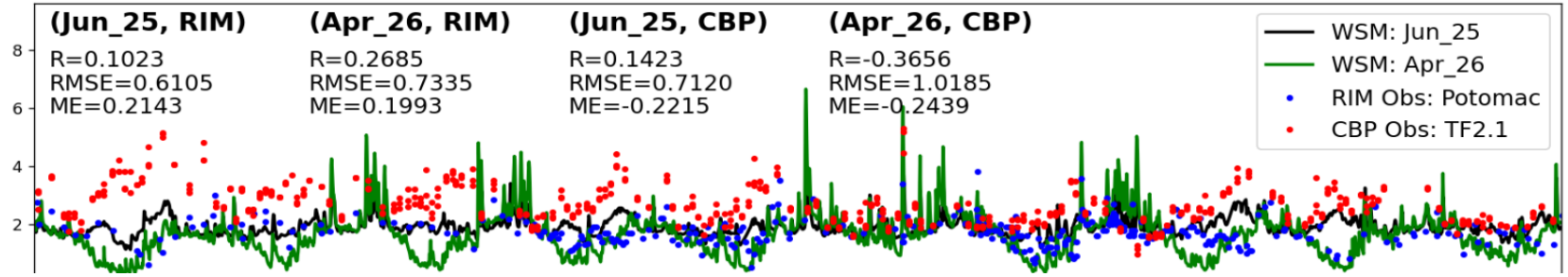


- For Susquehanna river, the nutrient concentrations between two WSM versions are rather close.
- In the upstream of Susquehanna river, the TN/TP simulated in MBM generally follows WSM concentrations; results from the 2 beta versions are close.

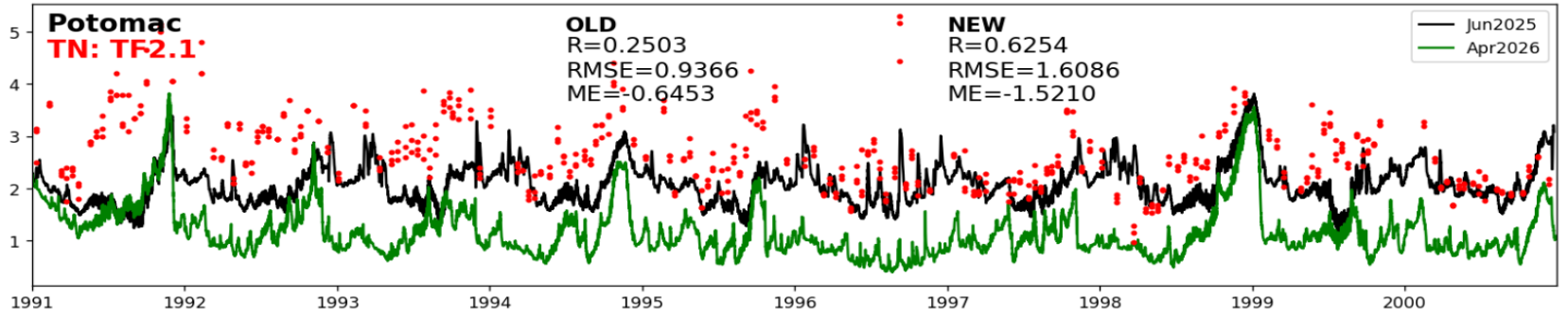
Note: There are differences between RIM and CPB observations.

