09/15/2026

Phase 7 Dynamic Watershed Model (DWSM) Sediment Simulation

Modeling Workgroup Meeting – September 2026

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Chesapeake Bay Program Office – [1] Penn State, [2] US EPA, [3] Koniag, [4] VA DEQ

Presentation Outline

Phase 7 Dynamic Watershed Model (DWSM)

1. **Dynamic Watershed Model overview**
2. **Overview of hydrology calibration**
3. **Review of DWSM sediment calibration**
   - Inputs and model setup
   - Calibration process
   - Results
4. **Summary and next steps**

Purpose

NHD Scale Dynamic Watershed Model (DWSM)

- Inputs for the estuarine models (MBM/MTMs)
- Watershed model calibration and scenario applications
- Support research and collaboration activities

Phase 7 watershed models and structure

CAST – Chesapeake Assessment Scenario Tool

Informs

Constrains

CalCAST

Average Load
+
Δ Inputs X Sensitivity
X
BMPs
X
Acres
X
Land to Water
X
River Delivery

Load by NHD catchment and land use

Tool for finding parameters that best match observations

Phase 7 CAST

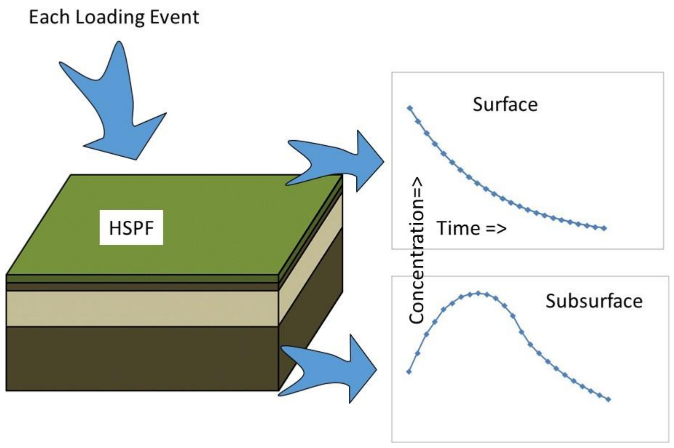
Average Load
+
Δ Inputs X Sensitivity
X
BMPs
X
Acres
X
Land to Water
X
River Delivery

Finalize

Load by land-river segment and land use

CBP management model for running scenarios and supporting decision-making

Dynamic Watershed Model (DWSM)



Load by NHD catchment and land use

Tool for loading estuarine models, calibrating against monitoring data, and collaborative projects

Aggregation of P7 CAST land uses for the DWSM

1. Impervious Roads
- MS4 Roads
- Non-Regulated Roads

2. Impervious Non-Roads
- MS4 Buildings and Other
- Non-Regulated Buildings and Other

3. Tree Canopy over Impervious
- MS4 Tree Canopy over Impervious
- Non-Regulated Tree Canopy over Impervious

4. Turfgrass
- MS4 Turf Grass
- Non-Regulated Turf Grass

5. Tree Canopy Over Turfgrass
- MS4 Tree Canopy over Turf Grass
- Non-Regulated Tree Canopy over Turf Grass

6. Solar Infrastructure
- MS4 Solar Infrastructure
- Non-Regulated Solar Infrastructure

7. Solar Pervious
- MS4 Solar Pervious
- Non-Regulated Solar Pervious

8. Compacted Pervious
- MS4 Compacted Pervious
- Non-Regulated Compacted Pervious

9. Construction

10. Forest

11. Harvested Forest

12. Floodplain Wetlands

13. Other Wetlands

14. Cropland
- Full Season Soybeans
- Grain with Manure
- Grain without Manure
- Silage with Manure
- Silage without Manure
- Small Grains and Grains
- Double Cropped Land
- Specialty Crop High
- Specialty Crop Low
- Other Agronomic Crops

15. Pasture and Hay
- Ag Open Space
- Leguminous Hay
- Hay Low
- Pasture Low
- Hay High
- Pasture High

16. Water

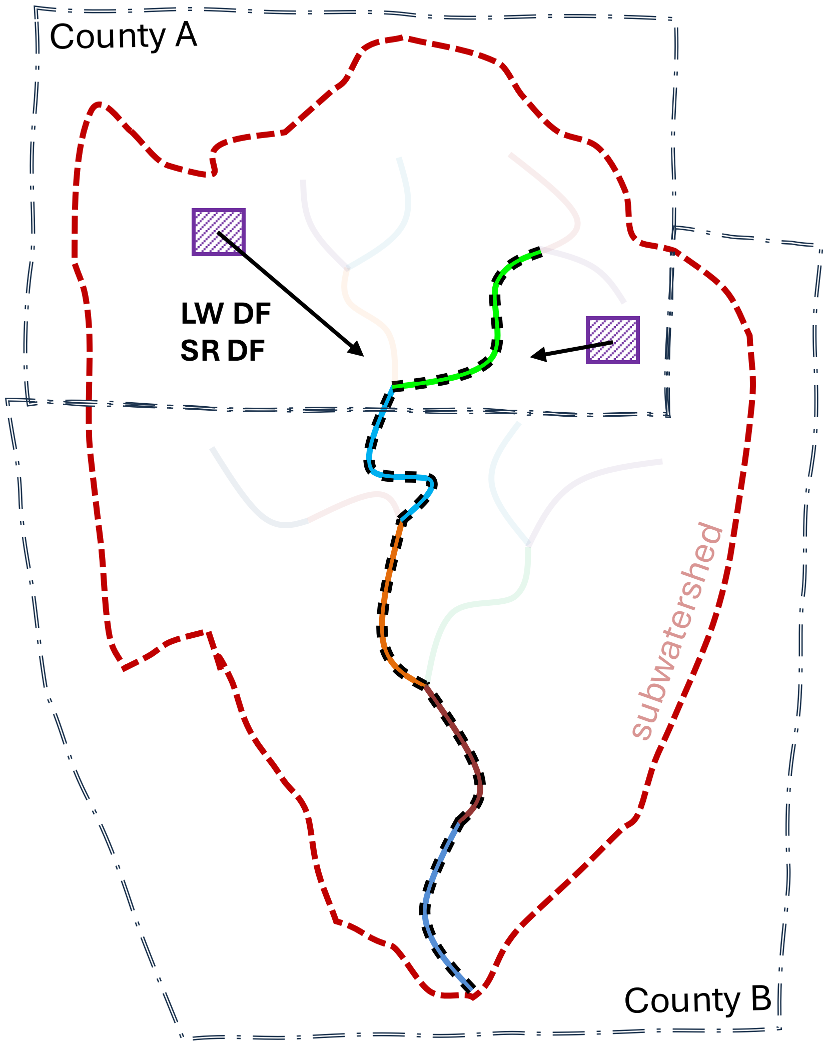
17. Feed Space
- Permitted Feeding Space
- Non-Permitted Feeding Space

18. Combined Sewer System
- CSS Roads
- CSS Buildings and Other
- CSS Tree Canopy over Impervious
- CSS Turf Grass
- CSS Tree Canopy over Turf Grass
- CSS Solar Infrastructure
- CSS Solar Pervious
- CSS Compacted Pervious
- CSS Construction
- CSS Forest
- CSS Harvested Forest

Thanks to Jessica, Sarah, and Peter!

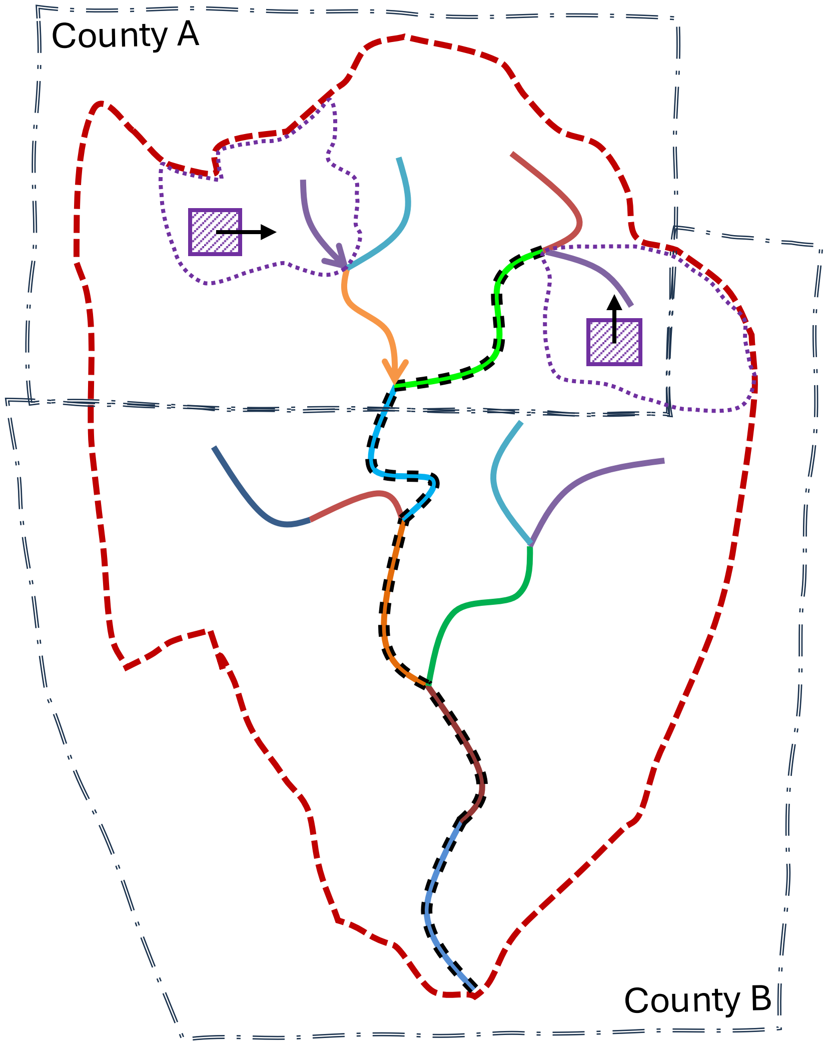
Routing

Phase 6



→ Lumped land to water delivery factor
→ Lumped stream to river delivery factor

Phase 7



→ Catchment's land to water delivery factor
→ Catchment's stream to river delivery factor

nested model segmentation of streams and river mainstems →

100K NHD STREAMS

simulated with →

> Generalized Stream Network (GSN)
Hydrology: Non-iterative routing
Water Quality: βs for trend, flow, & season

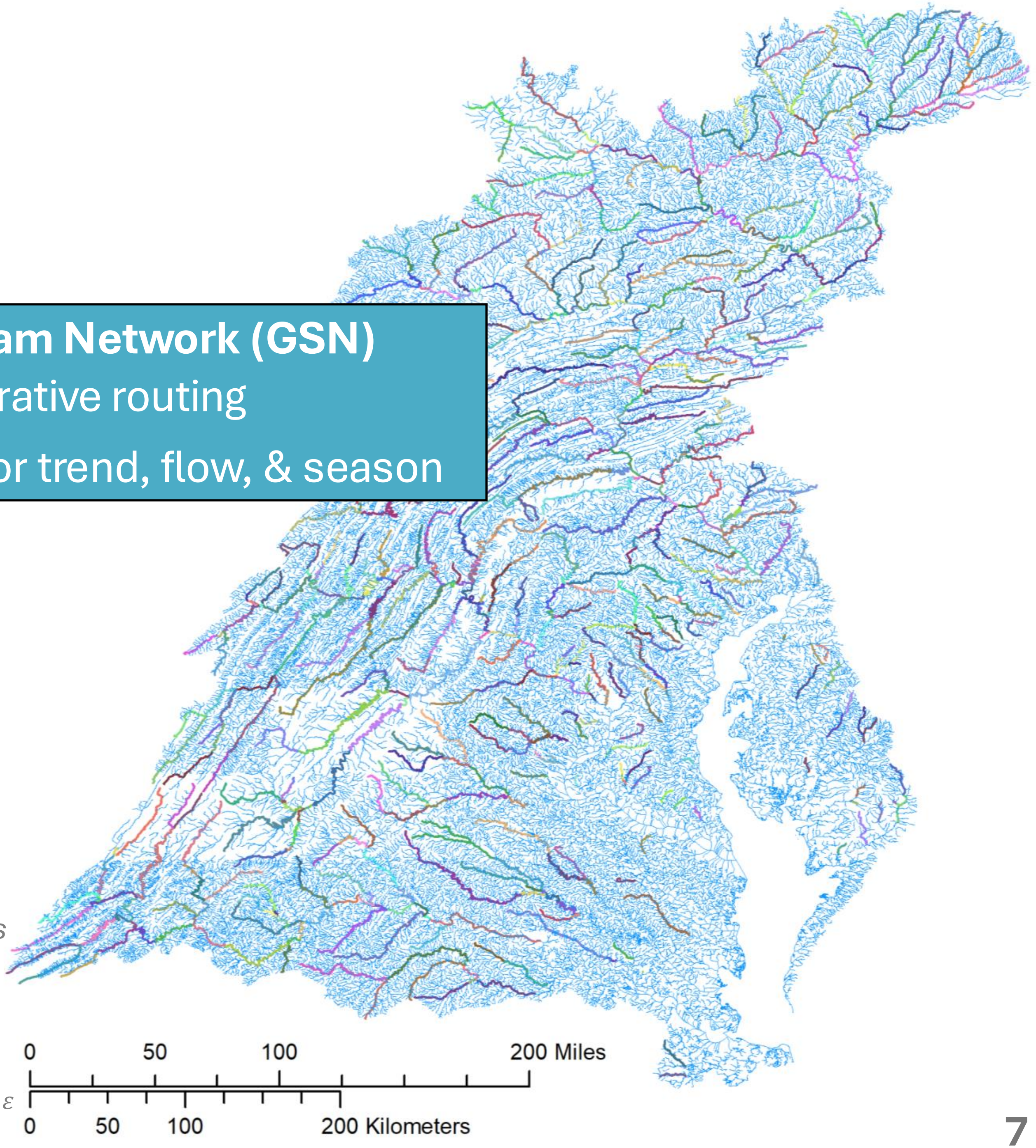
RIVER MAINSTEM

simulated with →

HSPF
Hydrologic Simulation Program - FORTRAN

→ GSN's Non-iterative routing of flow uses open channel flow (Manning's equation) and Euler's method for time stepping with mass-balance constraints
$S(t+1) = S(t) + (dS/dt)\Delta t$

→ GSN's TN, TP, and SS concentrations are based on an empirical formulation that is constrained by CalCAST stream delivery factors
$ln(c) = \beta_o + ln\left(c\_in\_steady\_state_{yr} \times STF\right) + \beta_2 ln(Q) + \beta_3 sin(2\pi t) + \beta_4 cos(2\pi t) + \varepsilon$



Framework: Statistical model (CalCAST) → Dynamic Watershed Model (DWSM)

Hydrology

CAST

- Annual land use data for 18 core land use types
- Direct loads: municipal, industrial, septic, rapid infiltration

