Phase 6 Watershed Model

Modeling Quarterly Review Meeting

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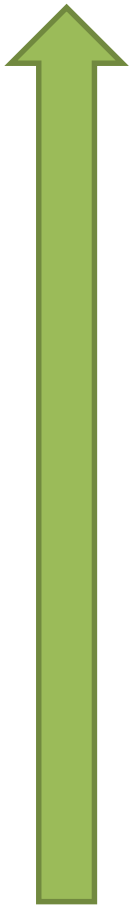
Evolution of Phase 6 Watershed Model



Phase 6 Jul'15	***Phase-6 land segmentations and land use***
Phase 6 Apr'15	Expand the simulation period to 2014
Phase 6 Oct'14	Incorporate lag-time in the transport of nutrients
Phase 6 Jul'14	Build 'sensitivities' in the modeling framework
Phase 6 Apr'14	1985-2005, Incorporate NLDAS-2 forcing (P, T, E, …)
Phase 6 Apr'14	1985-2005, Replace AGCHEM with PQUAL
Phase 6 Jul'13	2002-2011, Refine sediment calibration, PQUAL
Phase 5.3.2	Phase 5 watershed model

Outline of presentation

Phase 6 Watershed Model – **July'15**

1. Model structure updates
2. Hydrology parameterization & calibration
3. Sediment parameterization & calibration
4. Water temperature parameterization & calibration
5. Nutrient simulation
6. River water quality calibration

0. Data Summary

Landuse area – provisional pre-BMP acres

Scenario Builder inputs:

- Septic loads – provisional
- Detached sediment and cover data – partially Phase-6 data
- Nutrient application rates – based on Phase 5

Atmospheric deposition – interpolated based on FIPS units

Point-source dataset

Land to Water (L2W) variance, and Streams to River (S2R) factor – revised for P6

Observation dataset

- Flow: 1985 to 2014
- Water quality: 1985 to 2013
- WRTDS loads: 1985 to 2012

Objective: provisional data, put processes in place w.r.t. P6

Landuse export targets:

- Nutrients (N/P) – provisional based on Phase 5 application rates
- Sediment – provisional based on Phase 5 landuses

1. Model Structure Updates

*** P6 LAND-SEGMENTS SPECIFIC ***

- config/catalog/geo/p600/landnames.csv
- config/catalog/geo/p600/land_water_area.csv
- config/catalog/geo/p600/watershed_area.csv
- config/catalog/geo/p600/river_met_wdm.csv
- config/catalog/geo/p600/river_prad_wdm.csv
- config/catalog/iovars/p600/variable_l2r_factors/SEDM_to_CLAY.csv
- config/catalog/iovars/p600/variable_l2r_factors/SEDM_to_SAND.csv
- config/catalog/iovars/p600/variable_l2r_factors/SEDM_to_SILT.csv
- config/seglists/all_P6.land
- config/seglists/all_P6.riv

*** P6 LAND-USE SPECIFIC ***

- config/catalog/iovars/p600/implnd
- config/catalog/iovars/p600/land_to_river
- config/catalog/iovars/p600/load_simulation
- config/catalog/iovars/p600/perlnd
- run_bhatt/fragments/set_landuse
- run/fragments/set_landuse
- code/src/lib/inc/land_use.inc [& re-compile (1) code/src/makebinarytransfer (2) code/src/lug (3) code/src/etm/etm_and_postproc (4) code/src/postproc/del/dfs (5) code/src/postproc/del/tfs (6) code/src/postproc/del/otherDF_delload (7) code/src/postproc/del/delload (8) code/src/calibration_utils/change_param/calib_iter/SEDMNT_wFourParameters]

*** BOTH LAND-SEGMENTS & LAND-USES ***

- input/scenario/land/spec_flags/p600/spec_flags.csv
- input/param/transport/QNPSas1s.csv
- code/src/etm/make_binary_transfer_coeffs/gettransport.f [900 to 1200]

*** UNRELATED ***

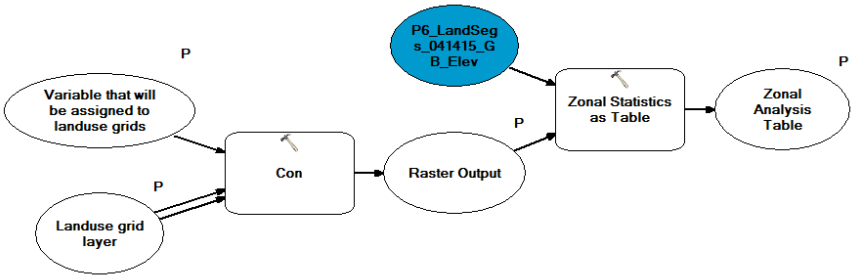
- config/catalog/modules/tables [updated VNN to VMN (manning's n) for consistency]
- input/param/transport/QNPSas1s.csv [flow, nitrogen, phosphorus, sediment as 1]

2.1 Hydrology Parameters

(a) geospatial parameters

- Phase-6 Landuses
  - Agriculture
    - Agriculture
      - Feeding Space — Non-Permitted Feeding Space (fnp)
      - Hay — Legume Hay (lhy); Other Hay (ohy)
      - Other Ag — Ag Open Space (aop); Farmstead (far)
      - Pasture — Pasture (pas)
      - *! Riparian Pasture* — *! Riparian Pasture Deposition (rpa)*
      - Row Crops — Grain without Manure (gom); Grain with Manure (gwm); Other Agronomic Crops (oac); Specialty Crop High (sch); Specialty Crop Low (scl); Small Grains and Grains (sgg); Small Grains and Soybeans (sgs); Silage without Manure (som); Full Season Soybeans (soy); Silage with Manure (swm)
    - Regulated Agriculture — Feeding Space — Permitted Feeding Space (fsp)
  - Developed
    - Non-Regulated Stormwater
      - Extractive — Abandoned Mines (abn); Active Mines (ext)
      - Impervious Developed — Non-Regulated Roads (nir); Non-Regulated Buildings and Other (nnr)
      - Pervious Developed — Non-Regulated Tree Canopy (ntc); Non-Regulated Turf Grass (ntg)
    - Regulated Stormwater
      - Construction — CSS Construction (ccn); MS4 Construction (mcn)
      - Impervious Developed — CSS Roads (cir); CSS Buildings and Other (cnr); MS4 Roads (mir); MS4 Buildings and Other (mnr)
      - Pervious Developed — CSS Tree Canopy (ctc); CSS Turf Grass (ctg); MS4 Tree Canopy (mtc); MS4 Turf Grass (mtg)
  - Natural
    - Forest
      - Forest — Disturbed Forest (dfr); Forest (for); Harvested Forest (hfr)
      - Open Space — Open Space (osp)
      - Wetland — Floodplain Wetland (fwt); Headwater Wetland (hwt); Tidal Emergent Wetland (twt)
    - Non-Tidal Water Deposition — Non-Tidal Water Deposition — Water (wat)
  - Point Source
    - ! Wastewater — ! Wastewater — *! Industrial (ind)*; *! Municipal (mun)*
    - ! Wastewater CSO — ! Wastewater CSO — *! Combined Sewer Overflow (cso)*
  - Septic
    - ! Septic — ! Septic — *! Septic-30 (s30)*; *! Septic-40 (s40)*; *! Septic-50 (s50)*; *! Septic-80 (s80)*

geospatial data processing



(a) geospatial parameters

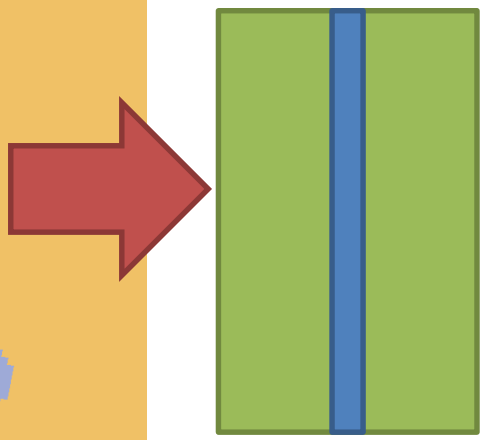
Raw Geospatial Data:
10-meter land cover marks
10-meter digital elevation

Derived Geospatial Data:
Slope
Length of flow plane

elevation

slope of flow plane

*length of flow plane**



**λ = A/2L*

2.1 Hydrology Parameters

(b) other parameters

forest
harvested forest
disturbed forest
other forest

impervious developed
pervious developed

feeding space
hay
other ag
pasture
row crops

2.1 Hydrology Parameters

(b) other parameters

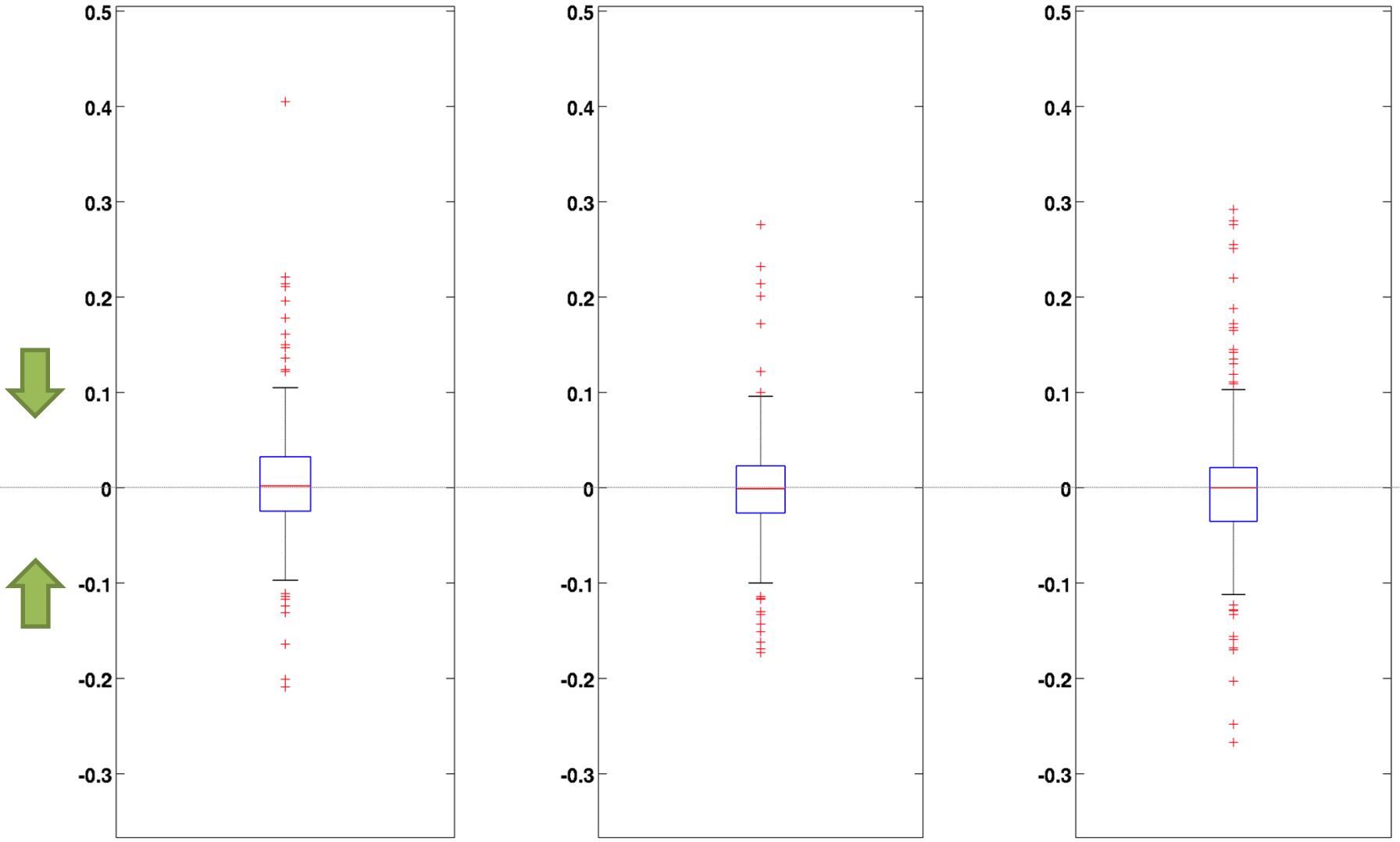
Parameter	INTFW	INFILT	AGWETP	UZSN
for	1.25	1.6	6	0.12
hvf	1	1.3	3	0.1
pas	1	1.5	1.5	0.1
npa	1	1.5	1.5	0.1
alf	1	1.5	1	0.12
nal	1	1.5	1	0.12
hyw	1	1.5	1	0.12
nhy	1	1.5	1	0.12
hyo	1	1.5	1	0.12
hwm	1	1	1	0.14
hom	1	1	1	0.14
nhi	1	1	1	0.14
nho	1	1	1	0.14
lwm	1	1.5	1	0.14
nlo	1	1.5	1	0.14
rpd	1	0.8	2	0.1
cpd	1	0.8	2	0.1
npd	1	0.8	2	0.1
trp	1	0.8	0.1	0.07
urs	1	0.8	0.1	0.07
rex	0.7	0.8	0.1	0.08
nex	0.7	0.8	0.1	0.08
cex	0.7	0.8	0.1	0.08
rcn	0.5	0.7	0.1	0.08
ccn	0.5	0.7	0.1	0.08

Phase 5

Parameter	INTFW	INFILT	AGWETP	UZSN
for	1.25	1.6	6	0.12
fwt	1	1.6	6	0.12
hwt	1	1.6	6	0.12
twt	1	1.6	6	0.12
dfr	1	1.5	5	0.11
hfr	1	1.3	3	0.1
osp	1	1.5	1	0.1
pas	1	1.5	1.5	0.1
lhy	1	1.5	1.5	0.1
ohy	1	1.5	1.5	0.1
gom	1	1	1	0.14
gwm	1	1	1	0.14
oac	1	1	1	0.14
sch	1	1	1	0.14
scl	1	1	1	0.14
sgg	1	1	1	0.14
sgs	1	1	1	0.14
som	1	1	1	0.14
soy	1	1	1	0.14
swm	1	1	1	0.14
aop	0.9	0.9	2	0.1
far	0.9	0.9	2	0.1
abn	0.9	0.9	2	0.1
ext	0.9	0.9	2	0.1
ctc	0.7	0.8	2	0.1
ctg	0.7	0.8	2	0.1
mtc	0.7	0.8	0.1	0.08
mtg	0.7	0.8	0.1	0.08
ntc	0.7	0.7	0.1	0.08
ntg	0.7	0.7	0.1	0.08
ccn	0.5	0.7	0.1	0.07
mcn	0.5	0.7	0.1	0.07

Phase 6

Model Bias at 191 Calibration Stations



Phase 5 [1985-2005]

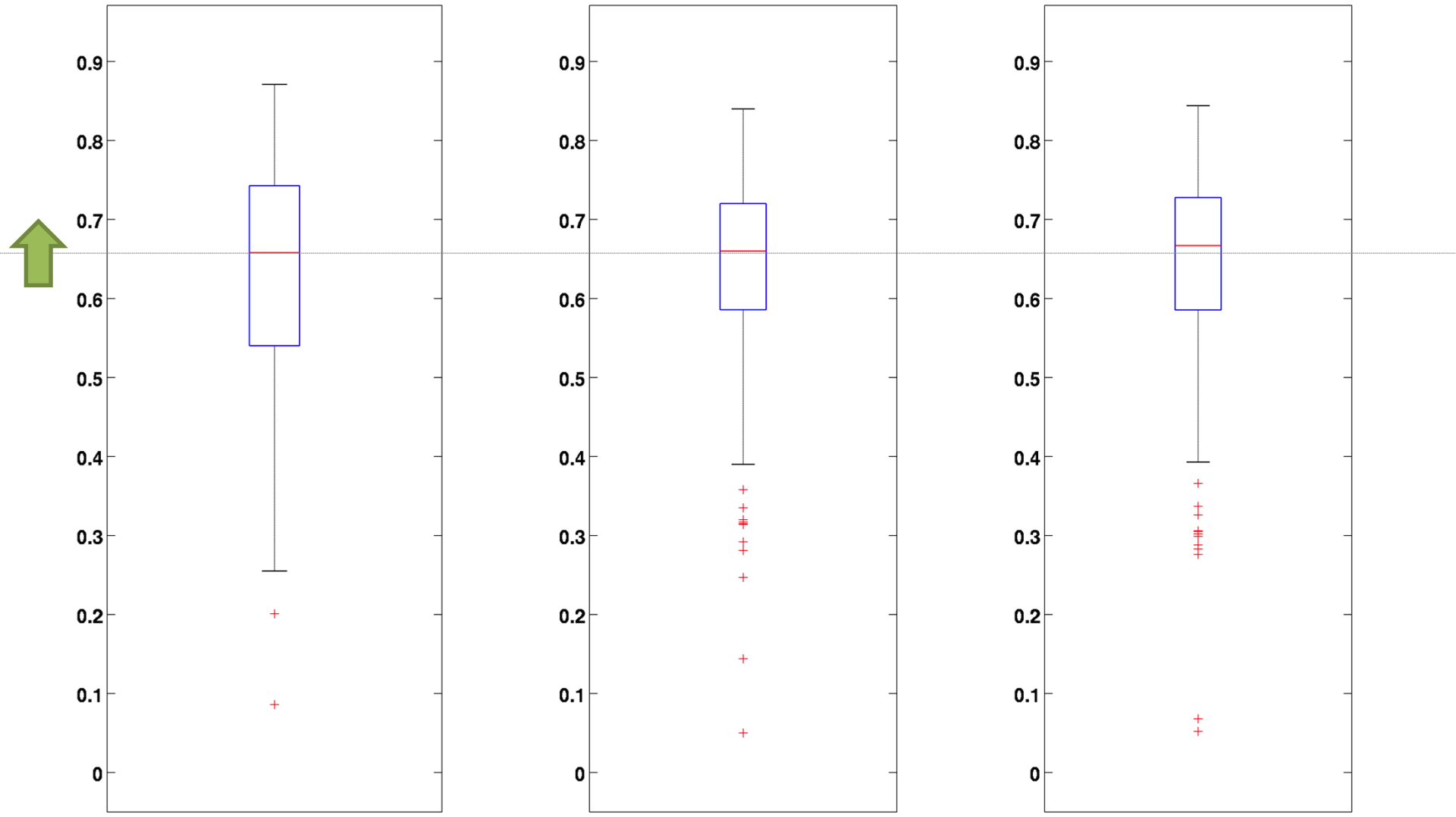
Phase 6 [1985-2014]
{precipitation and meteorology}

Phase 6 [1985-2014]
{P6 land segments and landuse}*

2.2 Hydrology Calibration

* provisional land-use acres

Nash-Sutcliffe Efficiency at 191 Calibration Stations



Phase 5 [1985-2005]

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{precipitation and meteorology}

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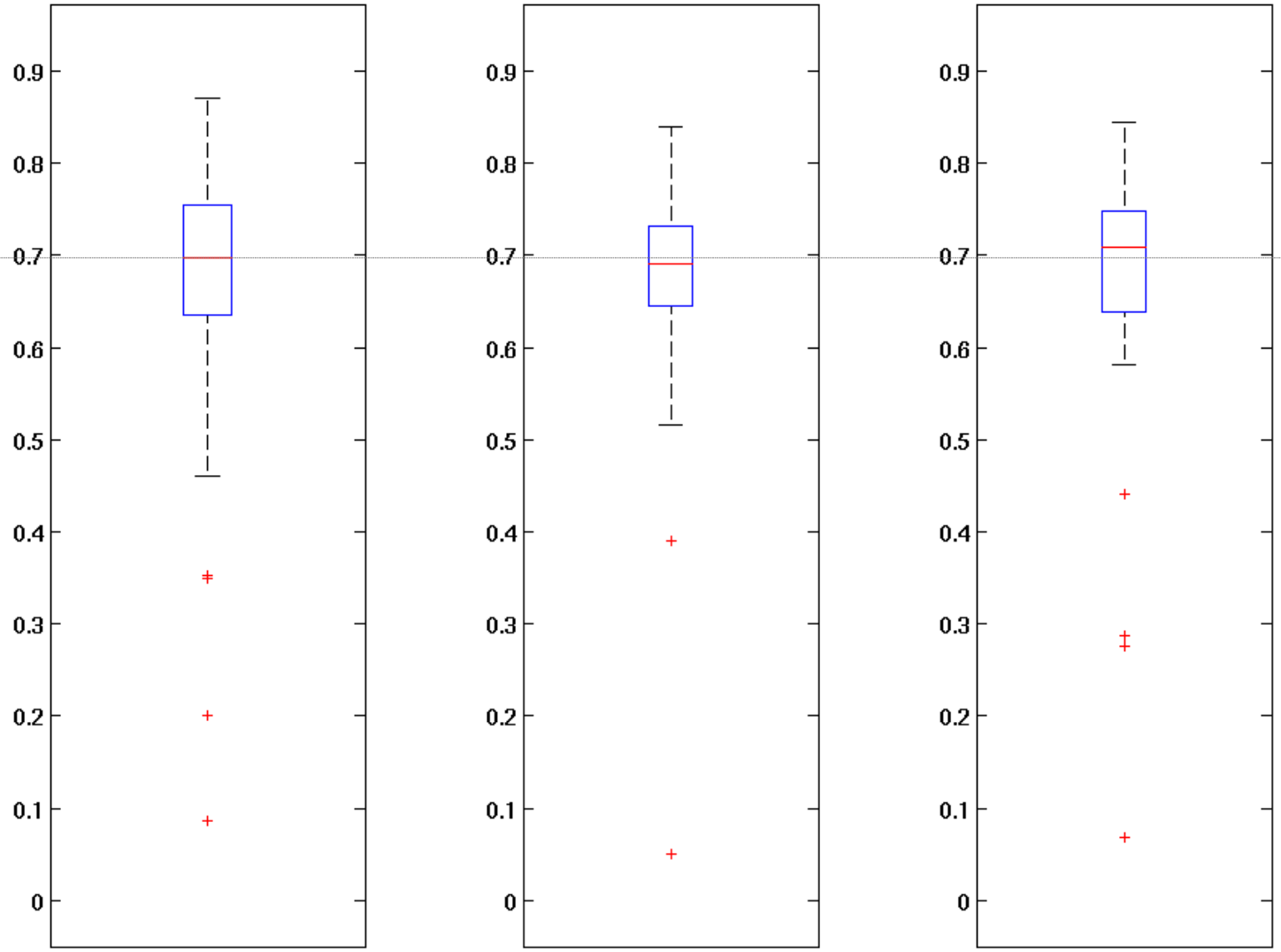
{P6 land segments and landuse}*