Assessment on the WSM loading: Potomac River

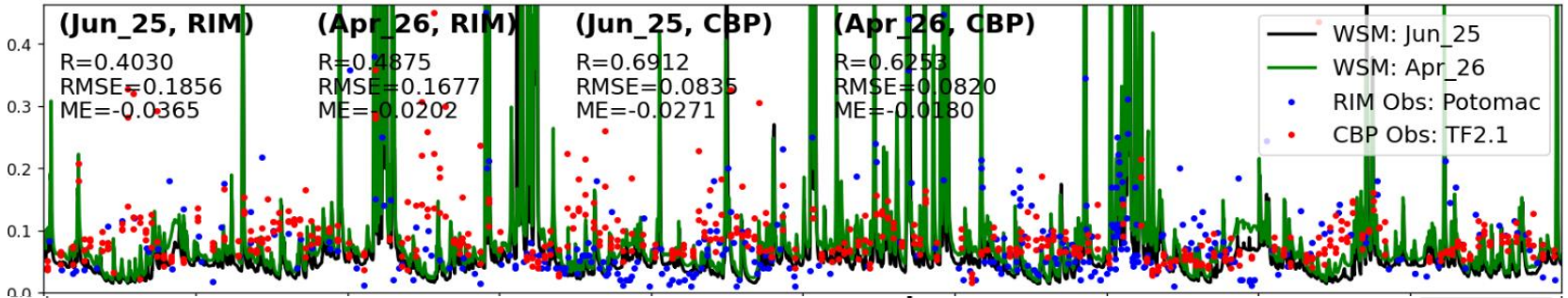
TN: WSM



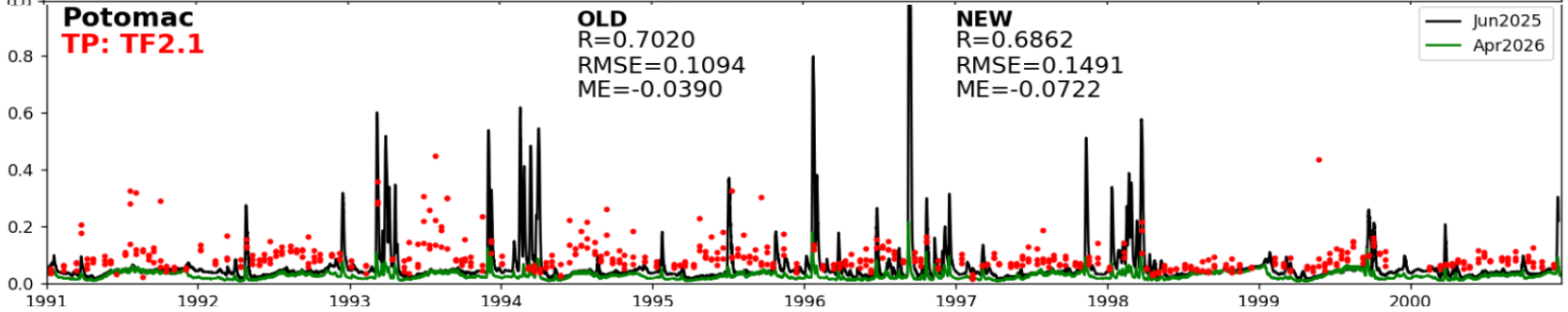
TN: MBM



TP: WSM



TP: MBM

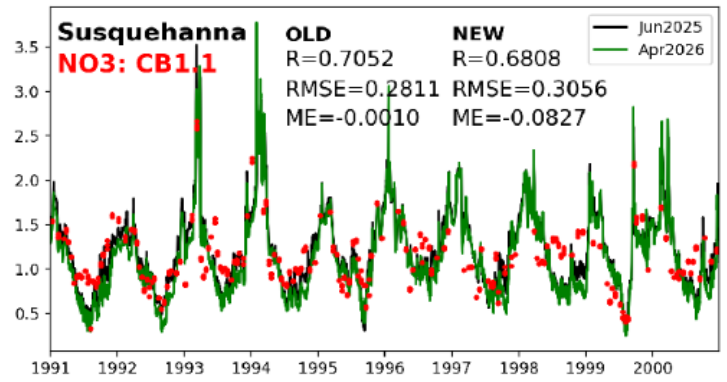


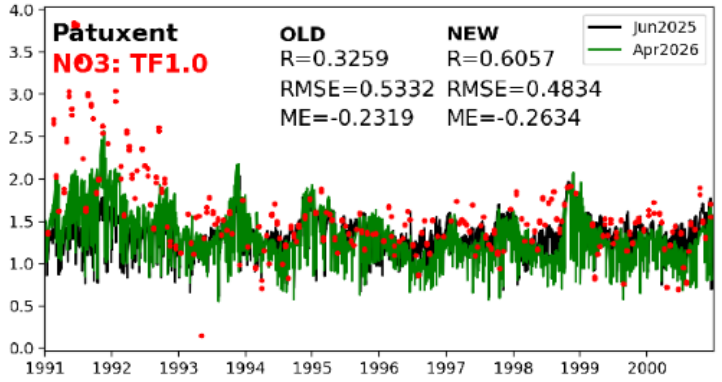
- In Potomac river, TN concentration in WSM_Apr2026 is lower than previous WSM_Jun2025, which adversely impacted the MBM simulation downstream.
- TP concentrations from WSM generally match RIM/CPB observation. However, MBM underestimates the TP concentration, which needs further investigation. Despite this bias, the two WSM beta versions produce similar temporal variations, although the newer version generally predicts lower TP concentrations.

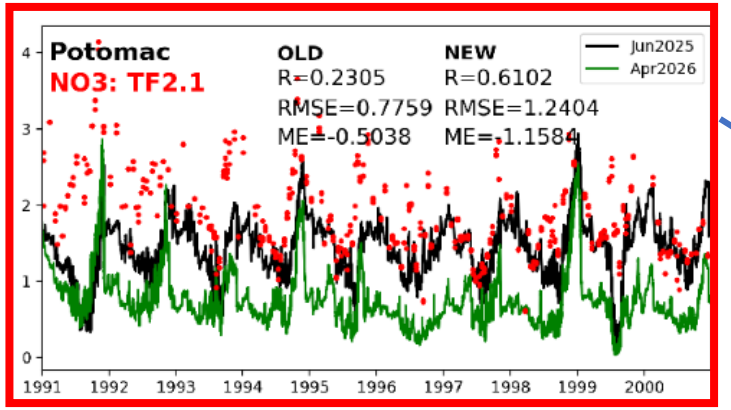
MBM assessment at RIM stations for NO3: WSM_Jun2025 vs. WSM_Apr2026

- ❑ NO3 simulation in MBM is overall satisfactory in most river upstream.
- ❑ Improvement is observed is Pamunkey river, and degradation is observed in Potomac river.

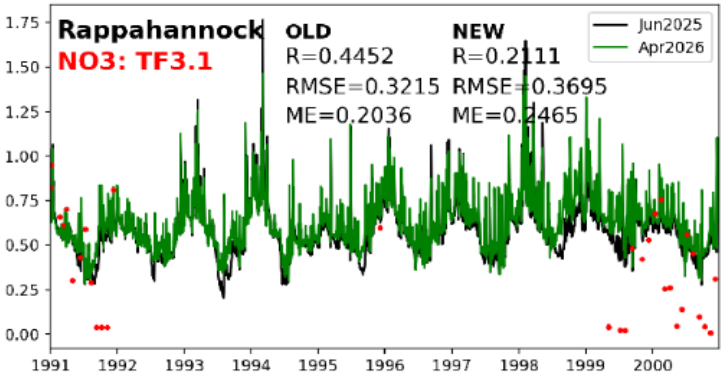
June 2025
April 2026
CBP Obs.

