James River Water Quality Model Refinement and Scenario Runs

Progress Report

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DEQ
Virginia Department of Environmental Quality

Outline

- Progress update
- Theoretical consideration under nutrient-limited condition
  - Parameter uncertainty
  - Model response to load reduction
- Model calibration results
- Model response to load reduction
- Discussion

Progress Update

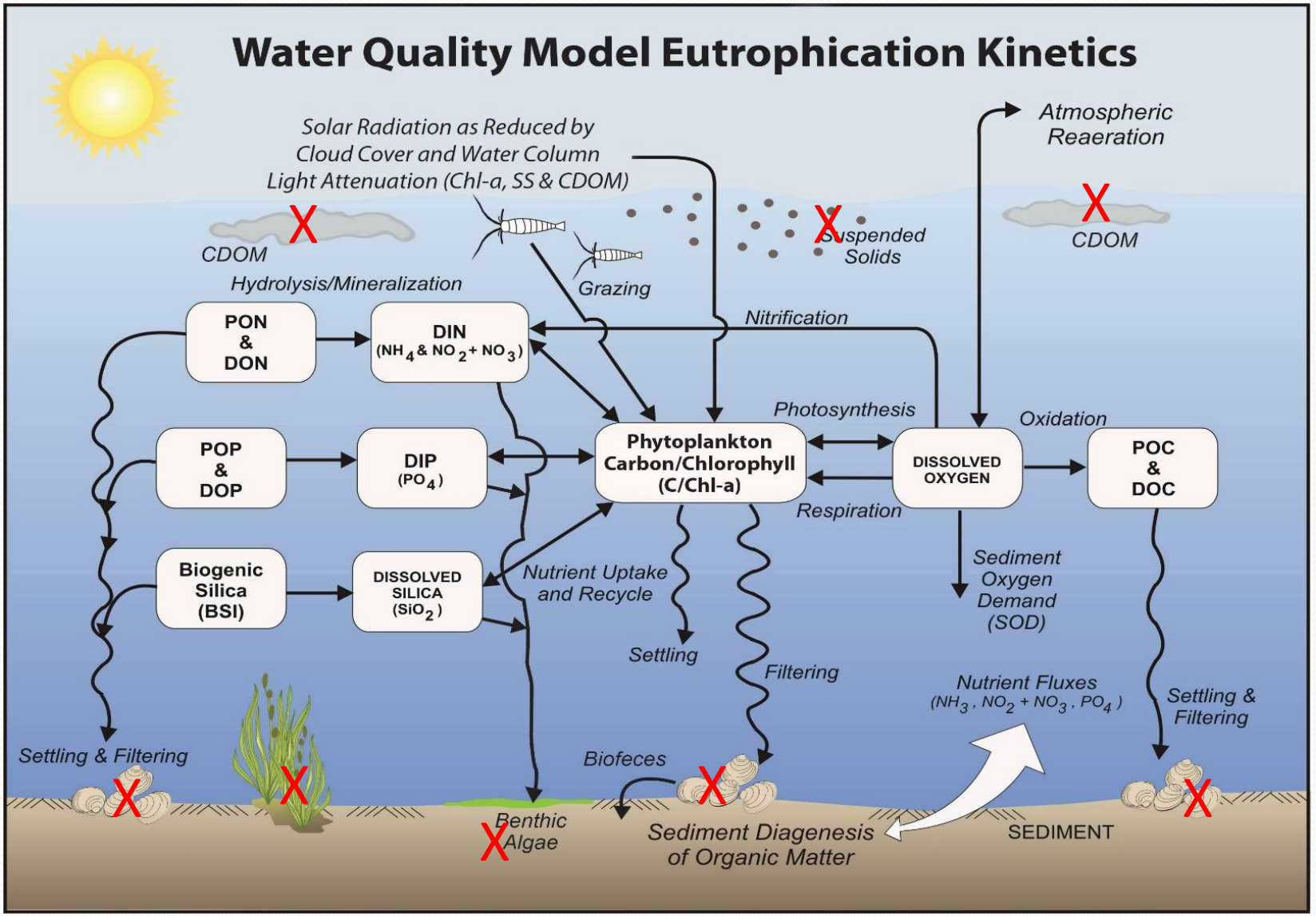
- Received data
  - latest Phases 6 watershed nonpoint source model results 1985-2014 (nonpoint/point, bank erosion, atmospheric deposition)
  - Draft WIP2 scenario 1985-2000
  - Boundary conditions (tide, salinity, temperature)
- Completed tools to convert data to EFDC inputs
- Conducted model calibration
  - Hydrodynamics (from 1991-2013)
  - Water quality (from 1991-2013)
- Sensitivity test for model response to load reduction

Comparison of Loading to James River Watershed Loading (2016)

1991-2000	TC (Mlb/yr)	TN(Mlb/yr)	TP(Mlb/yr)
Bay	156.7	36.93	4.69
DEQ (2016)	85.9	26.4	3.5
DEQ/Bay	55%	71%	75%
2006-2013	**TC (Mlb/yr)**	**TN(Mlb/yr)**	**TP(Mlb/yr)**
Bay	145.57	30.15	3.11
DEQ (2016)	78.4	21.2	2.49
DEQ/Bay	54%	70%	80%

Can we calibrate model to fit the observation data using different loadings?

Model Kinetic Processes

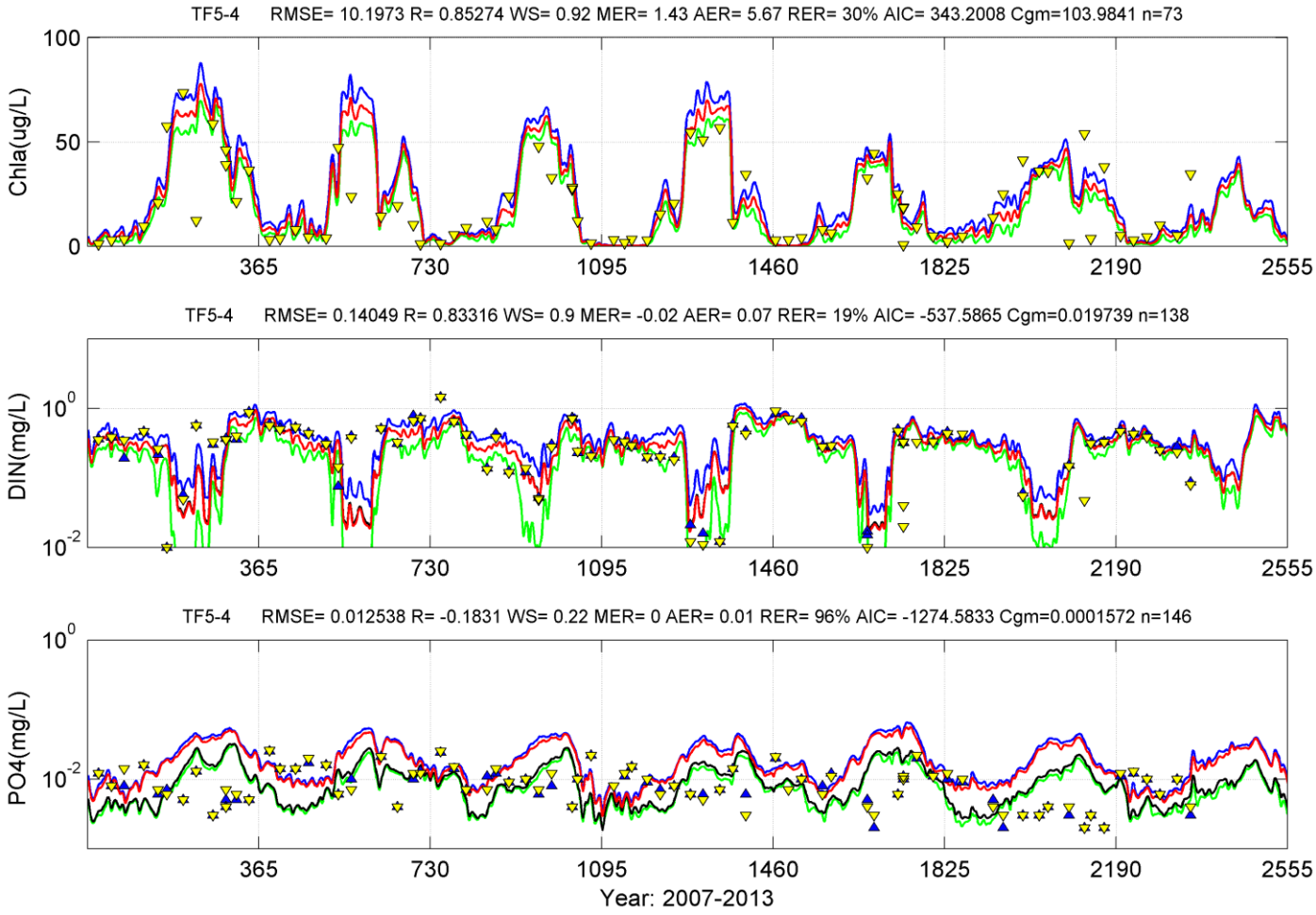


Model Configuration

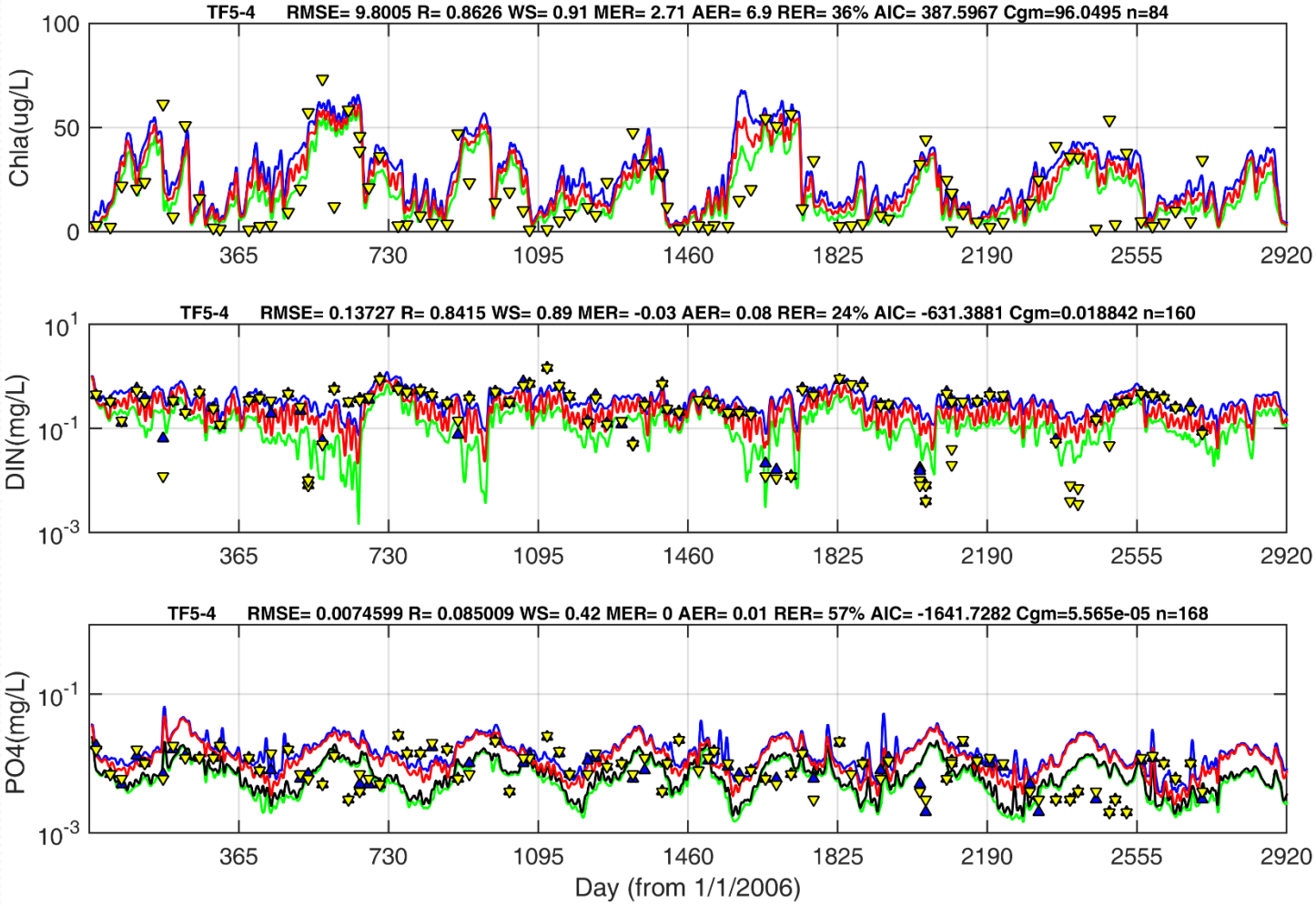
- Flow and loadings use WSM daily model outputs
  - POC, DOC, PON, DON, NH_4, NO_{23}, POP, DOP, PO_4, and DO
  - POC, DOC, PON, DON, POP, and DOP
- Solar radiation uses hourly observations at Norfolk and Richmond stations
- Open boundary condition
  - 1991-2000 uses Chesapeake Bay model outputs (tide, salinity, temperature, and water quality state variables
  - 2007-2013 uses observations and VIMS Bay model of salinity. Water quality state variables use interpolation of observations near the James River mouth.
- Hourly observed wind data are used for computing aeration.
- Suspended solids use spatially and temporally interpolated results based on observations.
- Initial condition for bottom sediment diagenesis model
  - Repeat simulations until dynamic equilibrium is reached.