2.2 Hydrology Calibration

* provisional land-use acres

Nash-Sutcliffe Efficiency at Susquehanna (73 stations)



Phase 5 [1985-2005]

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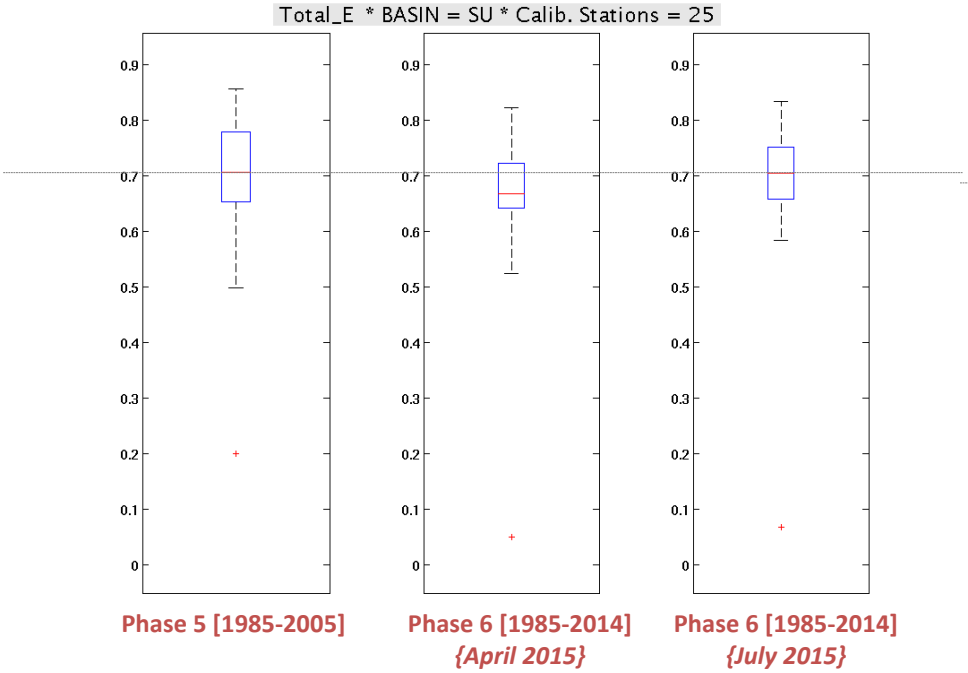
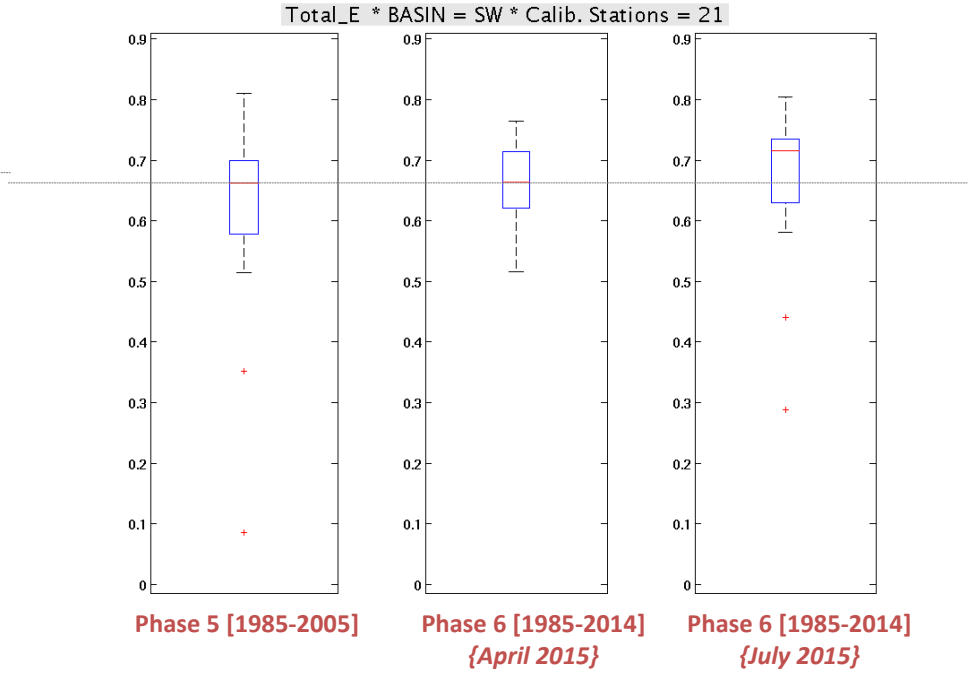
2.2 Hydrology Calibration



Phase 5 [1985-2005] | Phase 6 [1985-2014] *{April 2015}* | Phase 6 [1985-2014] *{July 2015}*



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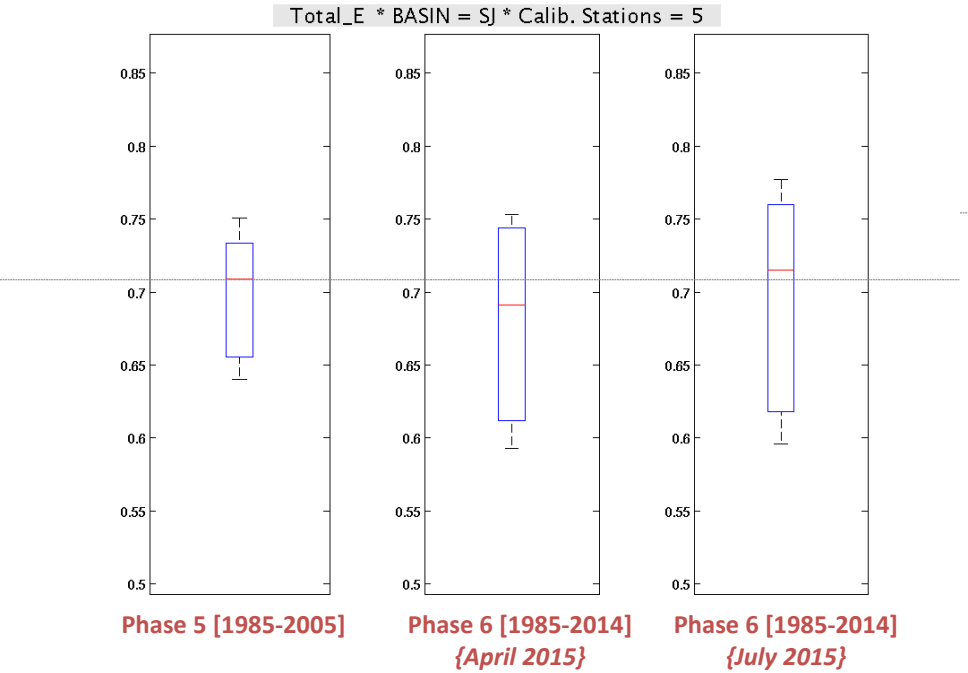

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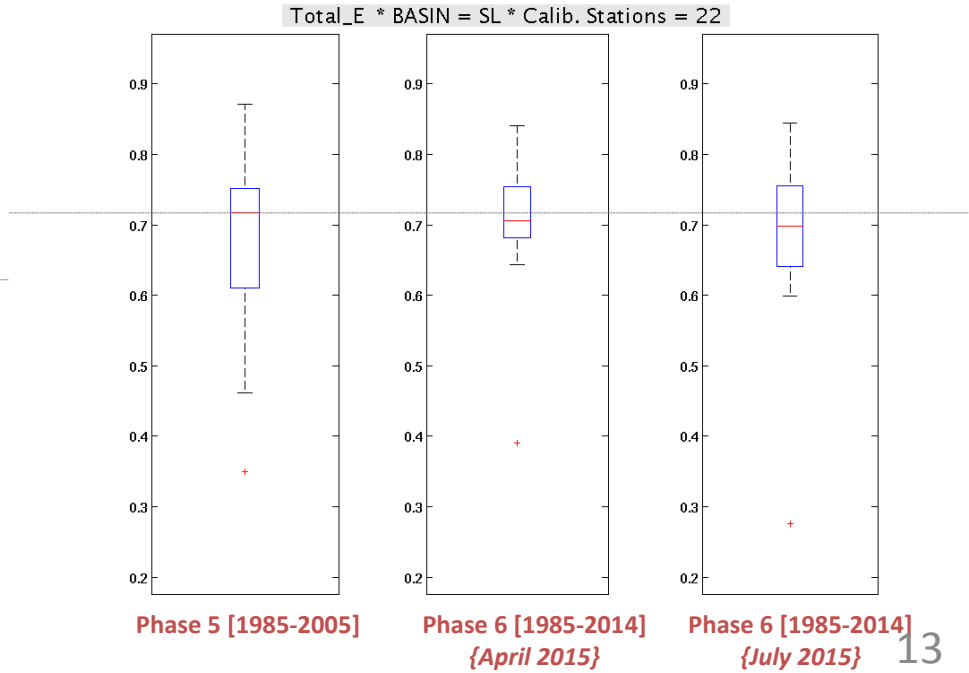

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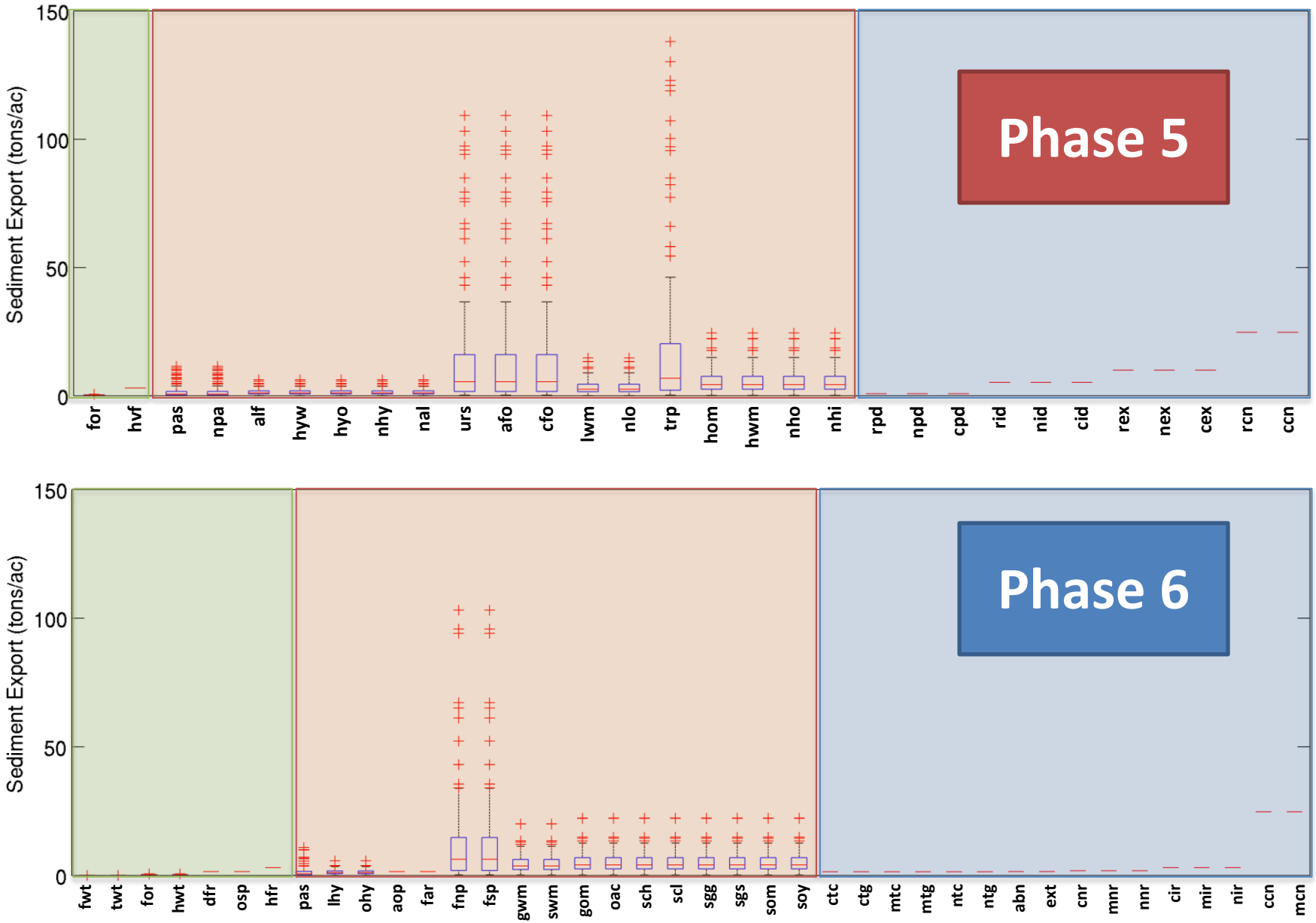
3.1 Land-use Sediment Export Targets



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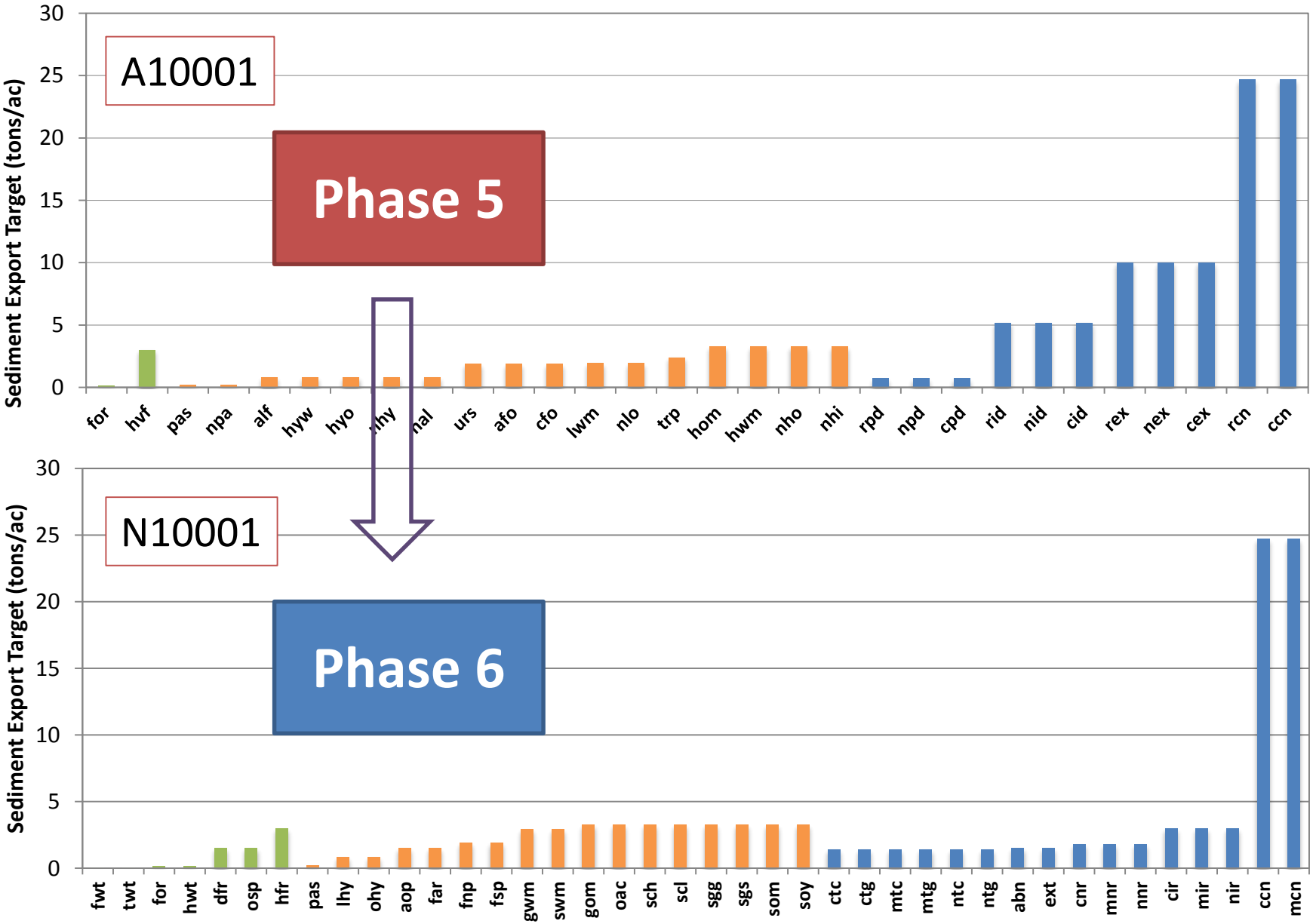
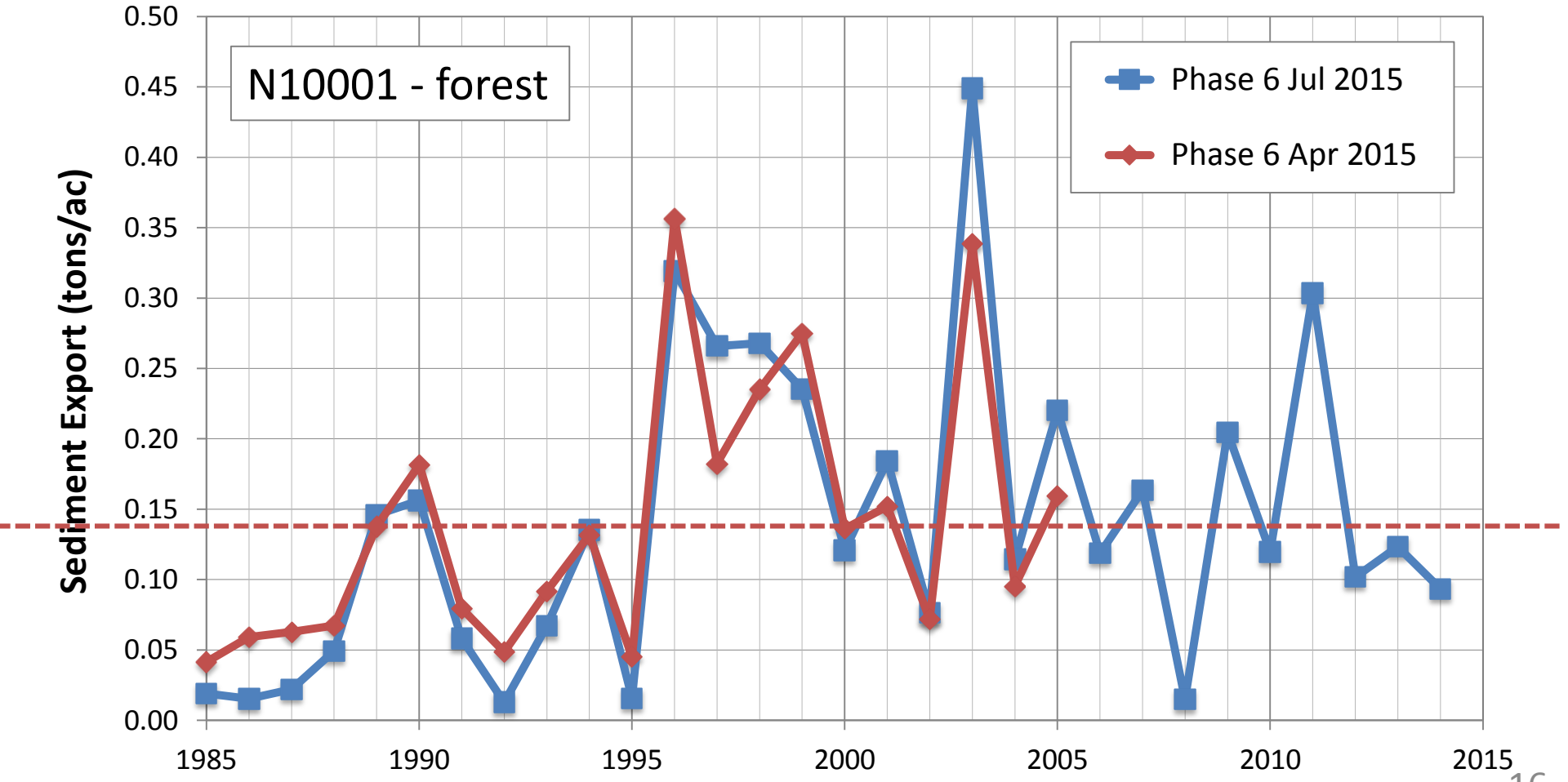