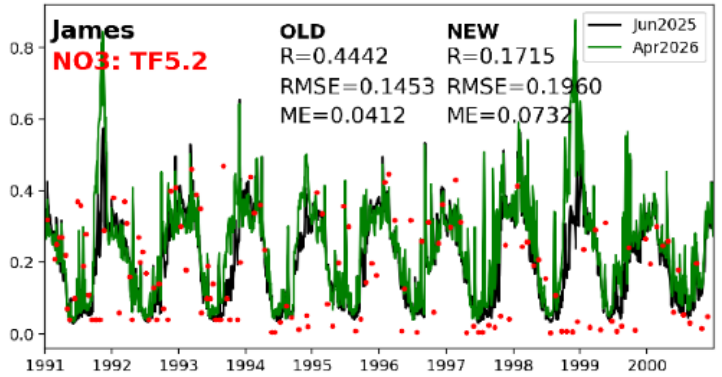


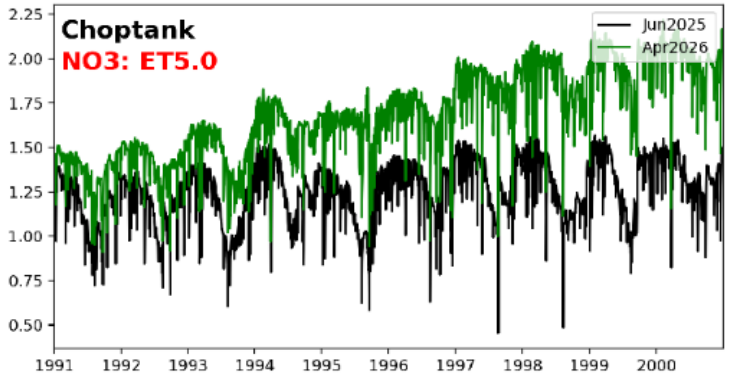


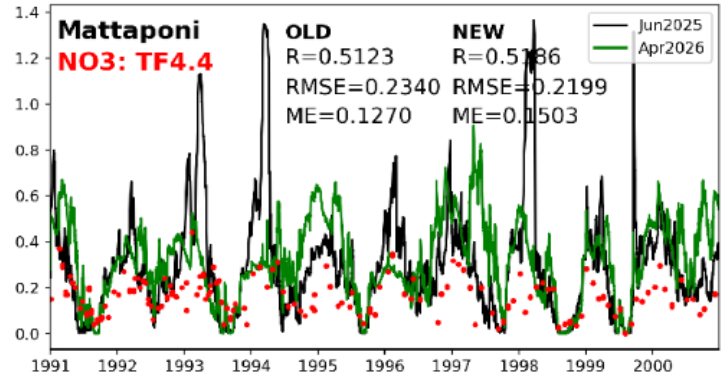


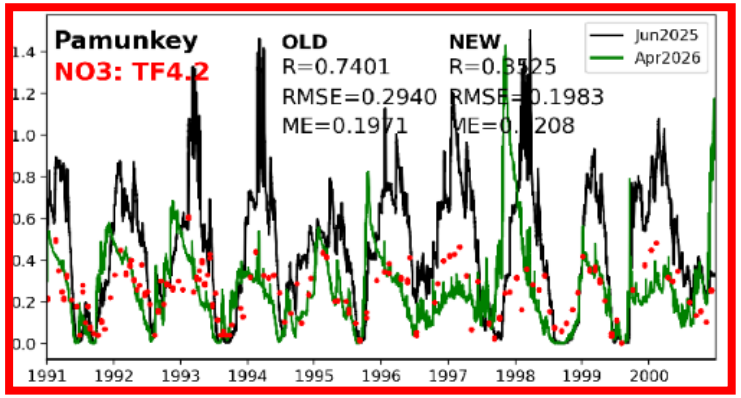
Degradation

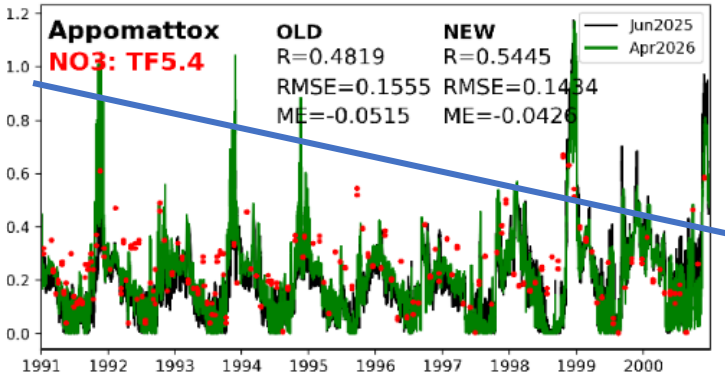








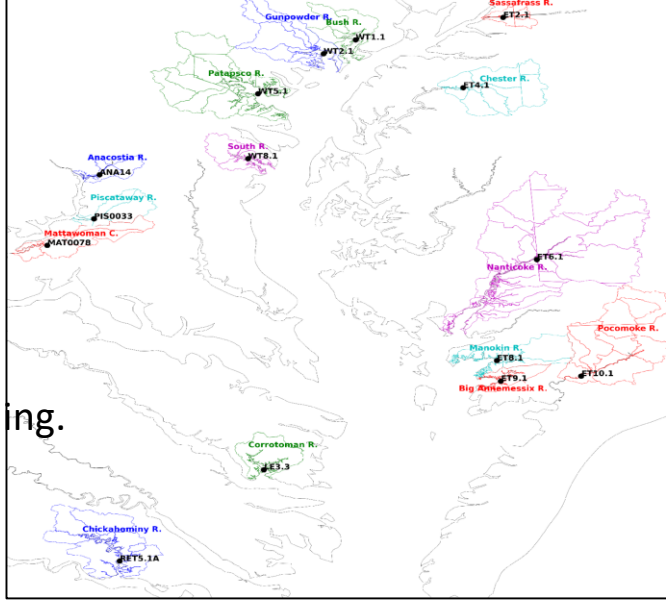




Improvement

WSM loading comparison at small embayments: WSM_Jun2025 vs. WSM_Apr2026

- For small embayments, the PO4 and TSS concentrations in the new WSM loading seems to be improved.
- For nitrogen concentrations, there are some stations with worse skill.



Note: In these small embayments, local biological processes may be equally important as WSM nutrient loading.