CalCAST

- Average annual yield of flow and stormflow

Sediment

CAST

- Monthly estimates of detached sediment (land segments)
- Monthly estimates of cover fraction (land segments)

CalCAST

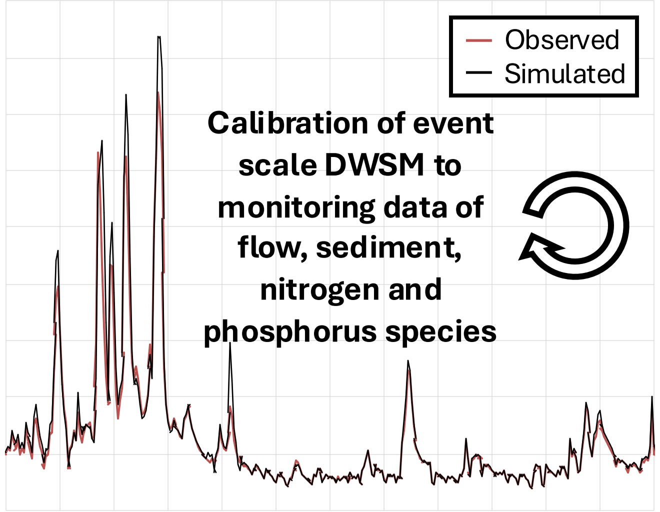
- Average annual RUSLE2 based EOF sediment
  - Aggregated to land segment for model calibration
  - Catchment scale data for sub-county spatial variability
- Transport factors (land to water and stream delivery)

P7 land catchment segment land use scale

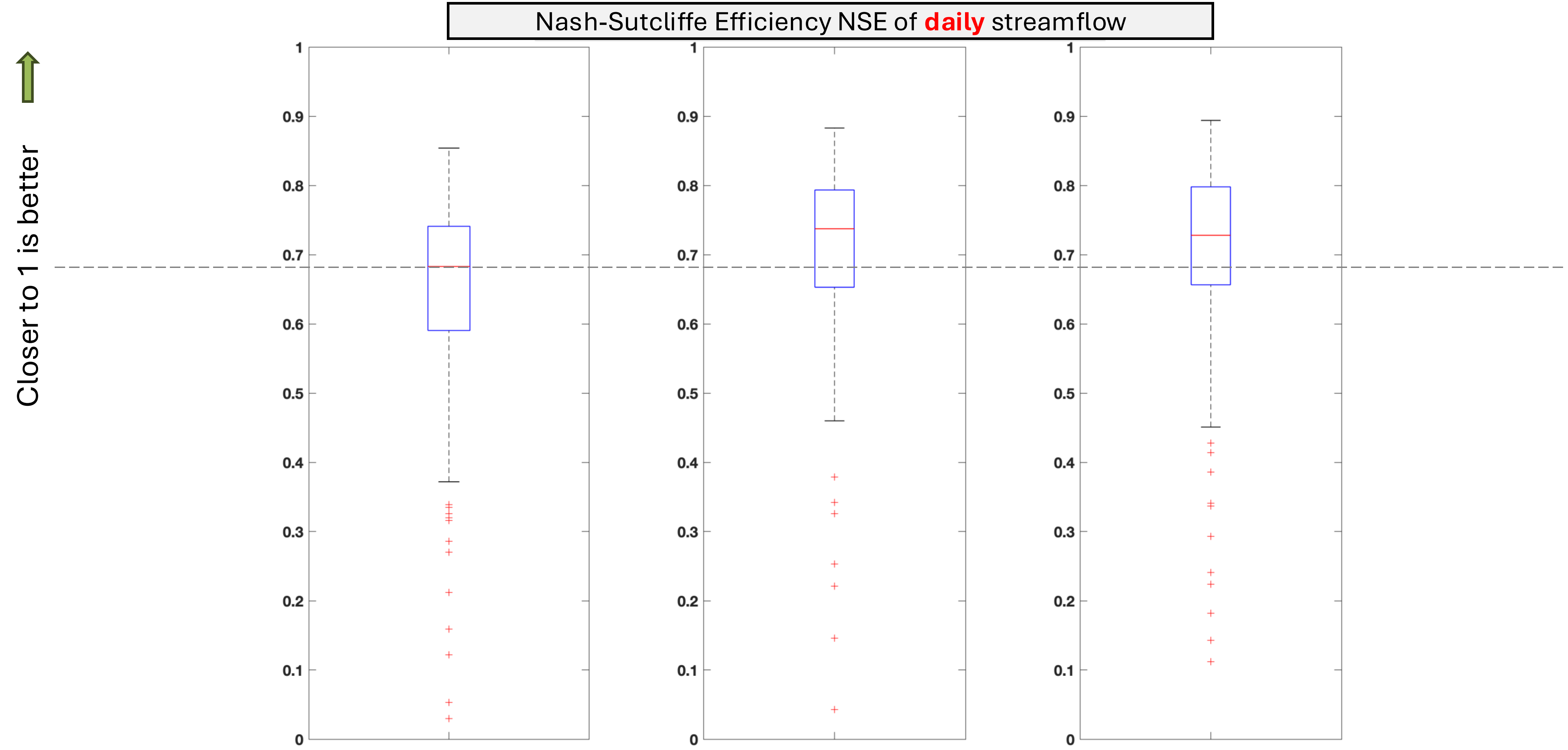
DWSM process-based hourly estimates

Meteorological inputs, DWSM parameters

temporal disaggregation



We have a ‘as good or better’ hydrology calibration

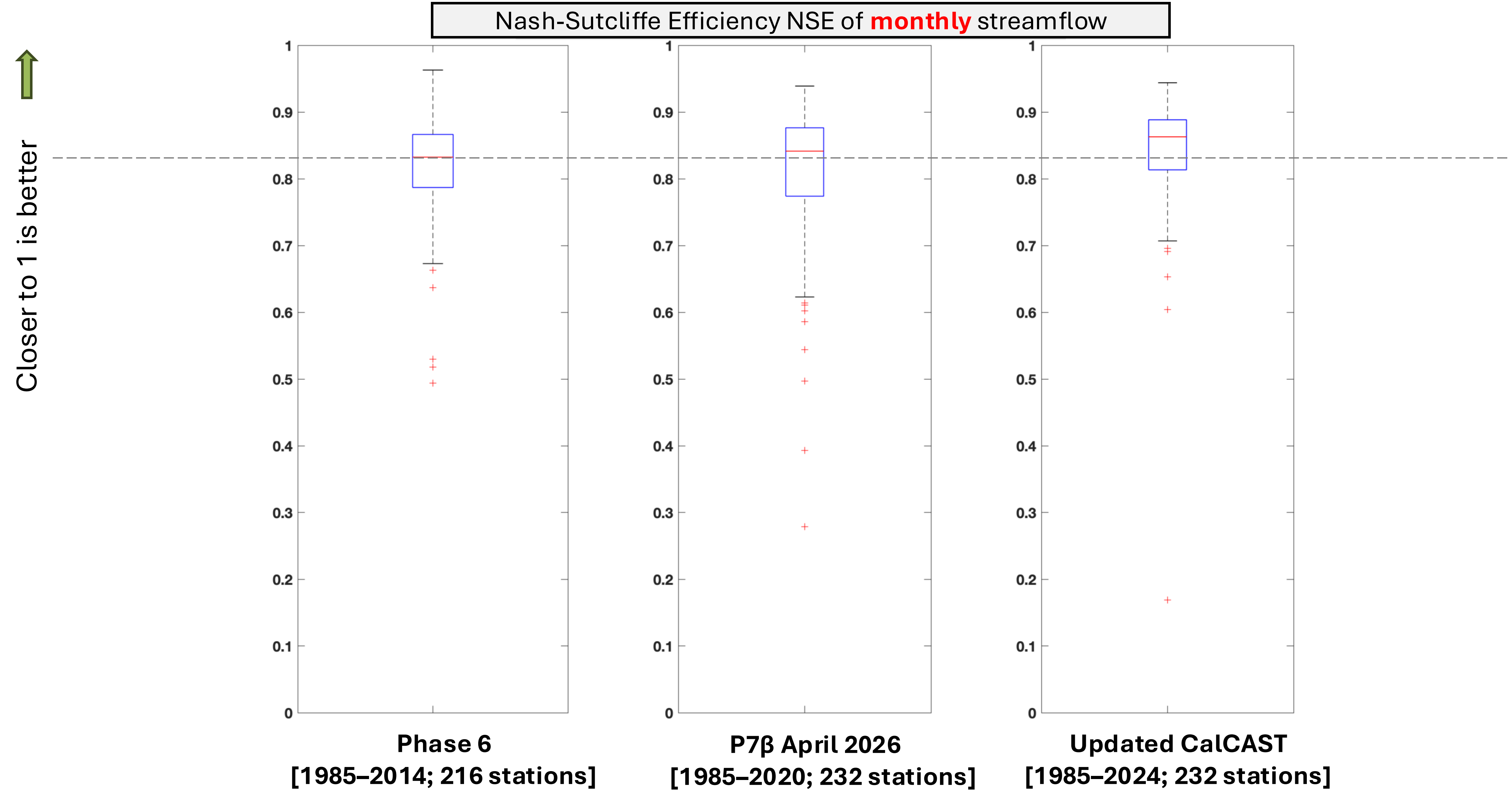


Phase 6
[1985–2014; 216 stations]

P7β April 2026
[1985–2020; 232 stations]

Updated CalCAST
[1985–2024; 232 stations]

We have a ‘as good or better’ hydrology calibration



We examined the outliers ...

- There are a total of 5 stations with bias more than ±30%

USGS	Station Name	Drainage area (sq. mi.)	CalCAST	DWSM
01643580	**Monocacy River Near Dickerson, MD**	**961**	**not used**	**new in P7; has only 1.5 years of data; x**
01617800	Marsh Run at Grimes, MD	18.9	has large bias	new in P7; 40 years
01642600	Linganore Creek at Linganore RD Near Frederick, MD	88.2	not used	new in P7; has a total of 4 months of data; x
01621410	Blacks Run at RT 726 at Harrisonburg, VA	10.9	not used	Nov 2000 to Sep 2002
01671025	North Anna River Above Little River NR Doswell, VA	467	not used	new in P7; 2005-2020; x

Sediment calibration process …

- Calibrate Edge of Field (EOF) sediment response
- Calibrate riverine water quality response
- Perform hand calibration as needed

RUSLE2 EOF sediment
Calibrated hydrology

Land use EOF response →

CalCAST land to water DFs
CalCAST stream DFs
β-parameters and trend

Small stream response →

Water quality observations
WRTDS loads

Riverine water quality response

Rule based calibration of EOF sediment model parameters

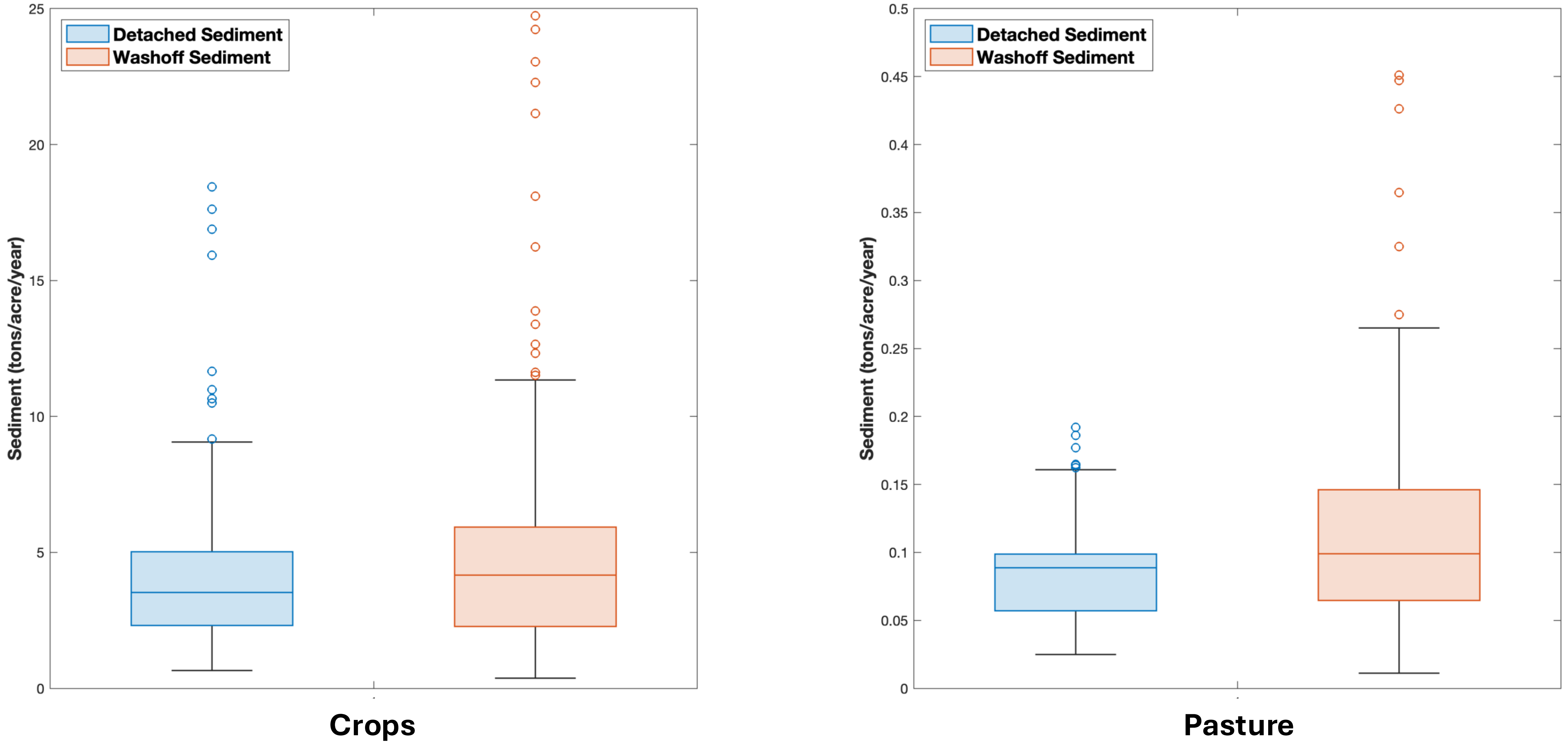
Parameter	Description
KRER	Coefficient that determines how much sediment is detaches from the soil matrix as a function of rainfall.
JRER	Exponent that determines how much sediment is detaches from the soil matrix as a function of rainfall.
KSER	Coefficient that determines the sediment transport capacity as a function of surface outflow.
JSER	Exponent that determines the sediment transport capacity as a function of surface outflow.
NVSI	Rate at which sediment is added to detached soil from atmosphere; Negative values can simulate removal of sediment by wind or human activities.
COVER	Fraction of soil surface in vegetative cover and unavailable for erosion by rainfall; COVER varies monthly by land use.
AFFIX	Rate at which detached sediment is re-attached to soil matrix due to compaction.