3.2 Land-use Sediment Calibration

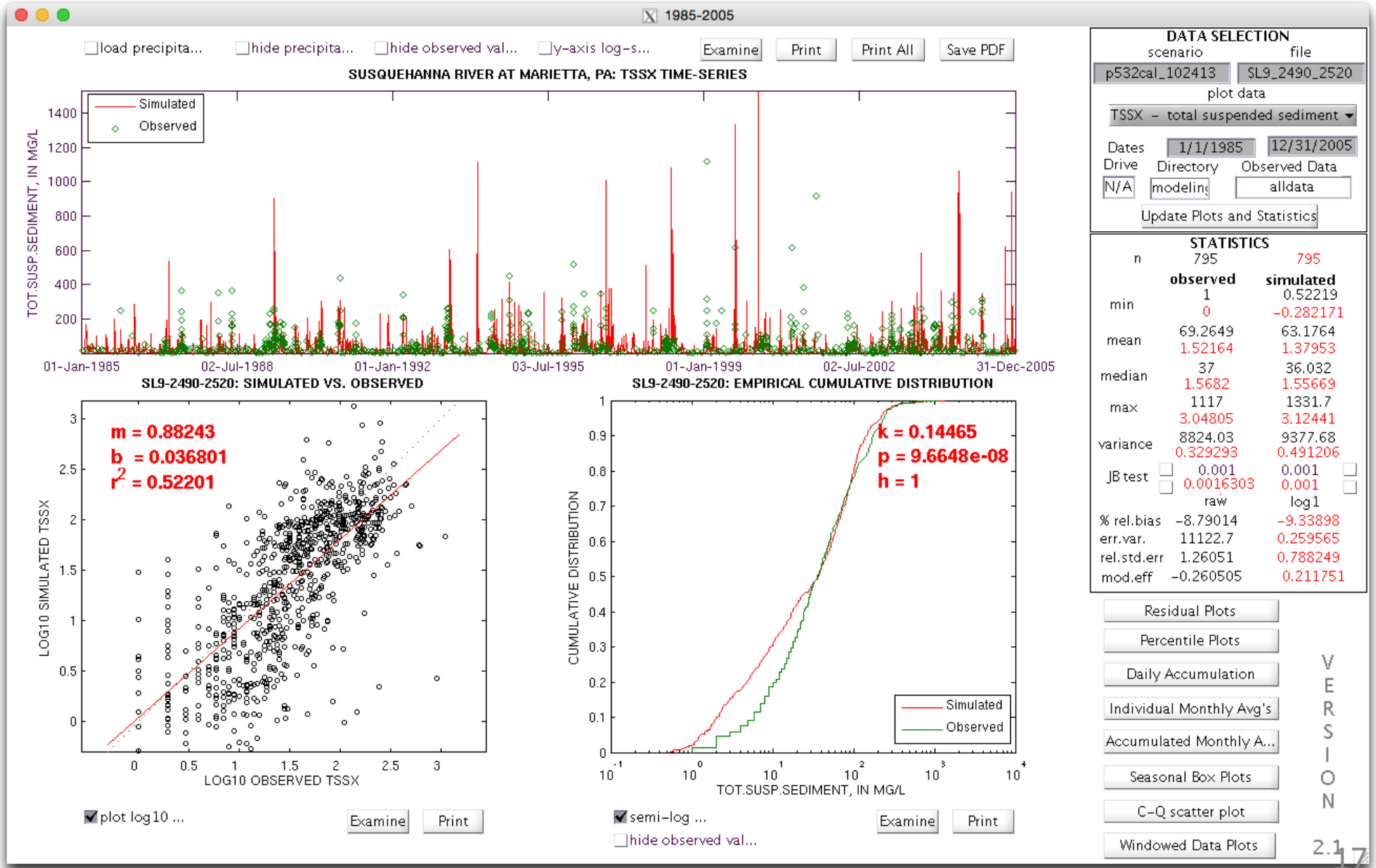
- Out of 9400 (235x40) land-segment x land-use pairs, 10 (< 0.1%) had sediment wash-off deficit.



SUSQUEHANNA AT MARIETTA

PHASE 5
1985 - 2005

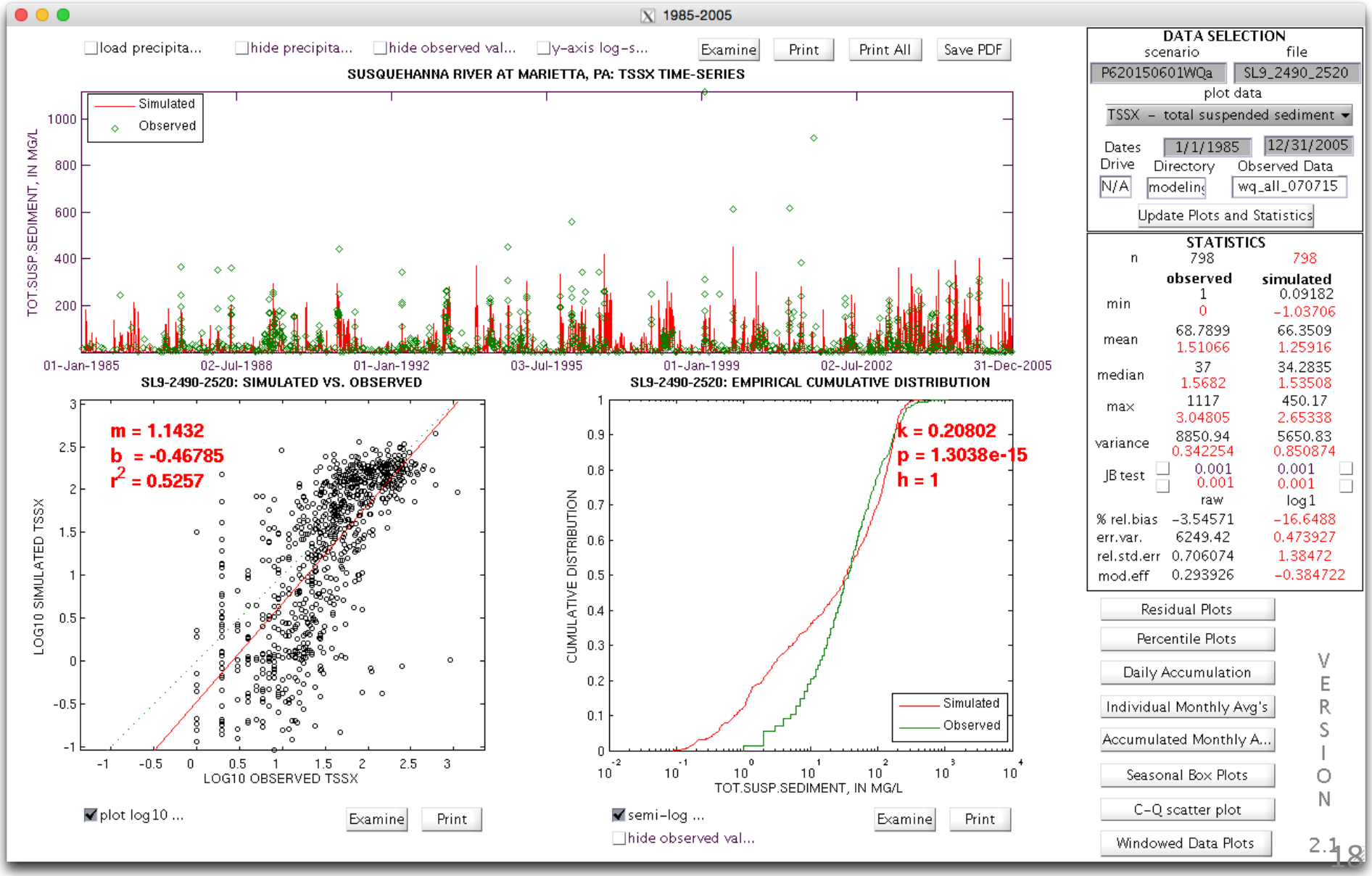
SEDIMENT



SUSQUEHANNA AT MARIETTA

PHASE 6
1985 - 2005

SEDIMENT



4.1 Water Temperature Parameterization

- An empirical transfer function for estimating monthly groundwater temperature from monthly ground surface temperature:

Kurylyk et al. 2013

$$GWT = MAGST + D' \left\{ GST_{i-L} - MAGST \right\} + B$$

GWT *is groundwater temperature for month* i *in* C

$MAGST$ *is average of monthly GST temperature*

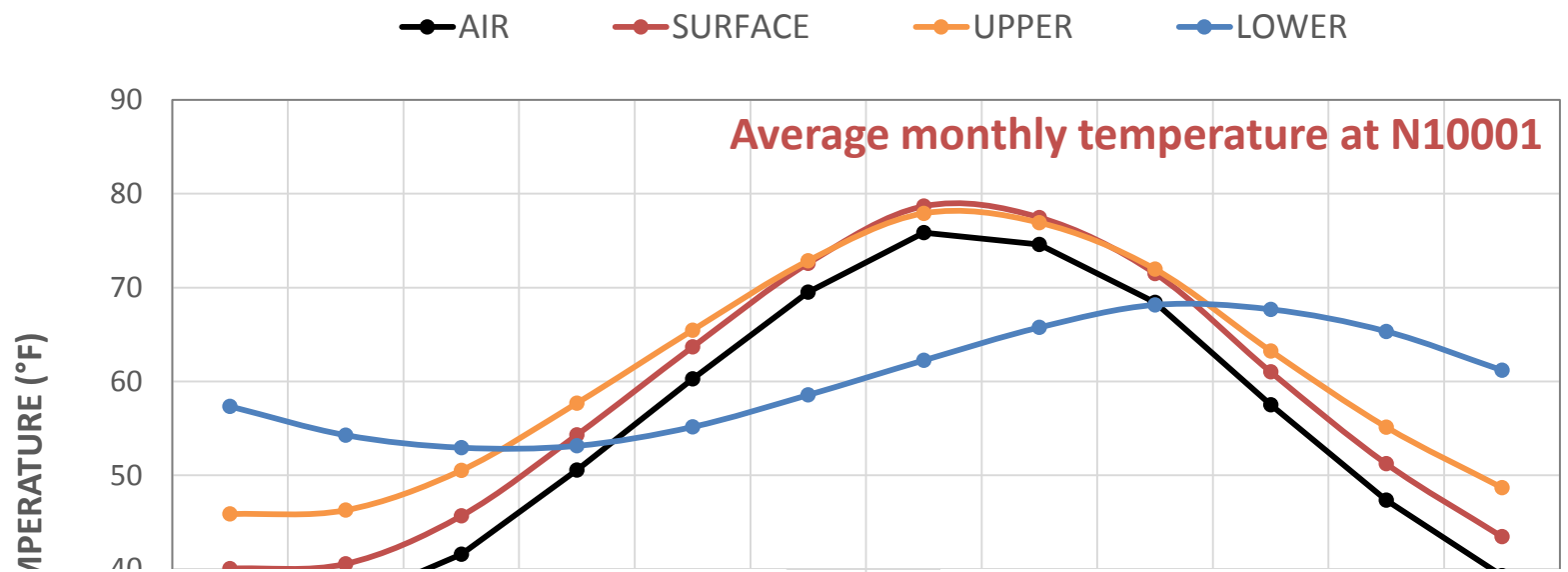
GST *is the GST for month* $(i - L)$ *in* C

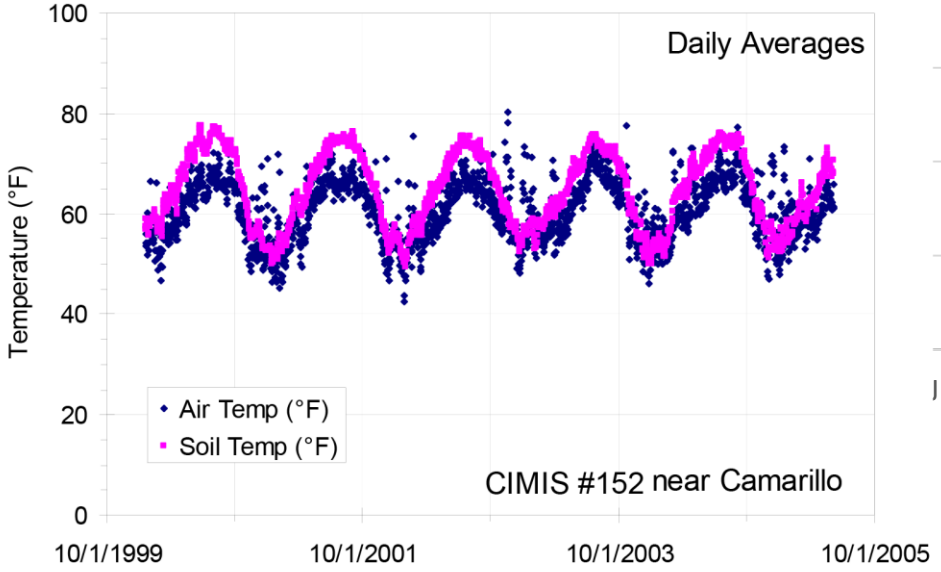
D ~ *damping effect of subsurface termal diffusivity*

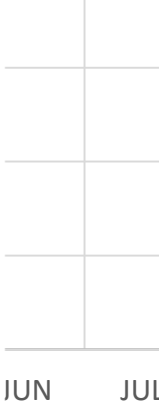
L ~ *lag parameter* (*months*)

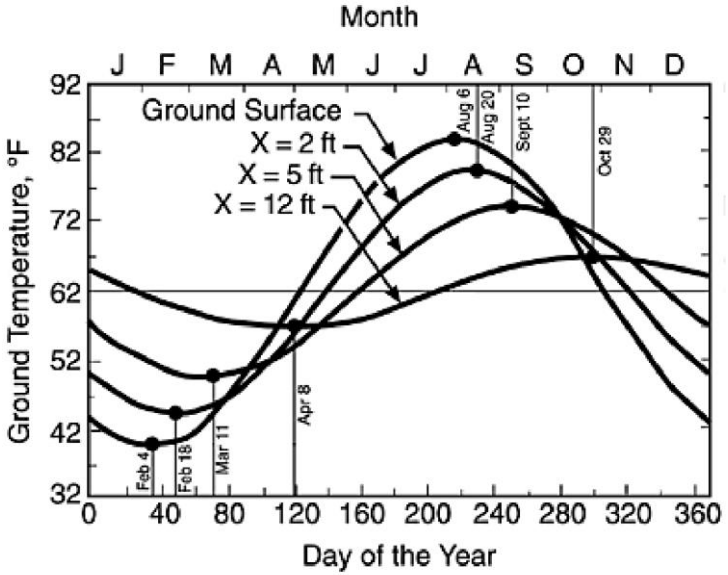
B ~ *accounts for shallow heat transfer*

4.1 Water Temperature Parameterization



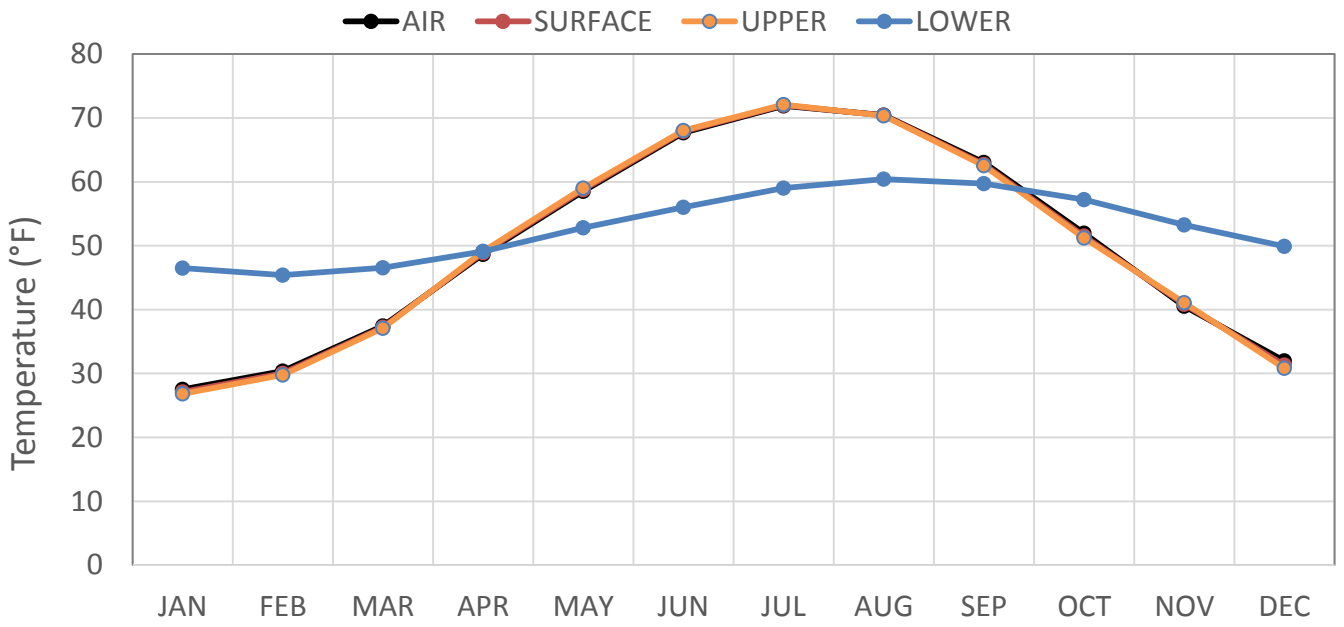




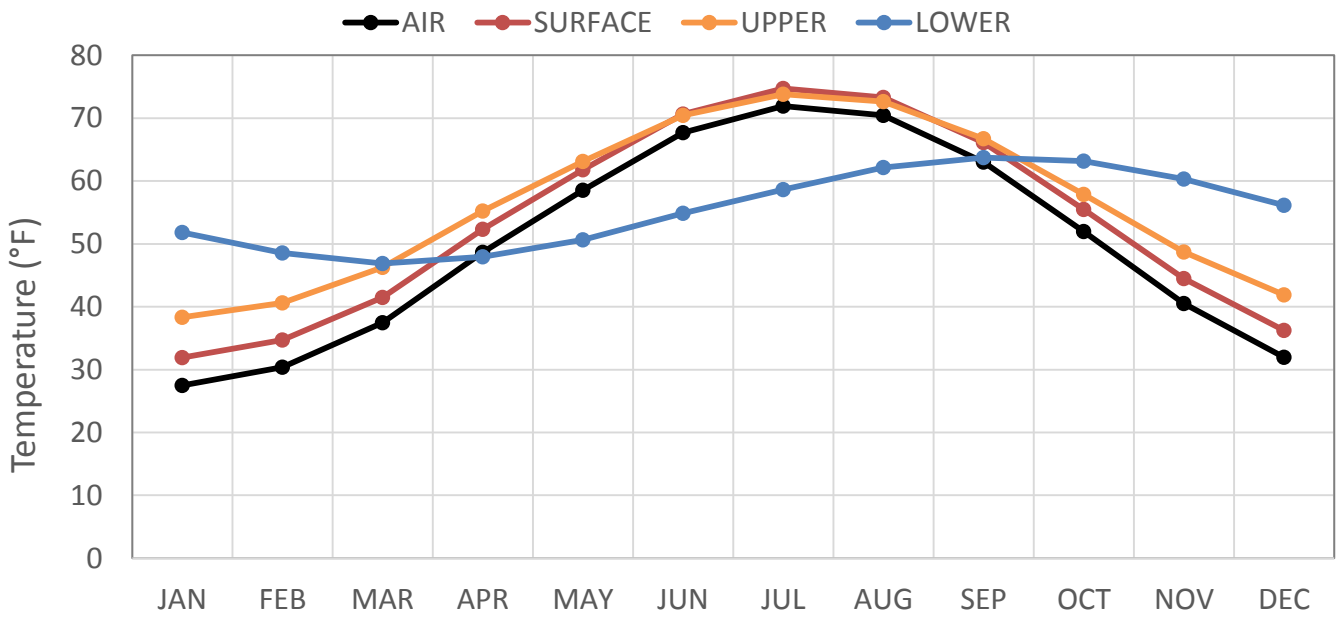


4.1 Water Temperature Parameterization

Phase 5

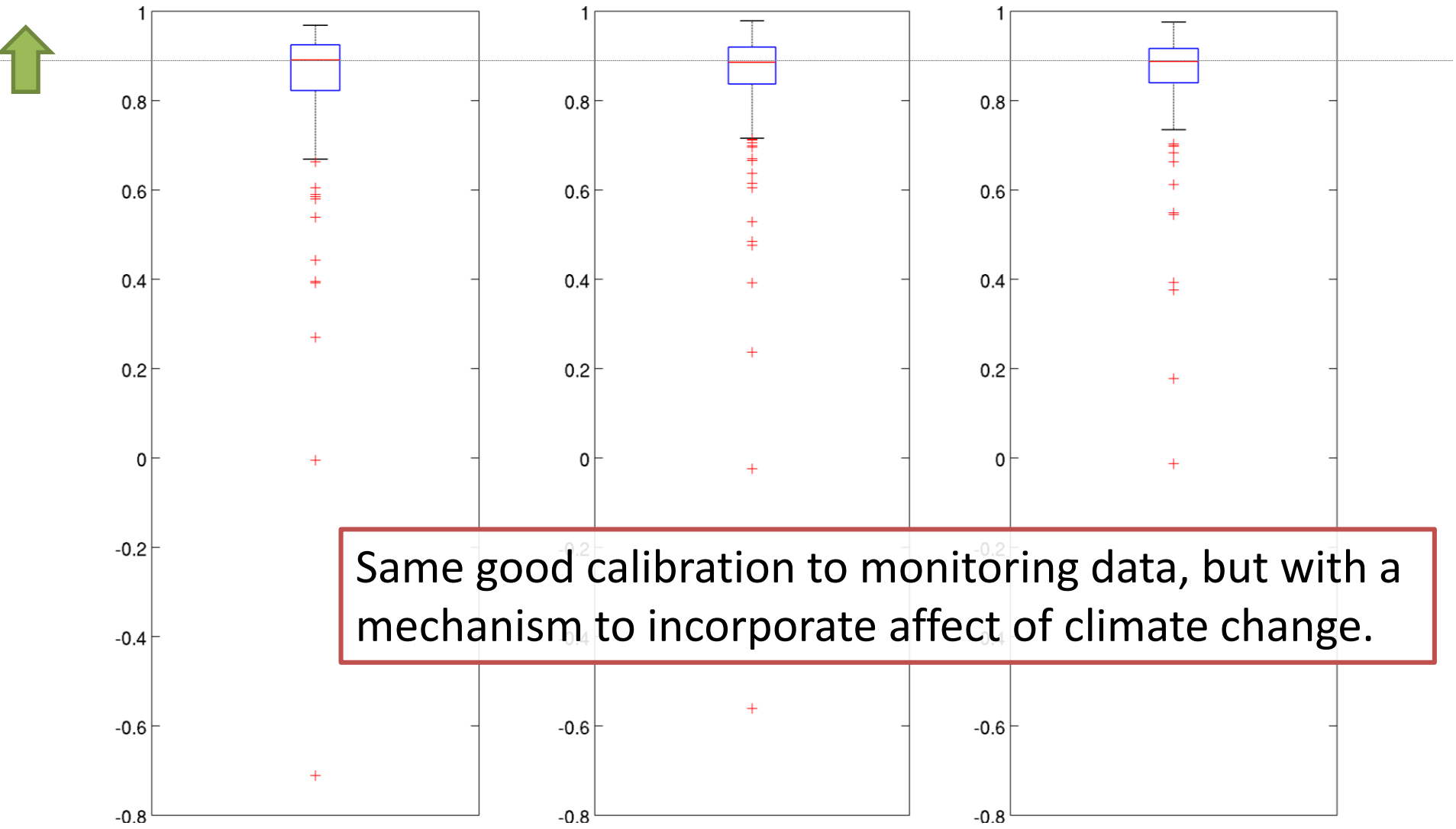


Phase 6



4.2 Water Temperature Calibration

Nash-Sutcliffe Efficiency at 209 Calibration Stations



Same good calibration to monitoring data, but with a mechanism to incorporate affect of climate change.