RMSE(WSM)	R. Impact	Mean Salinity	NH4	NO3	PO4	TN	TP	TSS
Sassafrass R.	99.5%	1.83	(0.1203, 0.1314)	(2.7988, 3.6949)	(0.0272, 0.0256)	(2.7292, 3.7628)	(0.0717, 0.0747)	(53.1171, 55.2341)
Bush R.	95.9%	0.88	(0.8616, 1.4102)	(2.6359, 2.1509)	(0.1112, 0.1139)	(2.6440, 2.6353)	(0.1190, 0.1362)	(42.7198, 36.6464)
Gunpowder R.	94.7%	1.72	(0.0548, 0.0617)	(0.6649, 0.6511)	(0.0132, 0.0117)	(0.4211, 0.4291)	(0.0439, 0.0475)	(29.5997, 28.7841)
South R.	69.1%	9.97	(0.1018, 0.1050)	(1.3140, 1.1060)	(0.0549, 0.0433)	(0.9247, 0.7340)	(0.0635, 0.0559)	(21.8353, 18.0022)
Piscataway R.	100.0%	0.00	(0.3288, 0.2288)	(3.5101, 4.0512)	(0.0426, 0.0462)	(3.7424, 3.9665)	(0.0910, 0.0876)	(38.0189, 38.3983)
Mattawoman C.	100.0%	0.01	(0.0950, 0.0789)	(1.5896, 1.4113)	(0.1019, 0.1079)	(1.4715, 1.5740)	(0.1433, 0.1570)	(38.0565, 27.6668)
Corrotoman R.	56.6%	14.81	(0.0518, 0.0614)	(0.7441, 0.8773)	(0.0448, 0.0340)	(0.5070, 0.6339)	(0.0442, 0.0399)	(7.0650, 7.4030)
Chickahominy R.	99.7%	1.17	(0.0616, 0.0623)	(0.1594, 0.1745)	(0.0264, 0.0229)	(0.4996, 0.5006)	(0.0662, 0.0701)	(49.3290, 49.7802)
Nanticoke R.	99.8%	0.22	(0.0970, 0.0964)	(1.4540, 1.5249)	(0.0611, 0.0562)	(1.2678, 1.3356)	(0.0746, 0.0758)	(31.2860, 31.3090)
Manokin R.	49.0%	14.01	(0.0871, 0.0962)	(1.8494, 2.0900)	(0.1605, 0.1326)	(1.6799, 1.9292)	(0.1800, 0.1752)	(23.5627, 24.6148)
Big_Annemessix R.	47.8%	15.53	(0.1759, 0.2133)	(2.3831, 2.4300)	(0.1923, 0.1406)	(2.5220, 2.5089)	(0.2274, 0.1923)	(11.9093, 11.6748)
Patapsco R.	80.8%	10.38	(3.2038, 2.9517)	(2.5952, 2.2166)	(0.2207, 0.2047)	(5.9827, 5.2255)	(0.3208, 0.2961)	(31.4976, 32.1610)
Anacostia R.	100.0%	0.19	(0.2731, 0.2557)	(0.2799, 0.2755)	(0.0492, 0.0475)	(1.0854, 1.1015)	(0.0654, 0.0721)	(49.3993, 44.9095)
Elizabeth S.	46.9%	19.09	(0.5286, 0.3305)	(1.6064, 1.3047)	(0.4116, 0.1260)	(2.0234, 1.8485)	(0.5894, 0.1727)	(14.8994, 13.7727)
Chester R.	99.3%	0.54	(0.0970, 0.0933)	(2.3797, 2.8736)	(0.0602, 0.0490)	(1.8468, 2.3707)	(0.1086, 0.1293)	(83.3568, 84.0235)
Pocomoke R.	100.0%	0.18	(0.0624, 0.0767)	(1.2220, 1.0718)	(0.0909, 0.0701)	(0.9525, 0.8497)	(0.1147, 0.1129)	(20.0412, 20.4293)

In brackets, the 1st number is June 2025 error, and 2nd number is April 2026 error.

WSM_Apr2026 better | **Close (<5%)** | **WSM_Jun2025 better**

MBM assessment at embayments: WSM_Jun2025 vs. WSM_Apr2026

- ❑ For TP, NH4 and PO4, MBM results are generally comparable between two WSM loadings.
- ❑ For TN and NO3, MBM results with new WSM loading show some setback.

RMSE(Embayment)	Station	TN	TP	NH4	NO3	PO4
Sassafrass R.	ET2.1	(0.8457, 1.0836)	(0.1124, 0.1145)	(0.0973, 0.0977)	(0.6504, 0.7976)	(0.0280, 0.0280)
Bush R.	WT1.1	(0.5990, 0.5471)	(0.0700, 0.0673)	(0.2022, 0.1828)	(0.3207, 0.3419)	(0.0081, 0.0079)
Gunpowder R.	WT2.1	(0.4402, 0.4488)	(0.0575, 0.0566)	(0.0658, 0.0666)	(0.2870, 0.2975)	(0.0058, 0.0058)
South R.	WT8.1	(0.3770, 0.3776)	(0.0538, 0.0542)	(0.0763, 0.0764)	(0.1972, 0.1913)	(0.0357, 0.0357)
Piscataway R.	PIS0033	(3.7500, 6.6503)	(0.0958, 0.0869)	(0.3368, 0.4297)	(3.9111, 6.6740)	(0.0366, 0.0320)
Mattawoman C.	MAT0078	(0.6384, 0.5801)	(0.0635, 0.0517)	(0.0724, 0.0633)	(0.1784, 0.1318)	(0.0202, 0.0175)
Corrotoman R.	LE3.3	(0.2396, 0.2400)	(0.0260, 0.0258)	(0.0706, 0.0704)	(0.0656, 0.0745)	(0.0080, 0.0080)
Chickahominy R.	RET5.1A	(0.6098, 0.5875)	(0.0921, 0.0920)	(0.0583, 0.0579)	(0.1300, 0.1327)	(0.0116, 0.0118)
Nanticoke R.	ET6.1	(0.7423, 0.7665)	(0.0841, 0.0846)	(0.0858, 0.0872)	(1.0224, 1.0073)	(0.0132, 0.0133)
Manokin R.	ET8.1	(0.5840, 0.6359)	(0.0544, 0.0609)	(0.0691, 0.0693)	(0.3730, 0.5275)	(0.0076, 0.0093)
Big_Annemessix R.	ET9.1	(0.4768, 0.4823)	(0.0319, 0.0350)	(0.0766, 0.0770)	(0.1460, 0.1888)	(0.0060, 0.0068)
Patapsco R.	WT5.1	(0.5450, 0.5260)	(0.0483, 0.0482)	(0.2226, 0.2237)	(0.3285, 0.3222)	(0.0191, 0.0193)
Anacostia R.	ANA14	(0.8147, 1.0502)	(0.0841, 0.0845)	(0.3148, 0.3081)	(0.1828, 0.2315)	(0.0288, 0.0291)
Elizabeth S.	SBE2	(0.3933, 0.3671)	(0.0442, 0.0464)	(0.2254, 0.2217)		(0.0380, 0.0376)
Chester R.	ET4.1	(0.7618, 0.8059)	(0.1716, 0.1773)	(0.0688, 0.0656)	(0.9210, 0.7831)	(0.0190, 0.0210)
Pocomoke R.	ET10.1	(0.7100, 0.7495)	(0.1105, 0.1312)	(0.0424, 0.0420)	(0.6137, 0.6738)	(0.0412, 0.0436)

In brackets, the 1st number is June 2025 error, and 2nd number is April 2026 error.