$$NVSI = 1.5 \times EOF\ sediment\ yield$$

$$KRER = 0.075 \times KSER$$

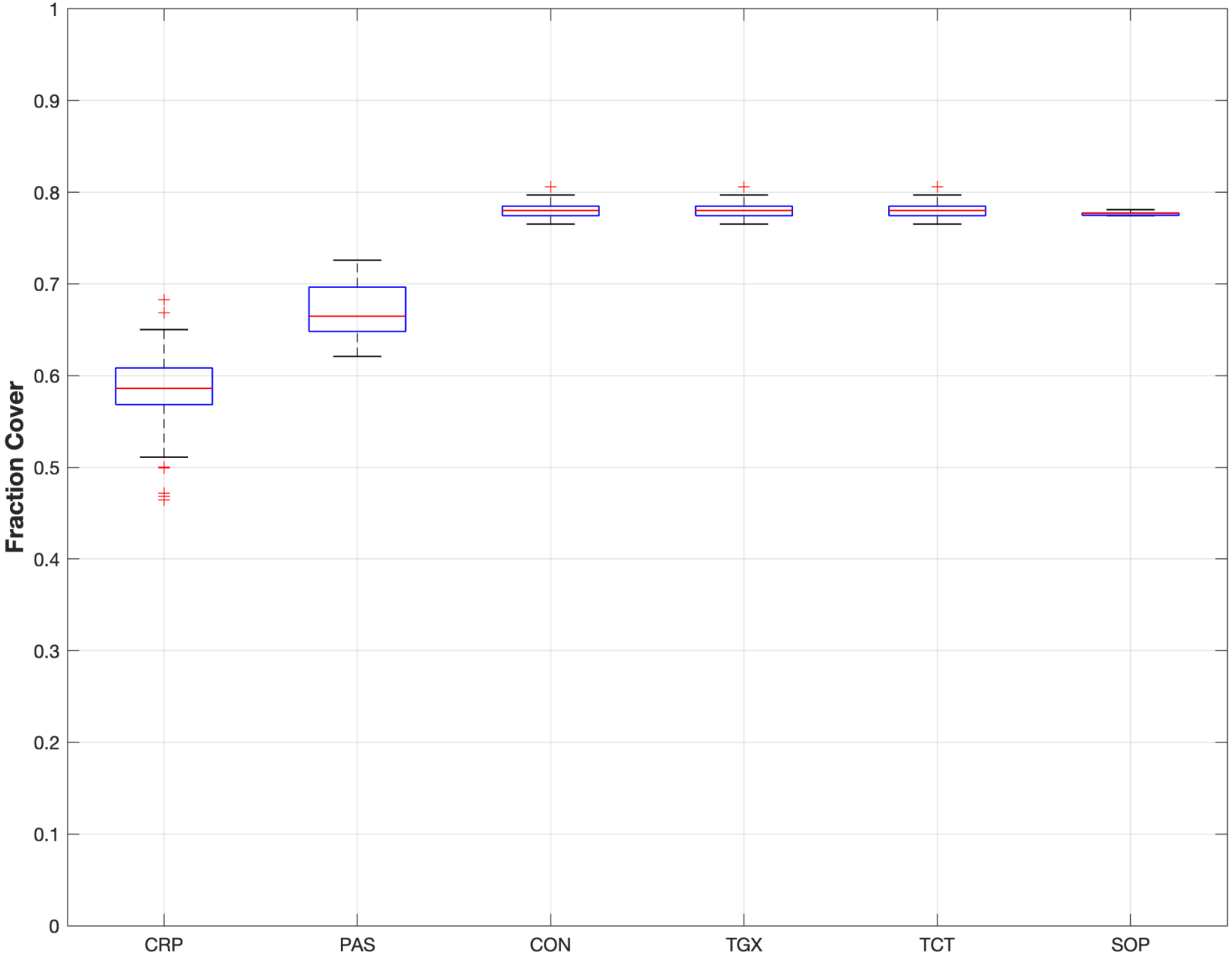
$$JRER = JSER = 6 \times exp(-KSER^{0.25})$$

Detached sediment and calibrated washoff



→ *Left and right panels show data for crops and pasture, respectively. Boxplots show variability in data for 235 land segments.*

Average annual fraction cover



CRP Cropland

PAS Pasture

CON Construction

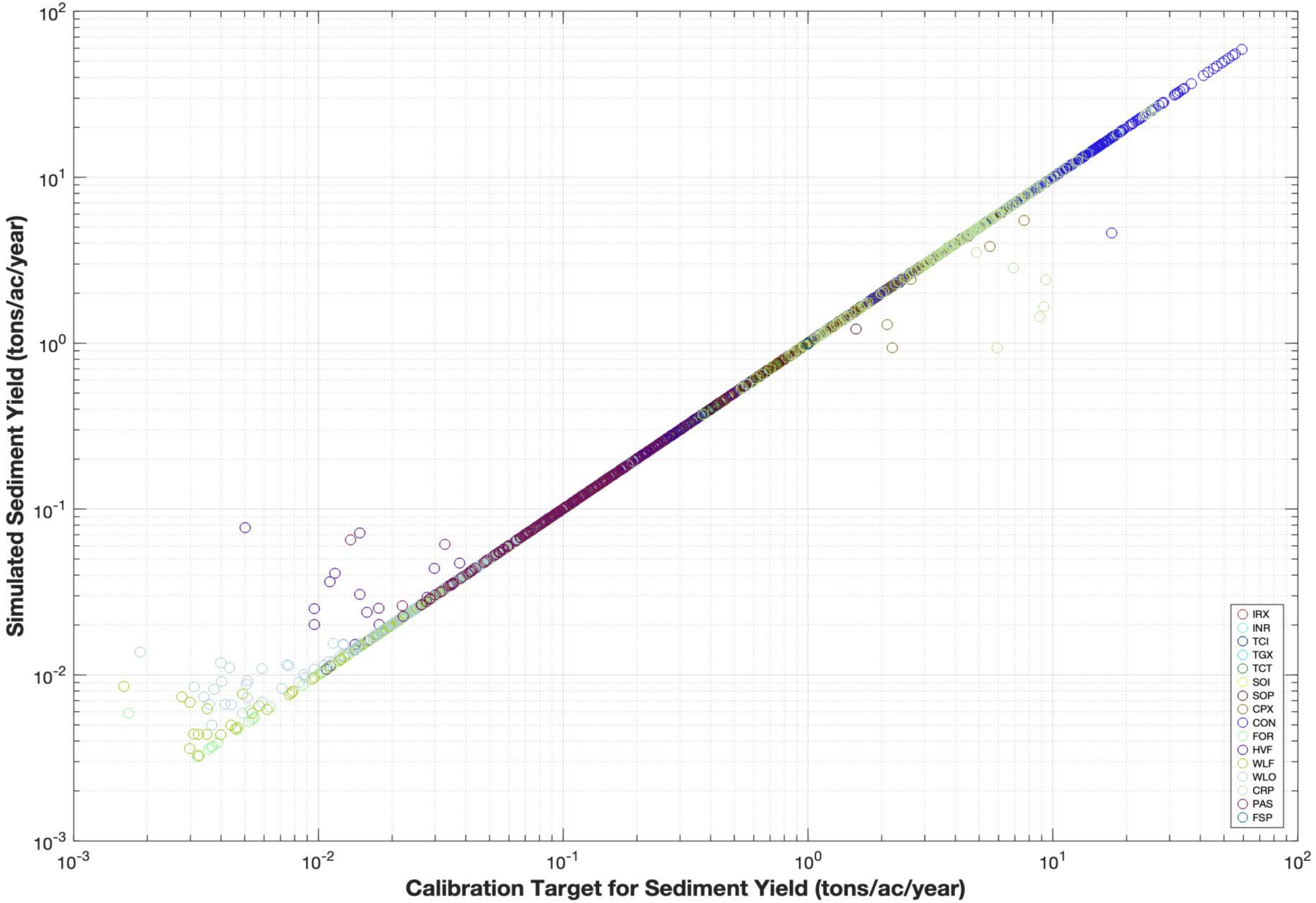
TGX Turfgrass

TCT Tree Canopy over Turfgrass

SOP Solar Pervious

→ *Each boxplot show variability in data for 235 land segments.*

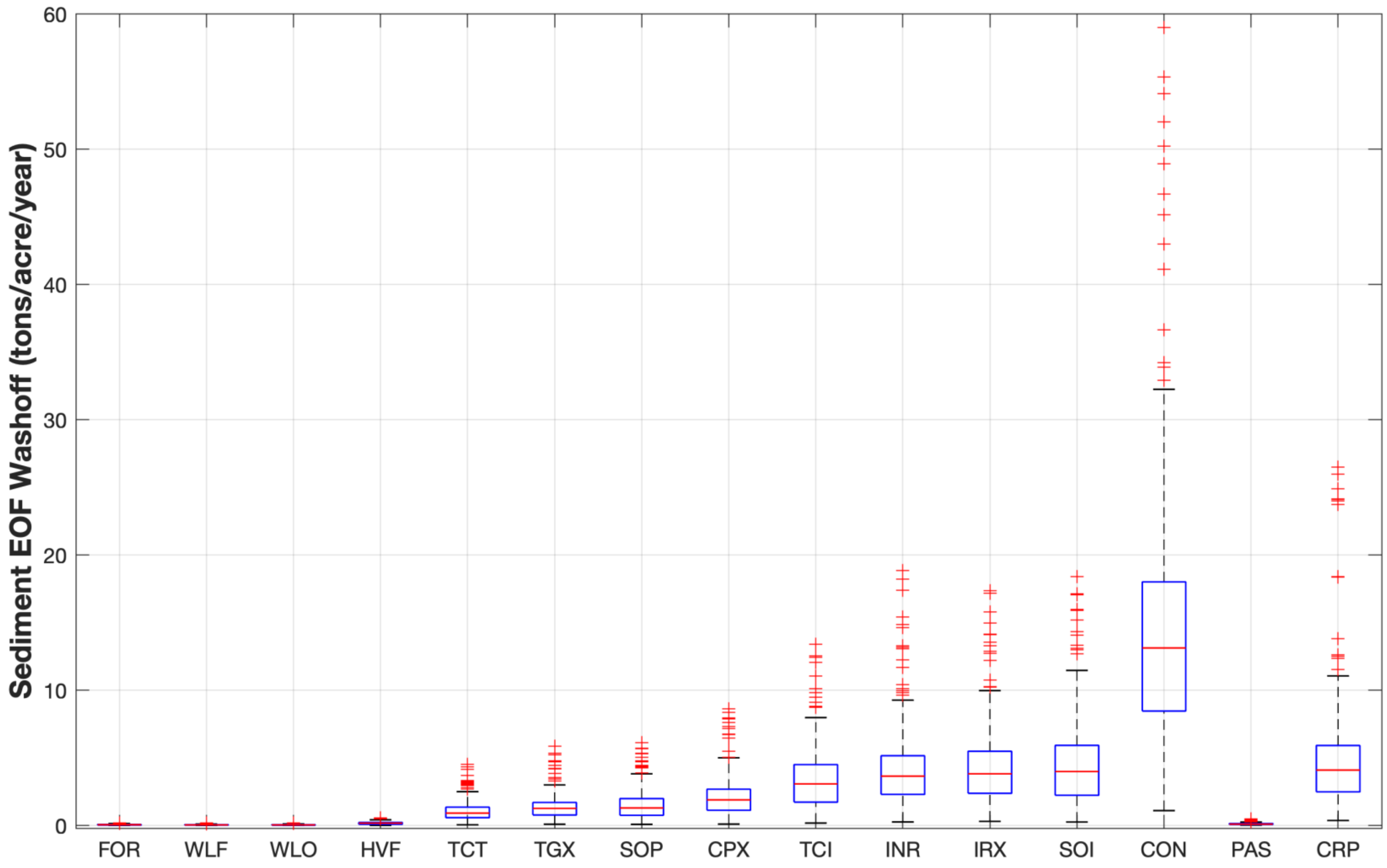
Calibration target vs. simulated EOF sediment yield



IRX Impervious Roads
INR Impervious Non-Roads
TCI Tree Canopy over Impervious
TGX Turfgrass
TCT Tree Canopy over Turfgrass
SOI Solar Infrastructure
SOP Solar Pervious
CPX Compacted Pervious
CON Construction
FOR Forest
HVF Harvested Forest
WLF Floodplain Wetlands
WLO Other Wetlands
CRP Cropland
PAS Pasture
FSP Feed Space

→ *1:1 agreement indicates calibrated parameters reproduced average annual estimates of land segment EOF sediment yields.*

Calibrated average annual EOF sediment yield



FOR Forest
WLF Floodplain Wetlands
WLO Other Wetlands
HVF Harvested Forest
TCT Tree Canopy over Turfgrass
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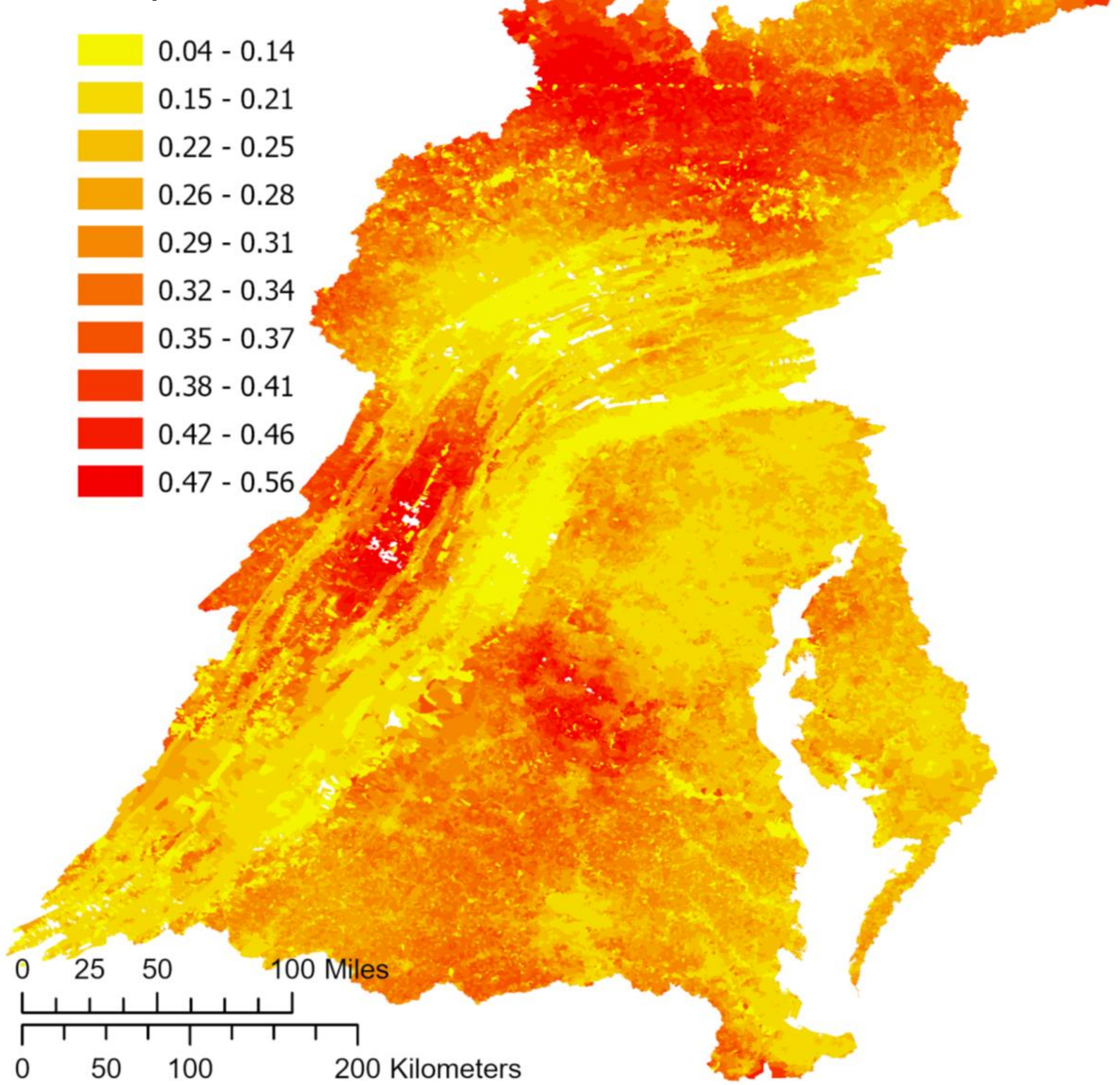
SOP Solar Pervious
CPX Compacted Pervious
TCI Tree Canopy over Impervious
INR Impervious Non-Roads
IRX Impervious Roads
SOI Solar Infrastructure
CON Construction
PAS Pasture
CRP Cropland
FSP Feed Space