Phase 5 [1985-2005]

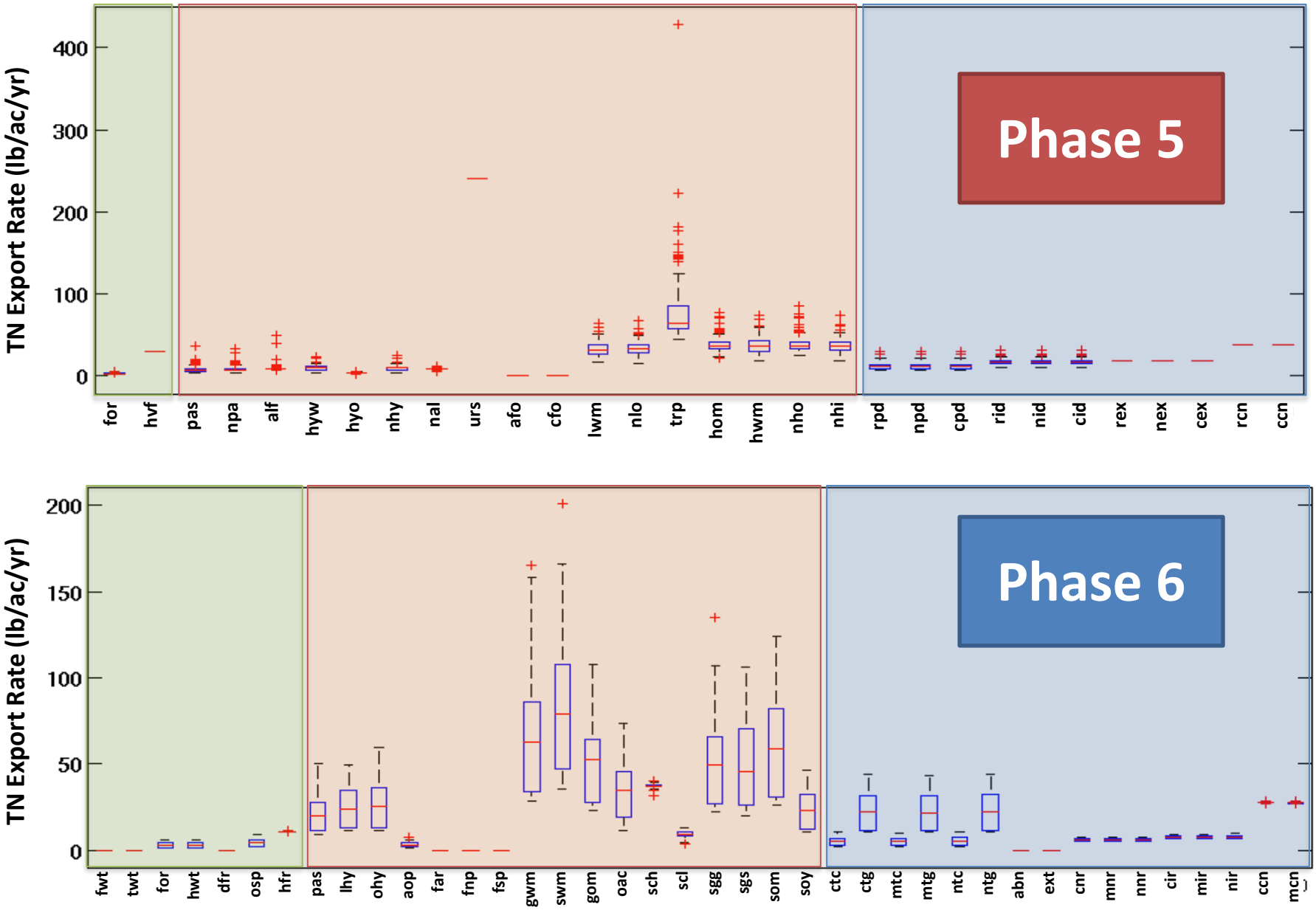
Phase 6 [1985-2014]
{precipitation and meteorology}

Phase 6 [1985-2014]
{P6 land segments and landuse}*

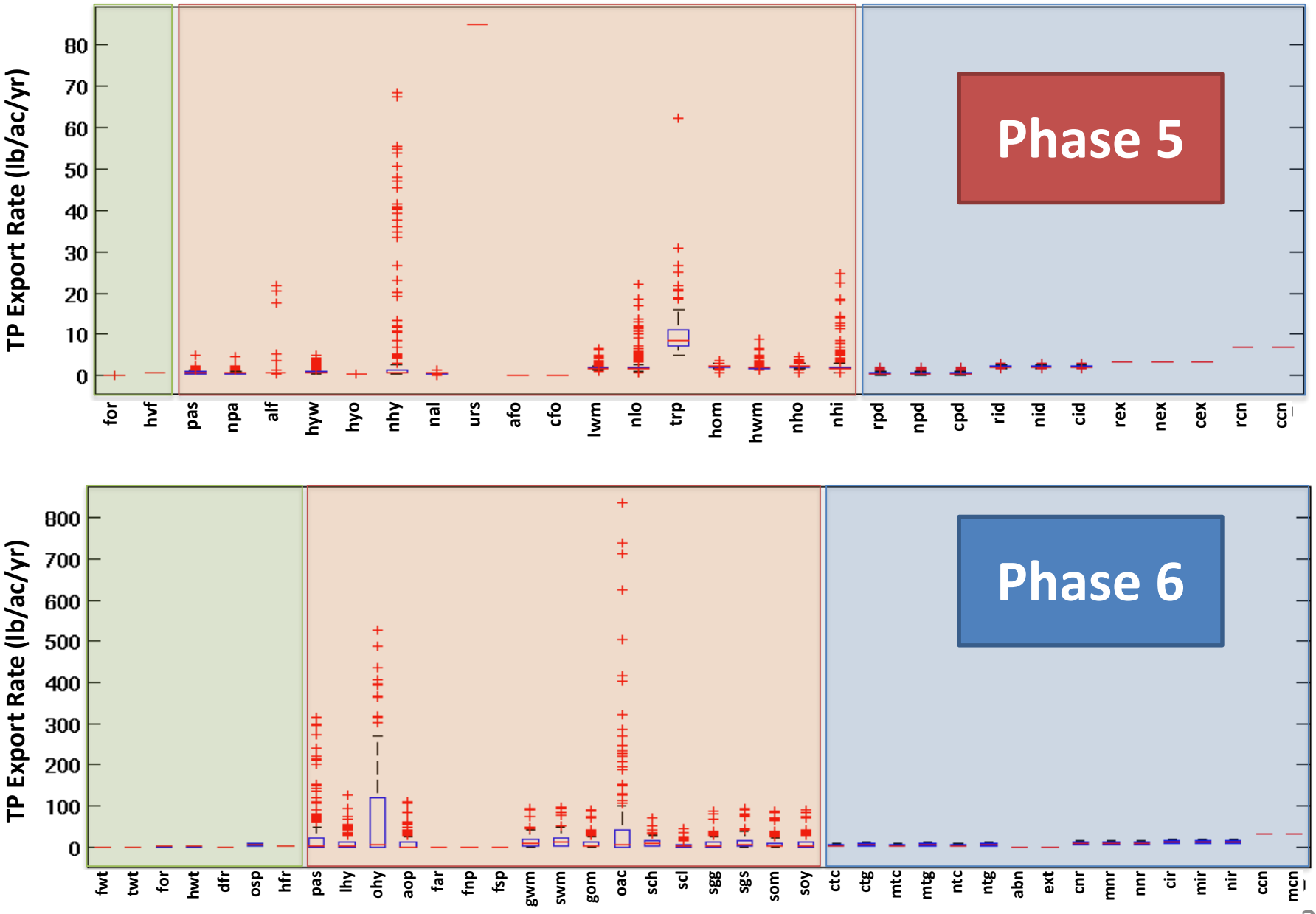
5.1 Nutrient Simulation

- New land-use export targets
- Separate simulation/accounting of *labile* and *refractory* organic phosphorus.
- Revised lag time estimates:
  - Revised mean residence time
  - Groundwater variability based on hydraulic conductivity of geology
  - Surface, interflow, and sediment based on flow plane length & slope
- Added a mechanism for spin-up

5.2 Total Nitrogen Land-use Export Targets



5.2 Total Phosphorus Land-use Export Targets



5.3 Spatially variable lag-time

- The USGS sampled 46 springs between 1996-1997. Chemical isotopic tracers were used for estimating the ages of groundwater.

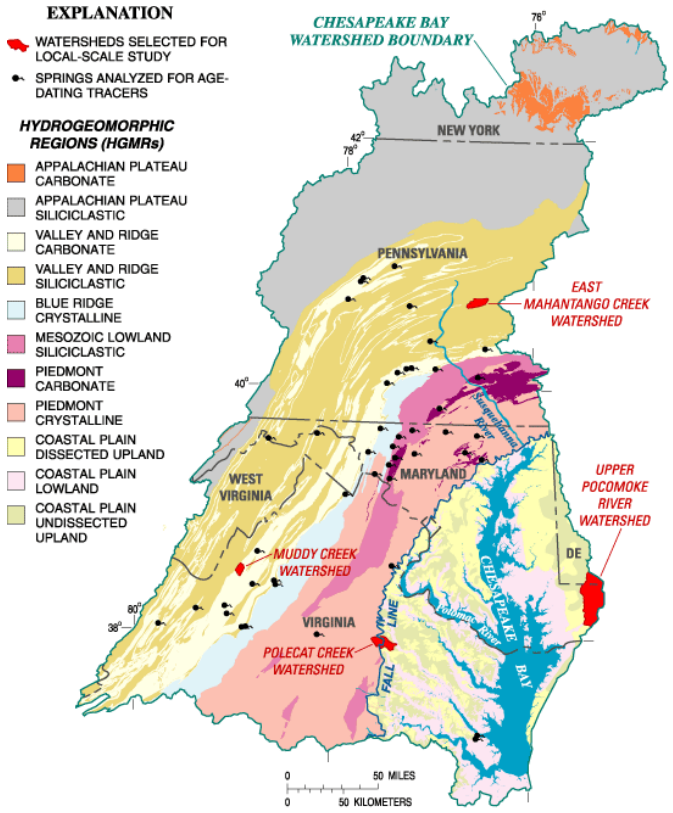


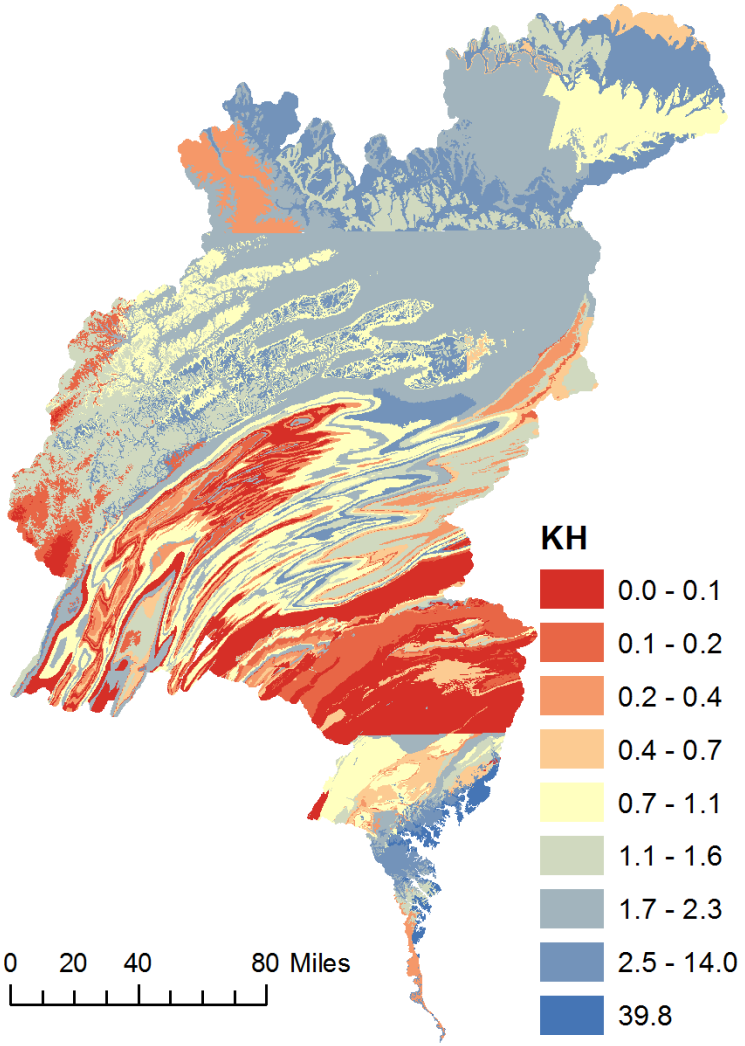
Figure 2. Location of springs and local-scale watersheds sampled in different hydrogeomorphic regions (HGMRs) in the Chesapeake Bay watershed (modified from Lindsey and others, 2003).

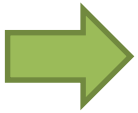
- "The median age of all samples was 10 years, with 25 percent of the samples having an age of 7 years or less and 75 percent of the samples having an age of up to 13 years."

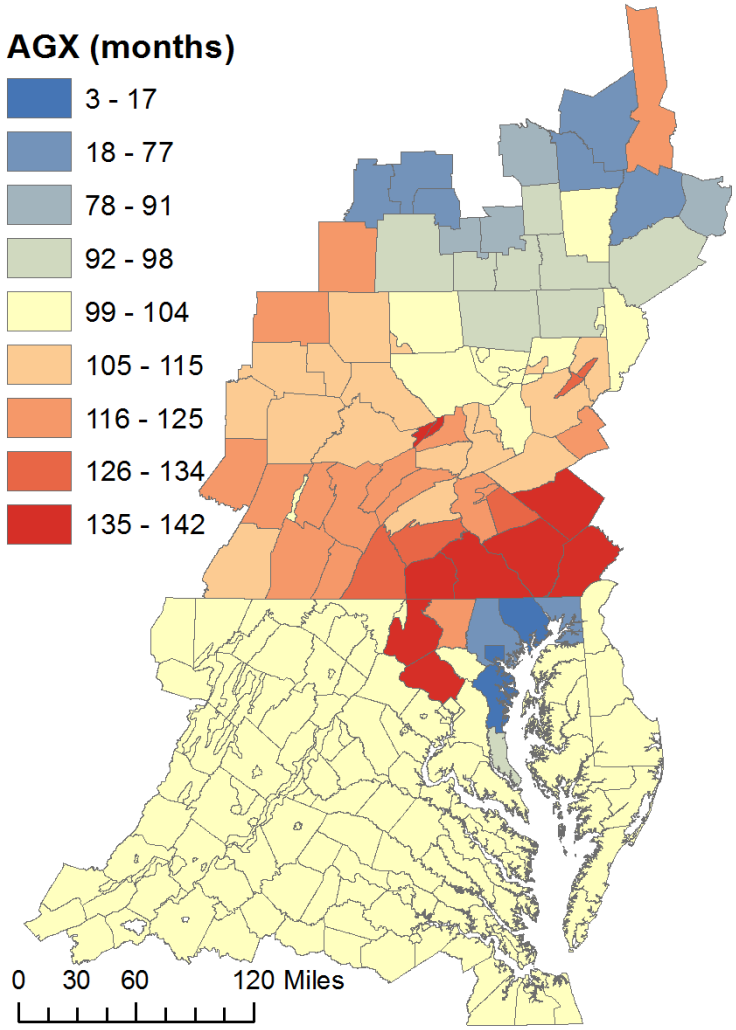
- The study did not find differences in age between the HGRMs.