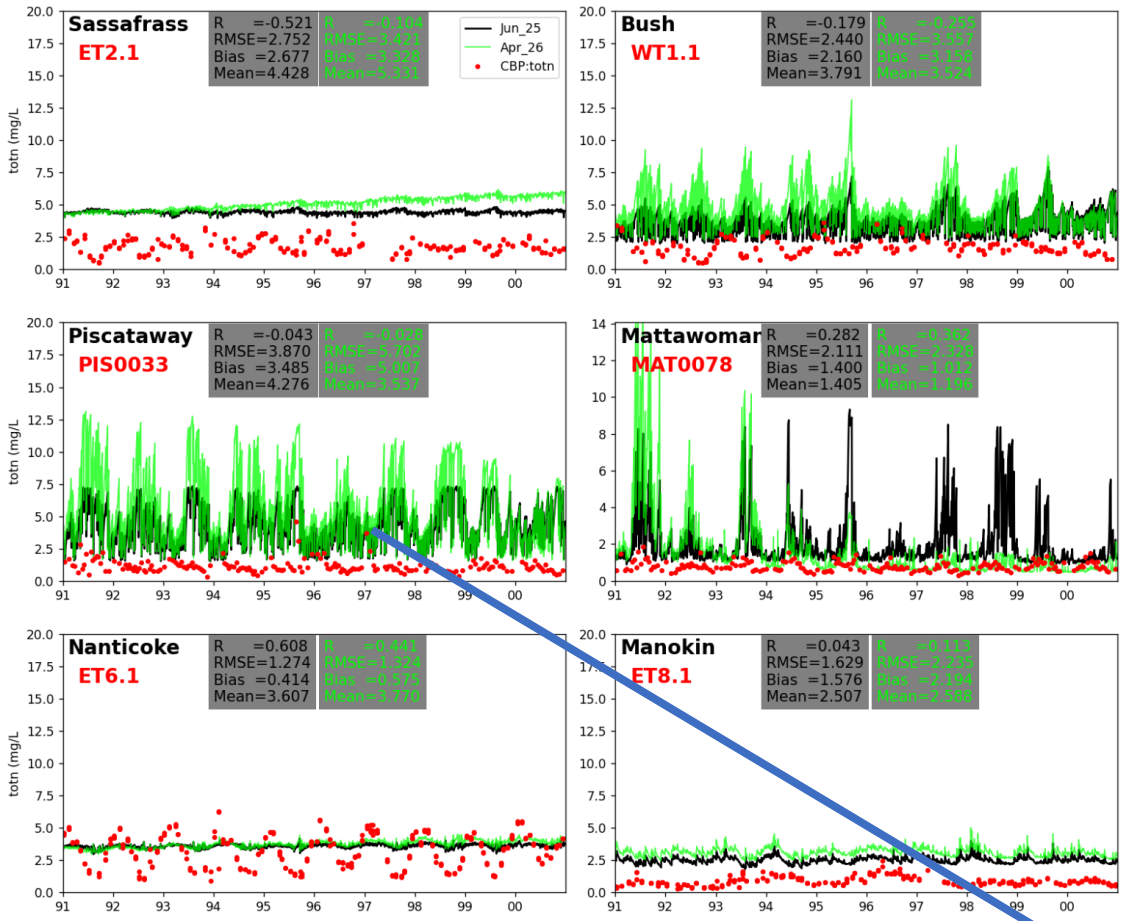
WSM_Apr2026 better | **Close (<5%)** | **WSM_Jun2025 better**