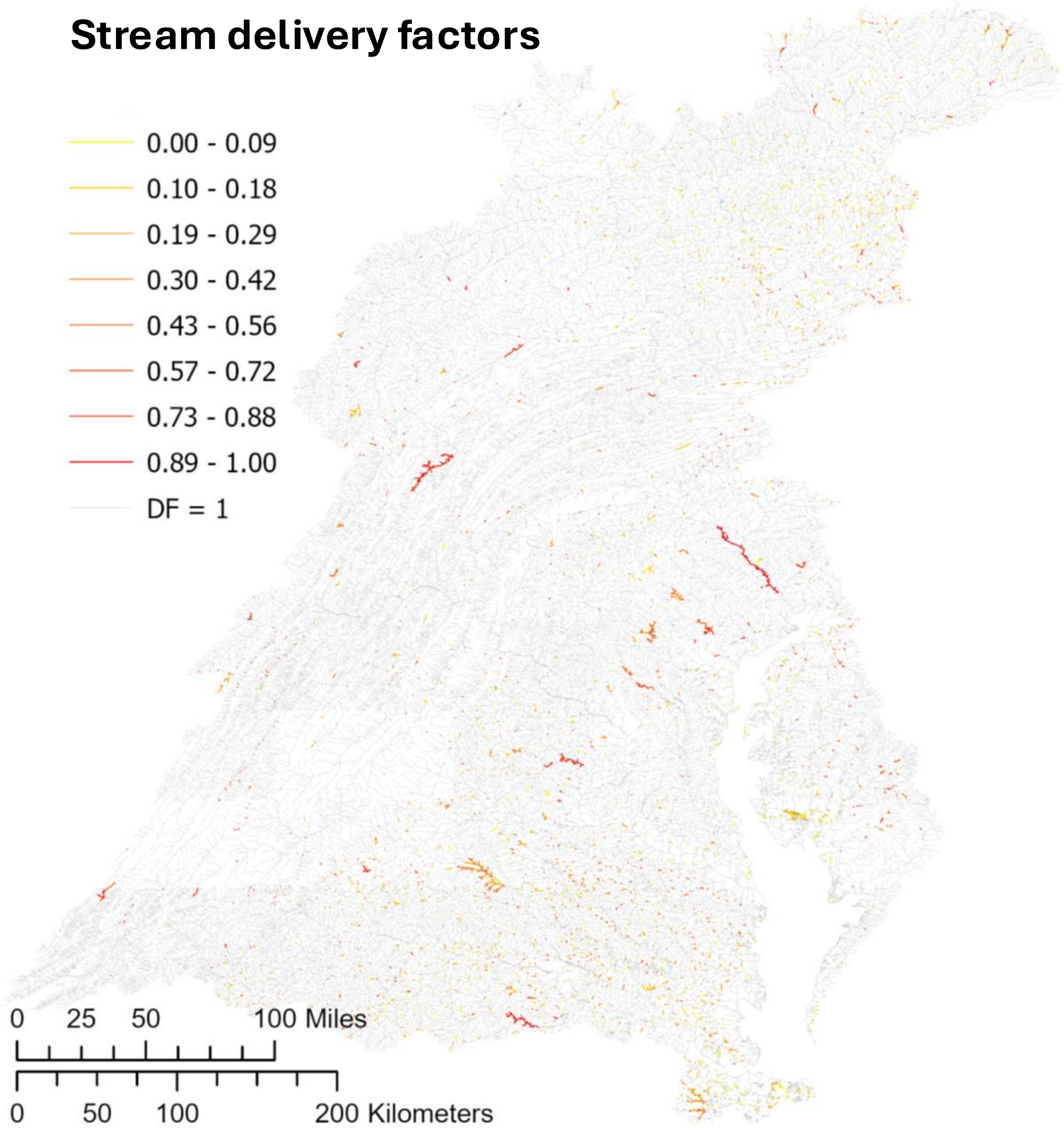
→ *Each boxplot show variability in data over the 235 Phase 7 land segments.*

Land to Water delivery factors

Crops



Stream delivery factors



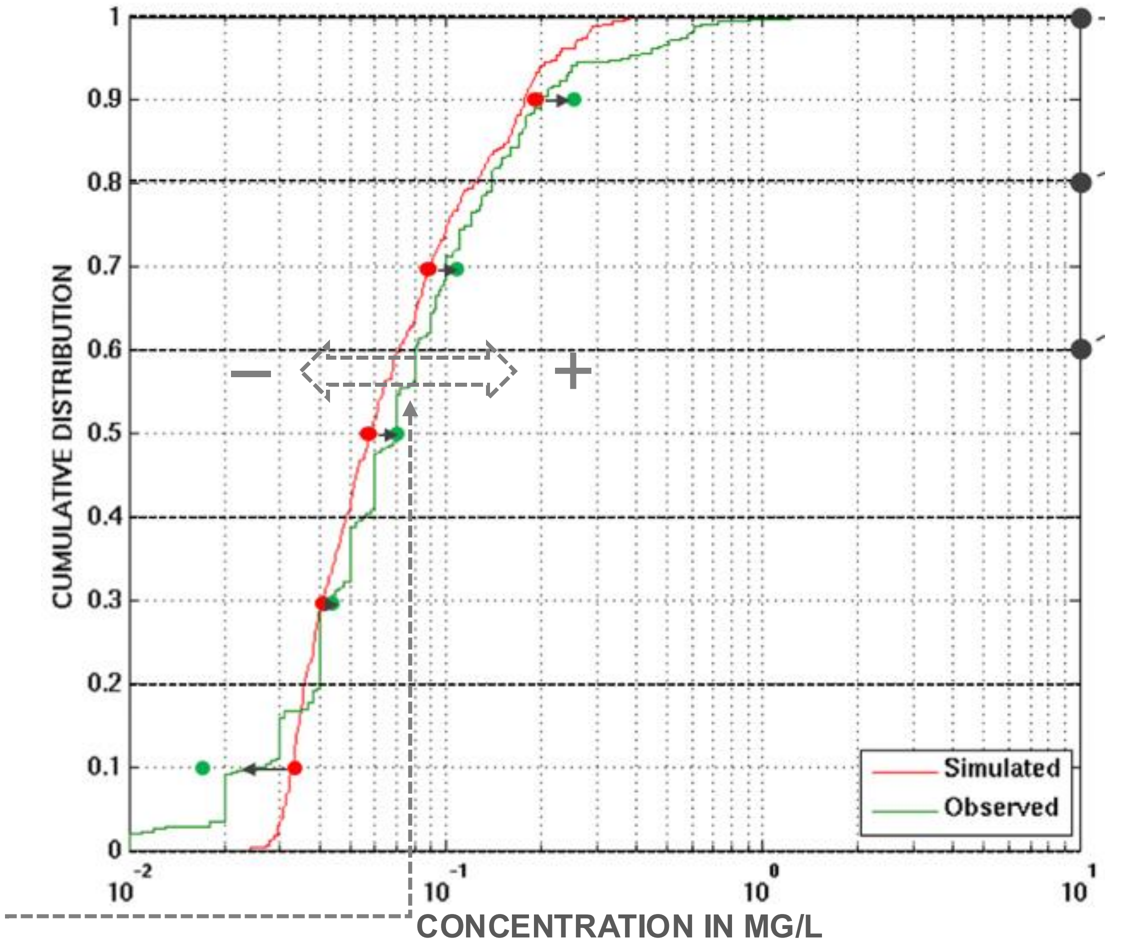
Riverine sediment (water quality) calibration

We calibrate DWSM/HSPF water quality parameters to improve agreement in cumulative frequency distributions (CFDs) of observed and simulated concentrations.

→ Information available for the calibration of model parameters:

- Observations of daily concentrations for nutrient species at monitoring stations
- ~~CalCAST transport factors for TN, TP, and SS for river mainstems~~
- WRTDS estimated TN, TP, and SS loads
  - We incorporated "adjustment factor" that nudges the simulated CFD within the automated calibration tool before parameters are adjusted
- ~~QC relationships (generalized β parameters for river mainstems)~~

Figure: Cumulative distribution of concentrations at a monitoring station



RIM stations: Phase 7 Sediment loads vs. WRTDS

(a) biases in 1985-2014 average loads as compared to WRTDS; (b) NSE of annual loads in parentheses;

Rivers	Phase 6*	April 2026	September 2026
Conowingo	+08.0% (+0.963)	+05.9% (+0.744)	+04.4% (+0.721)
Marietta	-00.9% (+0.833)	+09.1% (+0.160)	+07.9% (+0.191)
Potomac	+03.2% (+0.827)	+03.4% (-0.092)	+02.6% (+0.178)
James	+01.1% (+0.384)	-03.6% (+0.808)	-04.6% (+0.723)
Rappahannock	+00.1% (-0.356)	-07.1% (+0.656)	-00.6% (+0.456)
Appomattox	+13.8% (-0.567)	-09.7% (+0.534)	-08.2% (+0.340)
Pamunkey	+01.7% (-1.143)	-04.7% (+0.071)	-03.6% (-0.099)
Mattaponi	-00.9% (-0.120)	-07.7% (-0.350)	-05.0% (-0.330)
Patuxent	+10.3% (+0.678)	-13.5% (+0.458)	-15.1% (+0.401)
Choptank	+15.9% (+0.424)	+08.4% (-0.632)	+00.5% (-0.938)

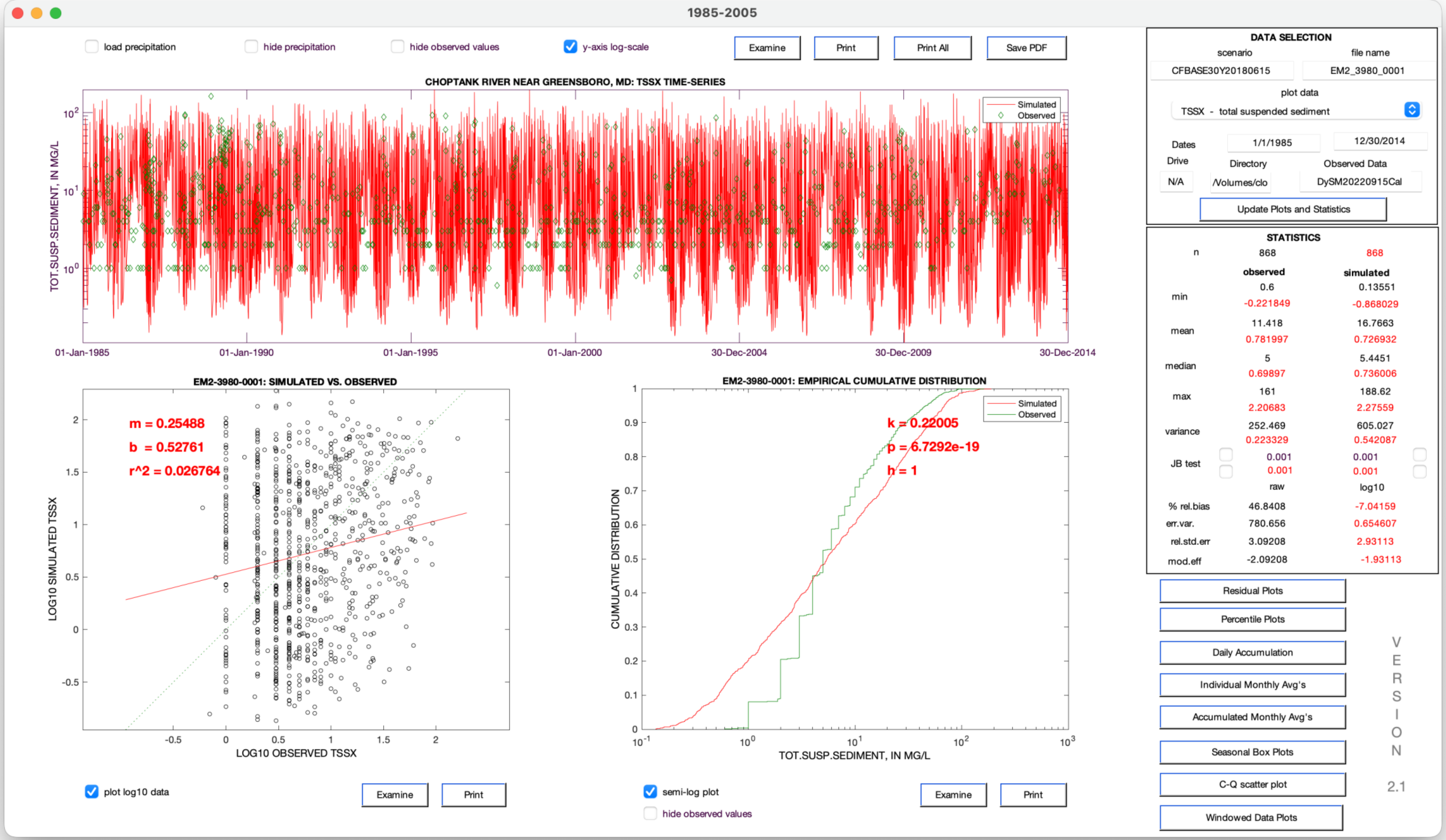
** after hand calibration*

→ *some differences from CalCAST can be attributed to WRTDS method and DWSM loads for the 1985-2014 averaging period*