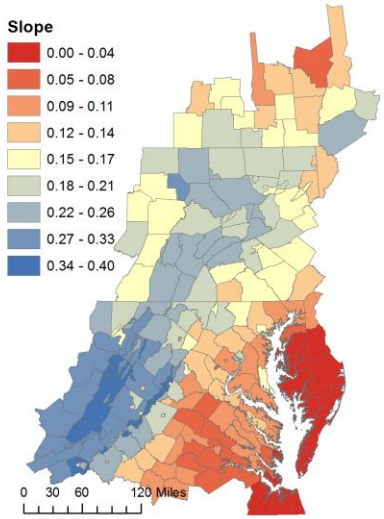
Phillips and Lindsey, http://md.water.usgs.gov/publications/fs-091-03/html/

5.3 Spatially variable lag-time

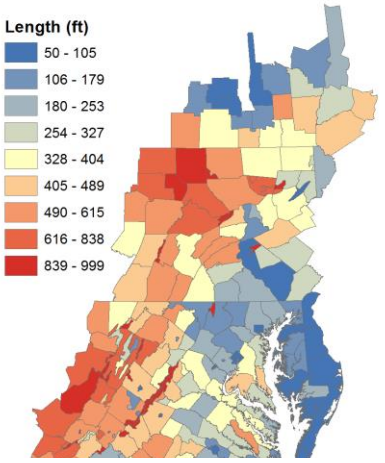


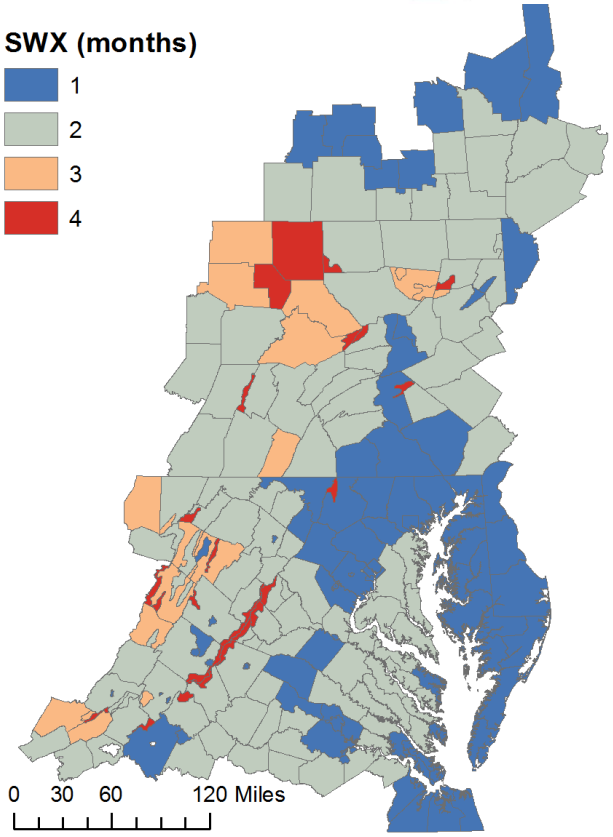


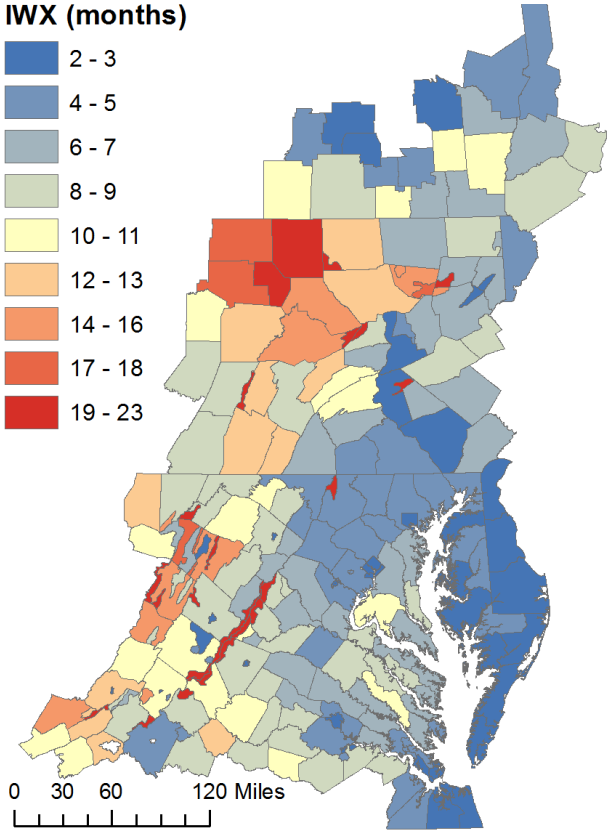


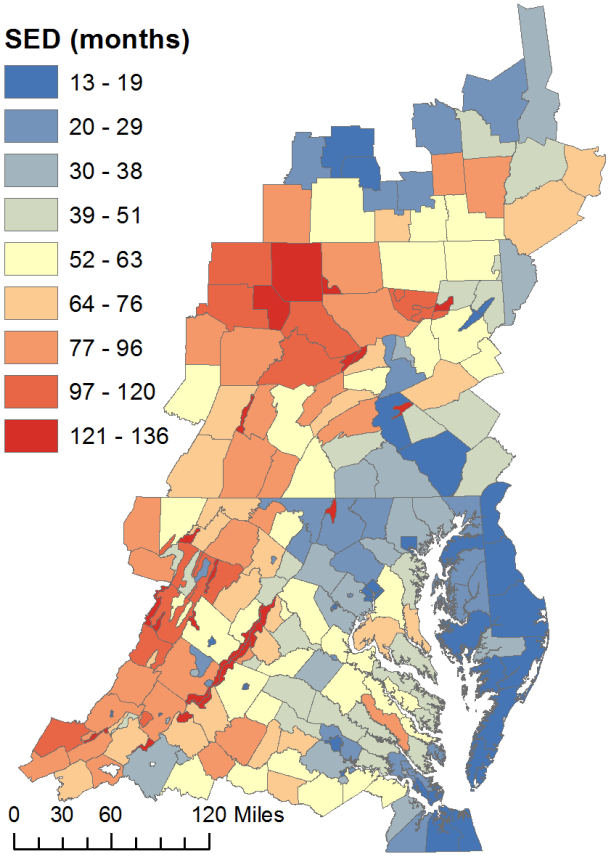


SLOPE LENGTH

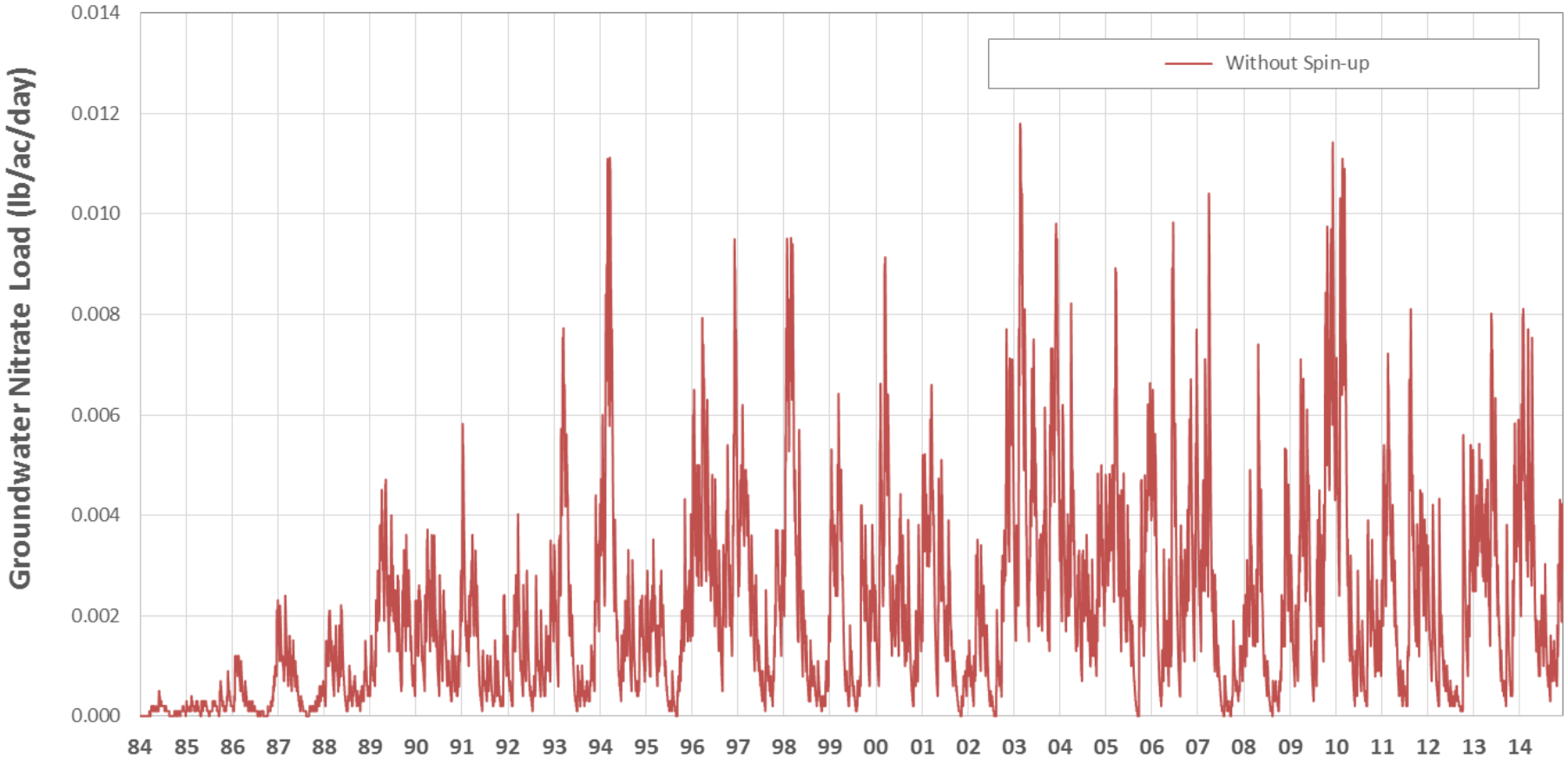








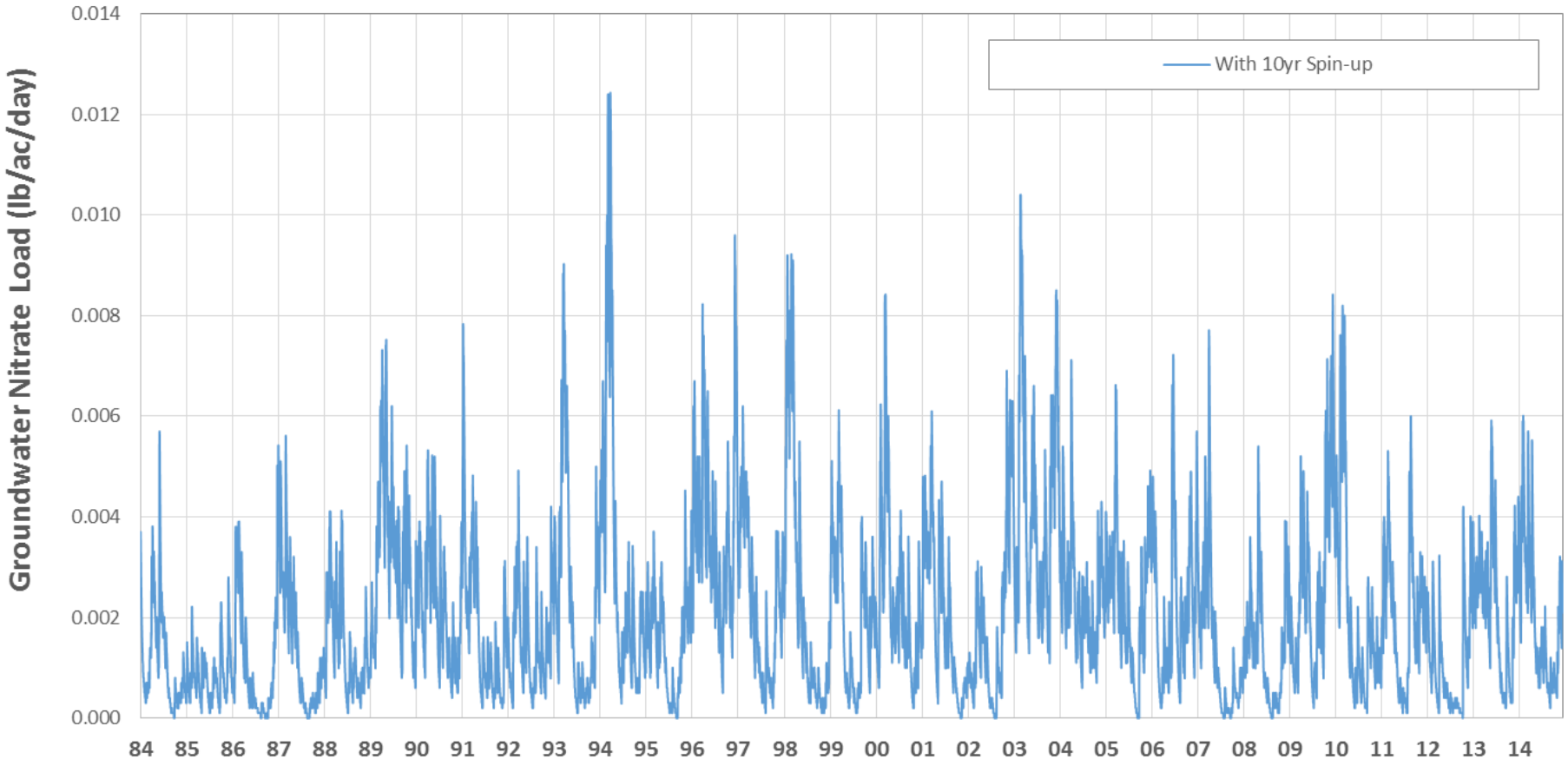
5.4 Simulation without any spin-up



Mean Residence Time = **8.5 Years**

Net Export of 23.81 lbs. over 1985 to 2014

5.4 Simulation with a 10-year spin-up

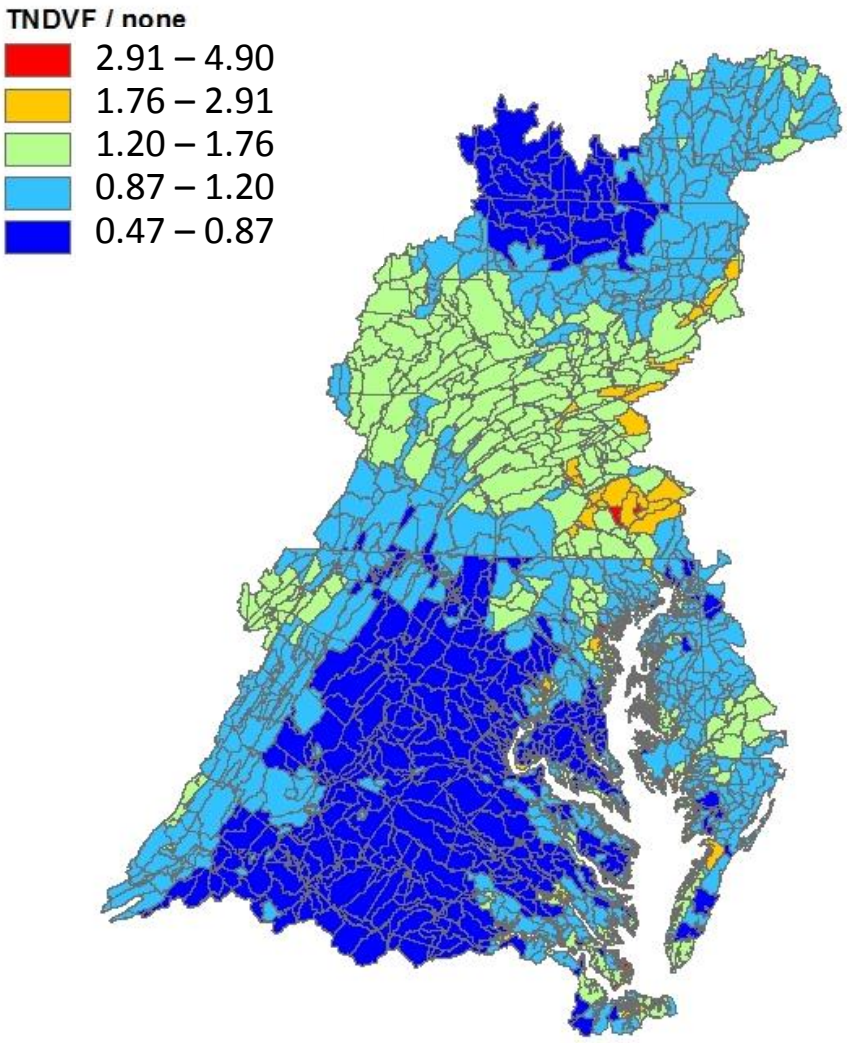


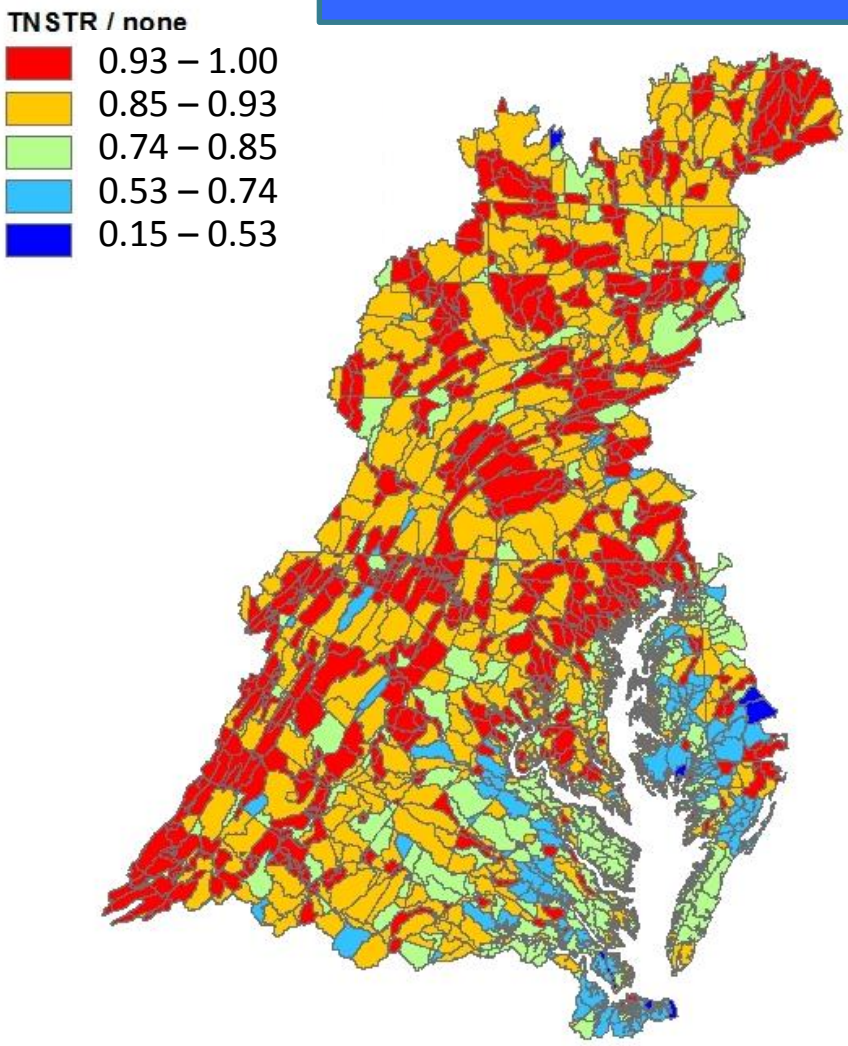