Assessment on the WSM TN concentrations

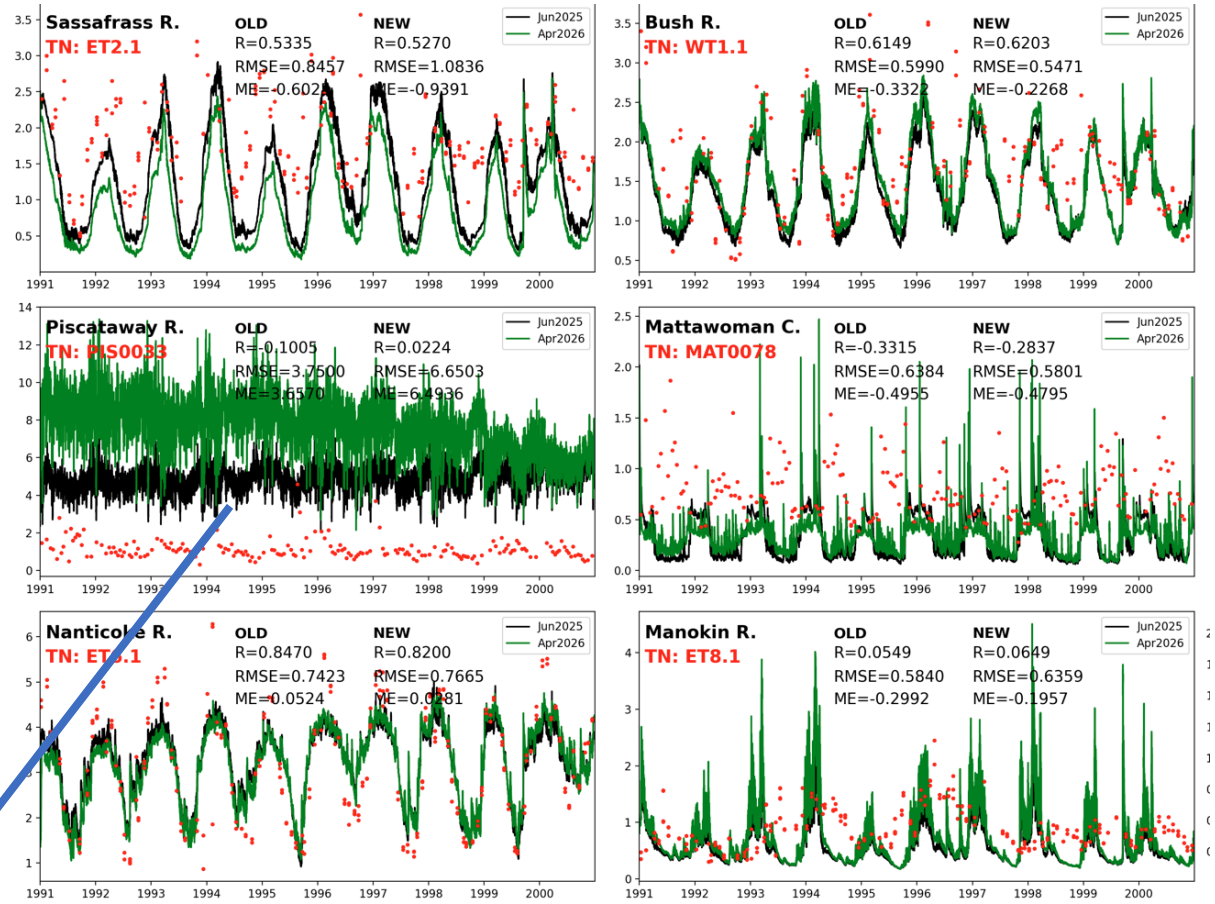
June 2025 | April 2026 | CBP Obs.

- Overall, TN simulation in small embayments is good capturing the seasonal cycles and some interannual variabilities.
- TN in new WSM loading shows some change, which is also reflected in the MBM simulation.

TN: WSM



TN: MBM



TN loading increases

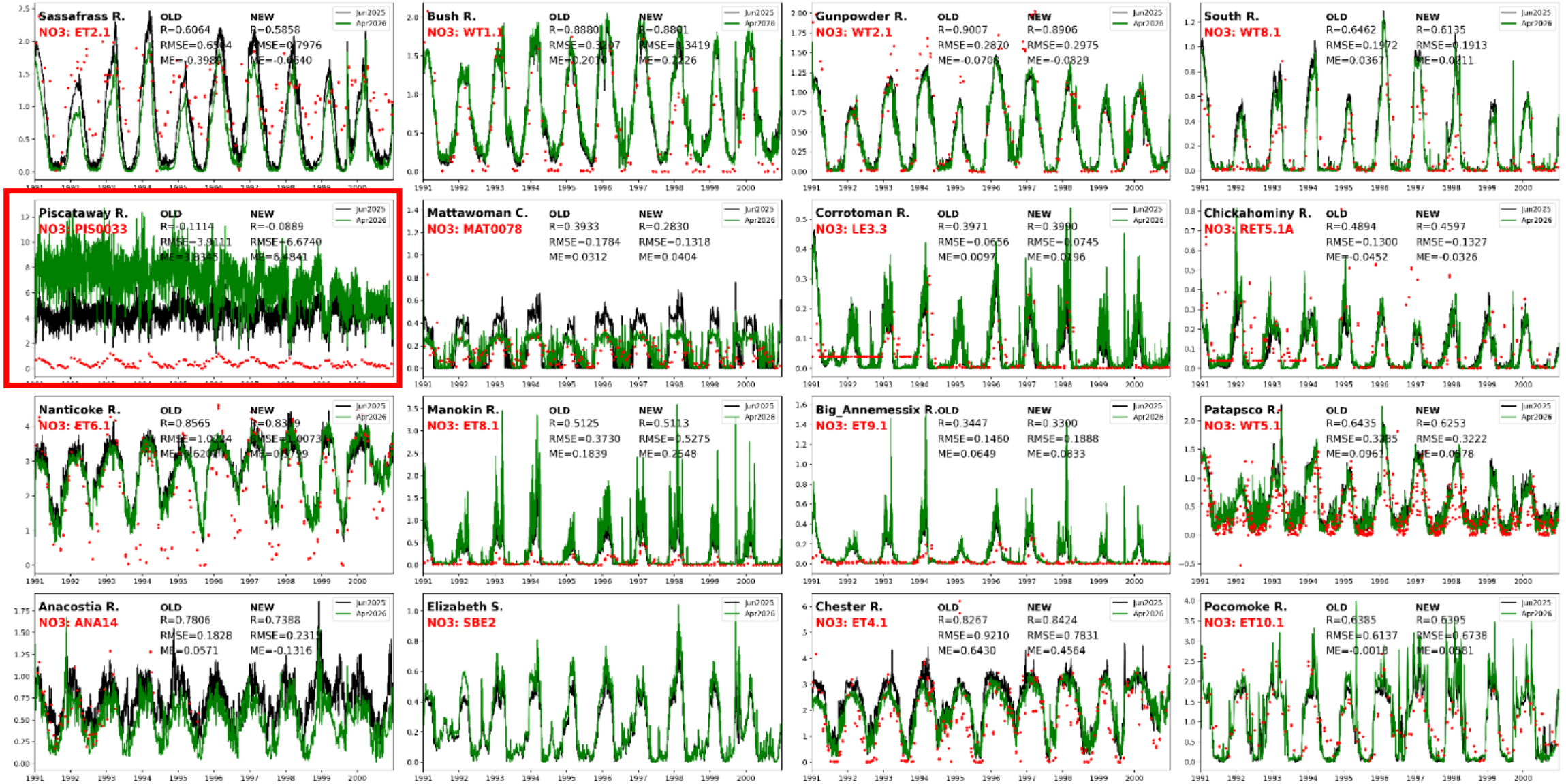
MBM assessment at Embayments for NO3 : WSM_Jun2025 vs. WSM_Apr2026

June 2025

April 2026

CBP Obs.