Example of Model Calibration Using Different Loadings

2016 Loading



Bay 2017 Loading



Consideration of a Simple System

$$\frac{\partial \mathrm{N}}{\partial t} = L - FN - \frac{N}{N + N_h} GC + \gamma RC$$

$$\frac{\partial \mathrm{C}}{\partial t} = \frac{N}{N + N_h} GC - RC - FC$$

Steady State

N=DIN
L=DIN loading (mass/volume/day)
F=flushing rate
N_h=DIN half saturation rate
γ = nutrient recycle

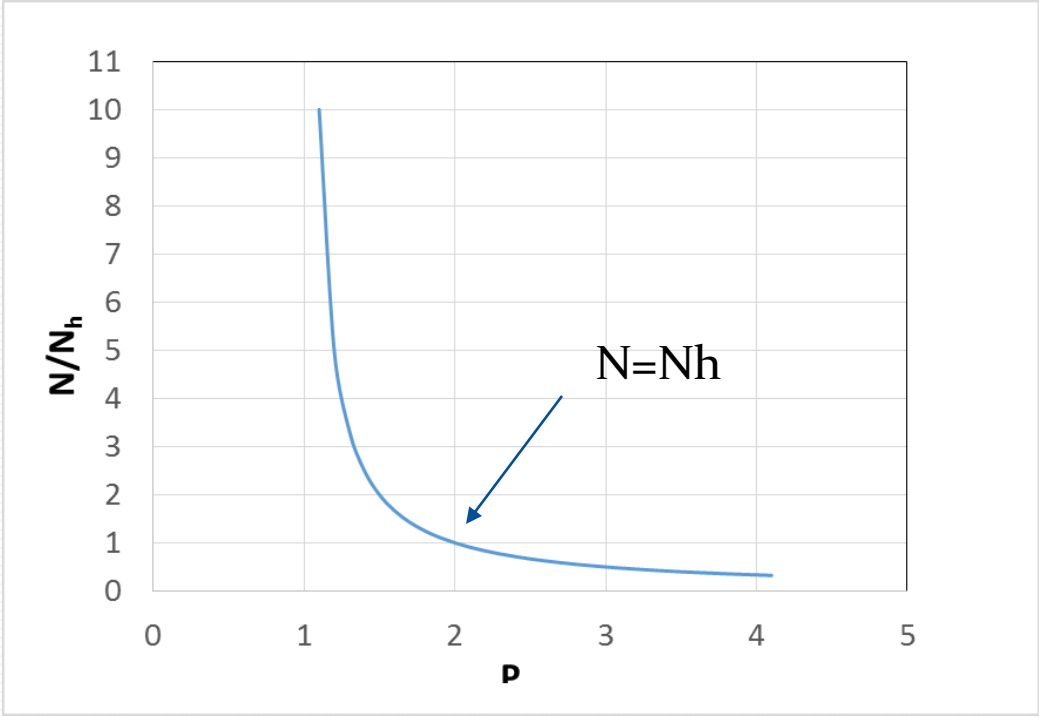
C= phytoplankton (nitrogen-based)
G= phytoplankton growth rate
R= total loss (respiration, mortality, settling)

$$\frac{N}{N + N_h} GC = (R + F)C$$

$$\frac{N}{N_h} = \frac{R + F}{G - (R + F)}$$

$$P = \frac{G}{R + F}$$

Nutrient Concentration



G=2(F+R), N=Nh

Example:
Residence time = 10 day
F=0.1
Respiration =0.1/d
Mortality =0.05/d
Settling =0.5 /d
R=0.65
G=1.3 /d

- It is possible to find a set of parameters to simulate DIN to its limiting level if nutrient is limited
- The parameter selection depends on dynamic conditions
- Parameters are correlated to each other

Phytoplankton Concentration

$$\frac{N}{N+N_h}=\frac{R+F}{G}=\frac{1}{P}$$

$$C=\frac{L-\mathrm{FN}}{(1-\gamma)R+F}$$

Assume load L is reduced to k*L* (k<1)

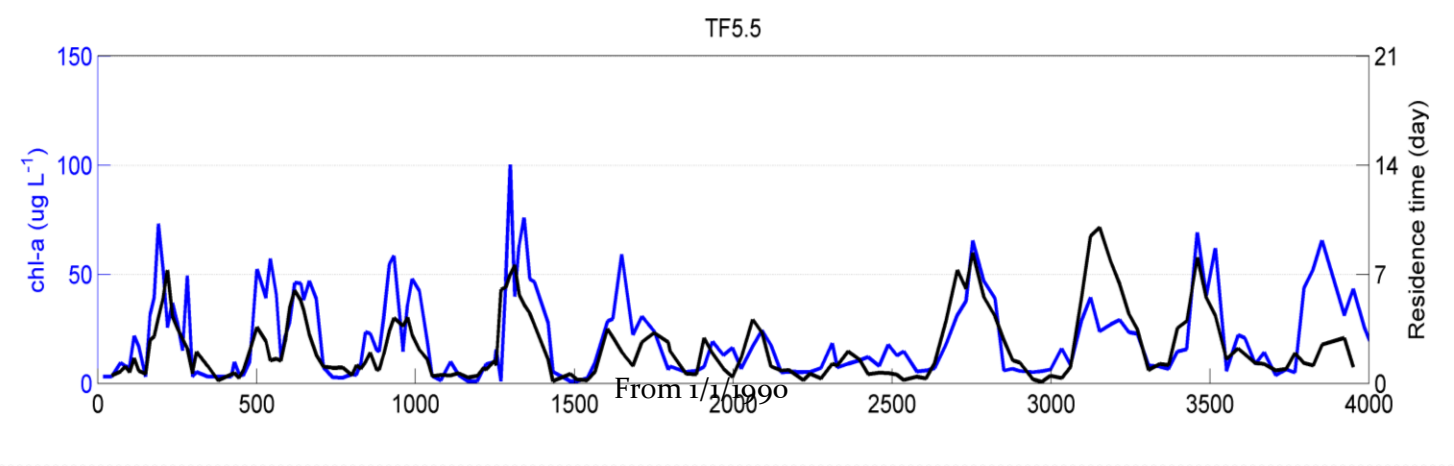
$$C1=\frac{kL-FN}{(1-\gamma)R+F}$$

$$C-C1=\frac{(1-k)L}{(1-\gamma)R+F}$$

$$\frac{C-C1}{C}=\frac{(1-k)L}{L-\mathrm{FN}}$$

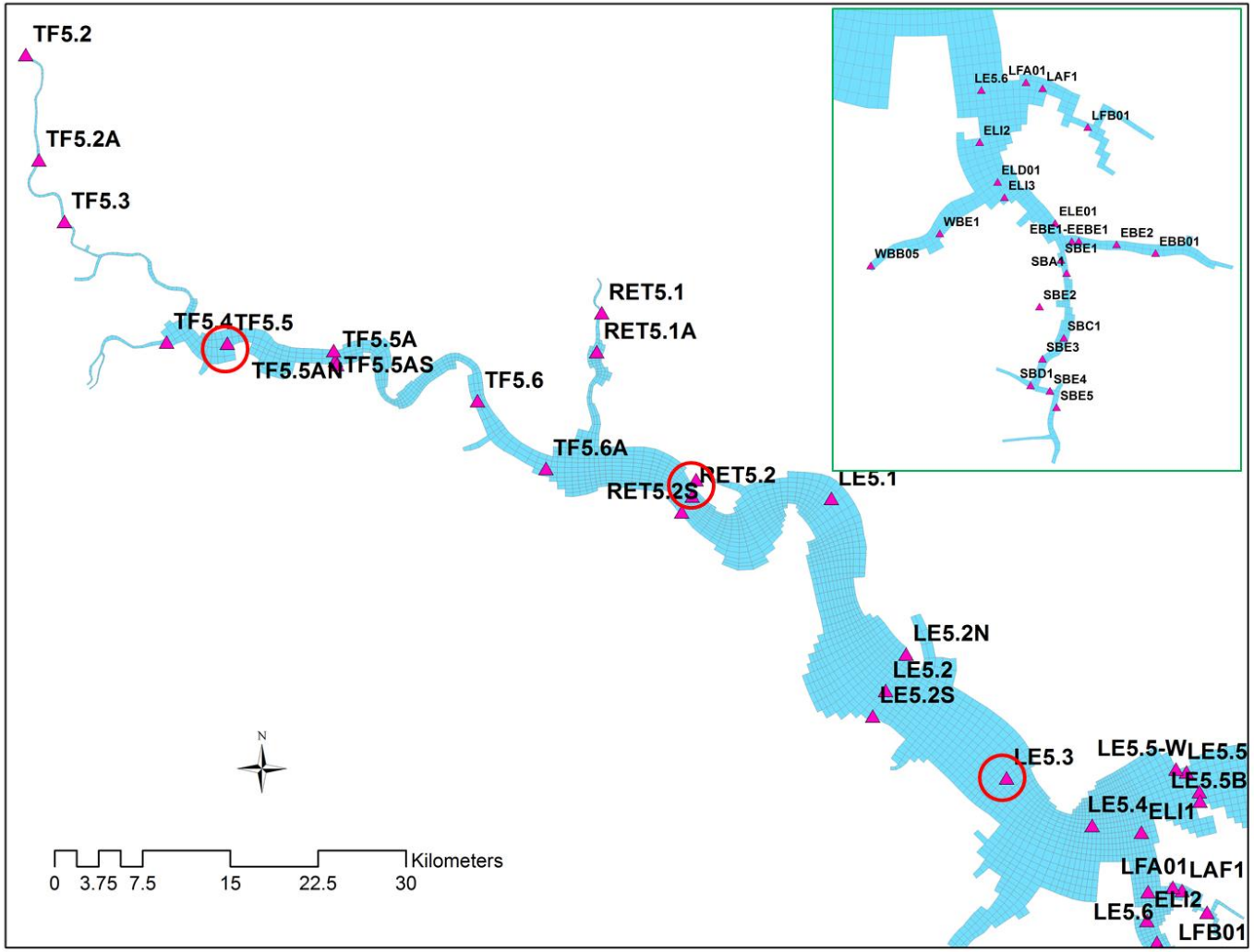
- The results show that the response of phytoplankton reduction depends on the flushing rate (residence time τ= 1/F)
- If a model has a short residence time, the phytoplankton concentration is more sensitive to the load reduction than a long residence time model

High Correlation of Residence Time and Phytoplankton Concentration



Model Results

- 2007-2013
- 1991-2000
- Stations:
  - TF5.1
  - RET5.2
  - LE5.3



Model Skill Assessment Criteria

- Model-data graphic comparison
  - Direct comparison
  - Scatter plots
  - Accumulative distribution
  - Error distribution
- Statistics
  - Correlation (R)
  - Root-mean-square error (ER)
  - Model Skill (SS, WS)
  - Mean error (ME)
  - Absolut mean error (AME)
  - Relative error (RE)
- Processes
  - Primary production
  - Respiration
  - Net ecosystem metabolism

$$ER = \sqrt{\frac{\sum_{k=1}^{n}(P_k - O_k)^2}{n}}$$

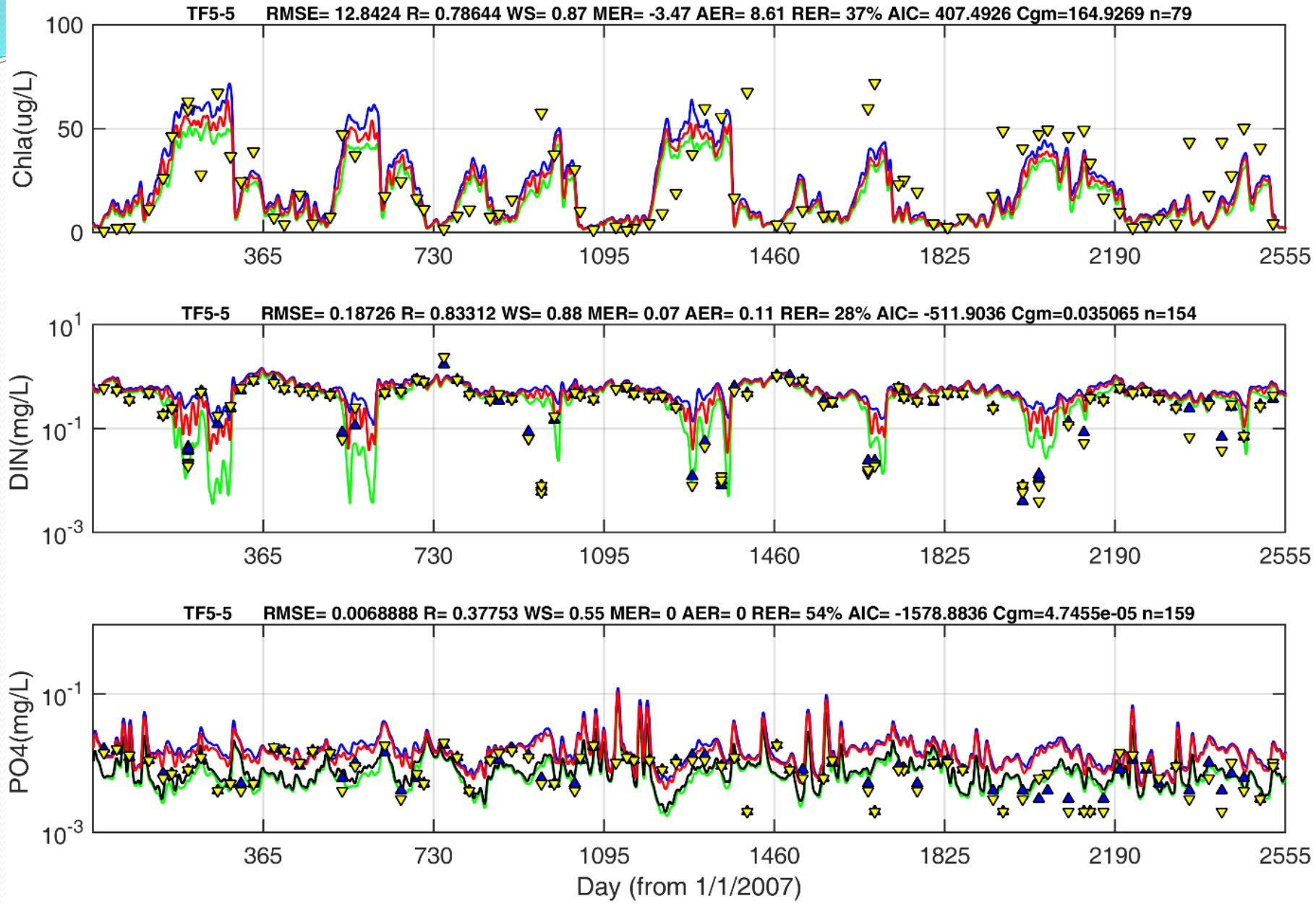
$$SS = 1 - \frac{\sum_{k=1}^{n}(P_k - O_k)^2}{\sum_{k=1}^{n}(O_k - \bar{O})^2}$$