SEDIMENT

Choptank River near Greensboro, MD

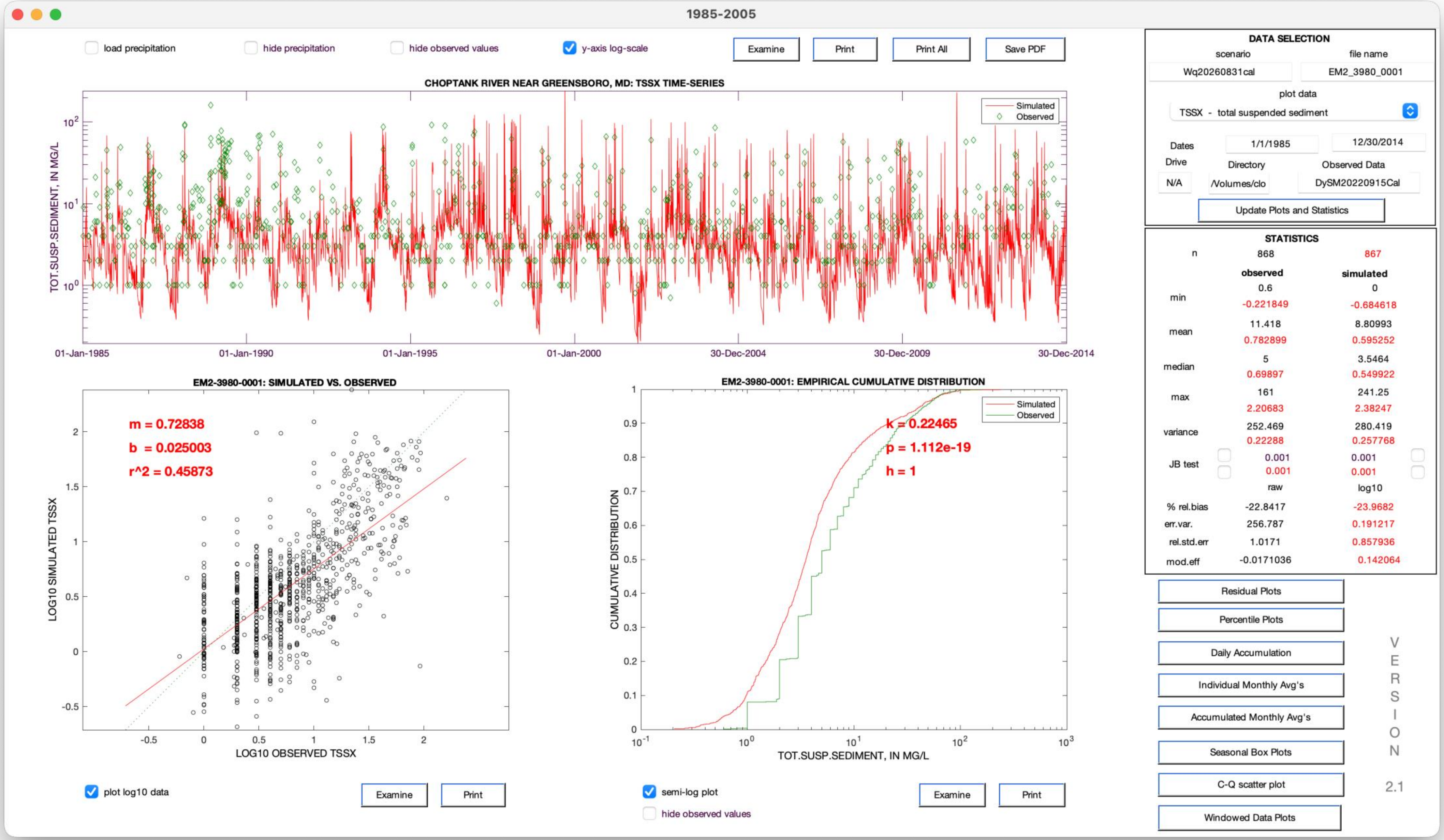
PHASE 6



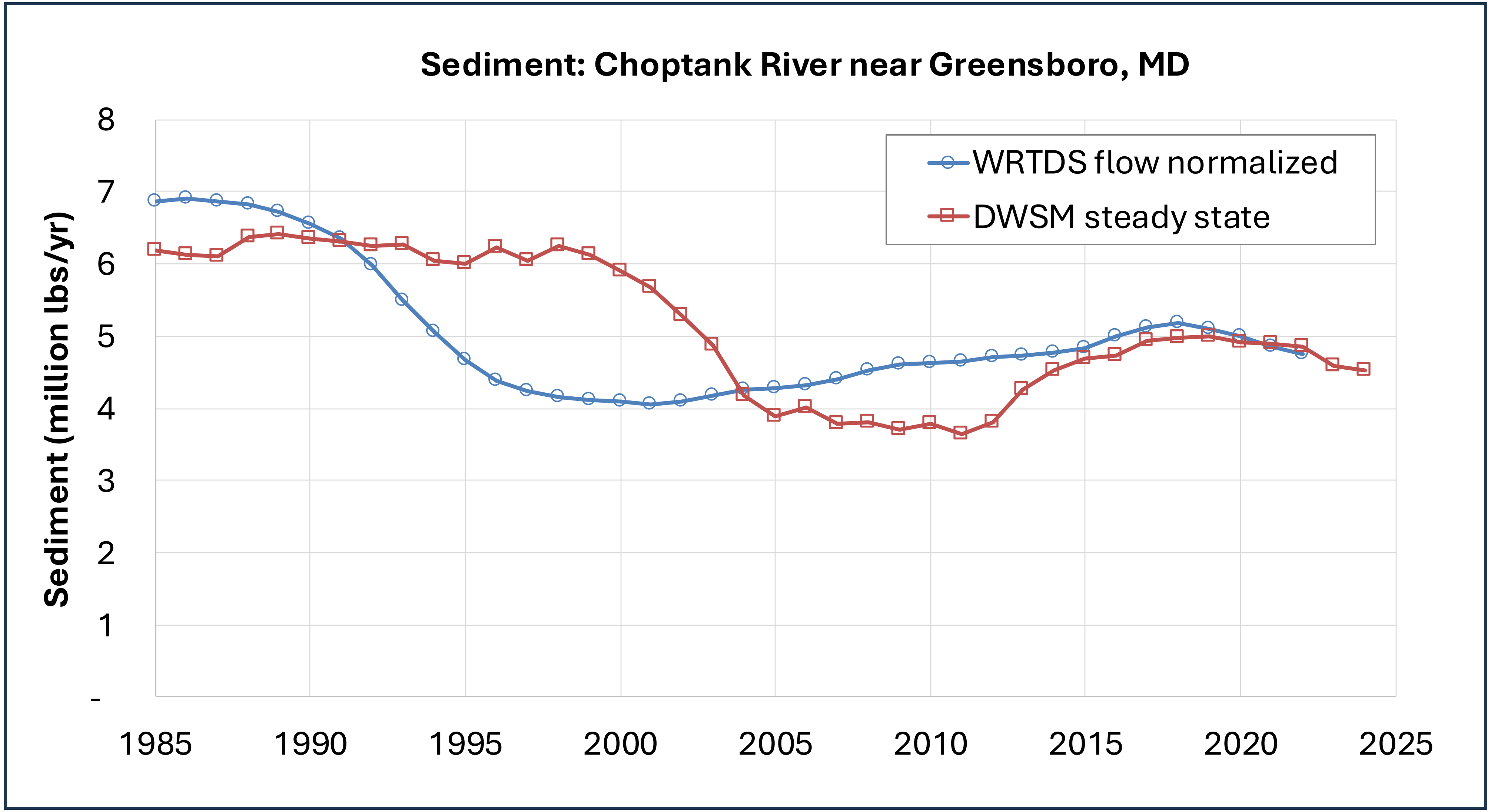
SEDIMENT

Choptank River near Greensboro, MD

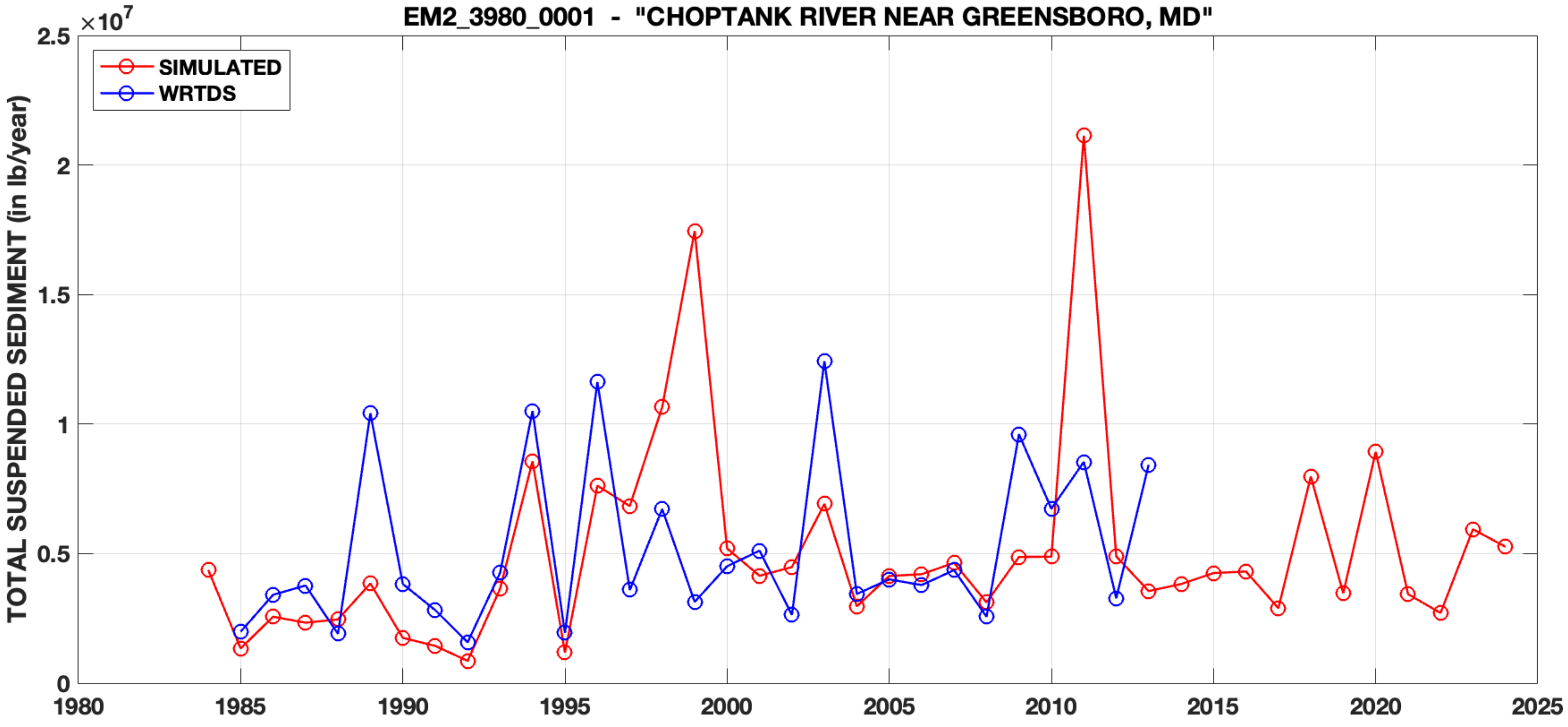
PHASE 7, SEPT 2026



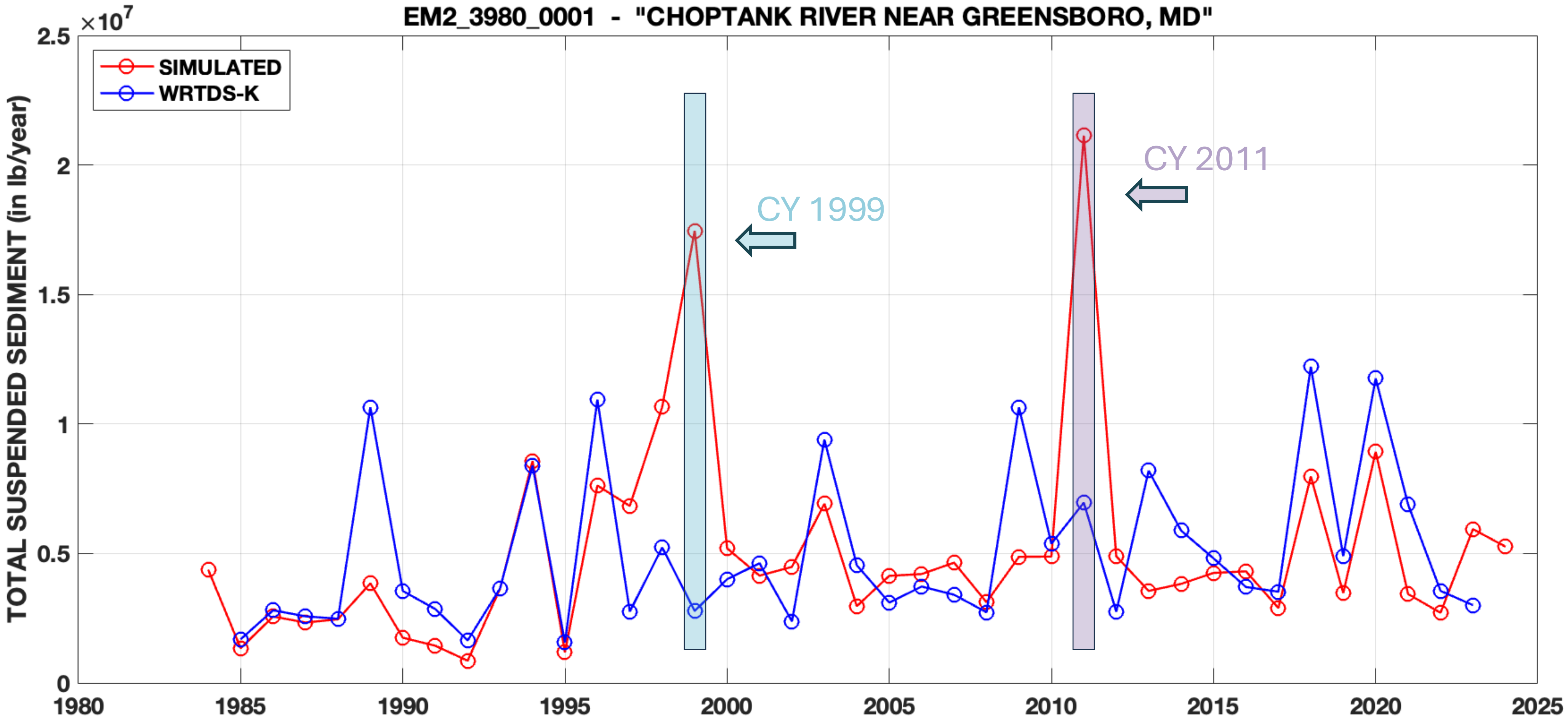
DWSM's steady state response



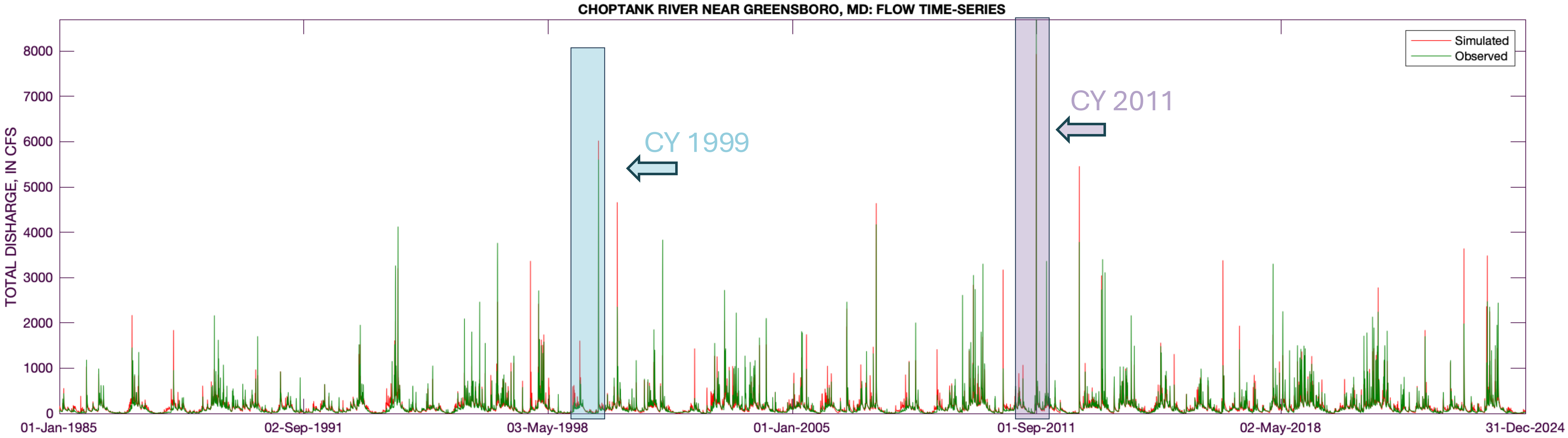
Simulated annual loads as compared to WRTDS are satisfactory …



WRTDS-K seems more promising here ...

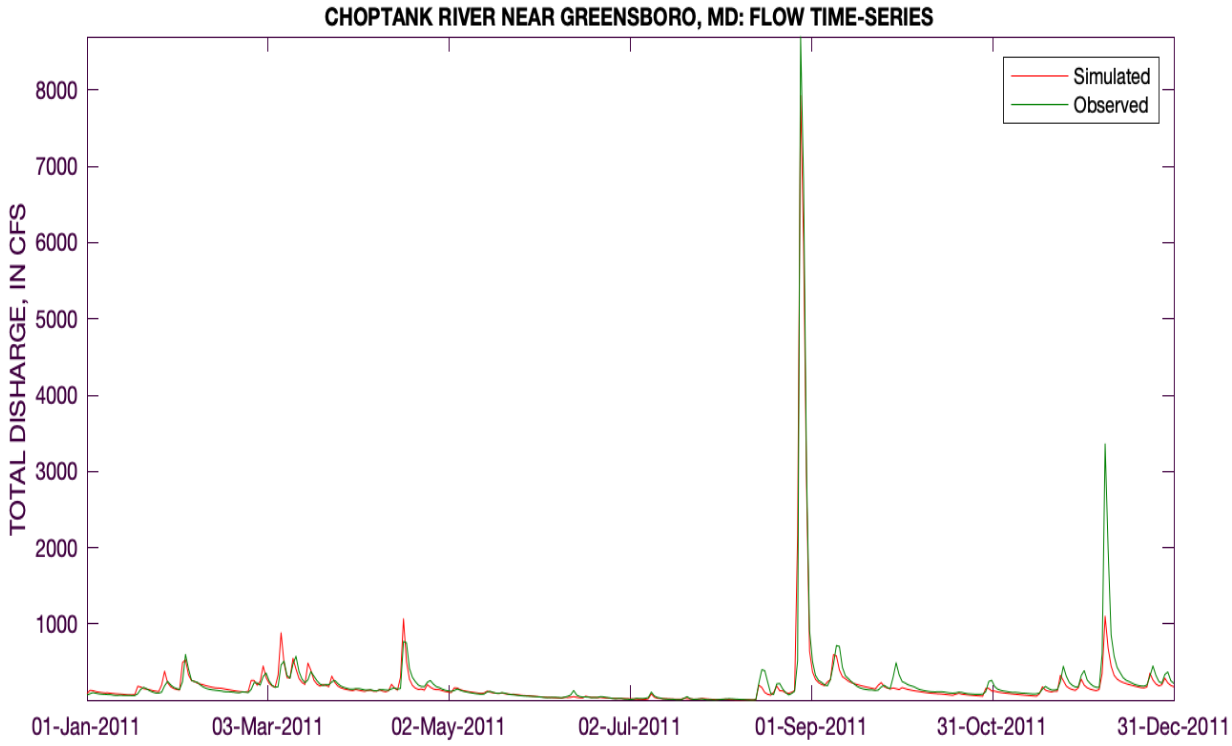


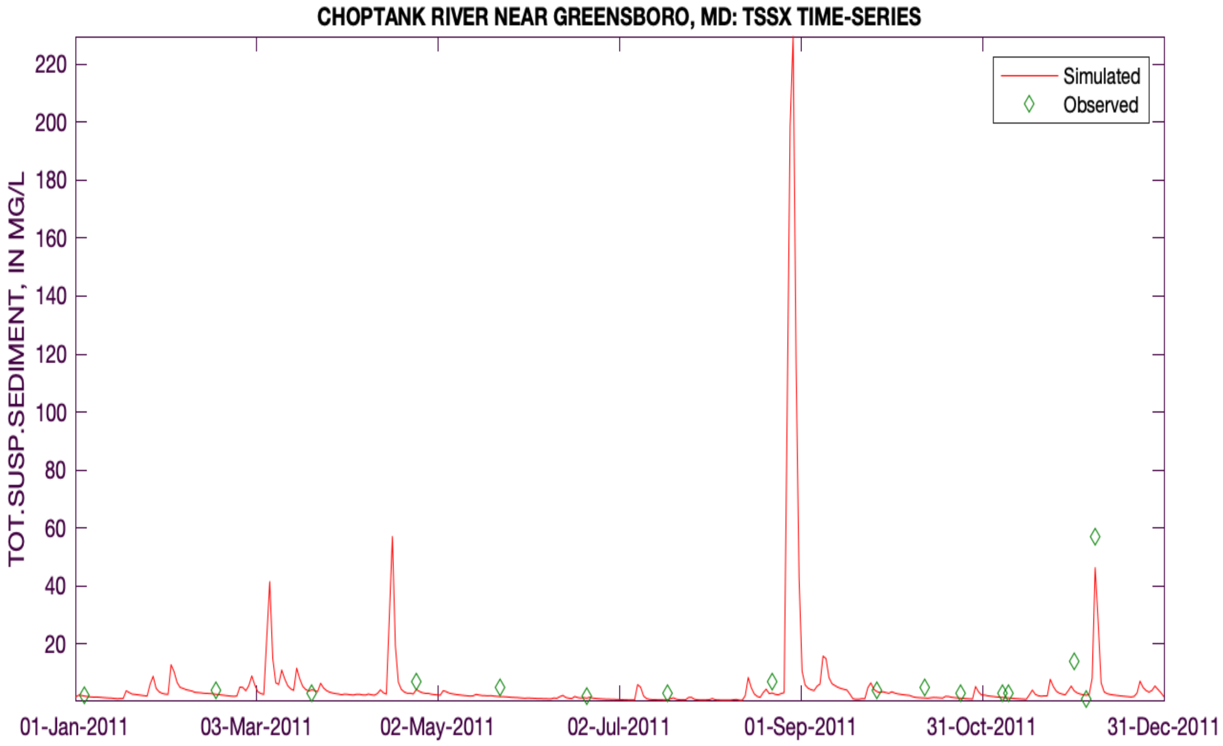
Long-term (40-years) of simulated and observed flow