- NO3 simulation in MBM is generally satisfactory, except at Piscataway river.



Summary comparison of MBM simulations: WSM_Jun2025 vs. WSM_Apr2026

More Details: ref. to Wenfan's talk

- ❑ For temperature and salinity, model skills are close between two WSM loadings
- ❑ For most water quality variables, the RMSEs are also very comparable.
- ❑ RMSEs for TN and NO3 get worse, but RMSEs for NH4 and DOP get better.

Physical Parameters | **Water Quality Parameters**

Major Variables

RMSE	temp	salt	chla	DO	TN	TP
surface	(0.741, 0.747)	(1.110, 1.128)	(11.970, 12.101)	(1.052, 1.067)	(0.329, 0.369)	(0.046, 0.046)
bottom	(0.979, 0.977)	(1.620, 1.675)	(11.790, 11.870)	(1.429, 1.461)	(0.414, 0.446)	(0.068, 0.069)

Nutrients

RMSE	NO3	NH4	PO4	DOC	DON	DOP	POC	PON	POP
surface	(0.232, 0.257)	(0.052, 0.049)	(0.011, 0.012)	(1.594, 1.669)	(0.165, 0.165)	(0.013, 0.012)	(1.199, 1.211)	(0.183, 0.184)	(0.035, 0.036)
bottom	(0.212, 0.234)	(0.074, 0.071)	(0.015, 0.015)	(1.575, 1.638)	(0.172, 0.170)	(0.014, 0.012)	(1.711, 1.701)	(0.245, 0.243)	(0.058, 0.059)

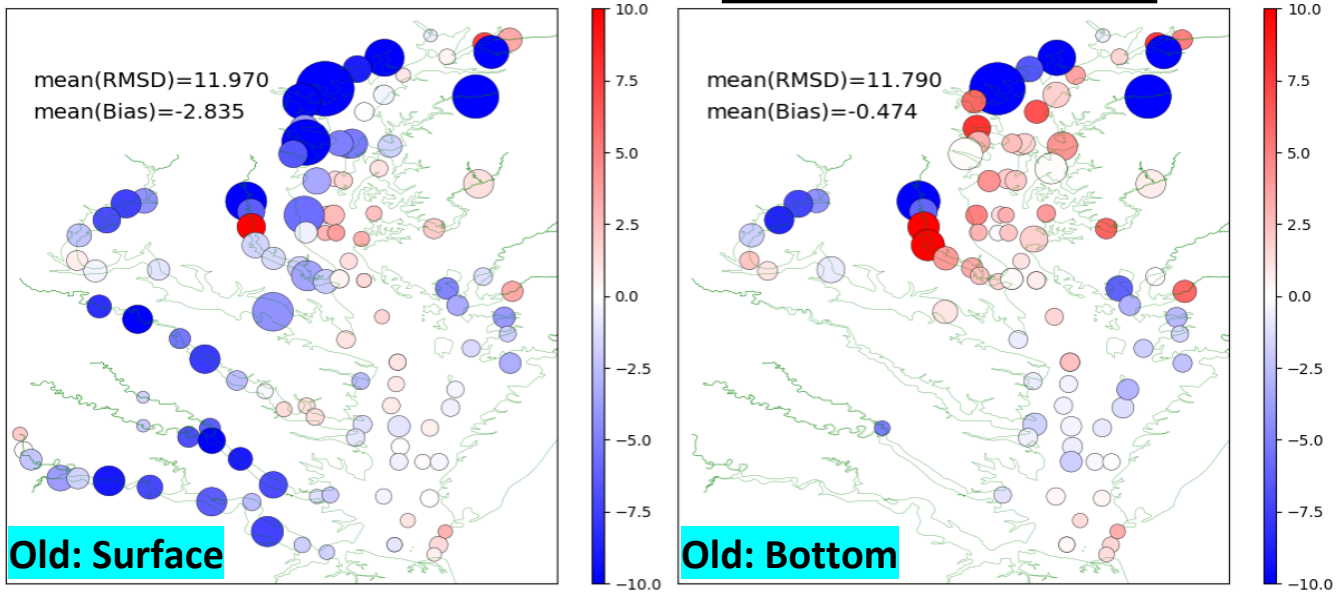
In brackets, the 1st number is Old MBM error, and 2nd number is current New MBM error.

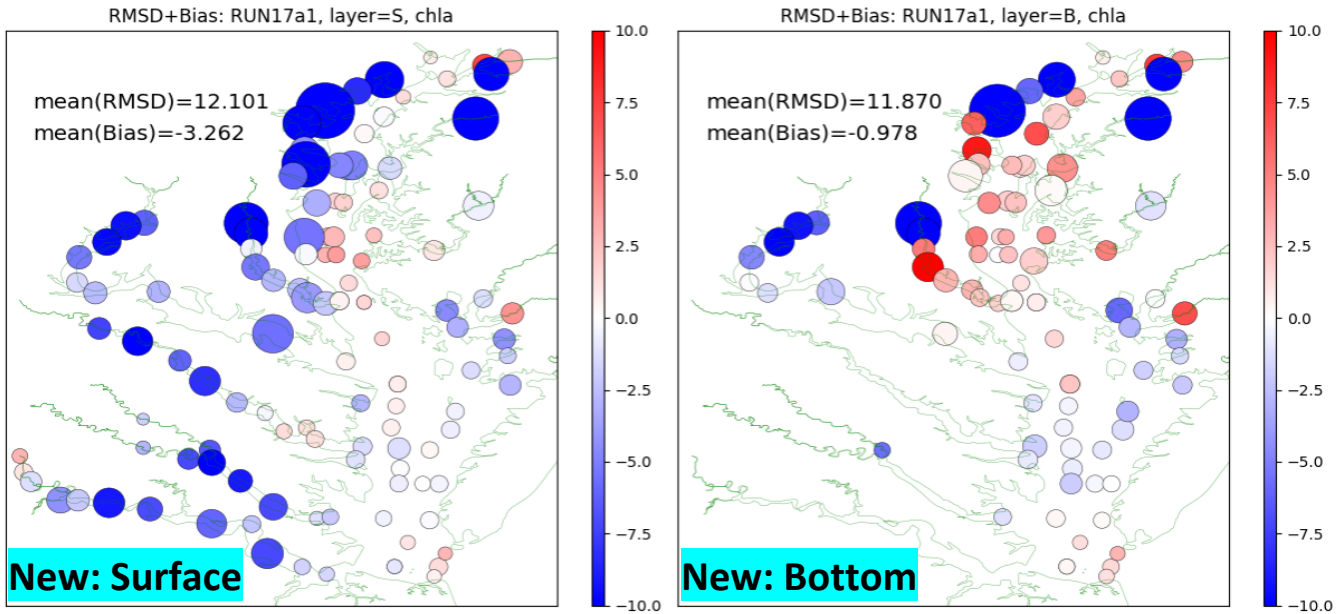
WSM_Apr2026 better | **Close (<5%)** | **WSM_Jun2025 better**