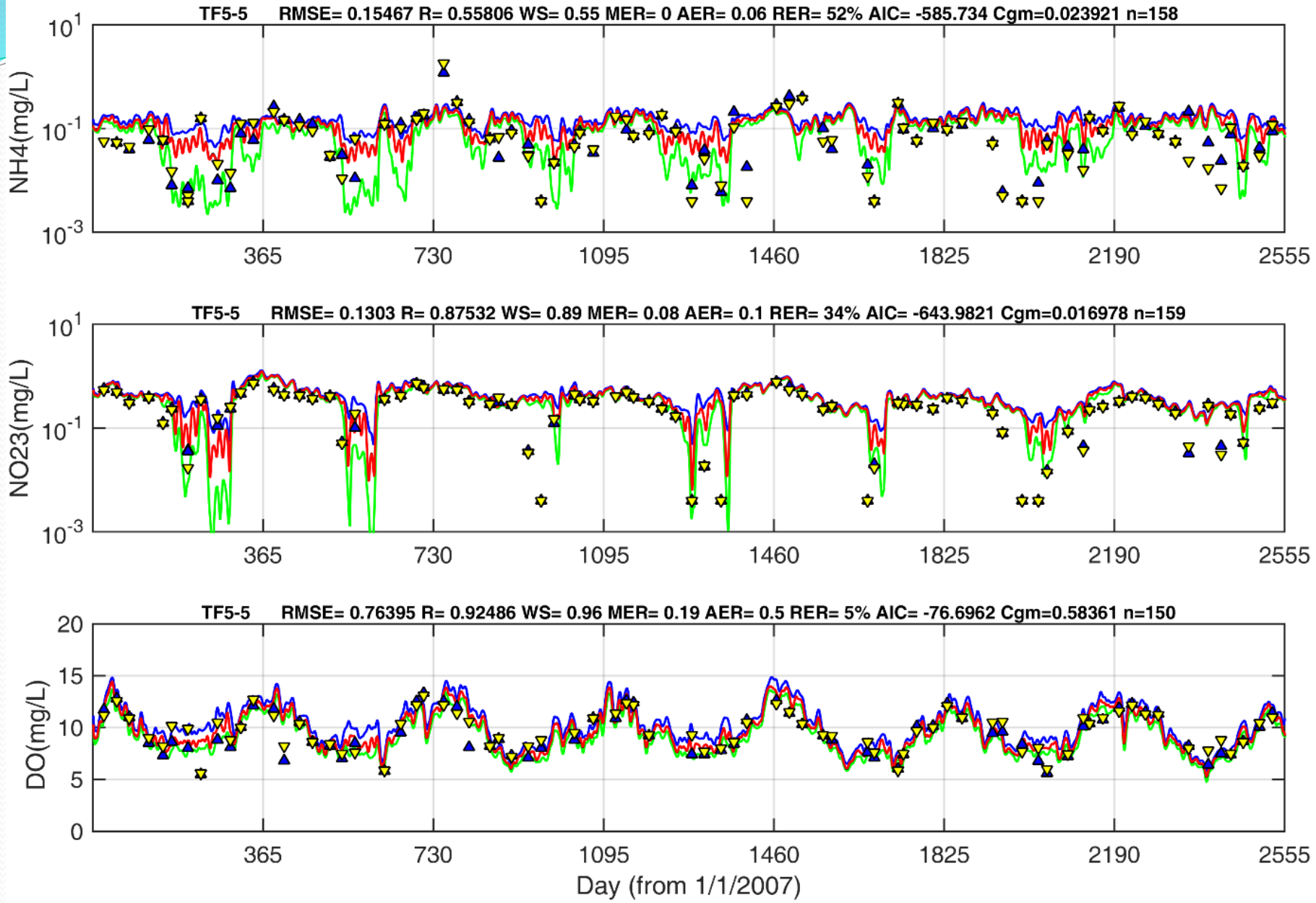
$$WS = 1 - \frac{\sum_{k=1}^{n}(P_k - O_k)^2}{\sum_{k=1}^{n}(P_k - \bar{P})^2}$$

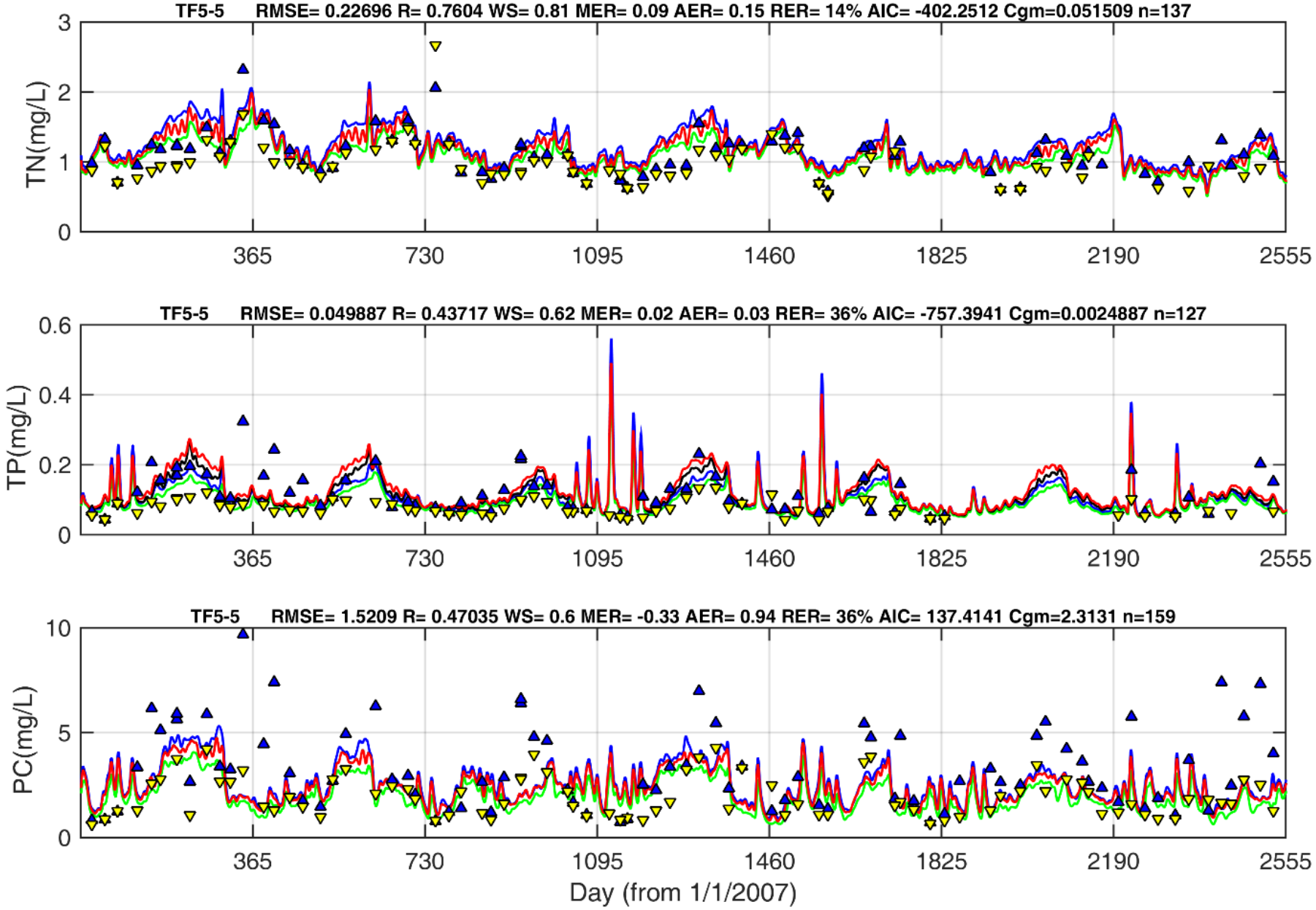
$$\mathrm{ME} = \sum_{k=1}^{n}(P_k - \mathrm{O}_k)/\mathrm{N}$$

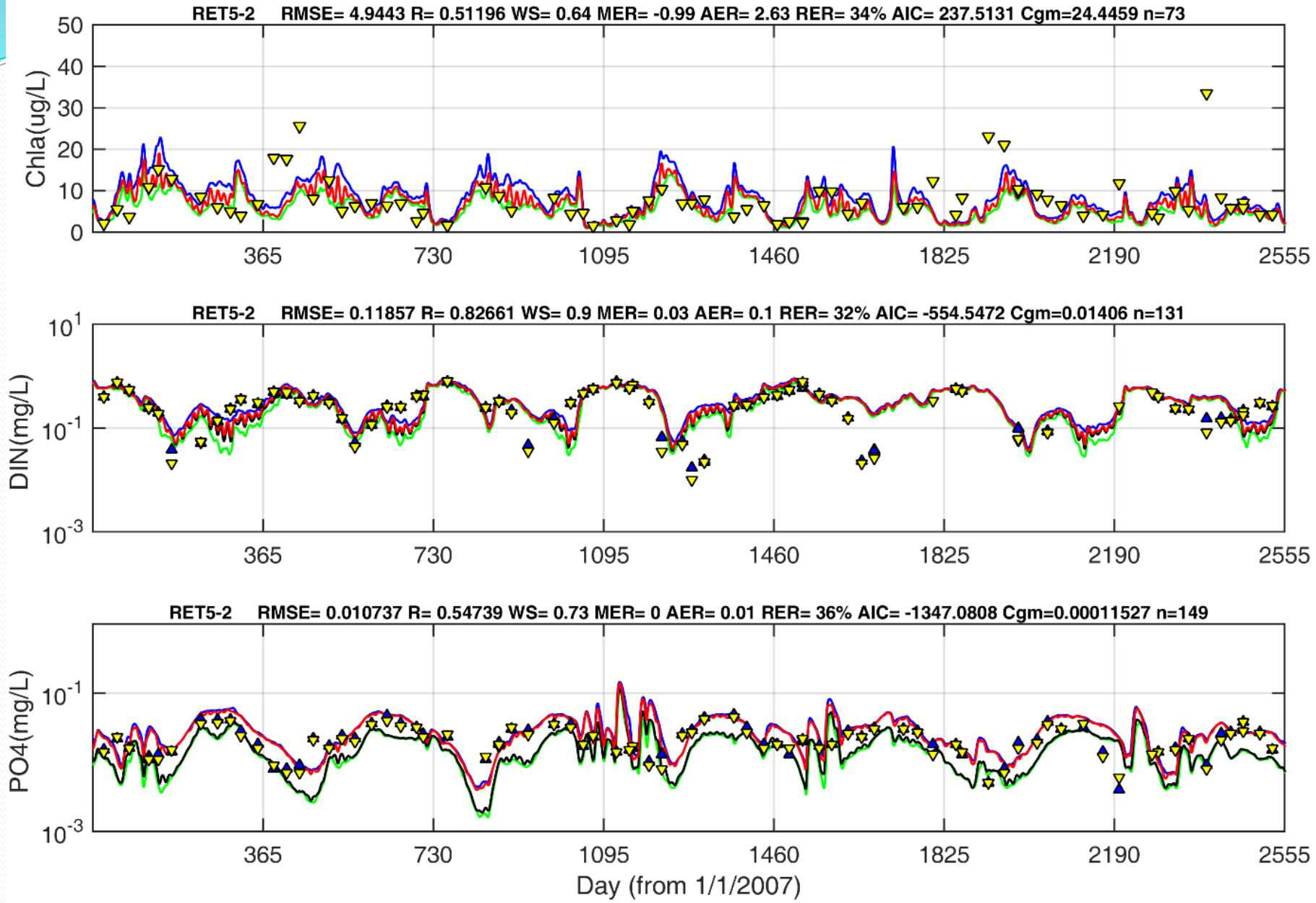
$$\mathrm{AME} = \sum_{k=1}^{n}|P_k - \mathrm{O}_k|/\mathrm{N}$$

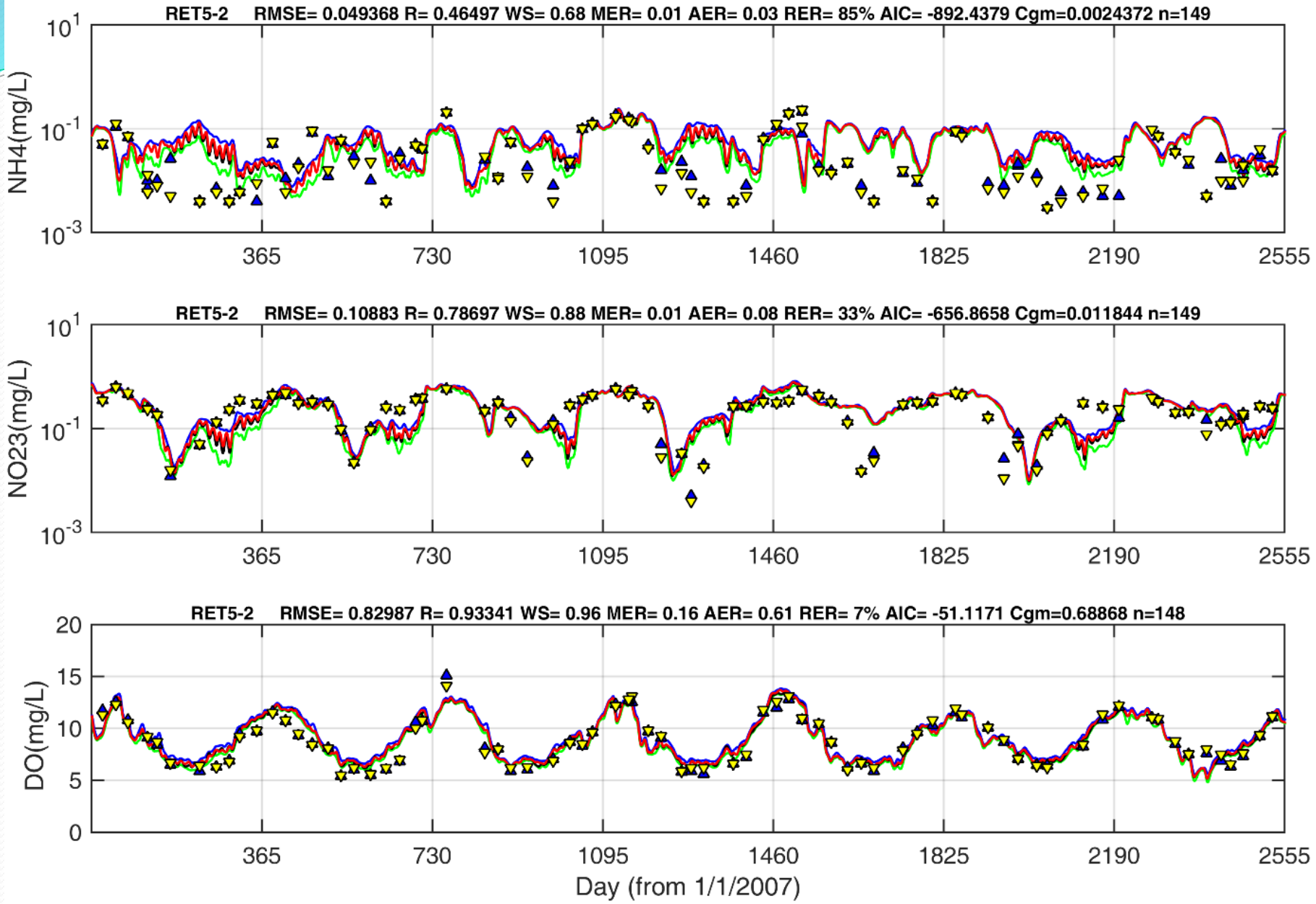
$$RE = \frac{\sum_{k=1}^{n}|P_k - O_k|}{\sum_{k=1}^{n} O_k}$$