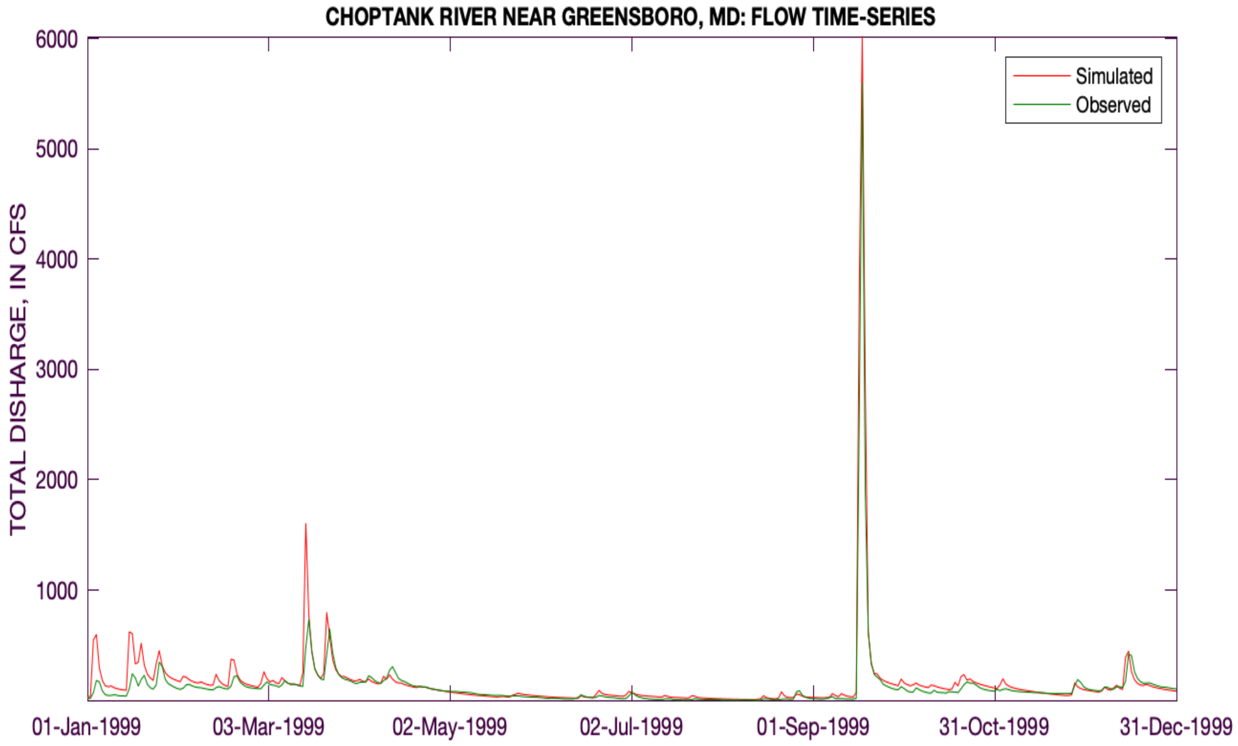
→ *CY 2011 and CY 1999 are top two high flow events with Q > 5,500 ft^3/s*

CY 2011

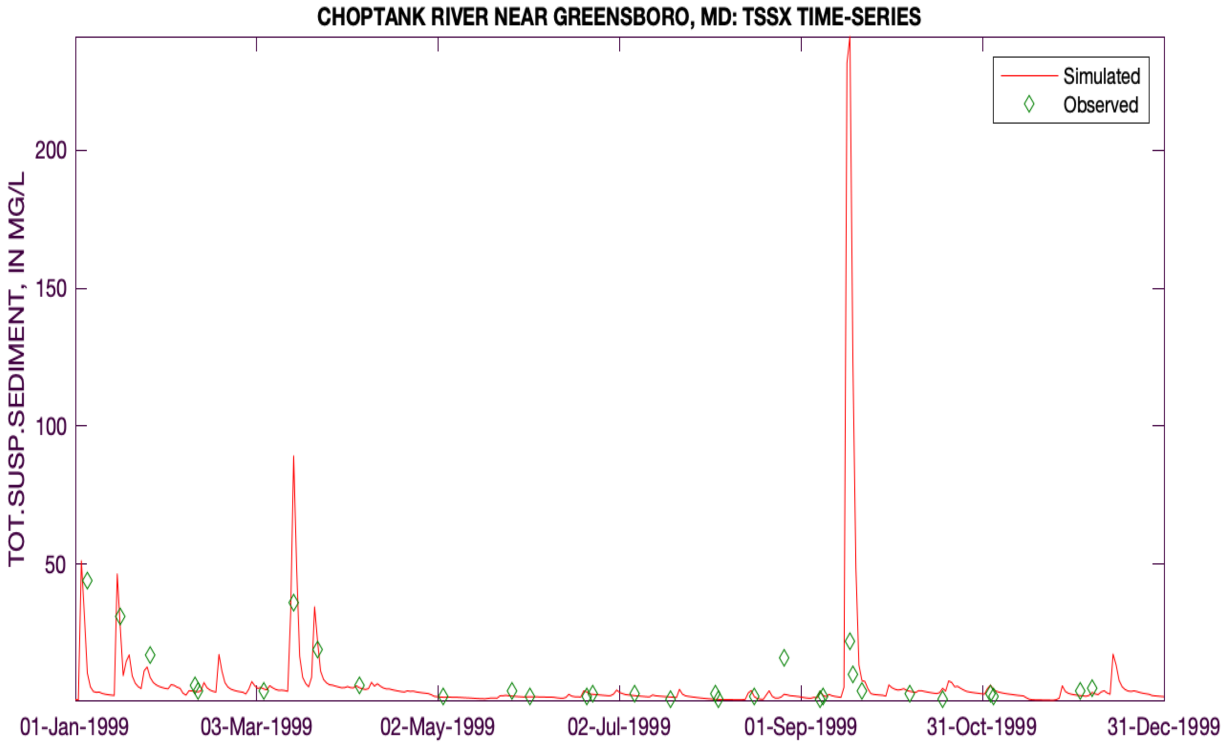

CHOPTANK RIVER NEAR GREENSBORO, MD: FLOW TIME-SERIES
Simulated
Observed
TOTAL DISHARGE, IN CFS
8000
7000
6000
5000
4000
3000
2000
1000
01-Jan-2011
03-Mar-2011
02-May-2011
02-Jul-2011
01-Sep-2011
31-Oct-2011
31-Dec-2011


CHOPTANK RIVER NEAR GREENSBORO, MD: TSSX TIME-SERIES
Simulated
Observed
TOT.SUSP.SEDIMENT, IN MG/L
220
200
180
160
140
120
100
80
60
40
20
01-Jan-2011
03-Mar-2011
02-May-2011
02-Jul-2011
01-Sep-2011
31-Oct-2011
31-Dec-2011