Comparison of MBM results for Chl-a: WSM_Jun2025 vs. WSM_Apr2026

Chl-a Error

size: RMSE **color**: Bias



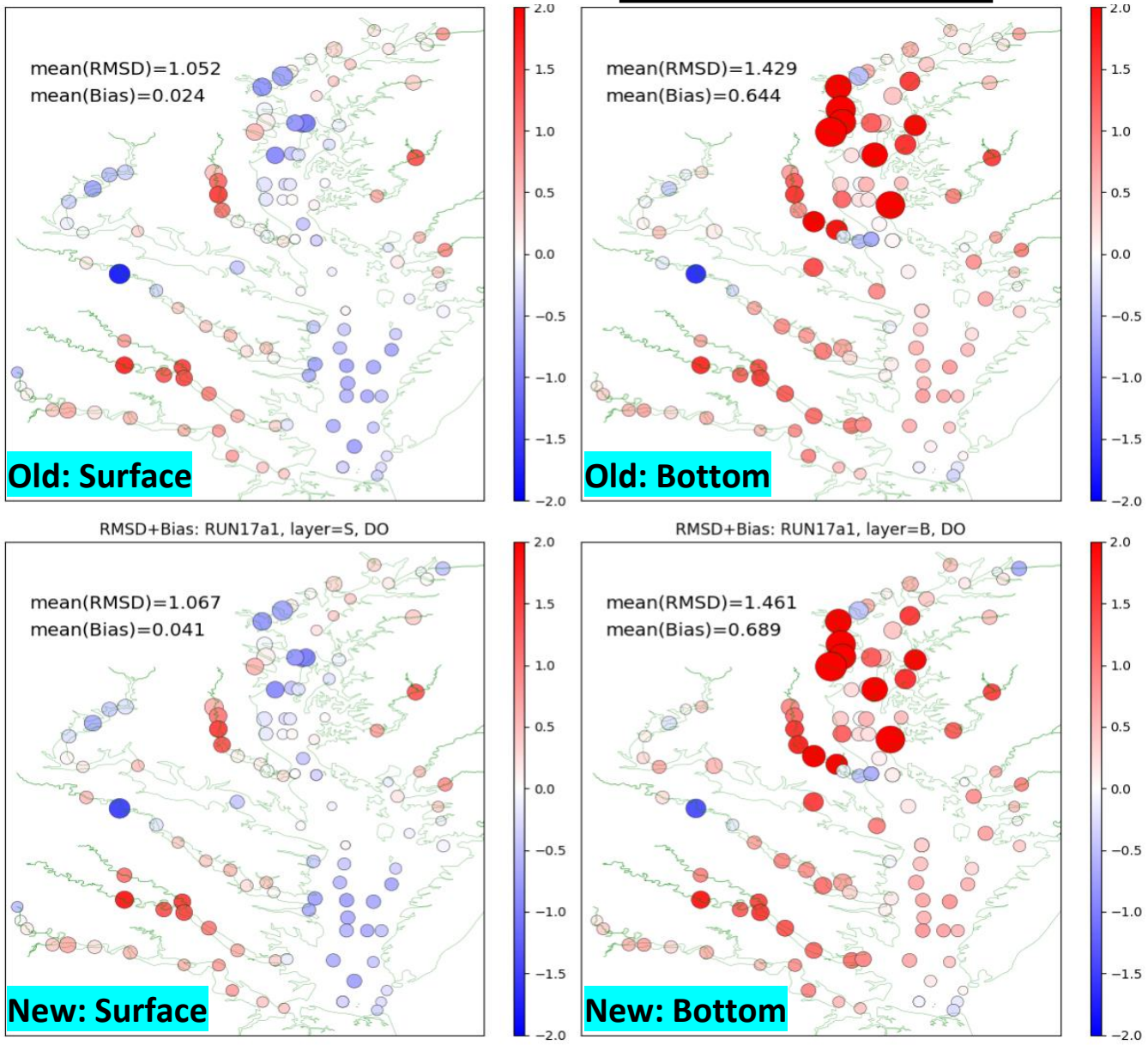


- Although there are some difference between two WSM loadings, average model skills of Chl-a in MBM are rather close, with the slightly larger errors for the new results.

Comparison of MBM results for DO: WSM_Jun2025 vs. WSM_Apr2026

DO Error

size: RMSE **color**: Bias



- Although there are some difference between two WSM loadings, average model skills of DO in MBM are rather close, with the slightly larger errors for the new results.

Summary and future work

- ❑ Incorporated the new WSM loading format into the MBM workflow and revamped the mapping method between WSM and MBM (MTM)

- ❑ Completed MBM simulation using the new WSM loading. Model performance is generally comparable to the previous loading in terms of RMSE, although biases are larger.

- ❑ Analyzed the new WSM loading at RIM stations and small embayments, and compared MBM simulation results between the old and new WSM loadings. The changes in MBM are correlated to those in WSM

- ❑ **Future Work**
  - Which WSM beta version?
  - MBM documentation.
  - Continue improving MBM performance, particularly for NO_3 and living resources.