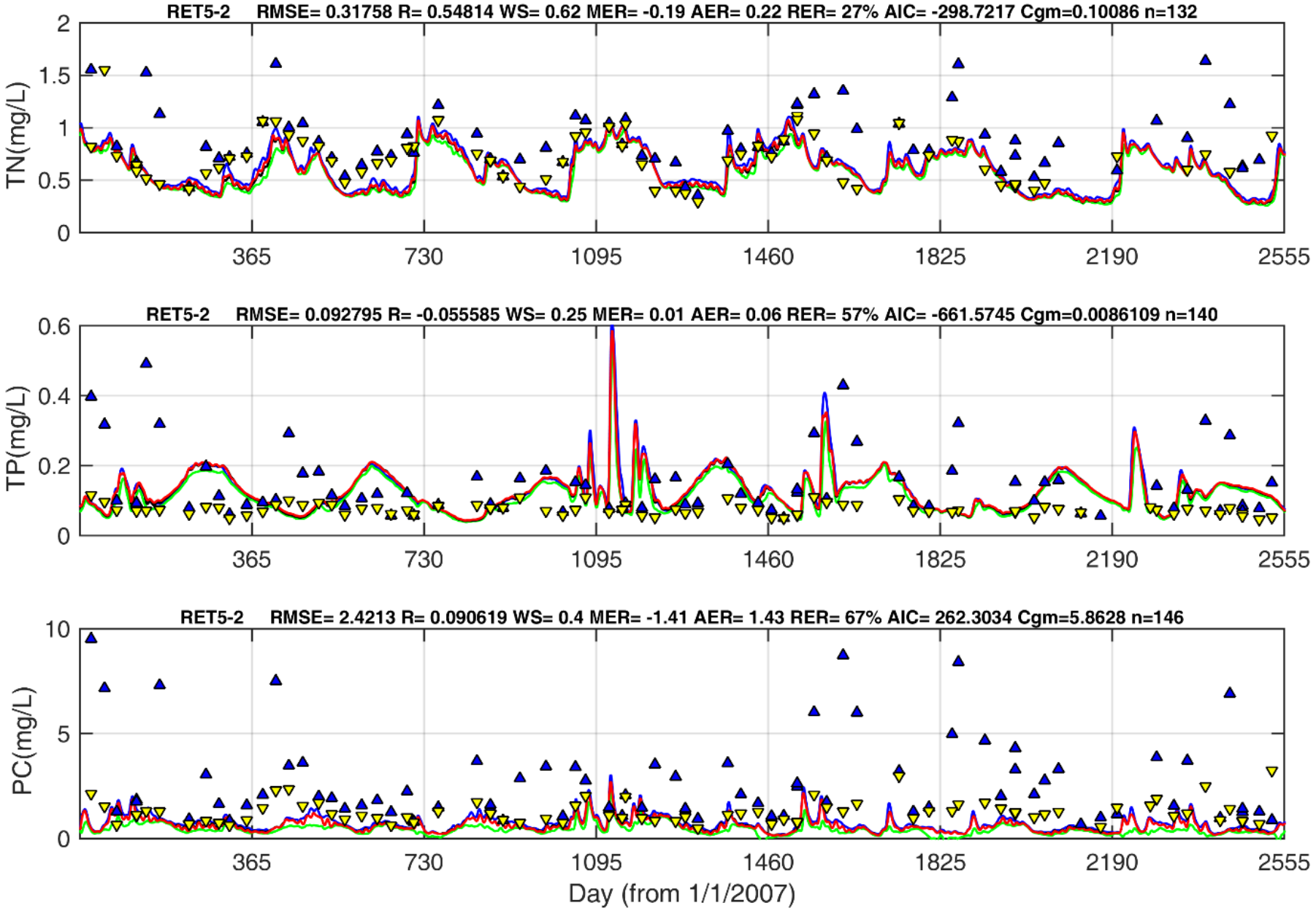

TF5-5 RMSE= 12.8424 R= 0.78644 WS= 0.87 MER= -3.47 AER= 8.61 RER= 37% AIC= 407.4926 Cgm=164.9269 n=79
Chla(ug/L)
100
50
0
365
730
1095
1460
1825
2190
2555
TF5-5 RMSE= 0.18726 R= 0.83312 WS= 0.88 MER= 0.07 AER= 0.11 RER= 28% AIC= -511.9036 Cgm=0.035065 n=154
DIN(mg/L)
10^1
10^-1
10^-3
365
730
1095
1460
1825
2190
2555
TF5-5 RMSE= 0.0068888 R= 0.37753 WS= 0.55 MER= 0 AER= 0 RER= 54% AIC= -1578.8836 Cgm=4.7455e-05 n=159
PO4(mg/L)
10^-1
10^-3
365
730
1095
1460
1825
2190
2555
Day (from 1/1/2007)

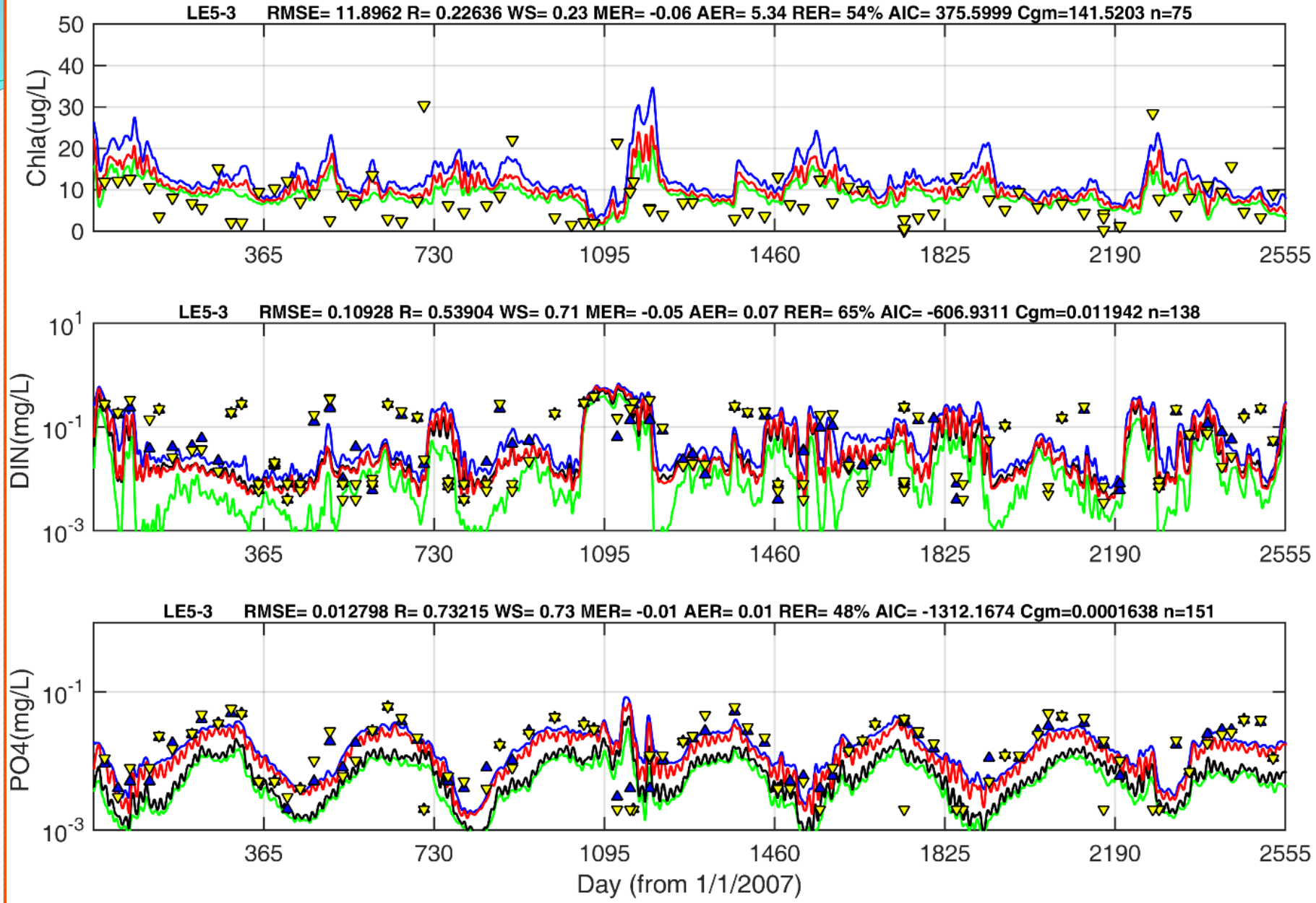

TF5-5 RMSE= 0.15467 R= 0.55806 WS= 0.55 MER= 0 AER= 0.06 RER= 52% AIC= -585.734 Cgm=0.023921 n=158
NH4(mg/L)
TF5-5 RMSE= 0.1303 R= 0.87532 WS= 0.89 MER= 0.08 AER= 0.1 RER= 34% AIC= -643.9821 Cgm=0.016978 n=159
NO23(mg/L)
TF5-5 RMSE= 0.76395 R= 0.92486 WS= 0.96 MER= 0.19 AER= 0.5 RER= 5% AIC= -76.6962 Cgm=0.58361 n=150
DO(mg/L)
365
730
1095
1460
1825
2190
2555
Day (from 1/1/2007)

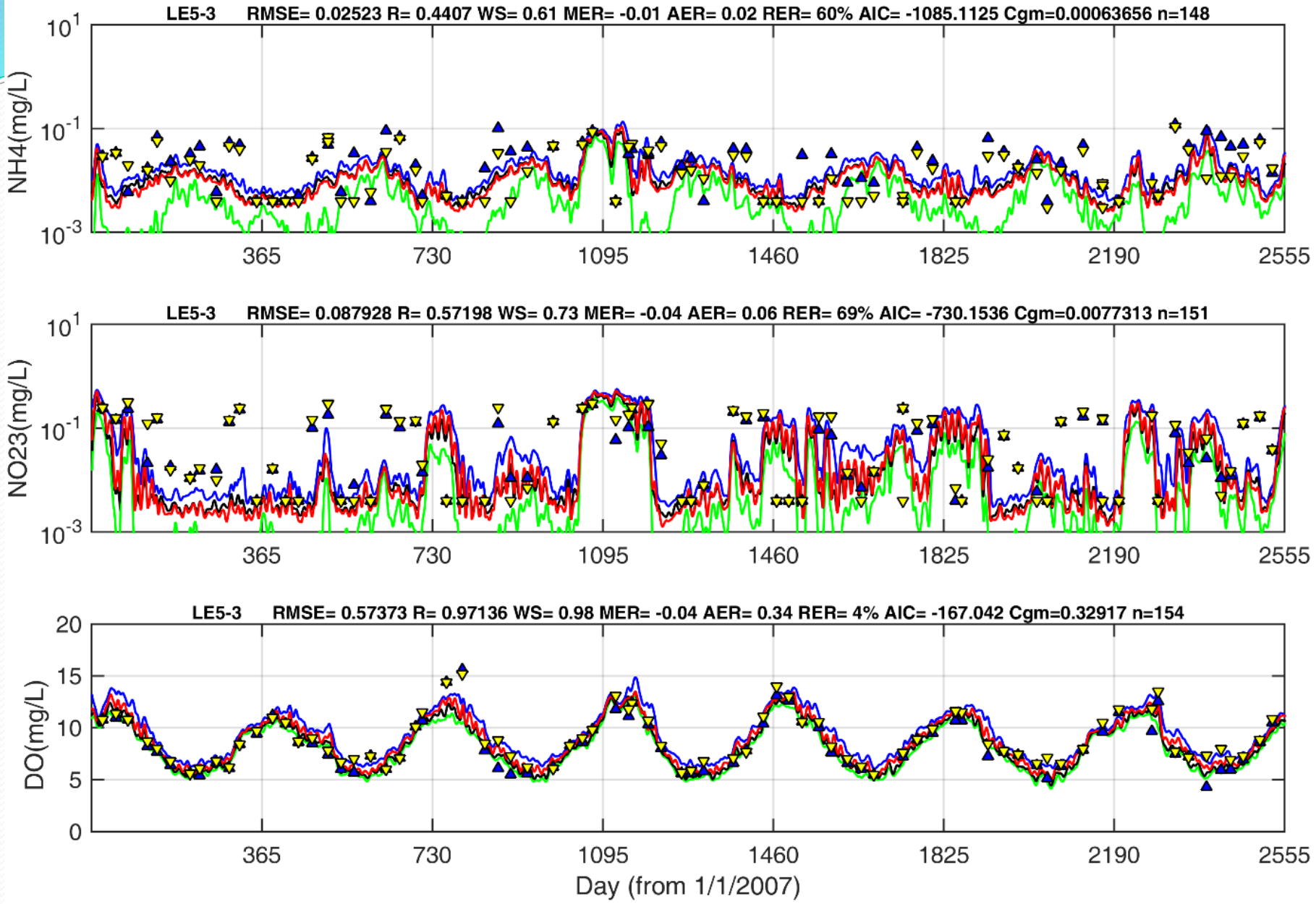

TF5-5 RMSE= 0.22696 R= 0.7604 WS= 0.81 MER= 0.09 AER= 0.15 RER= 14% AIC= -402.2512 Cgm=0.051509 n=137
TN(mg/L)
0
1
2
3
365
730
1095
1460
1825
2190
2555
TF5-5 RMSE= 0.049887 R= 0.43717 WS= 0.62 MER= 0.02 AER= 0.03 RER= 36% AIC= -757.3941 Cgm=0.0024887 n=127
TP(mg/L)
0
0.2
0.4
0.6
365
730
1095
1460
1825
2190
2555
TF5-5 RMSE= 1.5209 R= 0.47035 WS= 0.6 MER= -0.33 AER= 0.94 RER= 36% AIC= 137.4141 Cgm=2.3131 n=159
PC(mg/L)
0
5
10
365
730
1095
1460
1825
2190
2555
Day (from 1/1/2007)