CY 1999

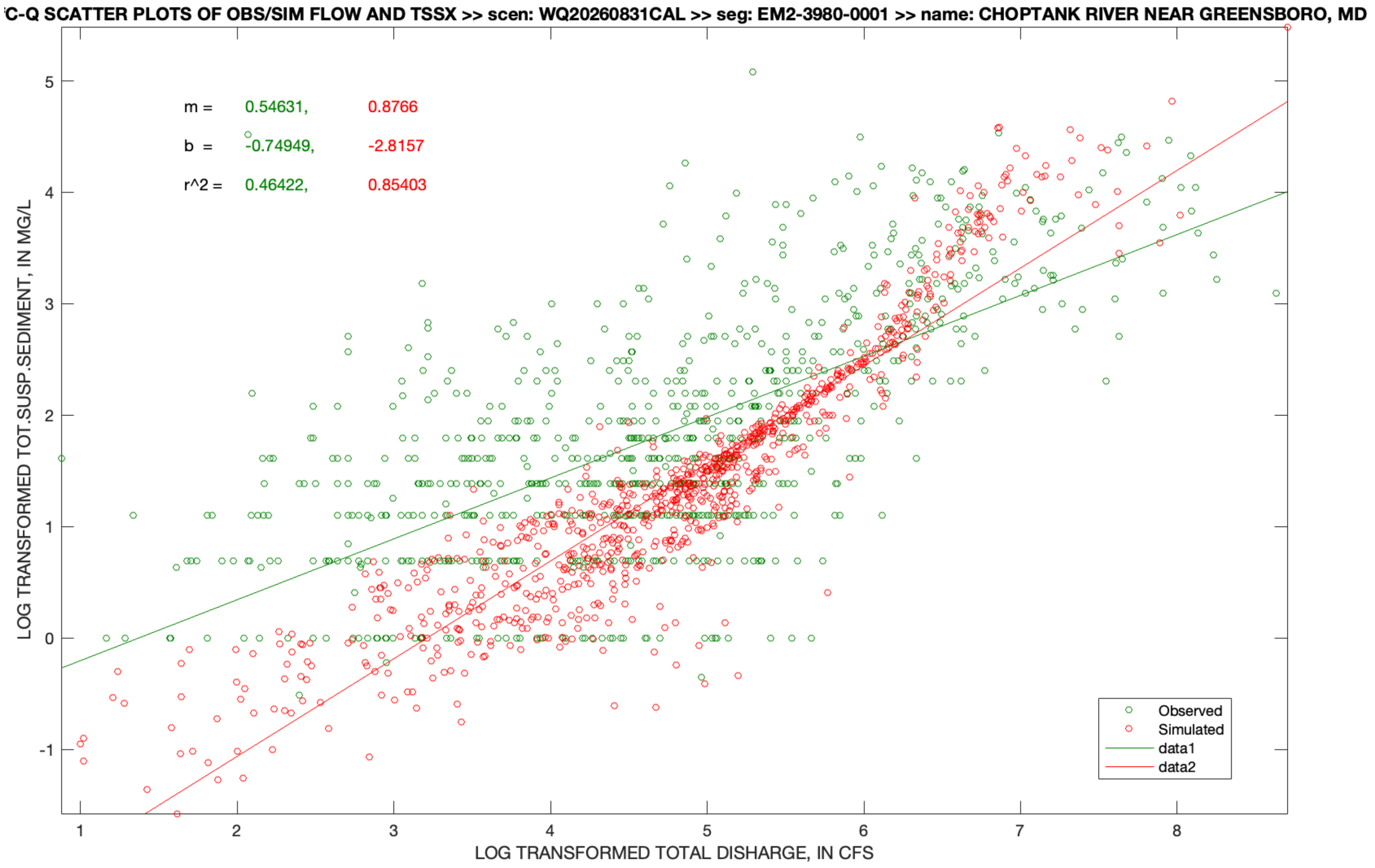


CHOPTANK RIVER NEAR GREENSBORO, MD: FLOW TIME-SERIES
TOTAL DISHARGE, IN CFS
6000
5000
4000
3000
2000
1000
Simulated
Observed
01-Jan-1999
03-Mar-1999
02-May-1999
02-Jul-1999
01-Sep-1999
31-Oct-1999
31-Dec-1999



CHOPTANK RIVER NEAR GREENSBORO, MD: TSSX TIME-SERIES
TOT.SUSP.SEDIMENT, IN MG/L
200
150
100
50
Simulated
Observed
01-Jan-1999
03-Mar-1999
02-May-1999
02-Jul-1999
01-Sep-1999
31-Oct-1999
31-Dec-1999

Some hand calibration can be exercised to reduce high flow concentrations ...



Summary and next steps

1. Sediment calibration was performed using RUSLE2 Edge of Field sediment loads and Phase 7 CalCAST sediment transport factors along with Phase 7 CAST inputs. Sediment model is performing *as good or better* to that of Phase 6 model.

2. Use the calibrated hydrology and sediment model setup for developing an integrated water quality calibration.

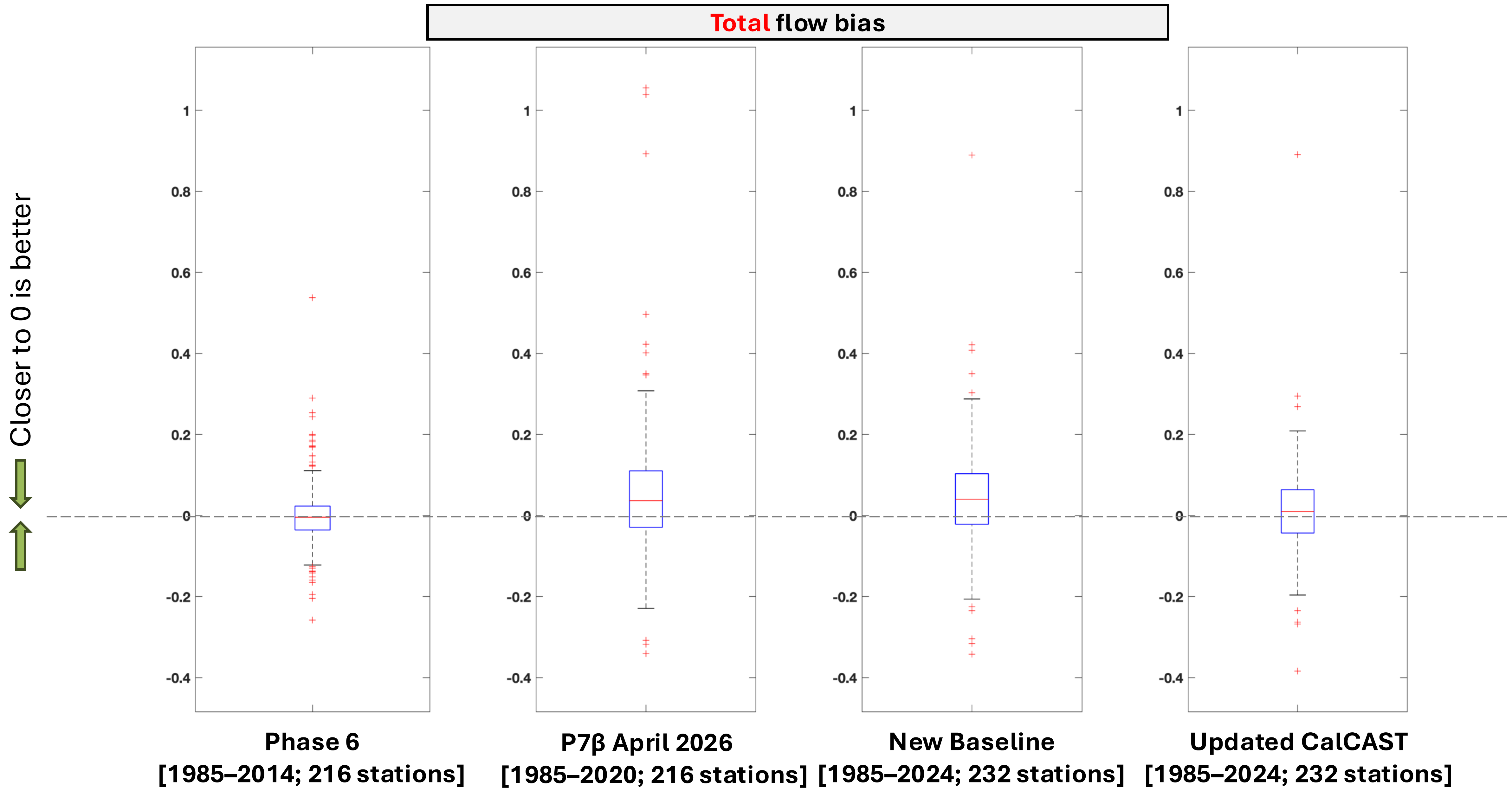
Requesting Modeling Workgroup …

… to approve the process used in the DWSM sediment calibration which incorporates Phase 7 inputs, RUSLE2 Edge of Field (EOF) sediment loads, and CalCAST transport factors along with previously approved DWSM hydrology calibration.

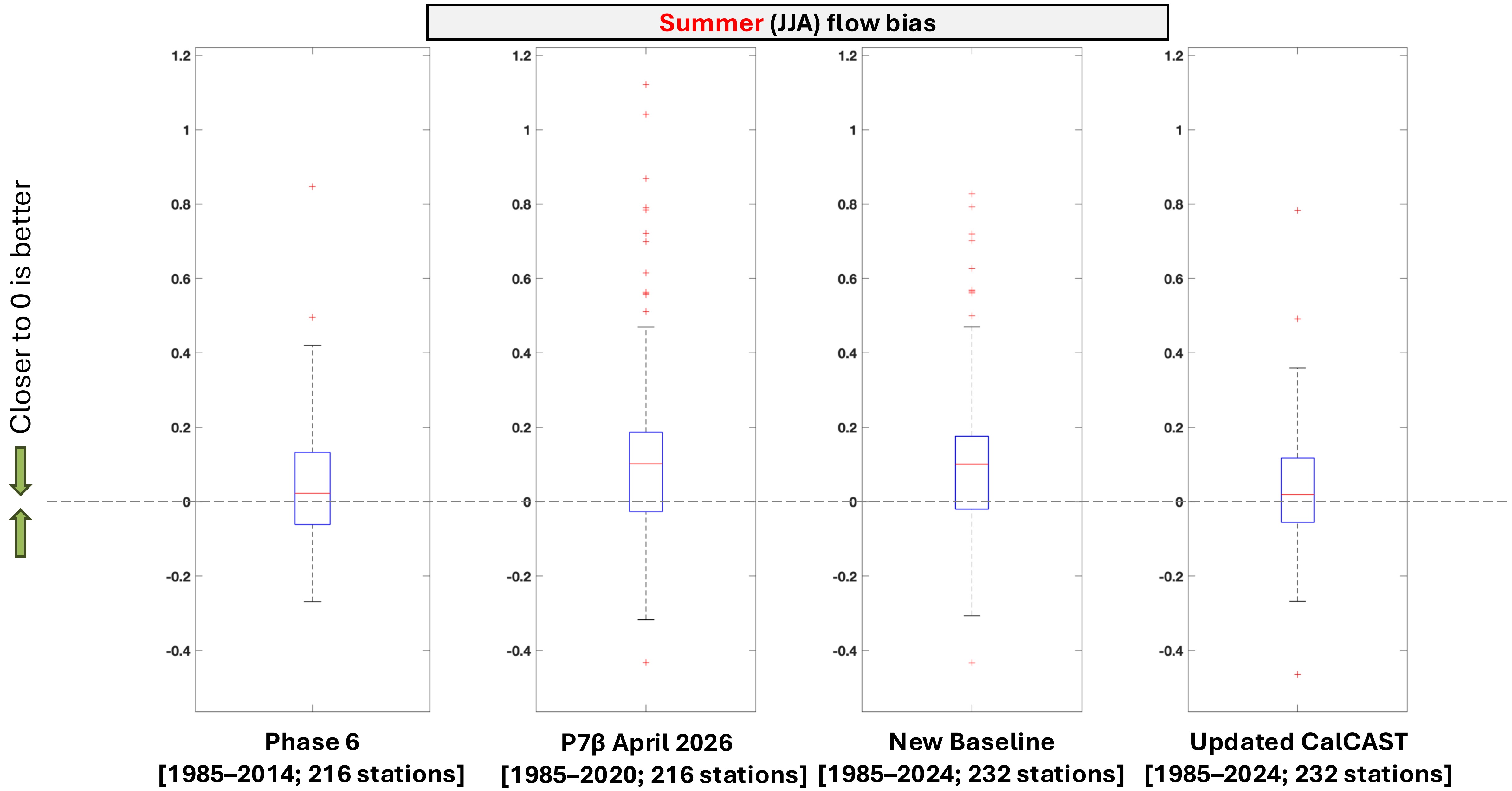
Following updates were made to the hydrology model

- We are using 1985-2024 P7 land use data replacing previously used pre-BMP land use
- Solar infrastructure land use was converted from pervious to impervious.
- CSS land use was added. It does not yield EOS flow.
- We tested corrections for precipitation in Potomac during Nov 1-4, 1985, hurricane Juan. It improved the model performance for Potomac river near Washington DC, but the performance deteriorated at a few upstream stations, and so it was excluded.
- Previously tested refinement of Ftables of terminal HSPF river segments for better handling of extremely low flow condition was imported.
- Hydrology code base was updated for using native P7 land uses rather than using proxy of P6 land uses.
- We fixed an error related to how evaporation parameters are updated during calibration.
- Assignment of a couple of stations to river mainstems were corrected.
- Regression between flow observations at USGS 01575585 (1985-01-01 to 2021-11-15) & USGS 01575598 (2019-10-01 to 2024-12-31) was used for reconstructing flow data for model calibration.
- An adjustment factor of 0.8829 was applied to all land uses above Mattaponi RIM station for constraining currently remaining bias in estimated average annual flow.
- Improved data for CalCAST total flow yield and fraction stormflow.