Mean Residence Time = **8.5 Years**

Net Export of 23.81 lbs. over 1985 to 2014

6.1 Land to Water Variances & Stream to River Factors

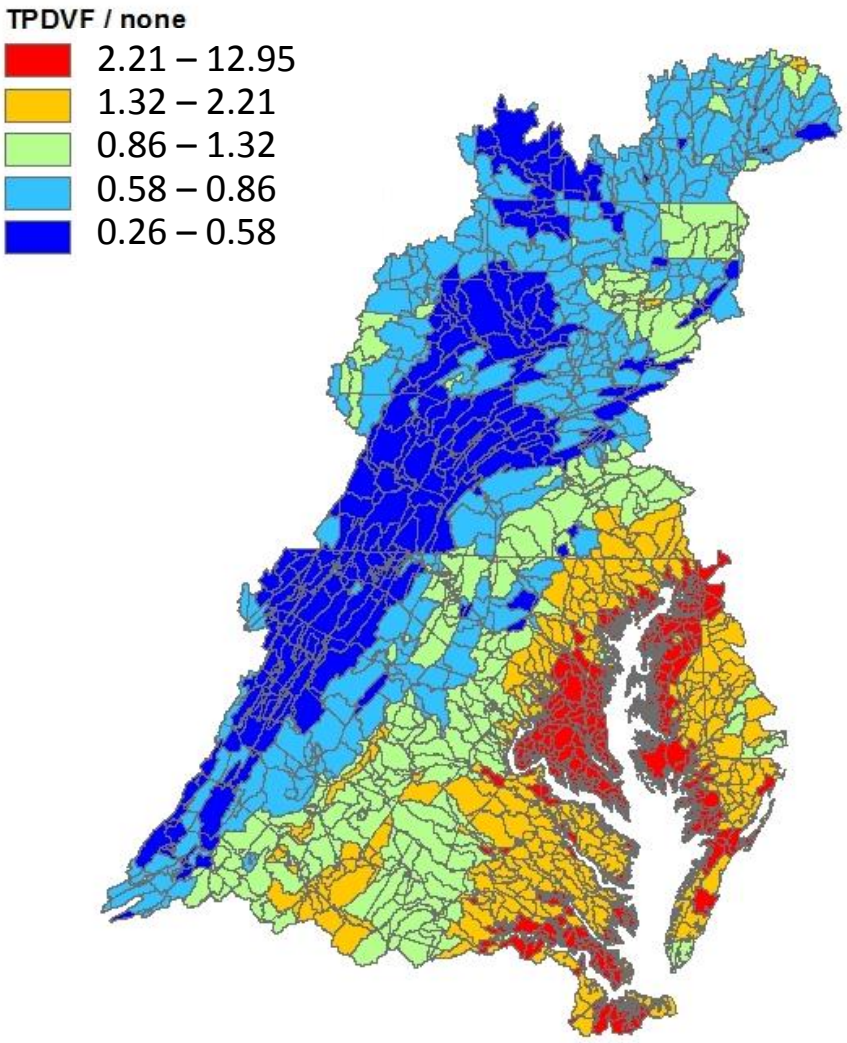
NITROGEN

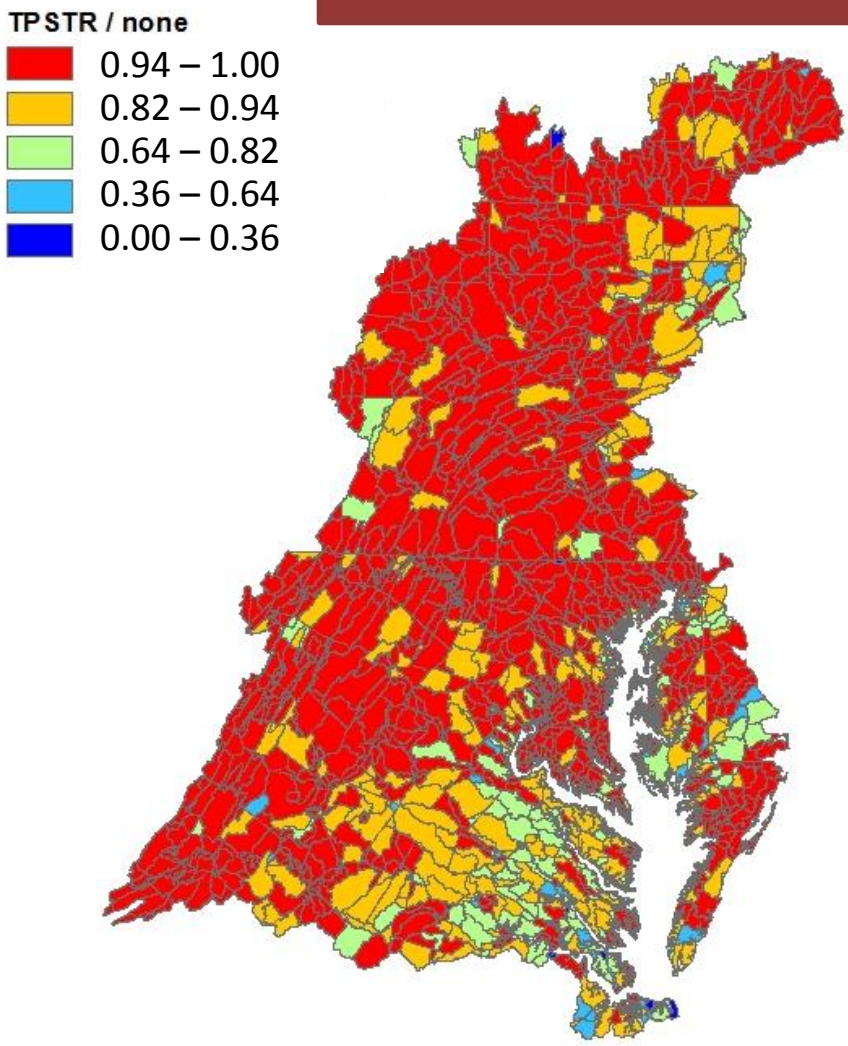




6.1 Land to Water Variances & Stream to River Factors

PHOSPHORUS

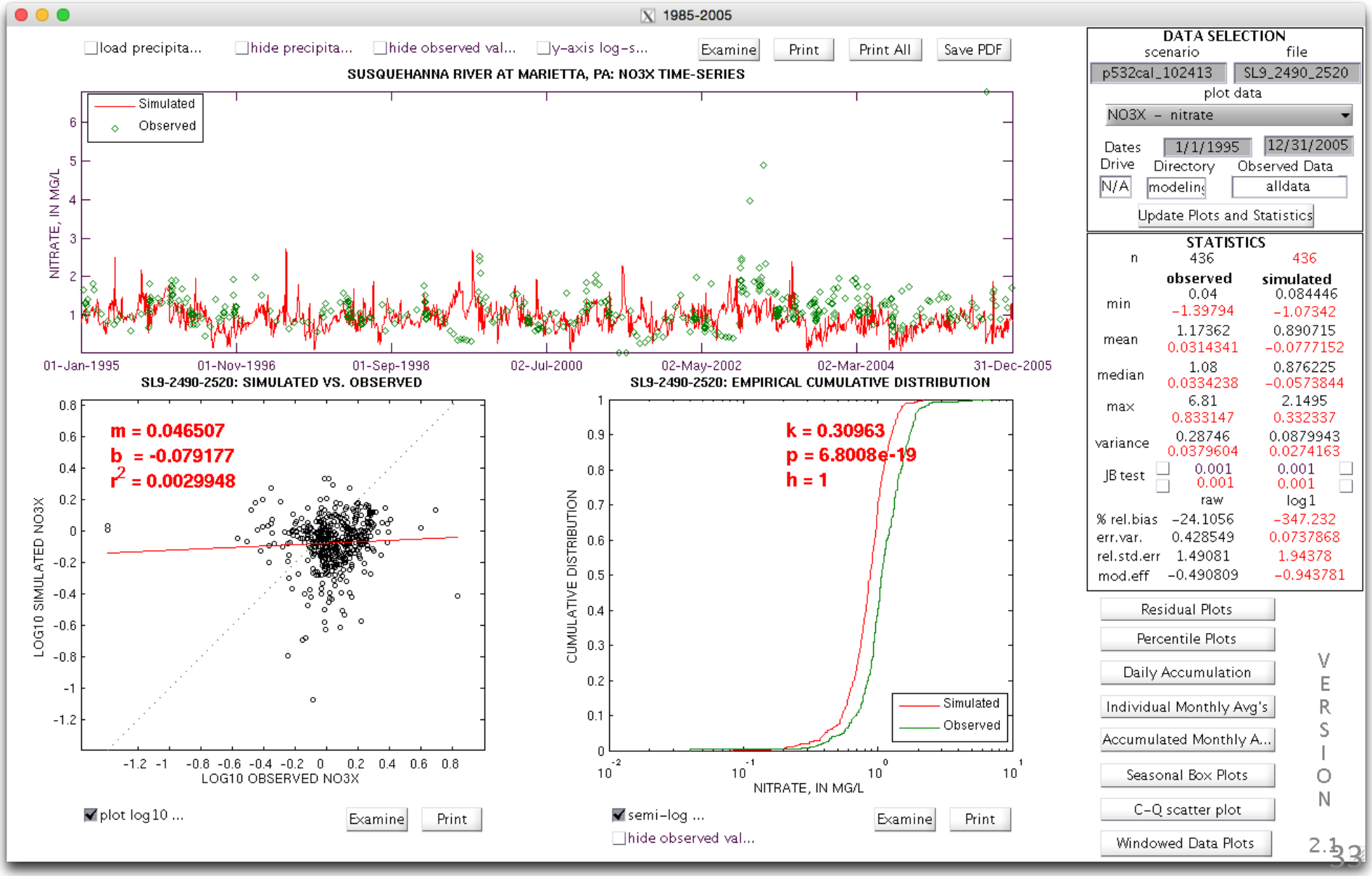




SUSQUEHANNA AT MARIETTA

PHASE 5
1995 - 2005

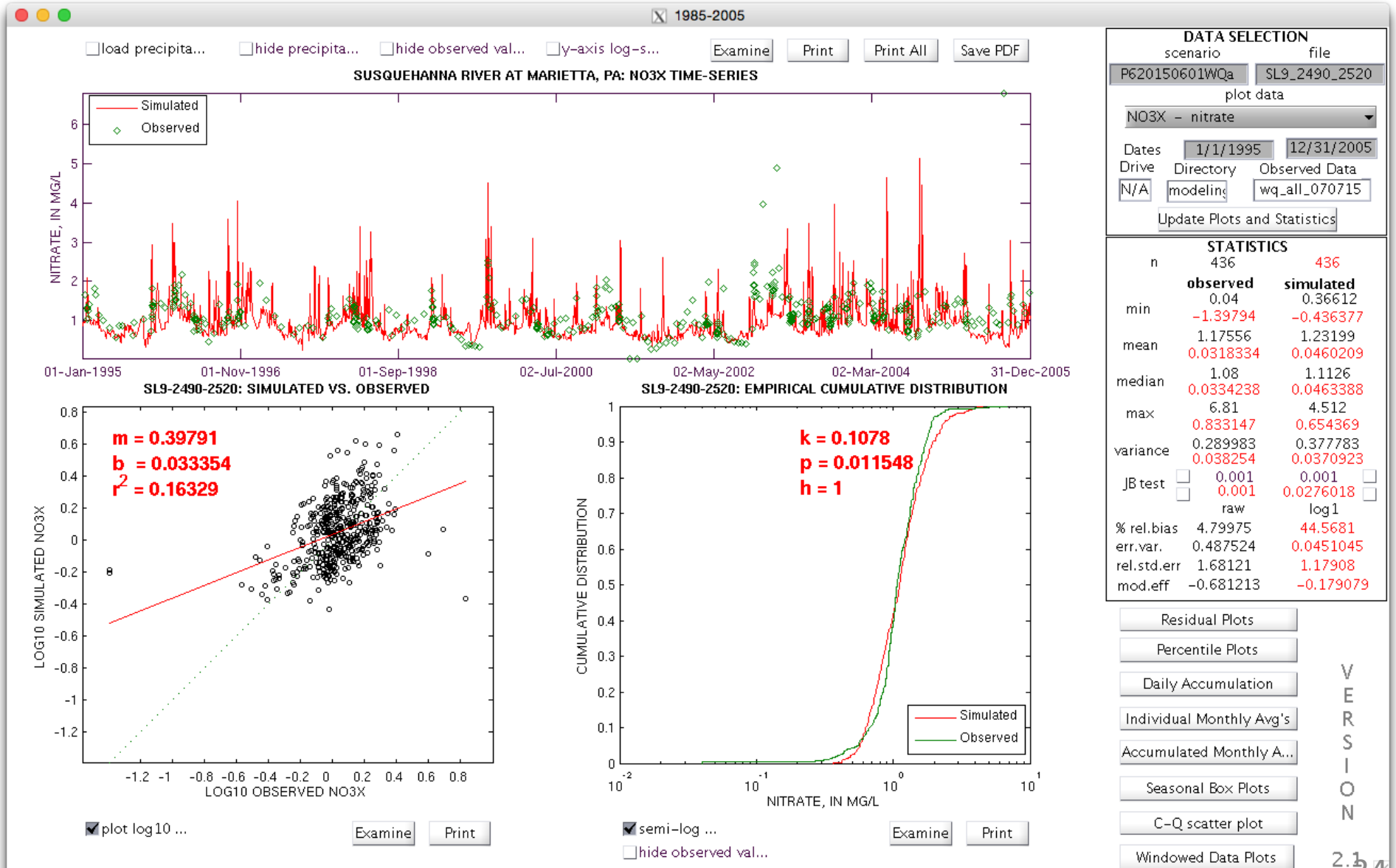
NITRATE



SUSQUEHANNA AT MARIETTA

PHASE 6
1995 - 2005

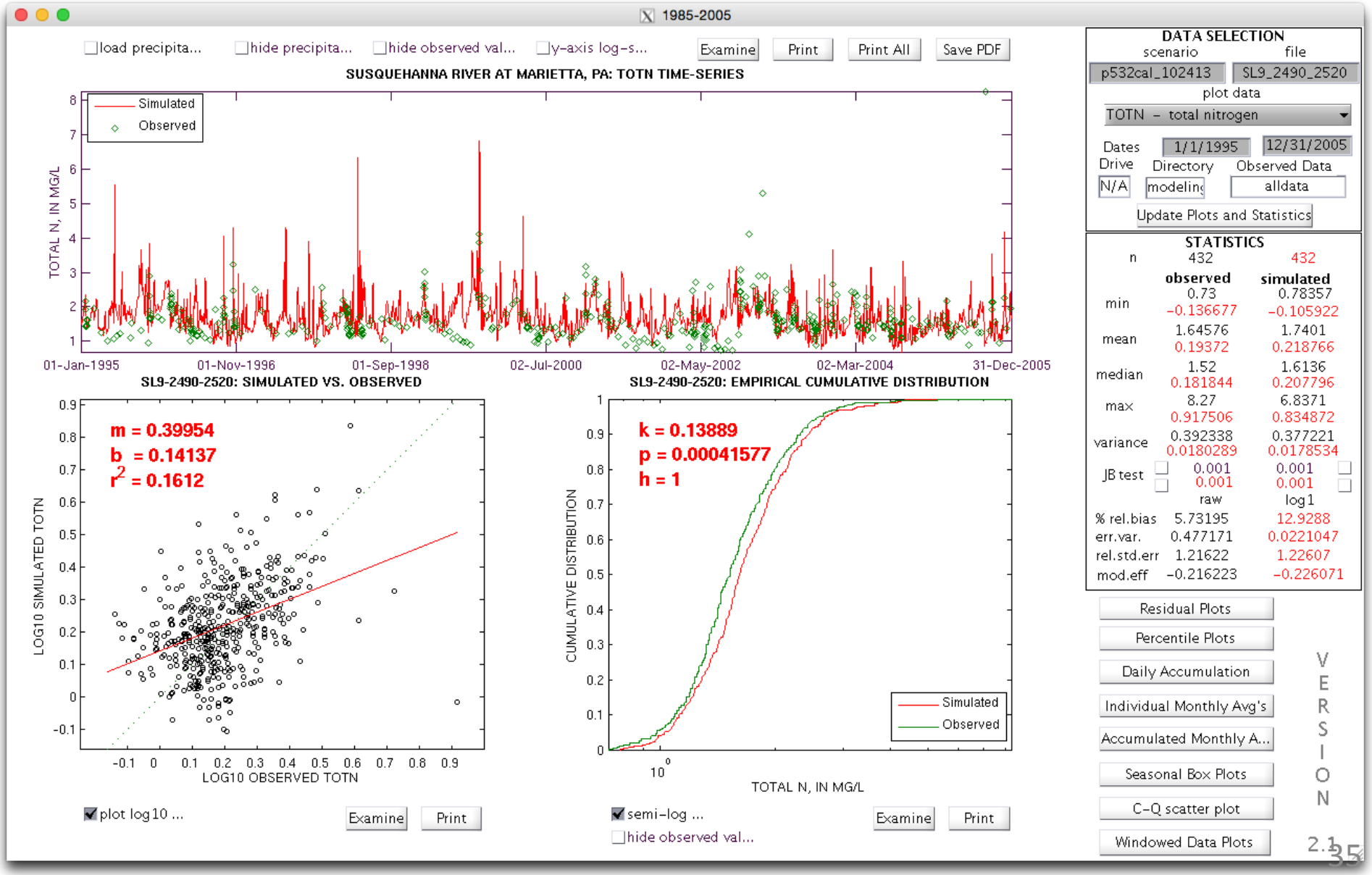
NITRATE



SUSQUEHANNA AT MARIETTA

PHASE 5
1995 - 2005

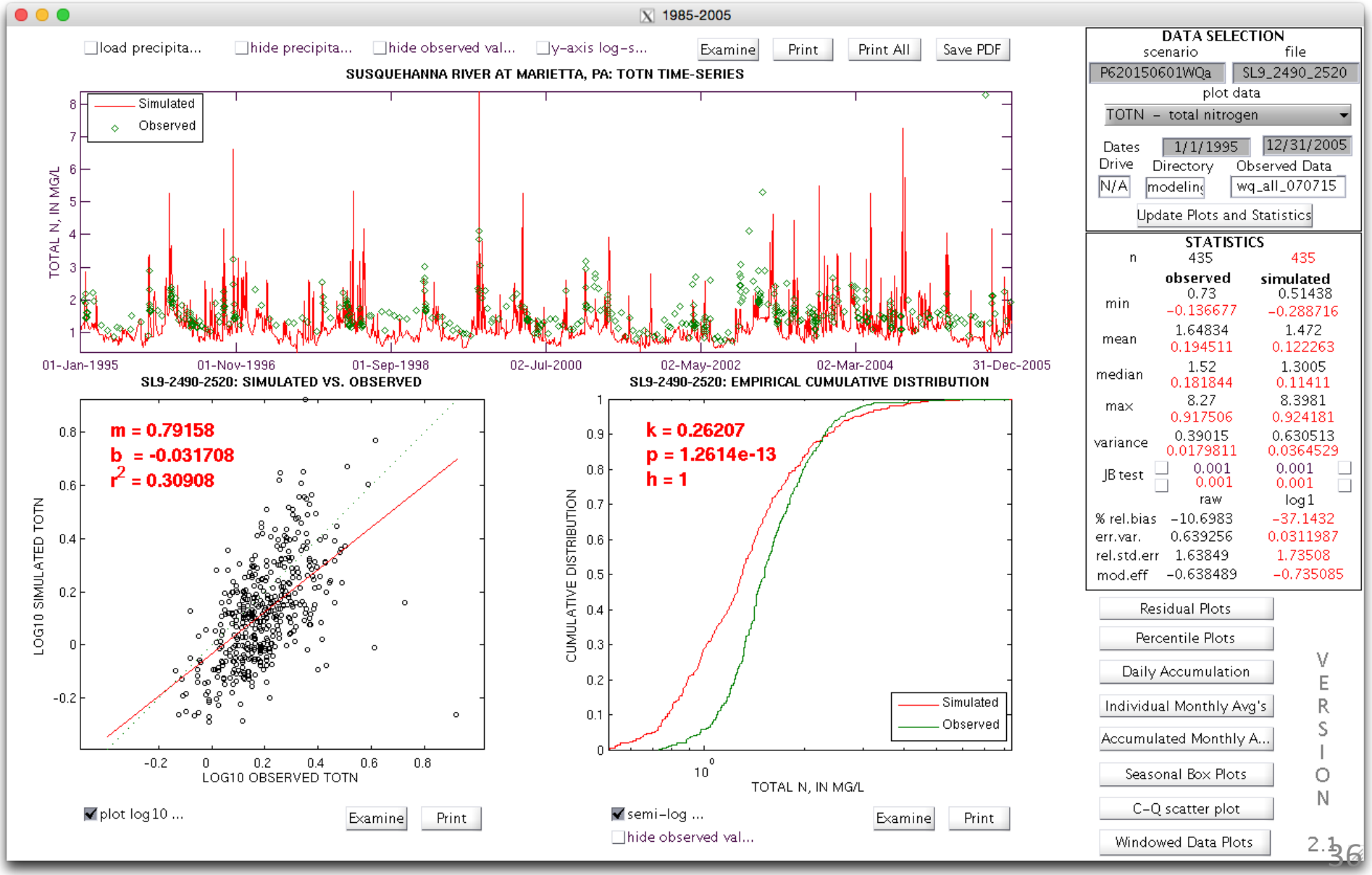
NITROGEN



SUSQUEHANNA AT MARIETTA

PHASE 6
1995 - 2005