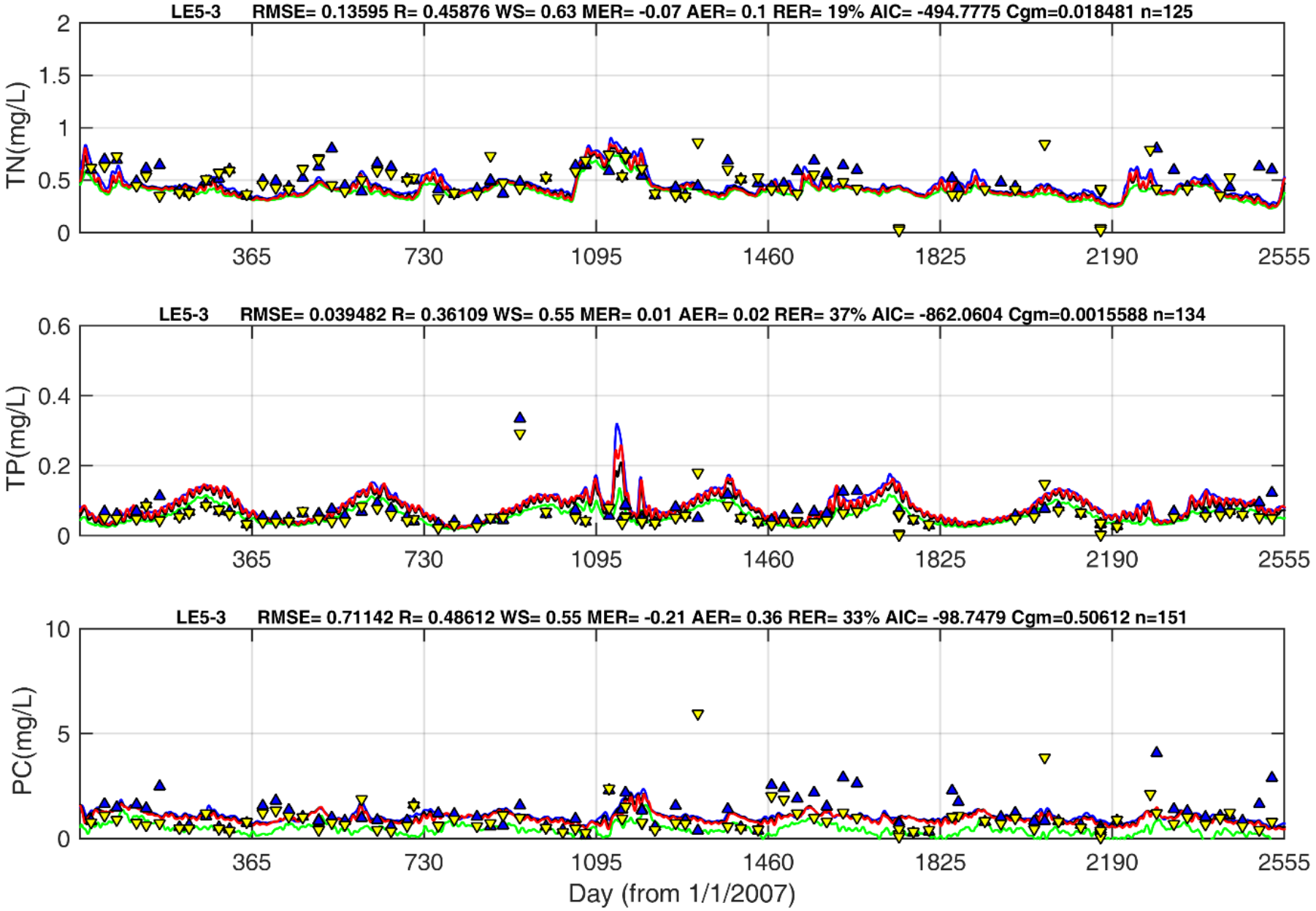

RET5-2 RMSE= 4.9443 R= 0.51196 WS= 0.64 MER= -0.99 AER= 2.63 RER= 34% AIC= 237.5131 Cgm=24.4459 n=73
Chla(ug/L)
50
40
30
20
10
0
365
730
1095
1460
1825
2190
2555
RET5-2 RMSE= 0.11857 R= 0.82661 WS= 0.9 MER= 0.03 AER= 0.1 RER= 32% AIC= -554.5472 Cgm=0.01406 n=131
DIN(mg/L)
10^{1}
10^{-1}
10^{-3}
365
730
1095
1460
1825
2190
2555
RET5-2 RMSE= 0.010737 R= 0.54739 WS= 0.73 MER= 0 AER= 0.01 RER= 36% AIC= -1347.0808 Cgm=0.00011527 n=149
PO4(mg/L)
10^{-1}
10^{-3}
365
730
1095
1460
1825
2190
2555
Day (from 1/1/2007)

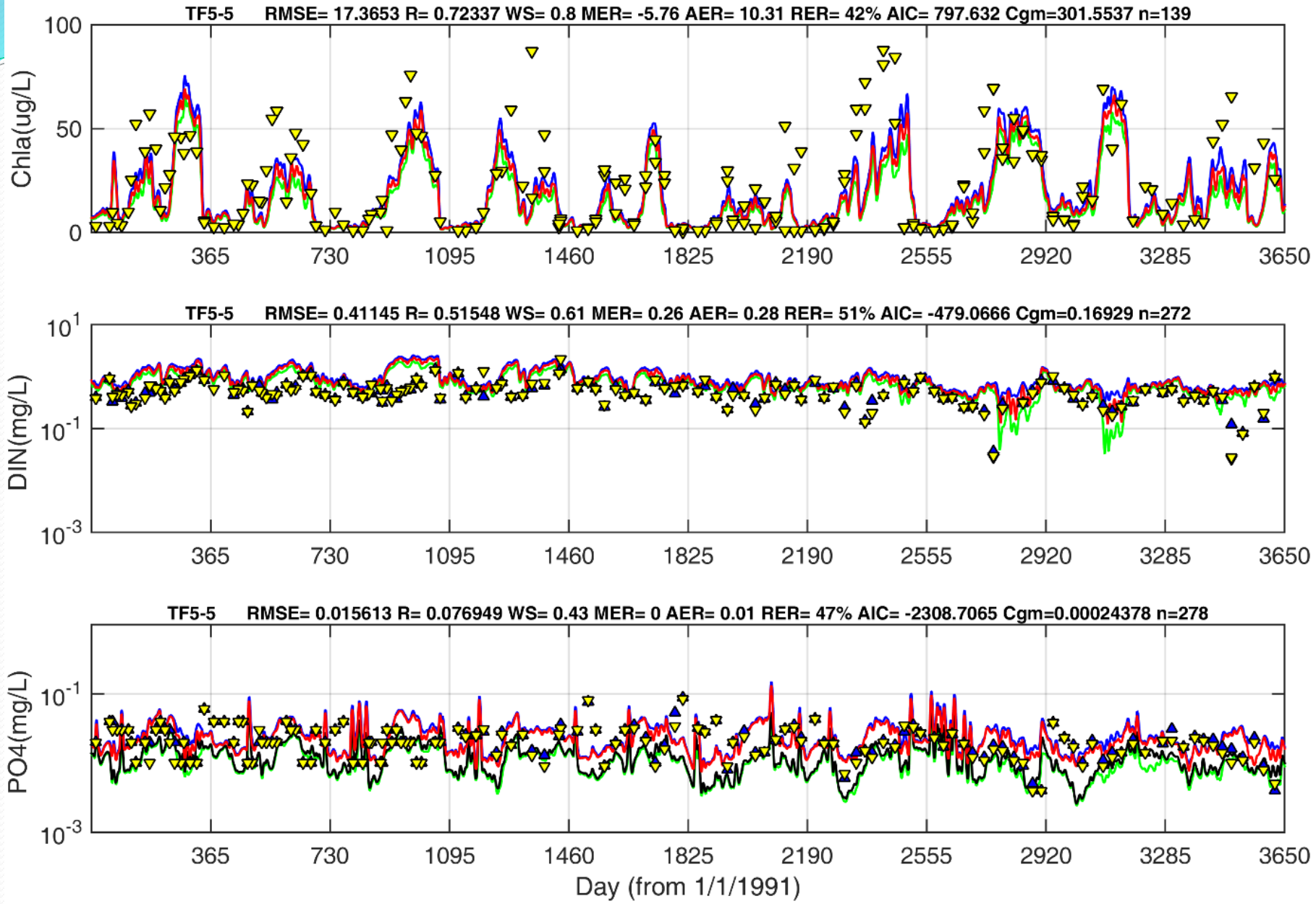

RET5-2 RMSE= 0.049368 R= 0.46497 WS= 0.68 MER= 0.01 AER= 0.03 RER= 85% AIC= -892.4379 Cgm=0.0024372 n=149
NH4(mg/L)
RET5-2 RMSE= 0.10883 R= 0.78697 WS= 0.88 MER= 0.01 AER= 0.08 RER= 33% AIC= -656.8658 Cgm=0.011844 n=149
NO23(mg/L)
RET5-2 RMSE= 0.82987 R= 0.93341 WS= 0.96 MER= 0.16 AER= 0.61 RER= 7% AIC= -51.1171 Cgm=0.68868 n=148
DO(mg/L)
365
730
1095
1460
1825
2190
2555
Day (from 1/1/2007)

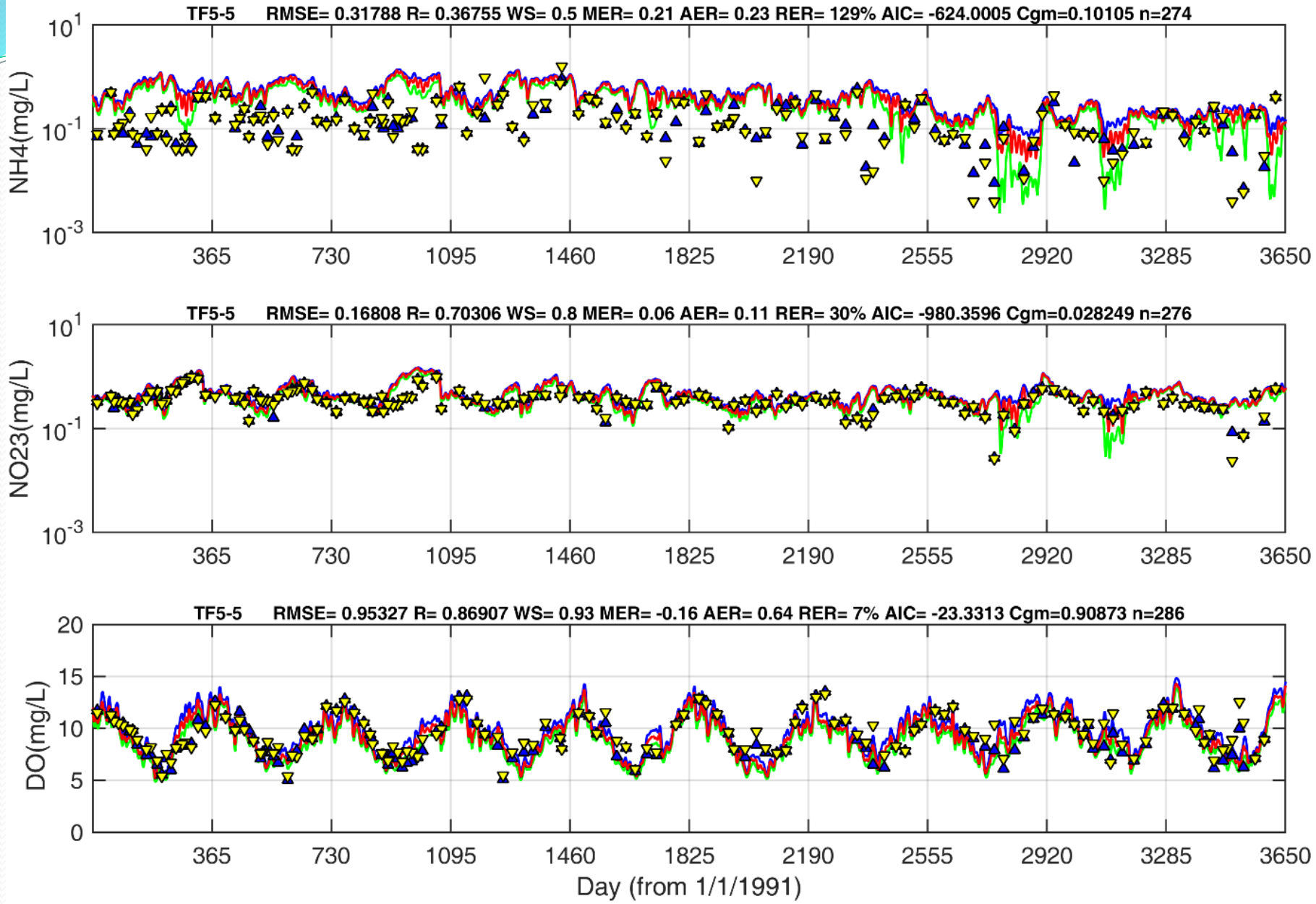

RET5-2 RMSE= 0.31758 R= 0.54814 WS= 0.62 MER= -0.19 AER= 0.22 RER= 27% AIC= -298.7217 Cgm=0.10086 n=132
TN(mg/L)
RET5-2 RMSE= 0.092795 R= -0.055585 WS= 0.25 MER= 0.01 AER= 0.06 RER= 57% AIC= -661.5745 Cgm=0.0086109 n=140
TP(mg/L)
RET5-2 RMSE= 2.4213 R= 0.090619 WS= 0.4 MER= -1.41 AER= 1.43 RER= 67% AIC= 262.3034 Cgm=5.8628 n=146
PC(mg/L)
365
730
1095
1460
1825
2190
2555
Day (from 1/1/2007)

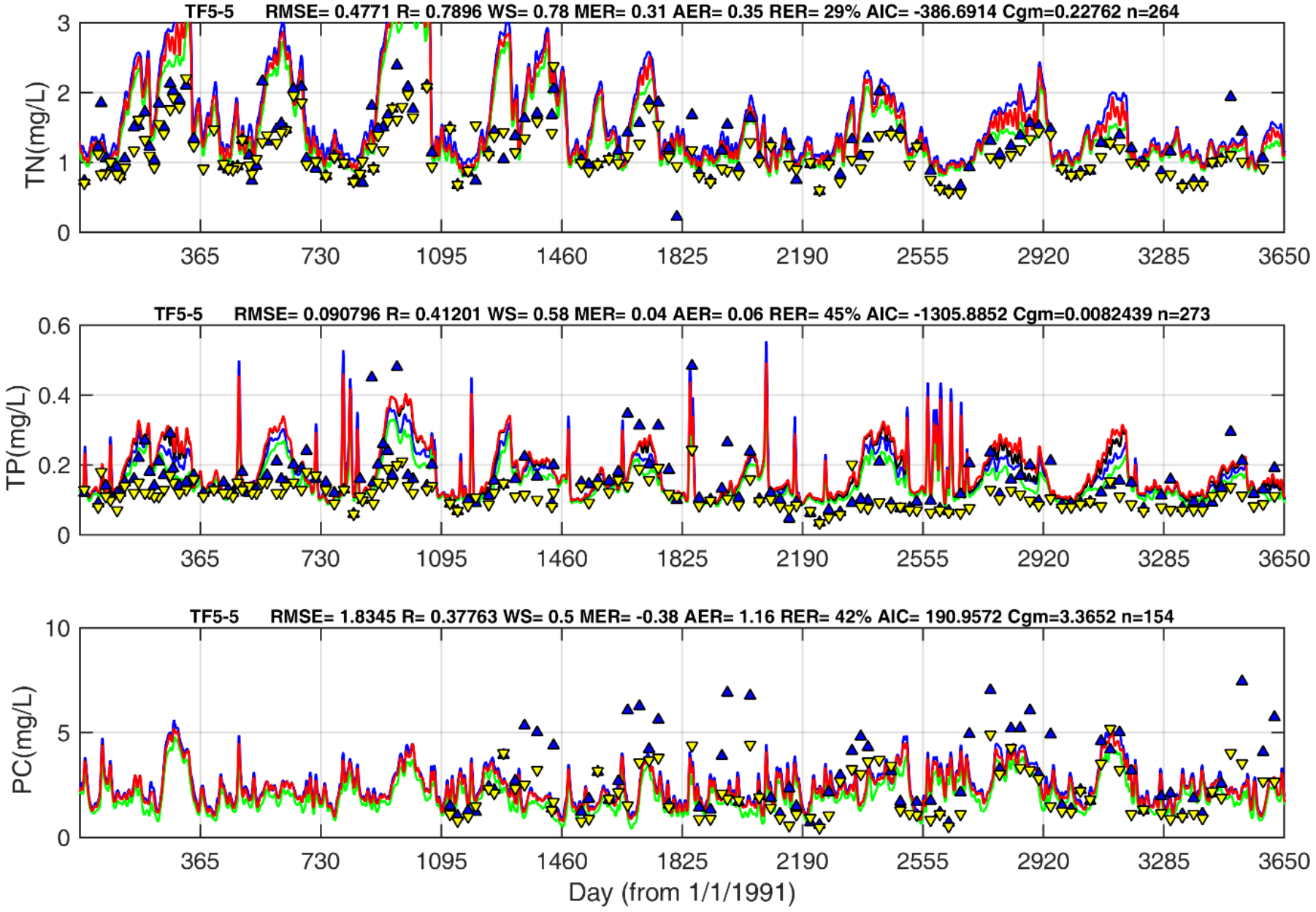

LE5-3 RMSE= 11.8962 R= 0.22636 WS= 0.23 MER= -0.06 AER= 5.34 RER= 54% AIC= 375.5999 Cgm=141.5203 n=75
Chla(ug/L)
50
40
30
20
10
0
365
730
1095
1460
1825
2190
2555
LE5-3 RMSE= 0.10928 R= 0.53904 WS= 0.71 MER= -0.05 AER= 0.07 RER= 65% AIC= -606.9311 Cgm=0.011942 n=138
DIN(mg/L)
10^1
10^-1
10^-3
365
730
1095
1460
1825
2190
2555
LE5-3 RMSE= 0.012798 R= 0.73215 WS= 0.73 MER= -0.01 AER= 0.01 RER= 48% AIC= -1312.1674 Cgm=0.0001638 n=151
PO4(mg/L)
10^-1
10^-3
365
730
1095
1460
1825
2190
2555
Day (from 1/1/2007)