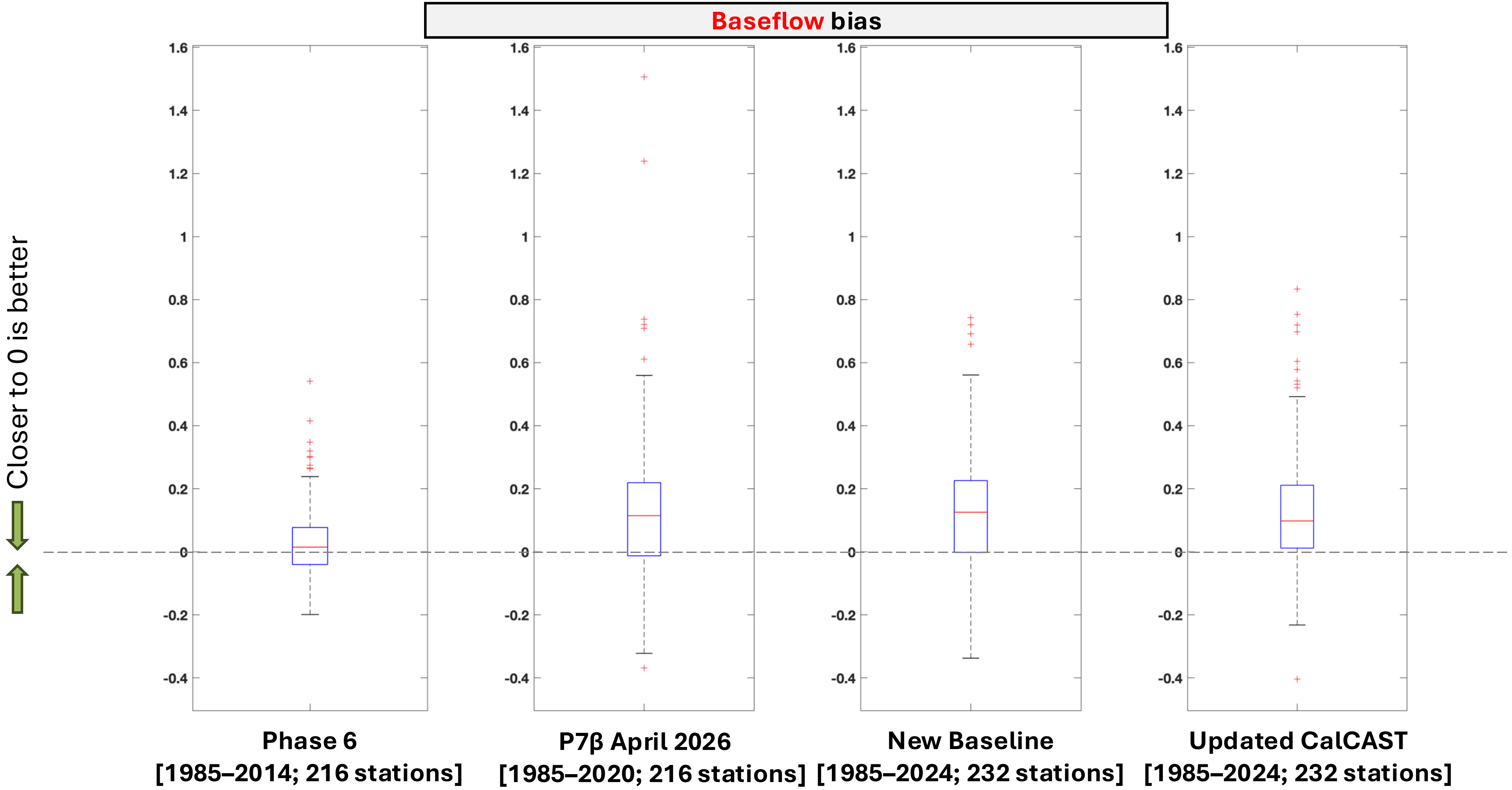
We have a ‘as good or better’ hydrology calibration



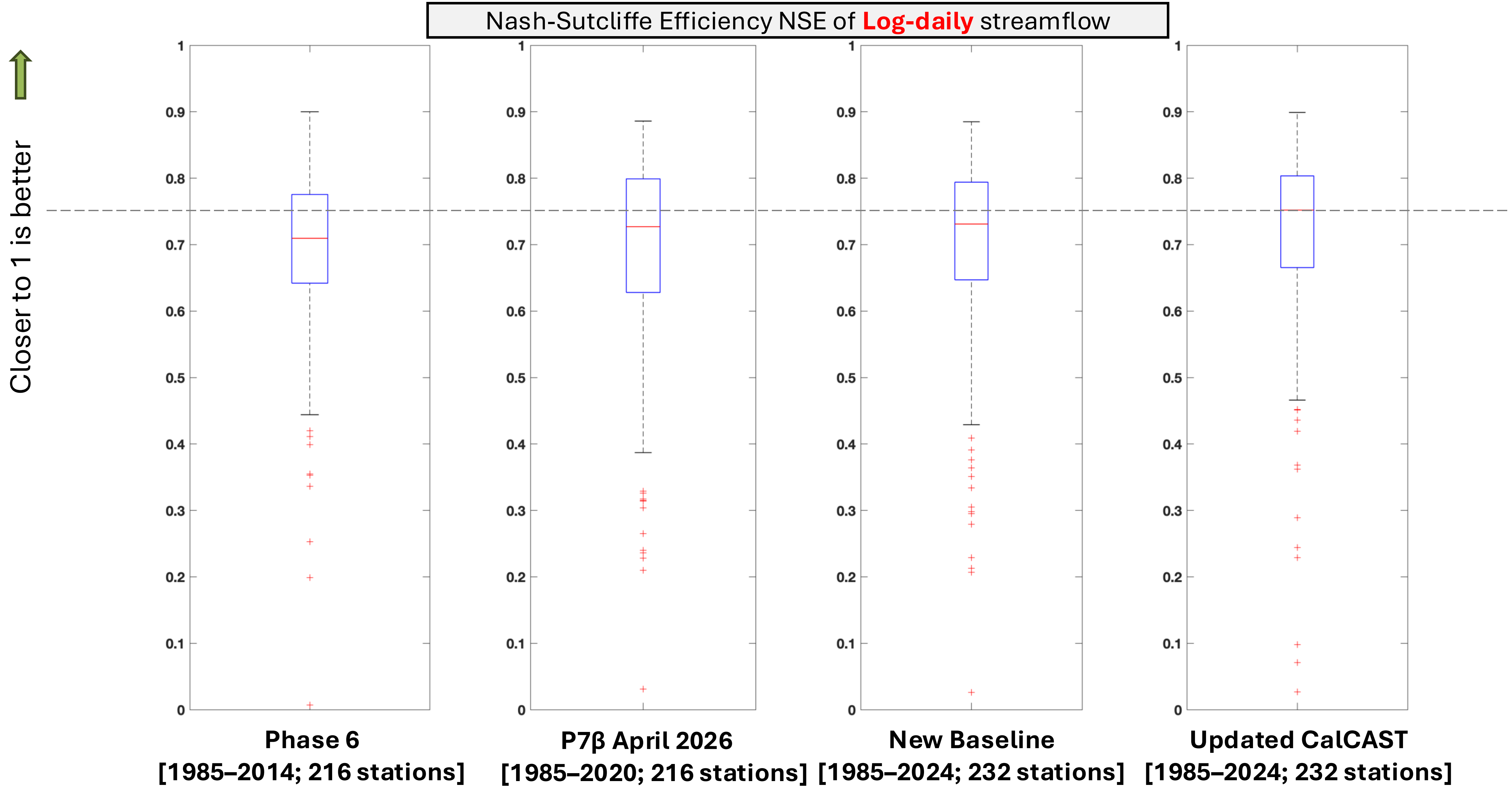
We have a ‘as good or better’ hydrology calibration



We have a ‘as good or better’ hydrology calibration



We have a ‘as good or better’ hydrology calibration



RIM stations and Marietta

NSE daily flow	Phase 6	April 2026	Baseline	+ CalCAST
Conowingo	0.836	0.845	0.847	0.851
Marietta	0.854	0.876	0.877	0.879
Potomac	0.844	0.816	0.849	0.865
James	0.841	0.881	0.883	0.880
Rappahannock	0.786	0.861	0.859	0.863
Appomattox	0.621	0.674	0.637	0.658
Pamunkey	0.679	0.778	0.758	0.768
Mattaponi *	0.262	0.253	0.201	0.341
Patuxent	0.531	0.633	0.628	0.674
Choptank	0.504	0.704	0.674	0.693

** with adjusted water yield*

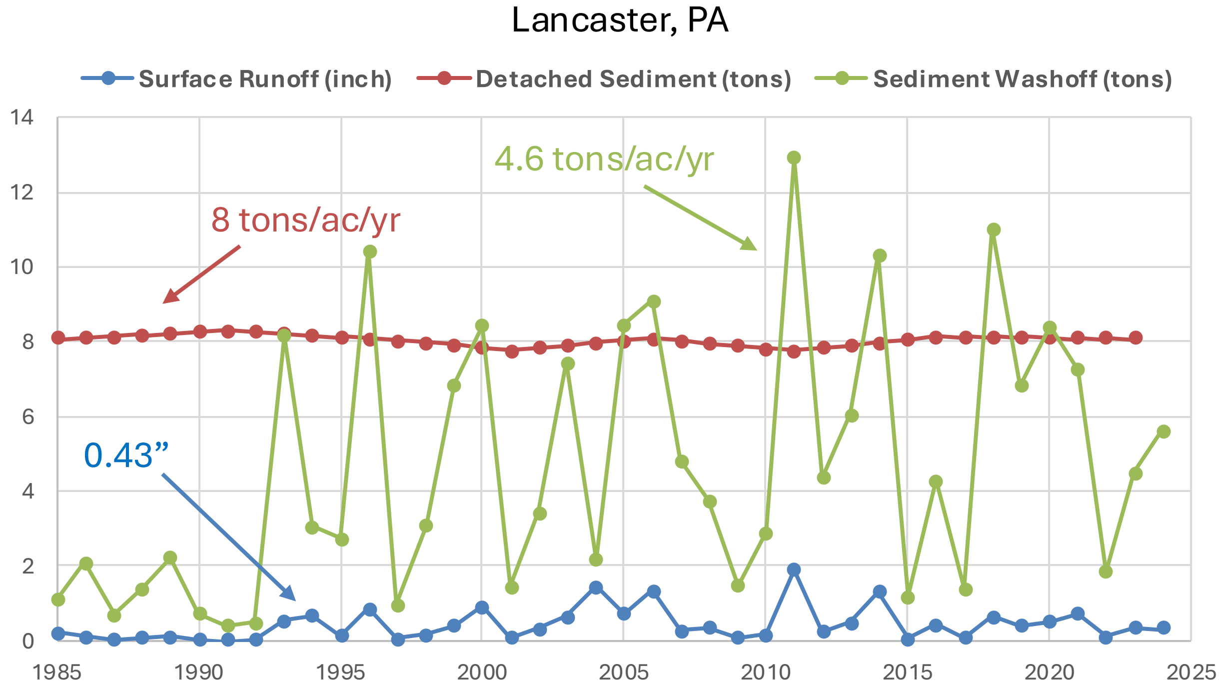
RIM stations and Marietta

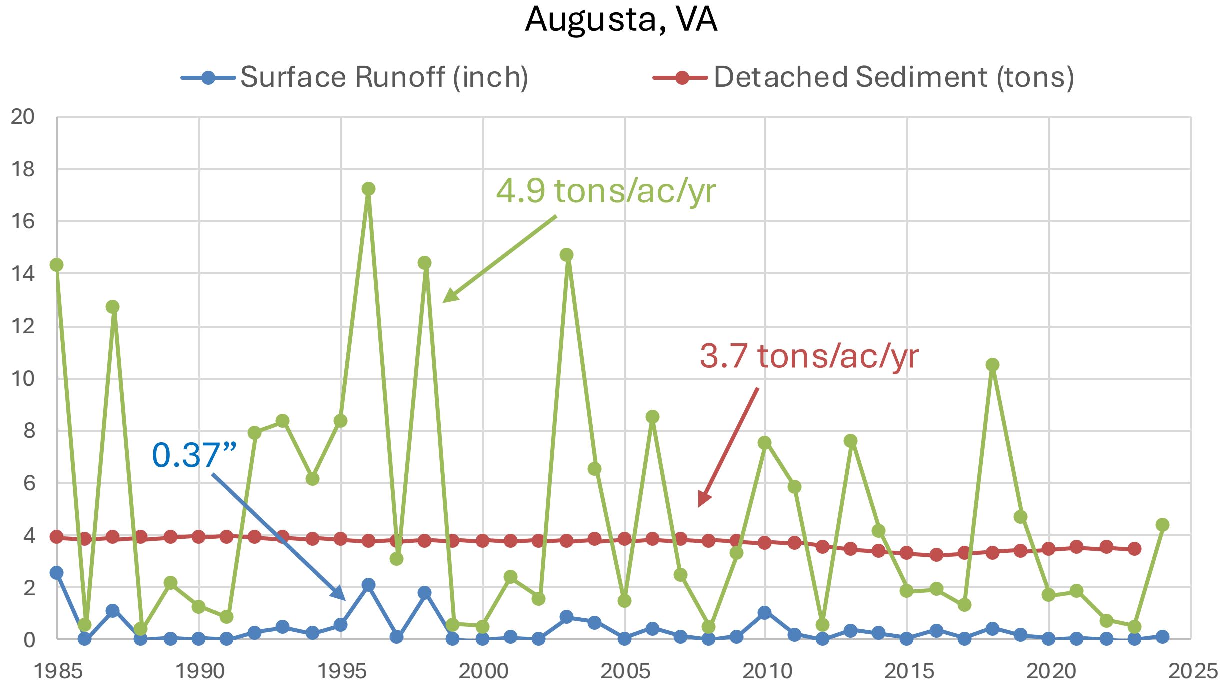
NSE monthly flow	Phase 6	April 2026	Baseline	+ CalCAST
Conowingo	0.879	0.906	0.906	0.914
Marietta	0.873	0.908	0.908	0.916
Potomac	0.903	0.896	0.909	0.927
James	0.919	0.927	0.924	0.941
Rappahannock	0.896	0.910	0.915	0.918
Appomattox	0.915	0.902	0.906	0.898
Pamunkey	0.894	0.892	0.897	0.900
Mattaponi *	0.846	0.810	0.813	0.855
Patuxent	0.899	0.869	0.866	0.886
Choptank	0.774	0.809	0.823	0.848

** with adjusted water yield*

Annual summary of hourly simulation

Process-based sediment model tracks storage of detached sediment (from rainfall, field operations, production/reattachment rates, etc.) and transport potential (surface flow) to estimate event scale storage and transport limiting conditions (e.g., higher concentration on the rising limb of the hydrograph than on the receding limb).





More monitoring data is being used in Phase 7

DWSM Variable	#Stations in Phase 6	#Stations in Phase 7	#Observation in Phase 6	#Observation in Phase 7	Change
Streamflow	249	266	2,749,709	3,245,529	+18%
Nitrogen	184	223	48,634	66,393	+37%
Phosphorus	211	244	55,115	66,136	+20%
Nitrate	217	245	56,514	66,045	+17%
Ammonia	212	245	54,904	66,260	+21%
Dissolve Phosphate	172	204	43,777	59,088	+35%
Suspended Sediment	164	223	57,814	68,970	+19%

→ In Q2, we will start using concentrations data beyond 2014 for (a) riverine water quality calibration, and (b) verification in small streams.

Geography	Flow (ac-feet)	Percent
Susquehanna	29,104,202	50%
Potomac	8,854,962	15%
James	5,238,615	9%
Rappahannock	1,281,614	2%
Appomattox	883,402	2%
Pamunkey	793,500	1%
Mattaponi	517,263	1%
Patuxent	294,536	1%
Choptank	110,873	0%
Other Terminal	8,322,492	14%
Tidal	2,583,911	4%

The DWSM with CalCAST total flow and stormflow inputs