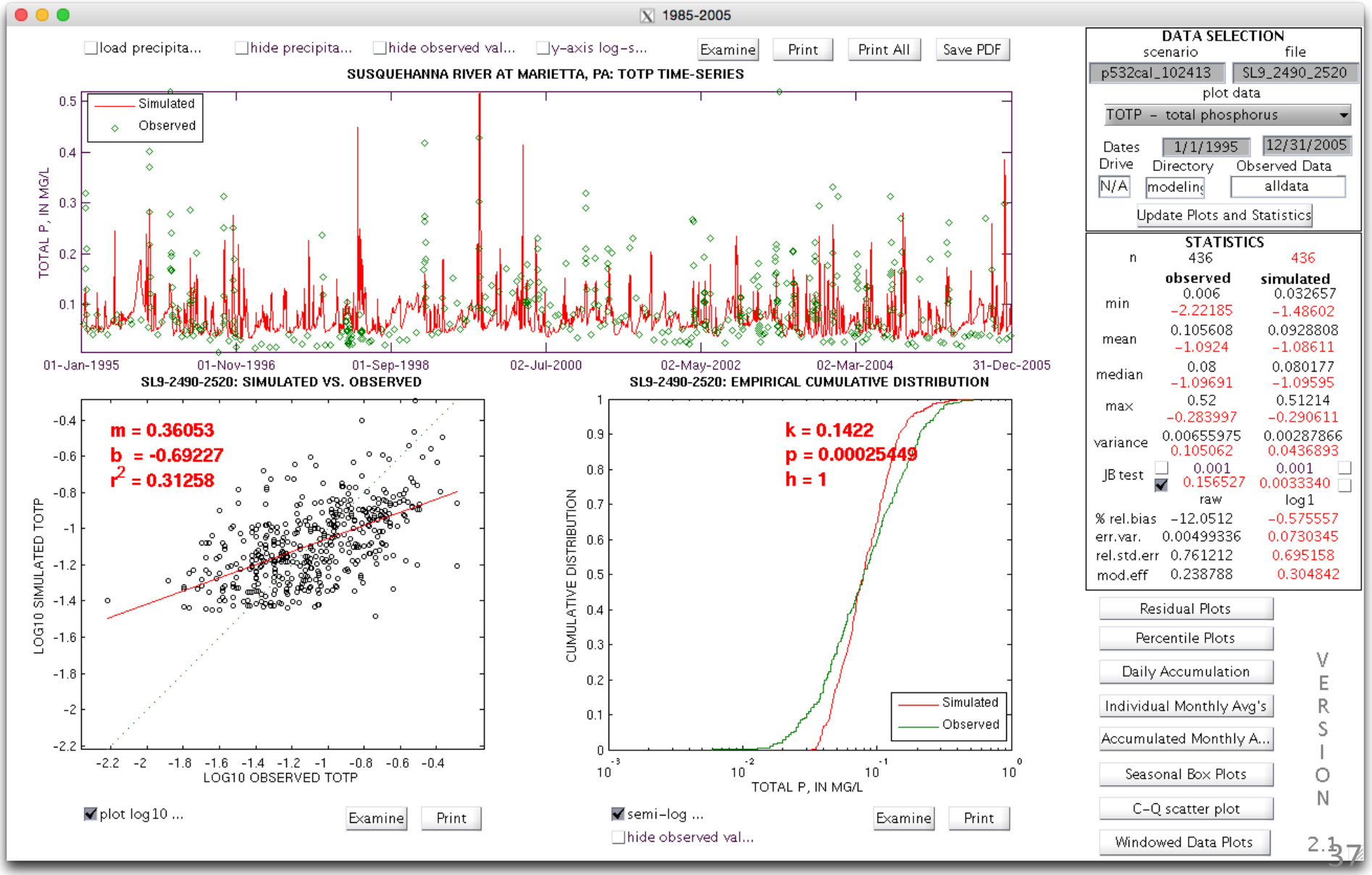
NITROGEN



SUSQUEHANNA AT MARIETTA

PHASE 5
1995 - 2005

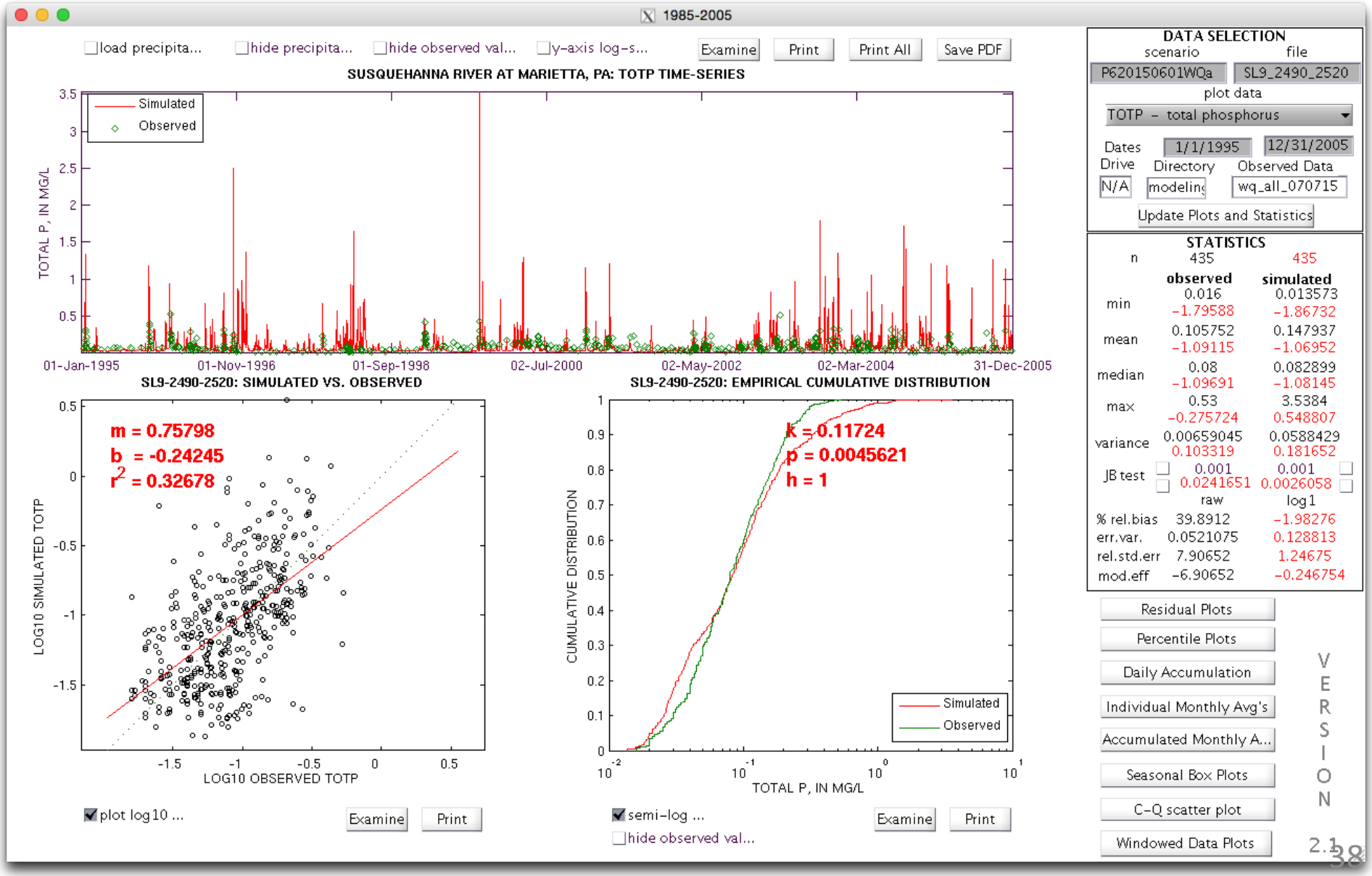
PHOSPHORUS



SUSQUEHANNA AT MARIETTA

PHASE 6
1995 - 2005

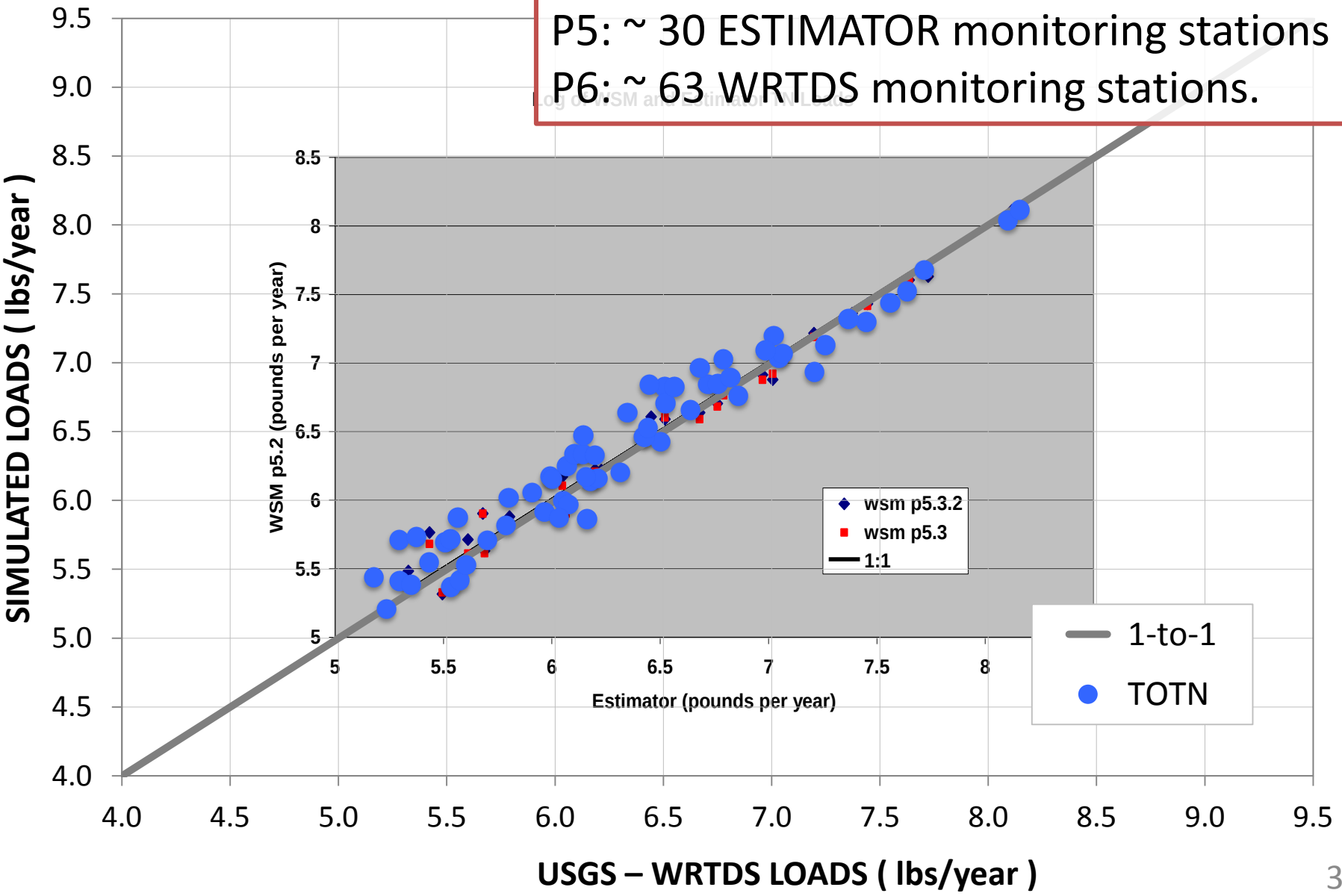
PHOSPHORUS



6.3 Average Annual Load

NITROGEN

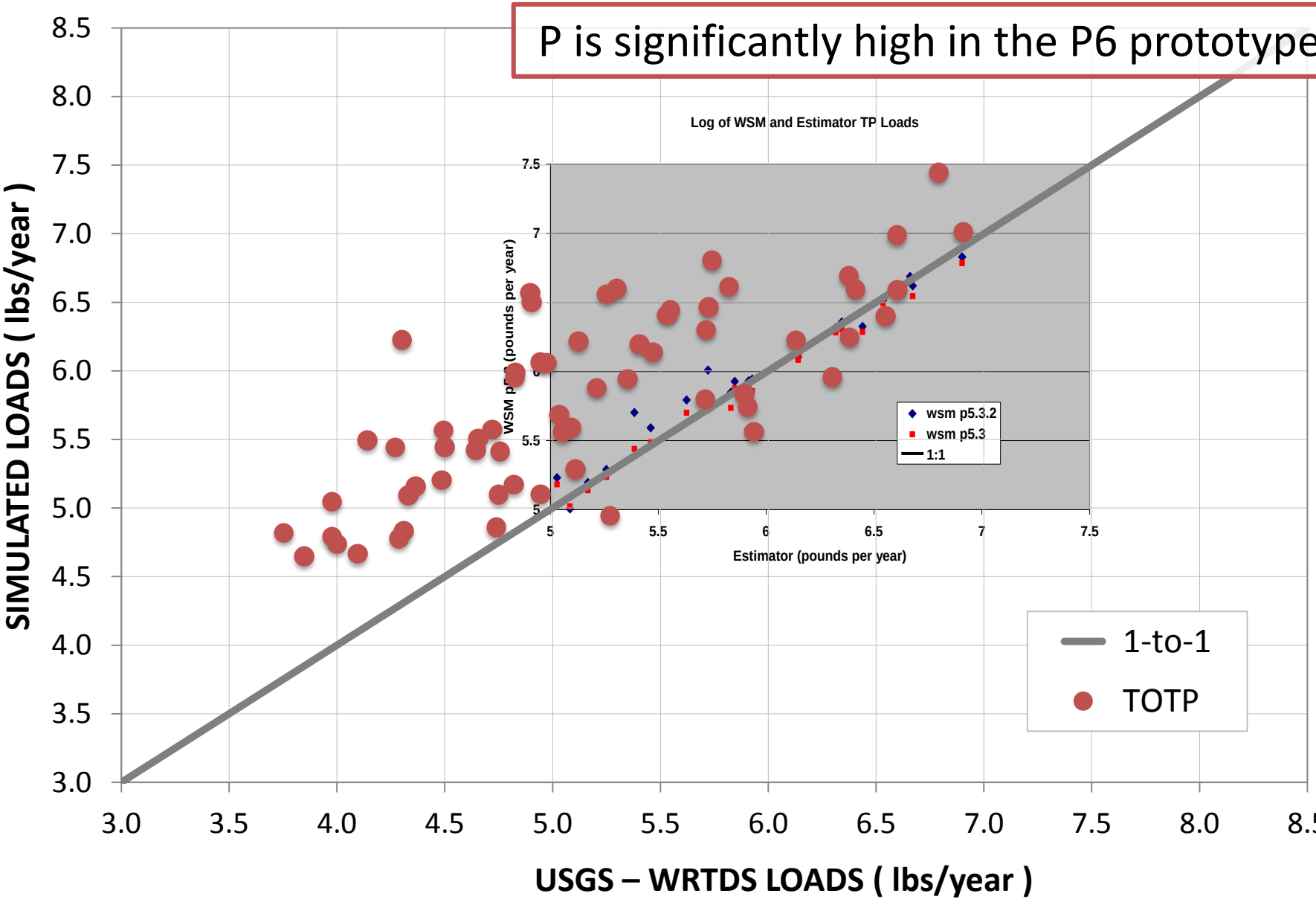
P5: ~ 30 ESTIMATOR monitoring stations
P6: ~ 63 WRTDS monitoring stations.



6.3 Average Annual Load

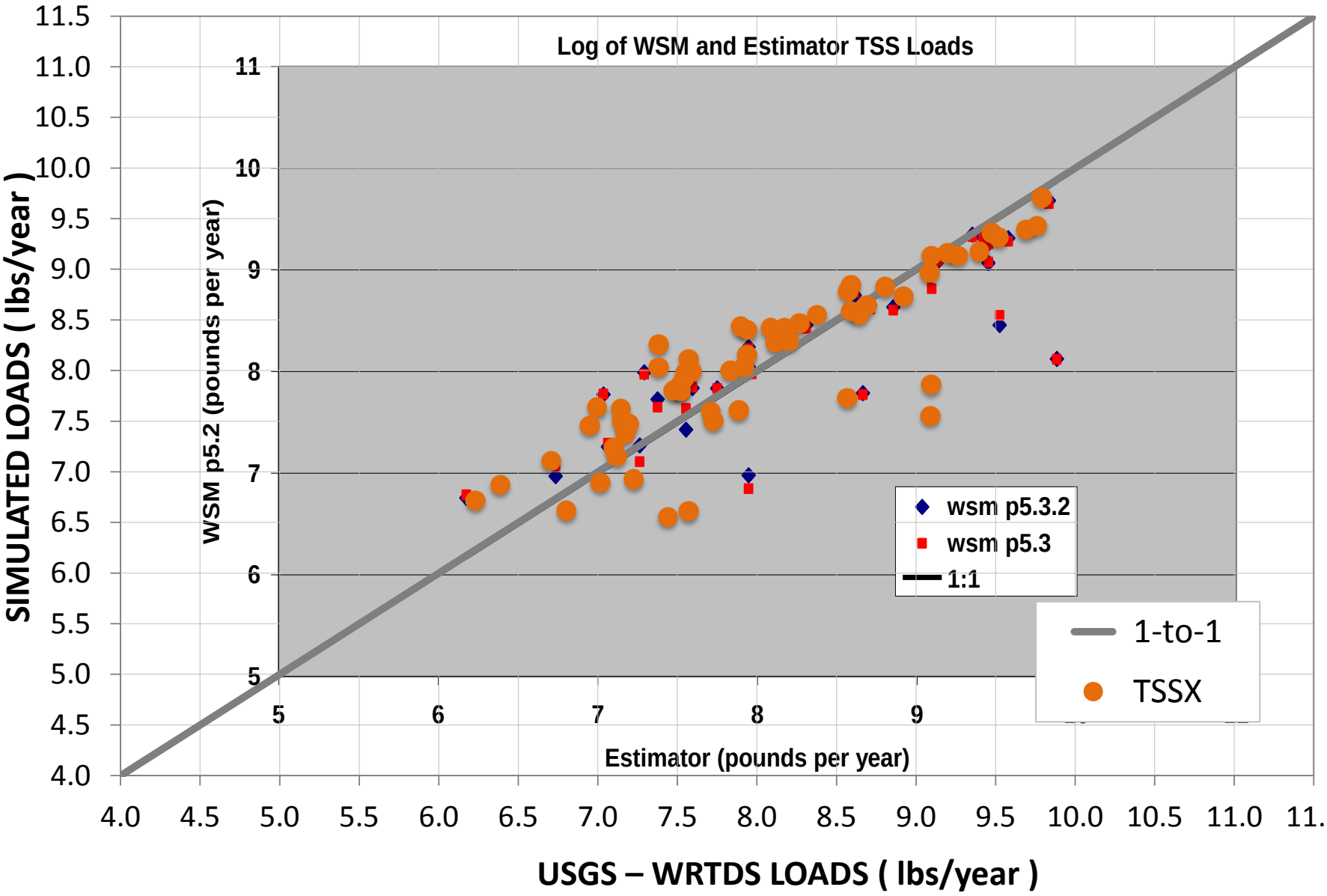
PHOSPHORUS

P is significantly high in the P6 prototype.



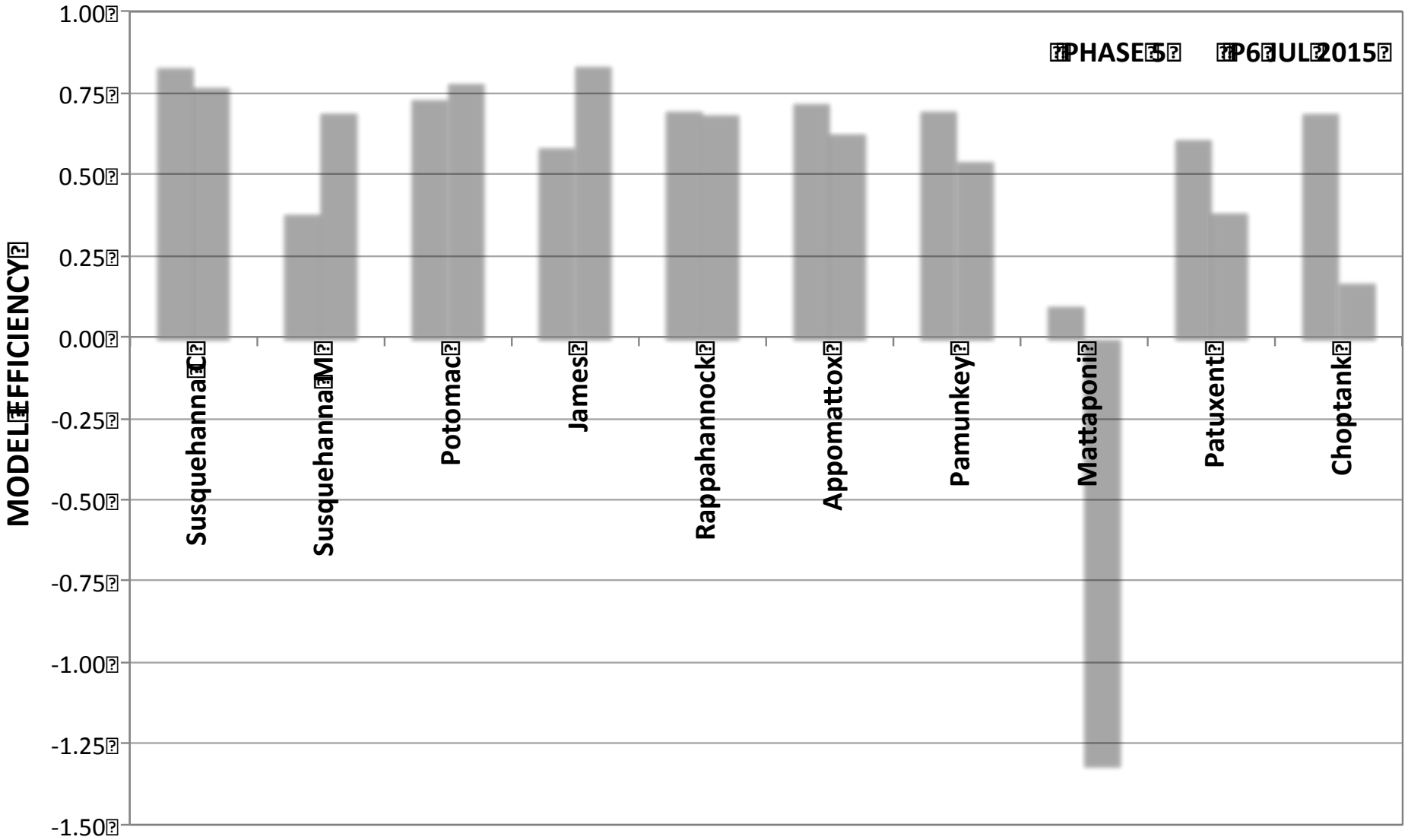
6.3 Average Annual Load

SEDIMENT



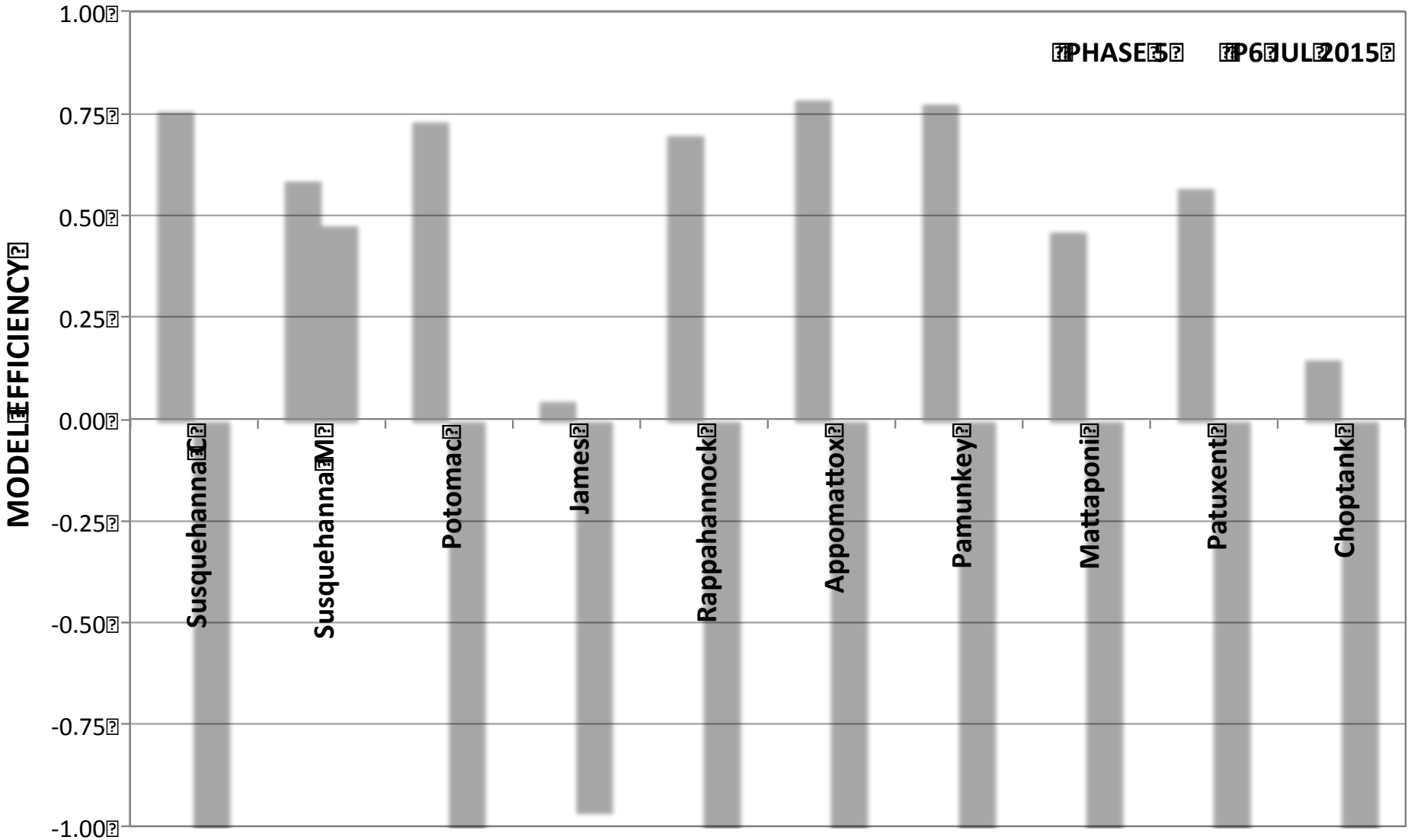
6.4 Monthly Load Efficiency (NSE)