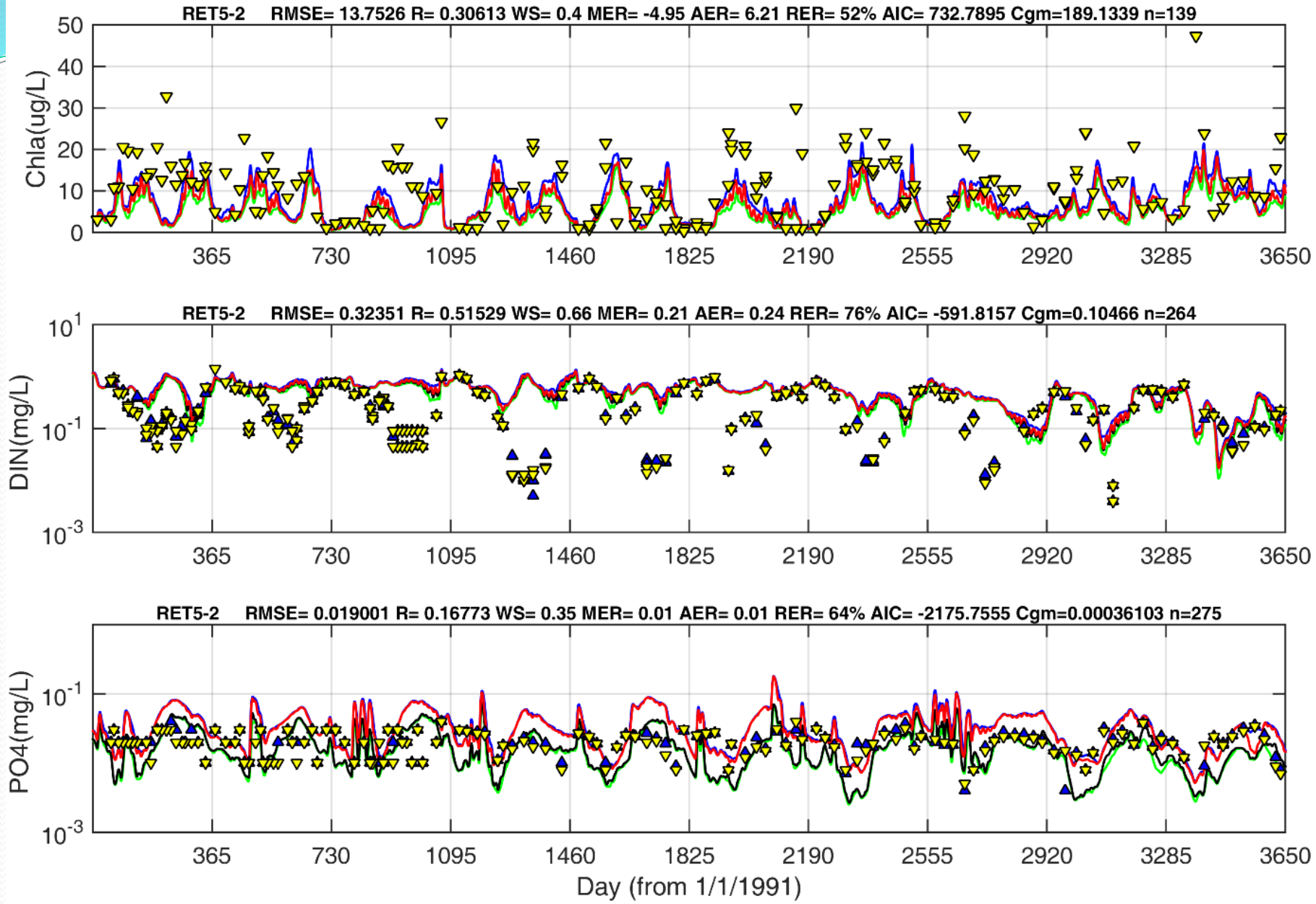

LE5-3 RMSE= 0.02523 R= 0.4407 WS= 0.61 MER= -0.01 AER= 0.02 RER= 60% AIC= -1085.1125 Cgm=0.00063656 n=148
NH4(mg/L)
LE5-3 RMSE= 0.087928 R= 0.57198 WS= 0.73 MER= -0.04 AER= 0.06 RER= 69% AIC= -730.1536 Cgm=0.0077313 n=151
NO23(mg/L)
LE5-3 RMSE= 0.57373 R= 0.97136 WS= 0.98 MER= -0.04 AER= 0.34 RER= 4% AIC= -167.042 Cgm=0.32917 n=154
DO(mg/L)
365
730
1095
1460
1825
2190
2555
Day (from 1/1/2007)

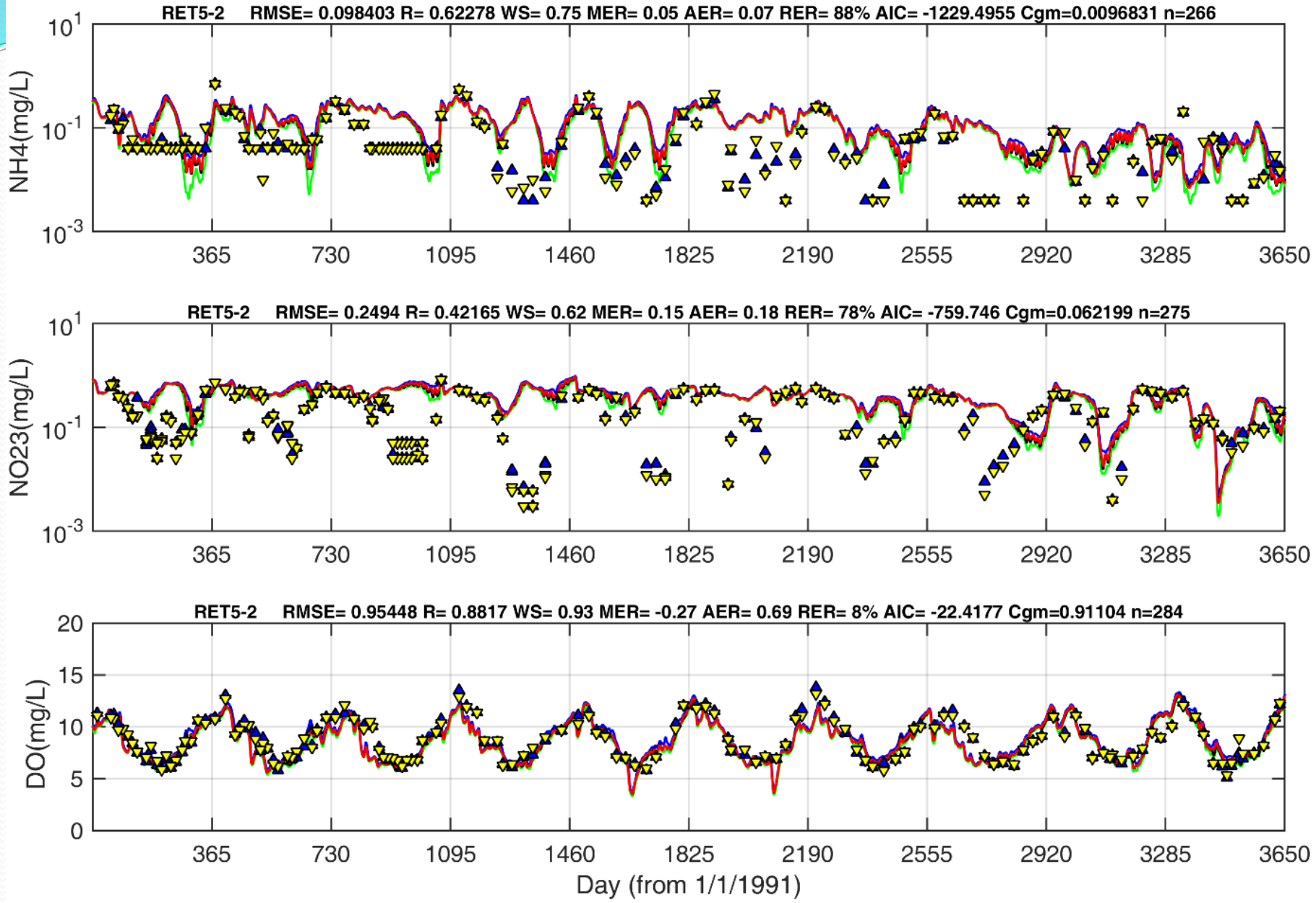

LE5-3 RMSE= 0.13595 R= 0.45876 WS= 0.63 MER= -0.07 AER= 0.1 RER= 19% AIC= -494.7775 Cgm=0.018481 n=125
TN(mg/L)
2
1.5
1
0.5
0
365
730
1095
1460
1825
2190
2555
LE5-3 RMSE= 0.039482 R= 0.36109 WS= 0.55 MER= 0.01 AER= 0.02 RER= 37% AIC= -862.0604 Cgm=0.0015588 n=134
TP(mg/L)
0.6
0.4
0.2
0
365
730
1095
1460
1825
2190
2555
LE5-3 RMSE= 0.71142 R= 0.48612 WS= 0.55 MER= -0.21 AER= 0.36 RER= 33% AIC= -98.7479 Cgm=0.50612 n=151
PC(mg/L)
10
5
0
365
730
1095
1460
1825
2190
2555
Day (from 1/1/2007)

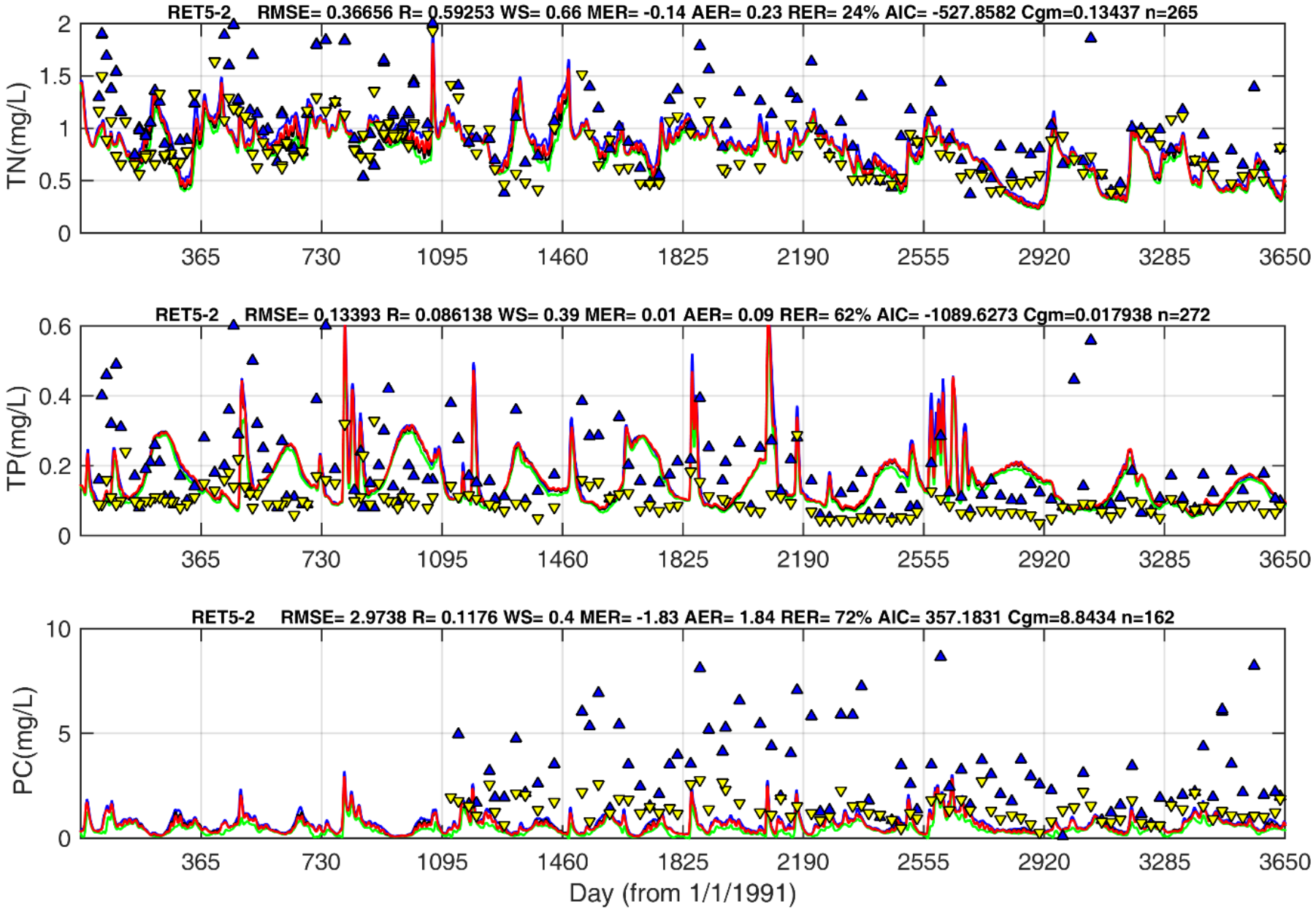

TF5-5 RMSE= 17.3653 R= 0.72337 WS= 0.8 MER= -5.76 AER= 10.31 RER= 42% AIC= 797.632 Cgm=301.5537 n=139
Chla(ug/L)
100
50
0
365
730
1095
1460
1825
2190
2555
2920
3285
3650
TF5-5 RMSE= 0.41145 R= 0.51548 WS= 0.61 MER= 0.26 AER= 0.28 RER= 51% AIC= -479.0666 Cgm=0.16929 n=272
DIN(mg/L)
10^1
10^-1
10^-3
365
730
1095
1460
1825
2190
2555
2920
3285
3650
TF5-5 RMSE= 0.015613 R= 0.076949 WS= 0.43 MER= 0 AER= 0.01 RER= 47% AIC= -2308.7065 Cgm=0.00024378 n=278
PO4(mg/L)
10^-1
10^-3
365
730
1095
1460
1825
2190
2555
2920
3285
3650
Day (from 1/1/1991)

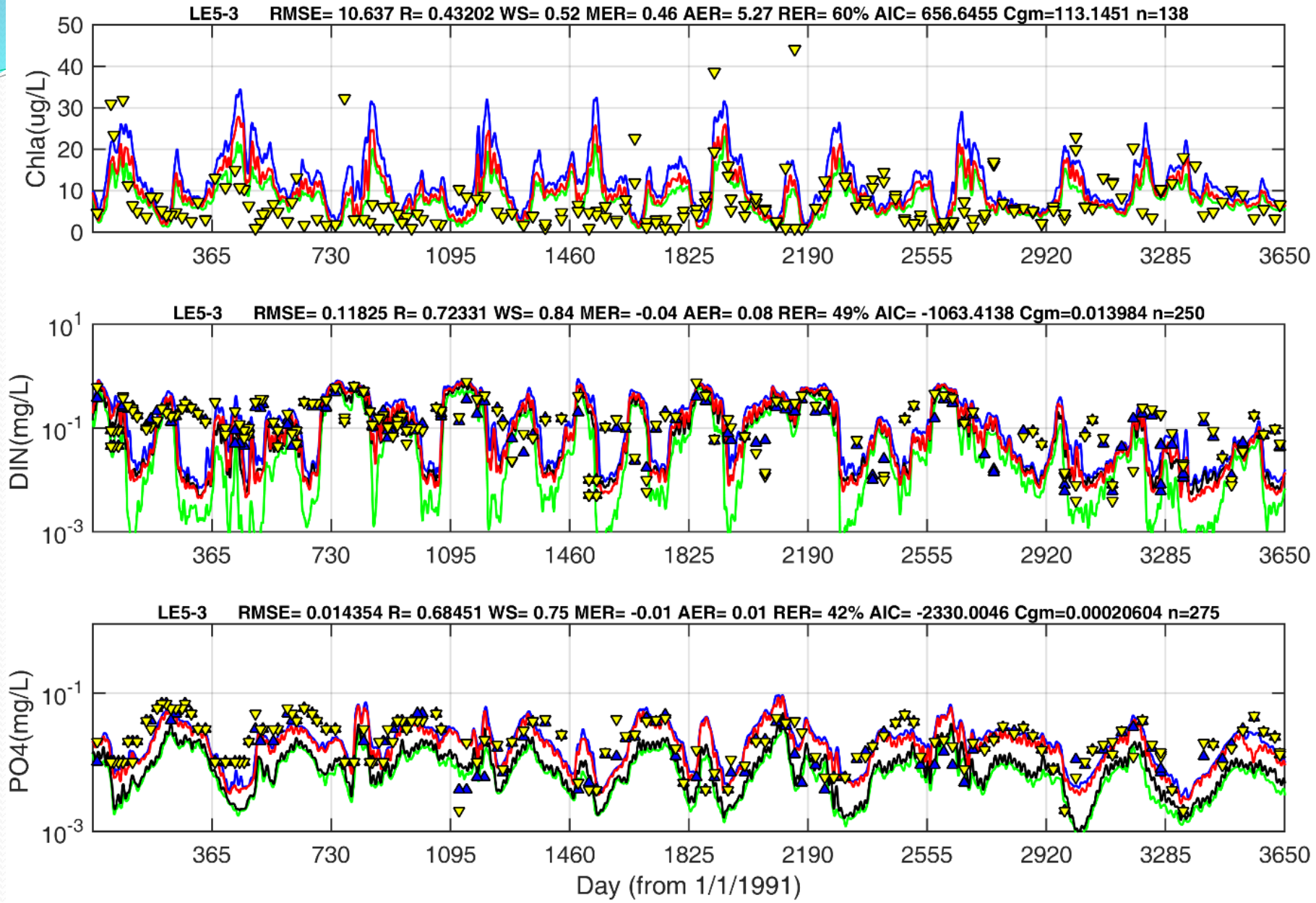

TF5-5 RMSE= 0.31788 R= 0.36755 WS= 0.5 MER= 0.21 AER= 0.23 RER= 129% AIC= -624.0005 Cgm=0.10105 n=274
NH4(mg/L)
TF5-5 RMSE= 0.16808 R= 0.70306 WS= 0.8 MER= 0.06 AER= 0.11 RER= 30% AIC= -980.3596 Cgm=0.028249 n=276
NO23(mg/L)
TF5-5 RMSE= 0.95327 R= 0.86907 WS= 0.93 MER= -0.16 AER= 0.64 RER= 7% AIC= -23.3313 Cgm=0.90873 n=286
DO(mg/L)
365 730 1095 1460 1825 2190 2555 2920 3285 3650
Day (from 1/1/1991)

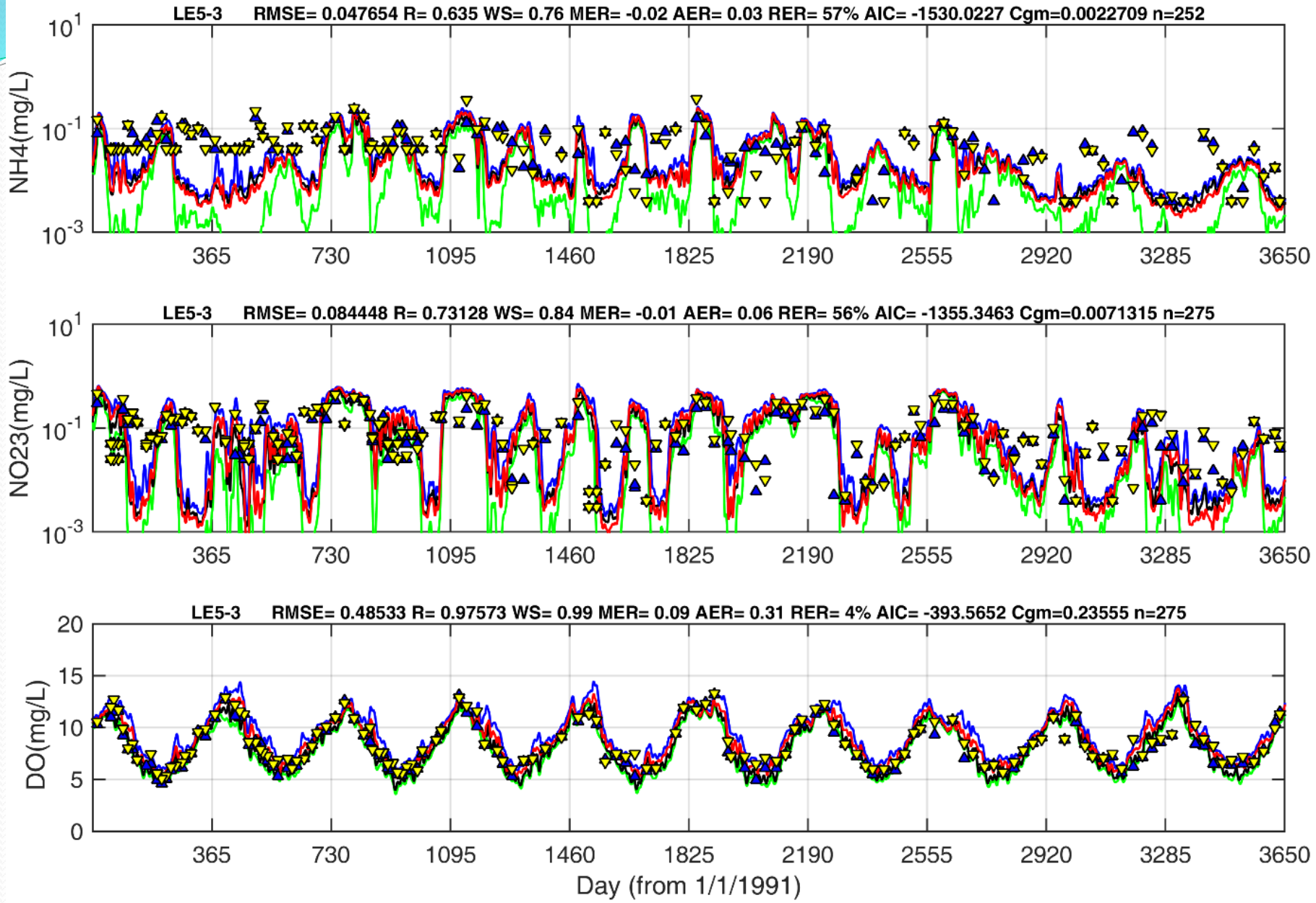

TF5-5 RMSE= 0.4771 R= 0.7896 WS= 0.78 MER= 0.31 AER= 0.35 RER= 29% AIC= -386.6914 Cgm=0.22762 n=264
TN(mg/L)
0
1
2
3
365
730
1095
1460
1825
2190
2555
2920
3285
3650
TF5-5 RMSE= 0.090796 R= 0.41201 WS= 0.58 MER= 0.04 AER= 0.06 RER= 45% AIC= -1305.8852 Cgm=0.0082439 n=273
TP(mg/L)
0
0.2
0.4
0.6
365
730
1095
1460
1825
2190
2555
2920
3285
3650
TF5-5 RMSE= 1.8345 R= 0.37763 WS= 0.5 MER= -0.38 AER= 1.16 RER= 42% AIC= 190.9572 Cgm=3.3652 n=154
PC(mg/L)
0
5
10
365
730
1095
1460
1825
2190
2555
2920
3285
3650
Day (from 1/1/1991)

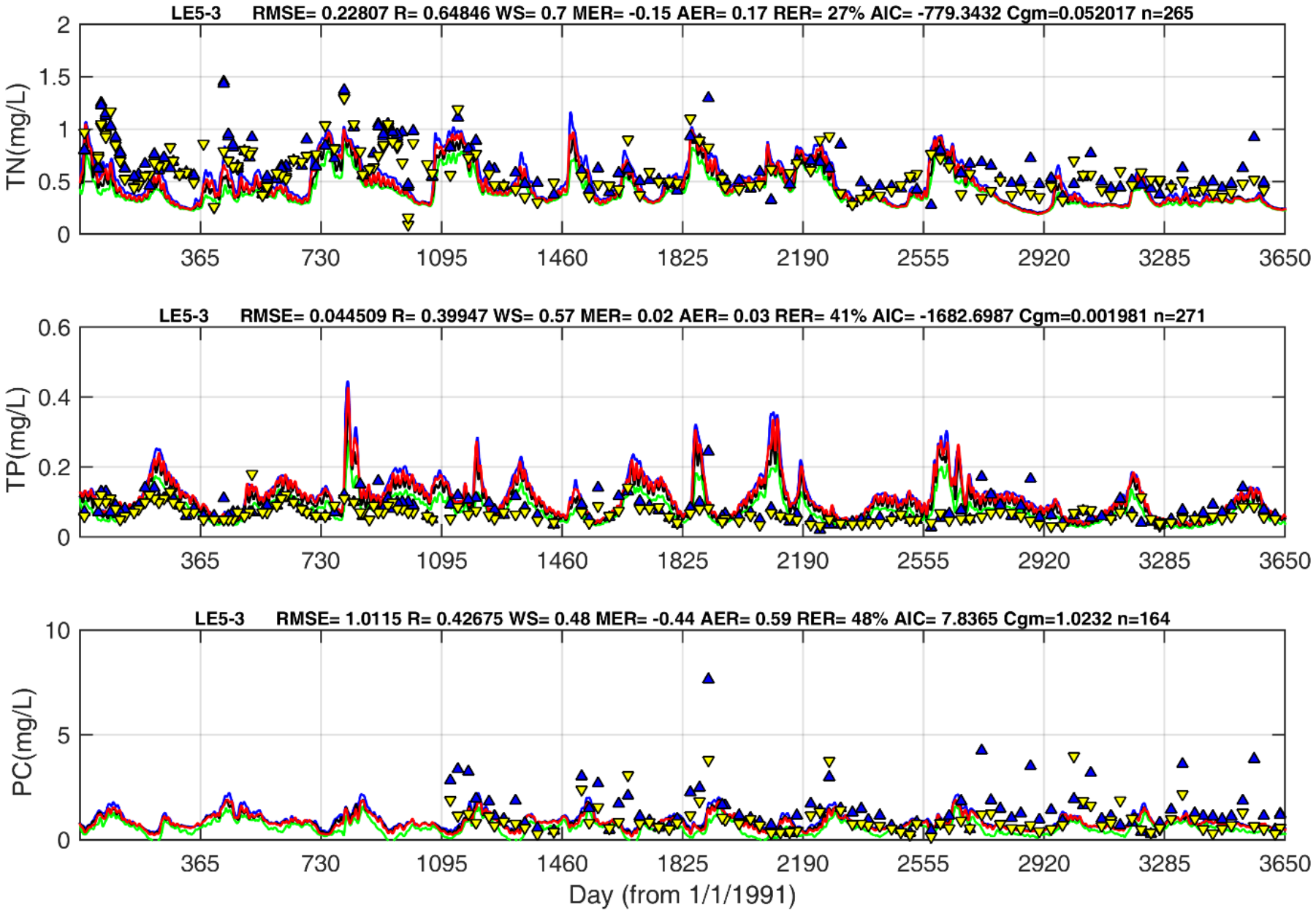

RET5-2 RMSE= 13.7526 R= 0.30613 WS= 0.4 MER= -4.95 AER= 6.21 RER= 52% AIC= 732.7895 Cgm=189.1339 n=139
Chla(ug/L)
50
40
30
20
10
0
365
730
1095
1460
1825
2190
2555
2920
3285
3650
RET5-2 RMSE= 0.32351 R= 0.51529 WS= 0.66 MER= 0.21 AER= 0.24 RER= 76% AIC= -591.8157 Cgm=0.10466 n=264
DIN(mg/L)
10^1
10^-1
10^-3
365
730
1095
1460
1825
2190
2555
2920
3285
3650
RET5-2 RMSE= 0.019001 R= 0.16773 WS= 0.35 MER= 0.01 AER= 0.01 RER= 64% AIC= -2175.7555 Cgm=0.00036103 n=275
PO4(mg/L)
10^-1
10^-3
365
730
1095
1460
1825
2190
2555
2920
3285
3650
Day (from 1/1/1991)