NITROGEN

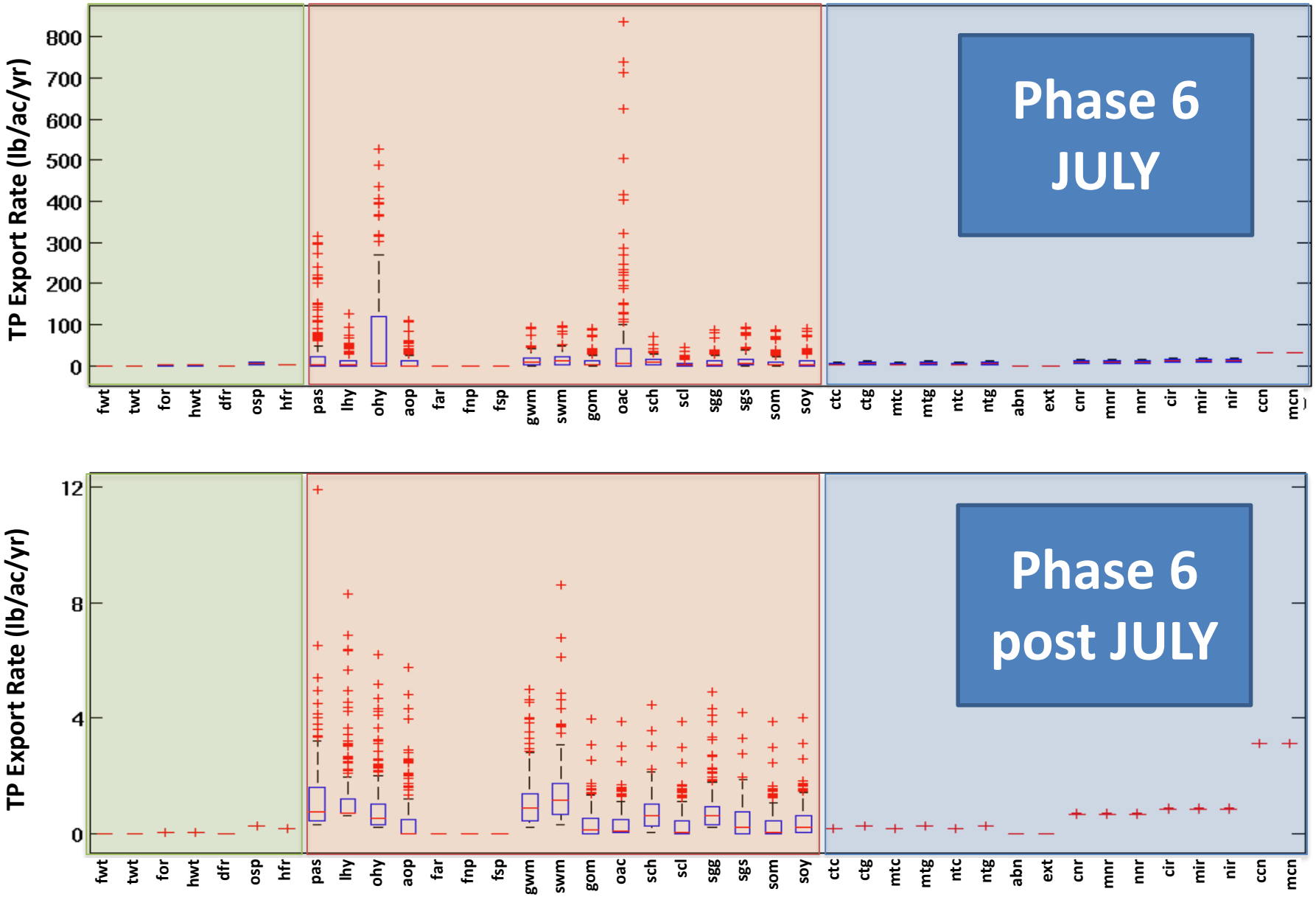


6.4 Monthly Load Efficiency (NSE)

PHOSPHORUS



7. Total Phosphorus Land-use Export Targets



Next Steps …

- Revise the model calibration using updated phosphorus land-use export targets.

- Incorporate the workgroup approved N/P sensitivities in the model to simulate key scenarios.

Appendices …

4.1 Water Temperature Parameterization

- Kurylyk et al. 2013 used this equation for estimating future ground water temperatures based on air temperatures projected from global climate models.

$$GWT = MAGST + D' \left\{ GST_{i-L} - MAGST \right\} + B$$

SURFACE	
Depth	**0.1 m**
D	0.963
L	0
B	2 °F

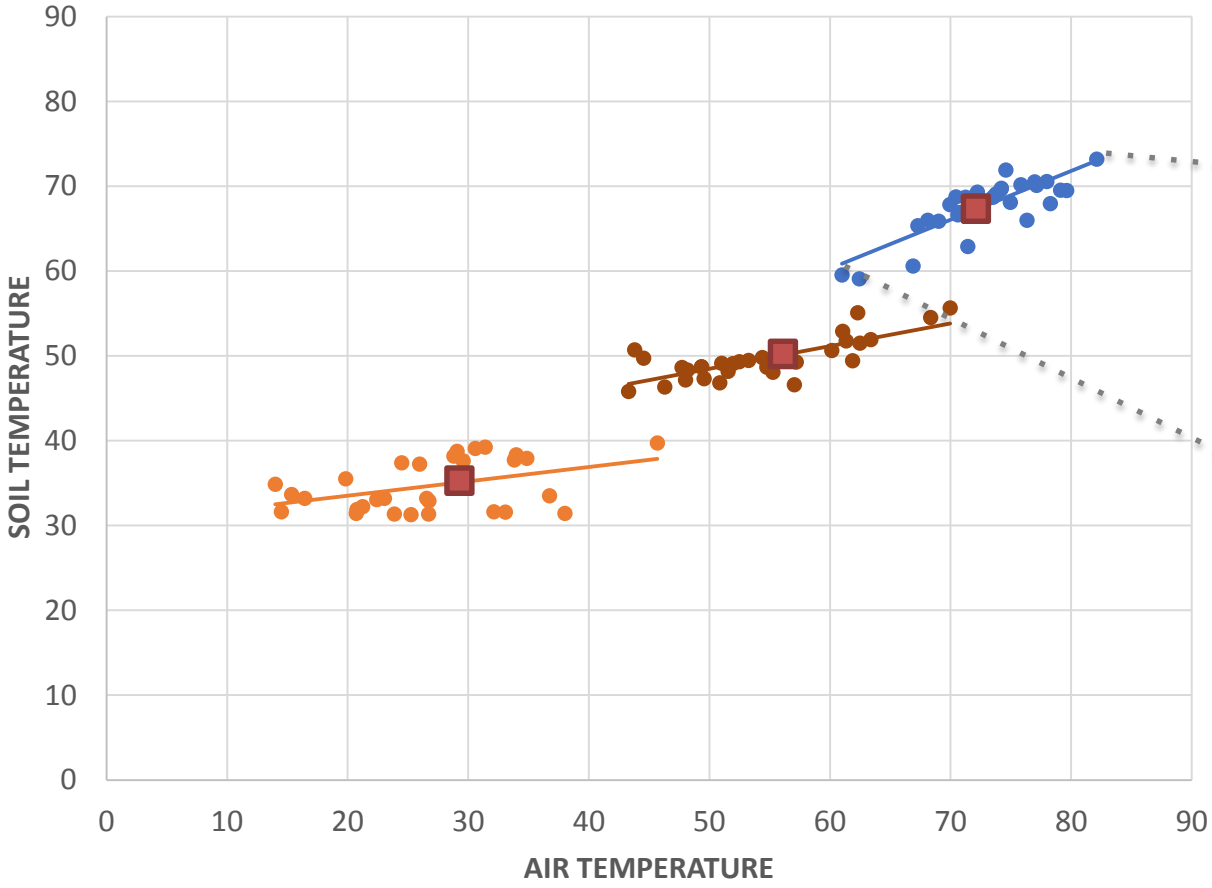
UPPER	
Depth	**0.5 m**
D	0.830
L	0
B	1.5 °F

LOWER	
Depth	**2.5 m**
D	0.394
L	2
B	1 °F

$$D = EXP\,[-3.724 \times Depth]$$

$$L = 0.6504 \times Depth$$

4.1 Water Temperature Parameterization (Slope & Intercept)



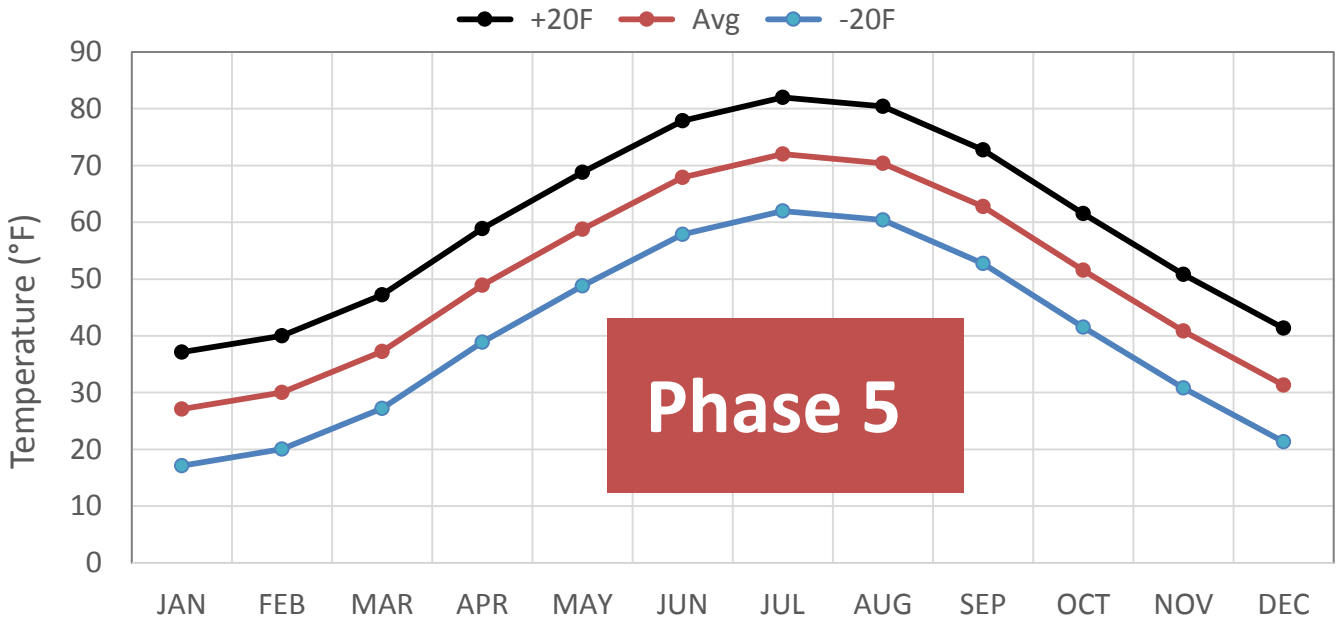
$$Slope = \frac{\Delta\ Soil\ Temperature}{\Delta\ Air\ Temperature}$$

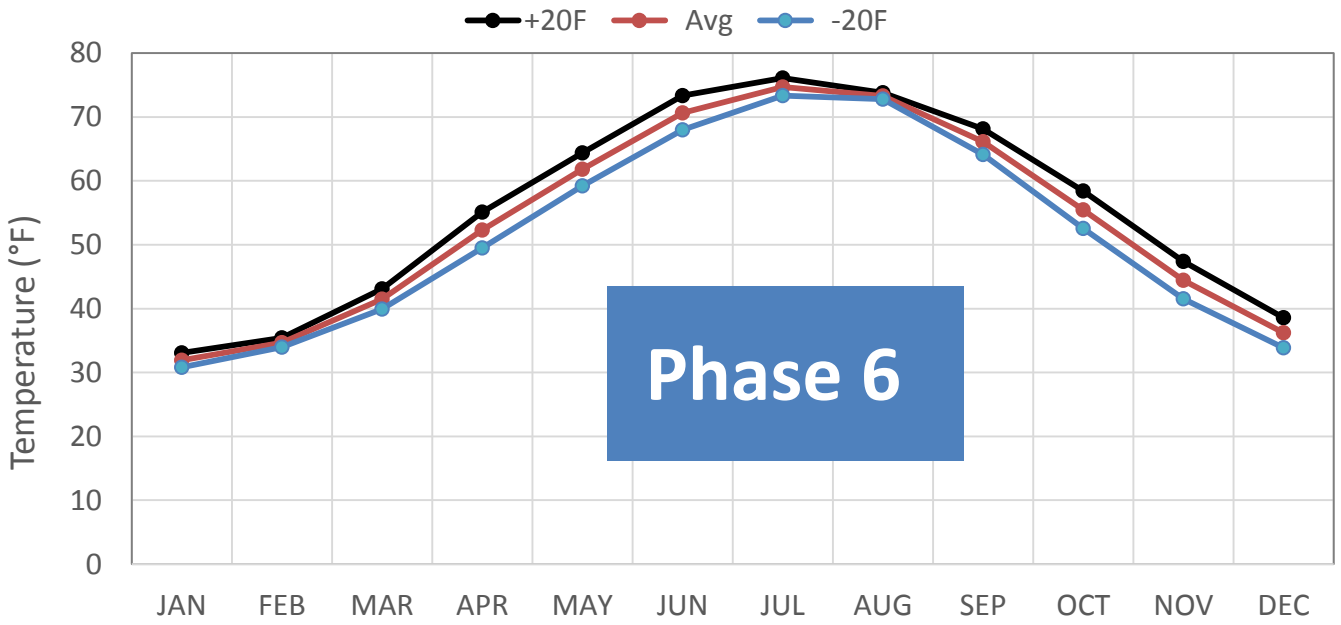
Δ hourly soil temperature was estimated as $2 \times \Delta$ monthly soil temperature

Δ hourly air temperature was calculated from the air temperature time series

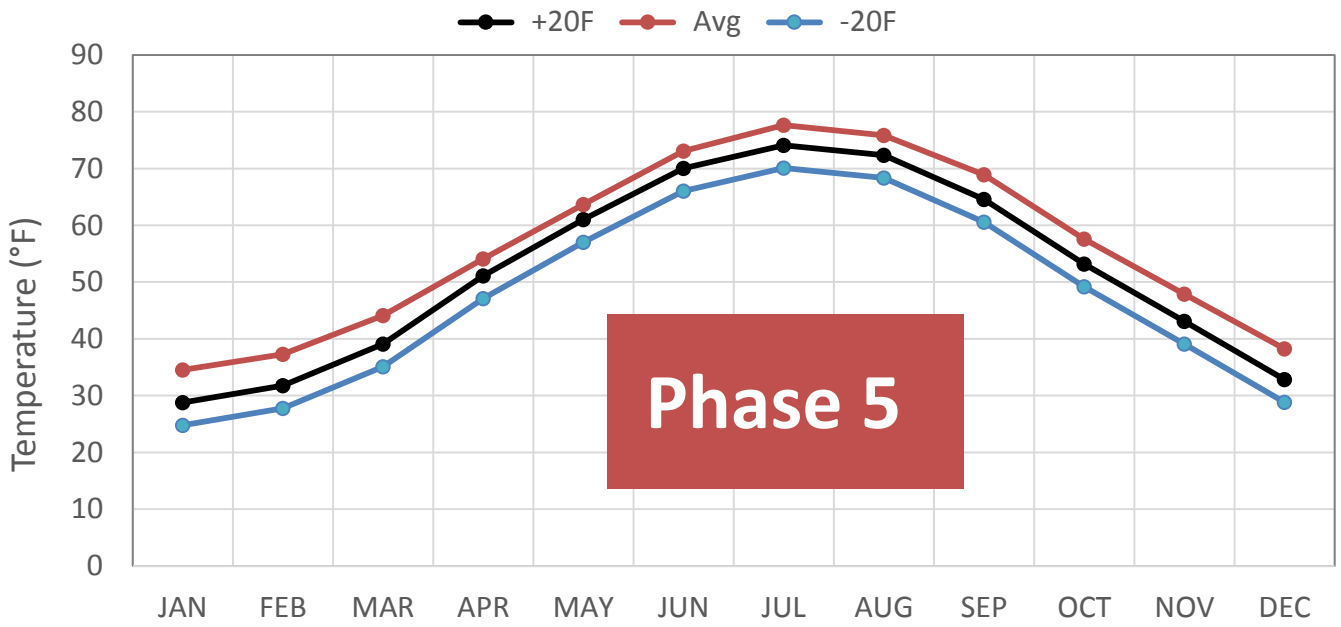
the intercept was calculated from slope and a known point (the monthly average)

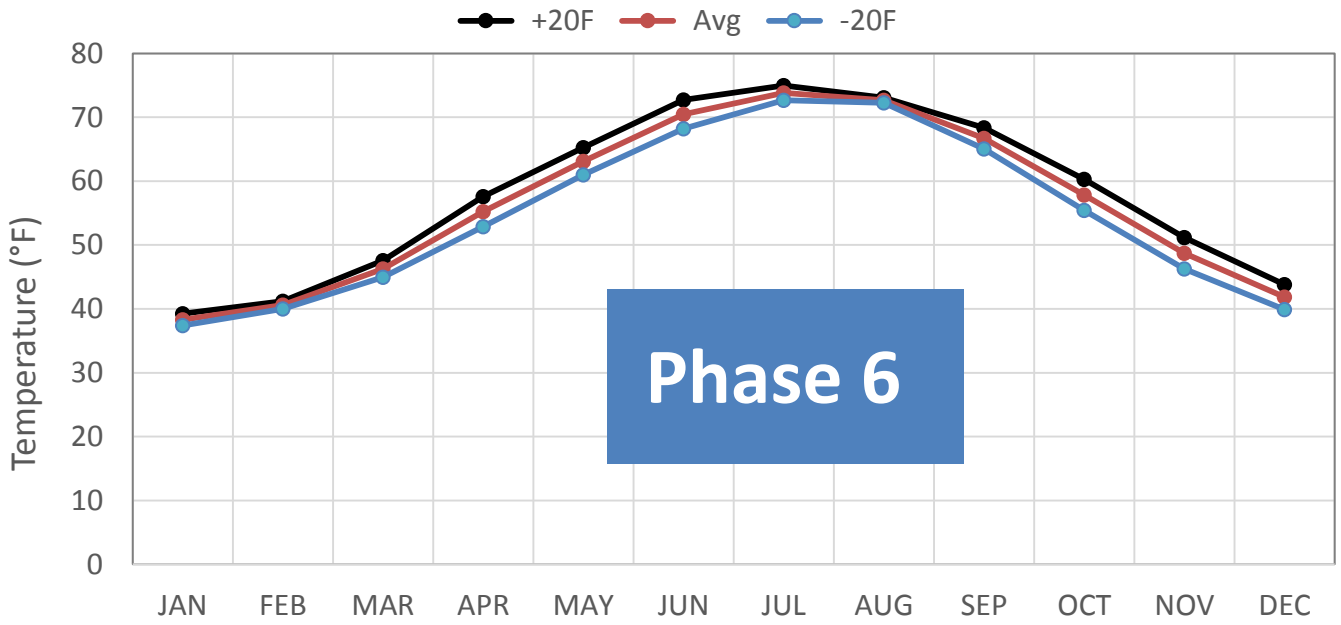
Estimated response of average monthly surface temperature





Estimated response of average monthly soil temperature





6.3 Average Annual Load

NITRATE