RET5-2 RMSE= 0.098403 R= 0.62278 WS= 0.75 MER= 0.05 AER= 0.07 RER= 88% AIC= -1229.4955 Cgm=0.0096831 n=266
NH4(mg/L)
RET5-2 RMSE= 0.2494 R= 0.42165 WS= 0.62 MER= 0.15 AER= 0.18 RER= 78% AIC= -759.746 Cgm=0.062199 n=275
NO23(mg/L)
RET5-2 RMSE= 0.95448 R= 0.8817 WS= 0.93 MER= -0.27 AER= 0.69 RER= 8% AIC= -22.4177 Cgm=0.91104 n=284
DO(mg/L)
365
730
1095
1460
1825
2190
2555
2920
3285
3650
Day (from 1/1/1991)

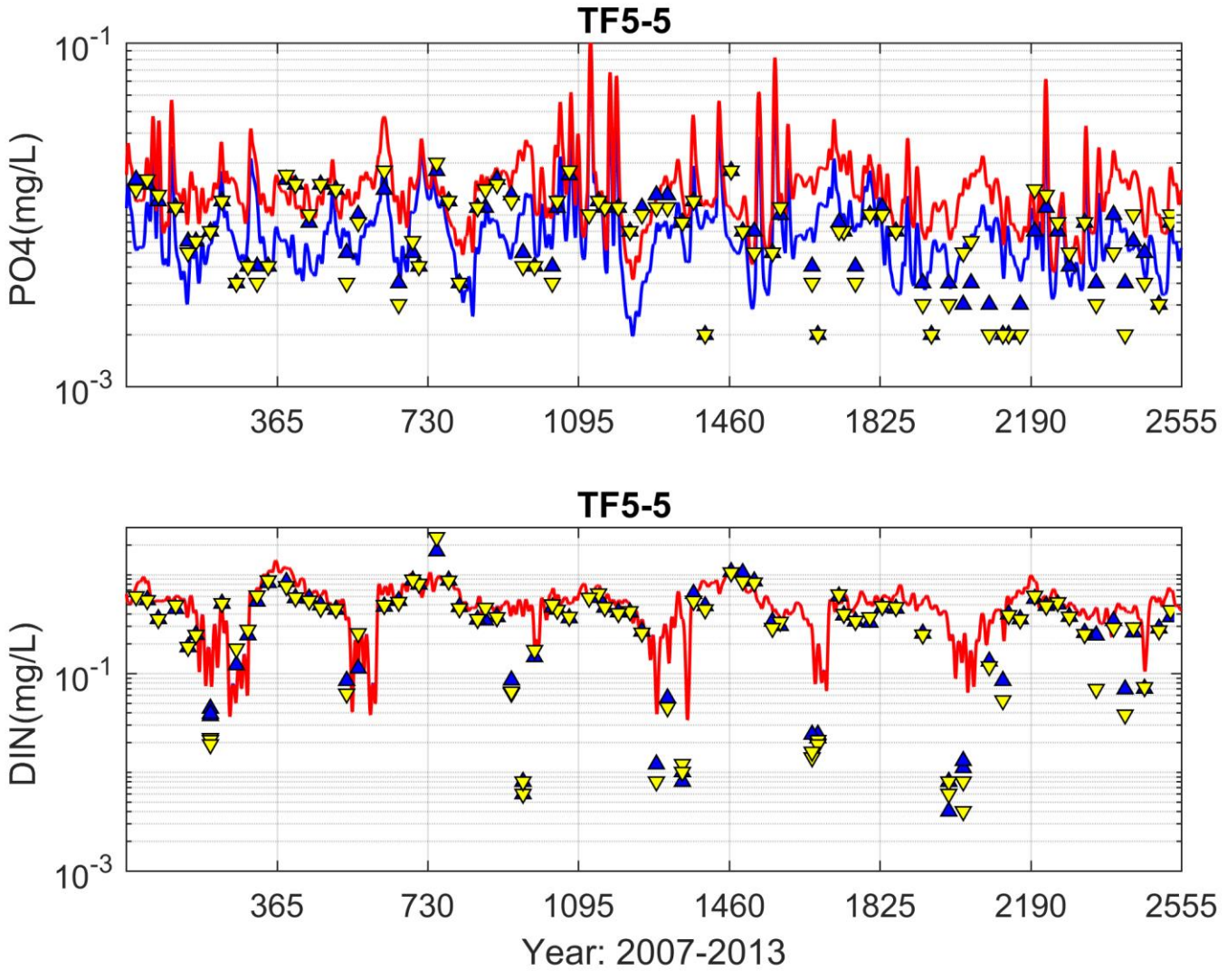

RET5-2 RMSE= 0.36656 R= 0.59253 WS= 0.66 MER= -0.14 AER= 0.23 RER= 24% AIC= -527.8582 Cgm=0.13437 n=265
TN(mg/L)
RET5-2 RMSE= 0.13393 R= 0.086138 WS= 0.39 MER= 0.01 AER= 0.09 RER= 62% AIC= -1089.6273 Cgm=0.017938 n=272
TP(mg/L)
RET5-2 RMSE= 2.9738 R= 0.1176 WS= 0.4 MER= -1.83 AER= 1.84 RER= 72% AIC= 357.1831 Cgm=8.8434 n=162
PC(mg/L)
365 730 1095 1460 1825 2190 2555 2920 3285 3650
Day (from 1/1/1991)

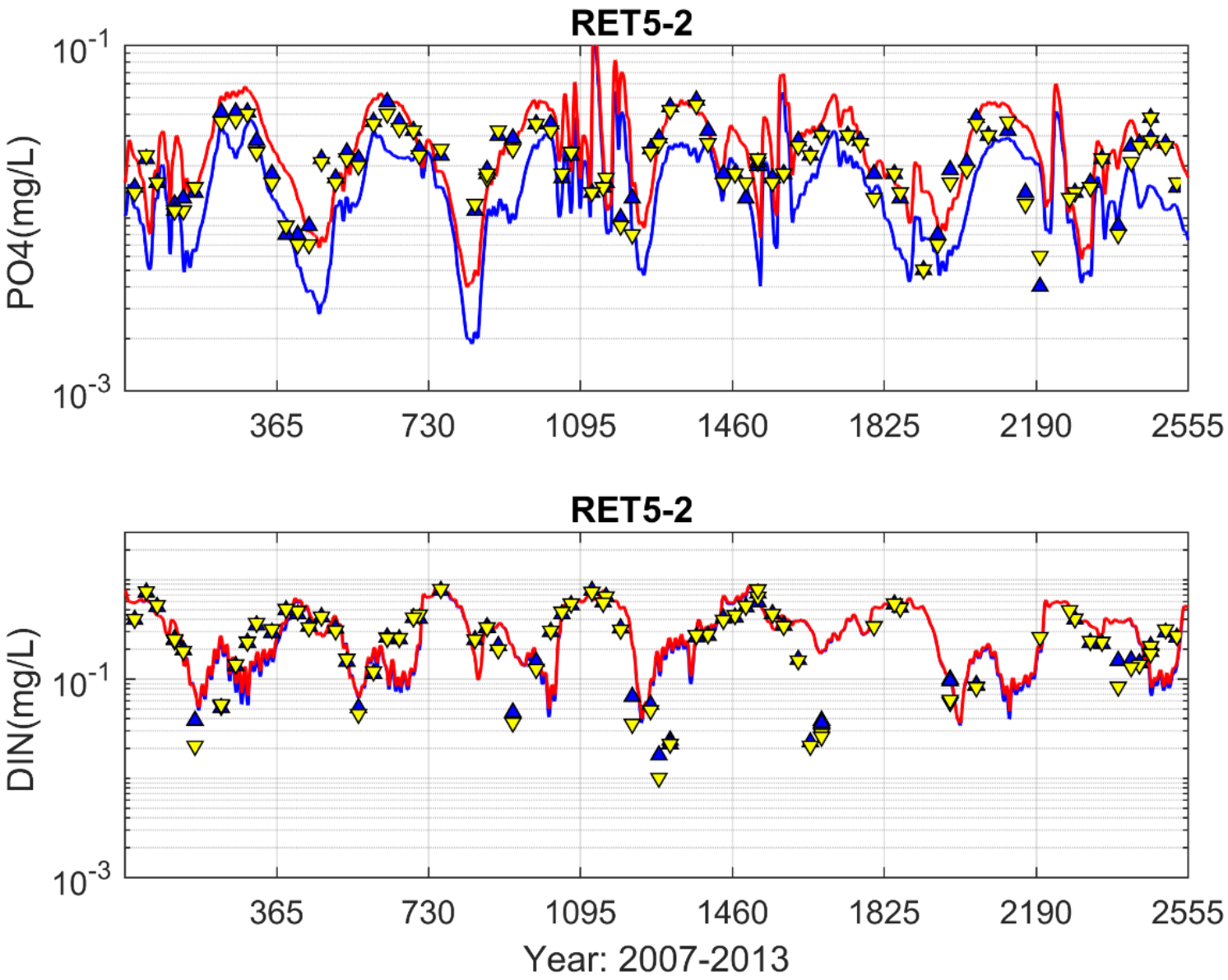

LE5-3 RMSE= 10.637 R= 0.43202 WS= 0.52 MER= 0.46 AER= 5.27 RER= 60% AIC= 656.6455 Cgm=113.1451 n=138
Chla(ug/L)
50
40
30
20
10
0
365
730
1095
1460
1825
2190
2555
2920
3285
3650
LE5-3 RMSE= 0.11825 R= 0.72331 WS= 0.84 MER= -0.04 AER= 0.08 RER= 49% AIC= -1063.4138 Cgm=0.013984 n=250
DIN(mg/L)
10^1
10^-1
10^-3
LE5-3 RMSE= 0.014354 R= 0.68451 WS= 0.75 MER= -0.01 AER= 0.01 RER= 42% AIC= -2330.0046 Cgm=0.00020604 n=275
PO4(mg/L)
Day (from 1/1/1991)

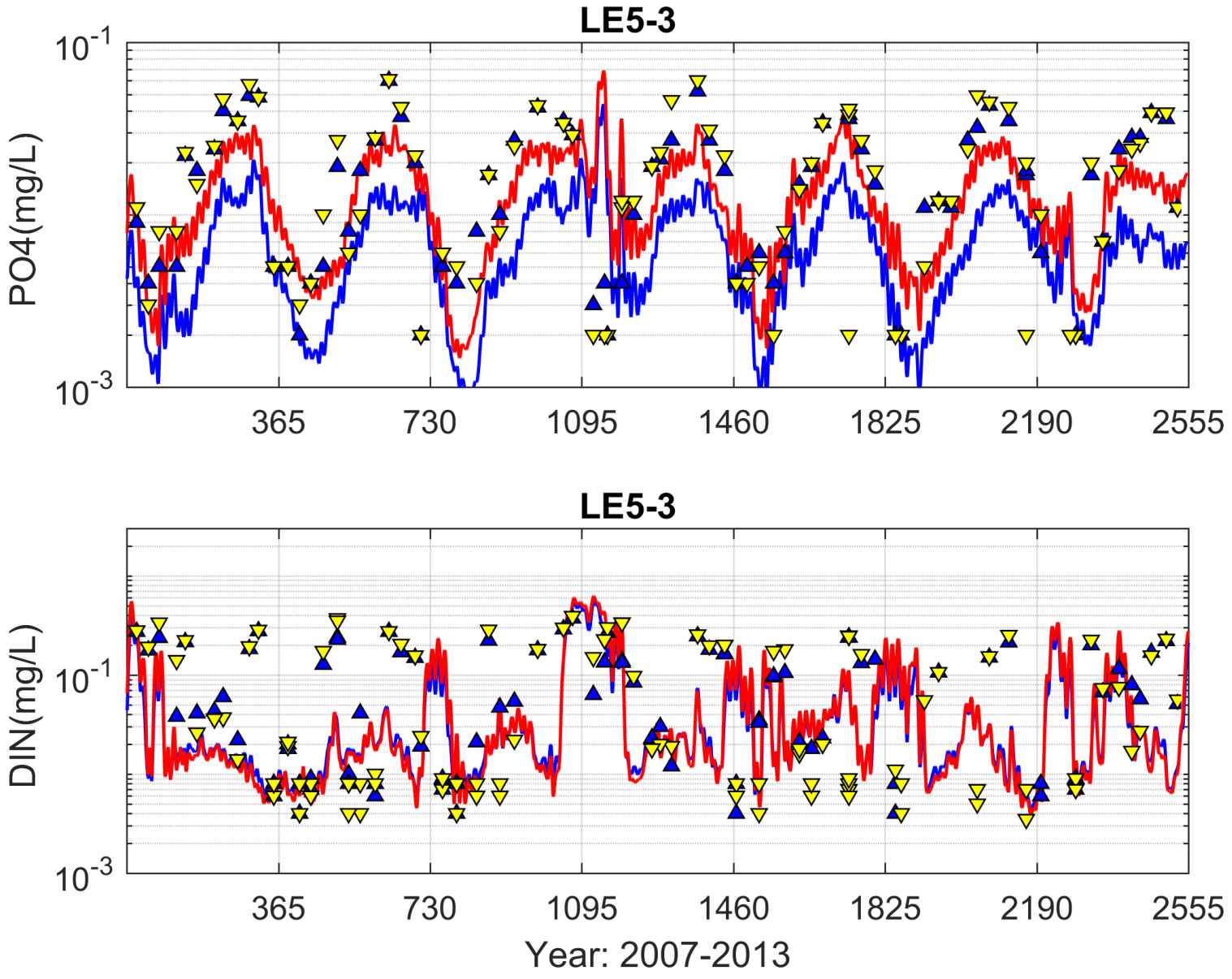

LE5-3 RMSE= 0.047654 R= 0.635 WS= 0.76 MER= -0.02 AER= 0.03 RER= 57% AIC= -1530.0227 Cgm=0.0022709 n=252
NH4(mg/L)
LE5-3 RMSE= 0.084448 R= 0.73128 WS= 0.84 MER= -0.01 AER= 0.06 RER= 56% AIC= -1355.3463 Cgm=0.0071315 n=275
NO23(mg/L)
LE5-3 RMSE= 0.48533 R= 0.97573 WS= 0.99 MER= 0.09 AER= 0.31 RER= 4% AIC= -393.5652 Cgm=0.23555 n=275
DO(mg/L)
365 730 1095 1460 1825 2190 2555 2920 3285 3650
Day (from 1/1/1991)


LE5-3 RMSE= 0.22807 R= 0.64846 WS= 0.7 MER= -0.15 AER= 0.17 RER= 27% AIC= -779.3432 Cgm=0.052017 n=265
TN(mg/L)
LE5-3 RMSE= 0.044509 R= 0.39947 WS= 0.57 MER= 0.02 AER= 0.03 RER= 41% AIC= -1682.6987 Cgm=0.001981 n=271
TP(mg/L)
LE5-3 RMSE= 1.0115 R= 0.42675 WS= 0.48 MER= -0.44 AER= 0.59 RER= 48% AIC= 7.8365 Cgm=1.0232 n=164
PC(mg/L)
365 730 1095 1460 1825 2190 2555 2920 3285 3650
Day (from 1/1/1991)

Nutrient Limiting

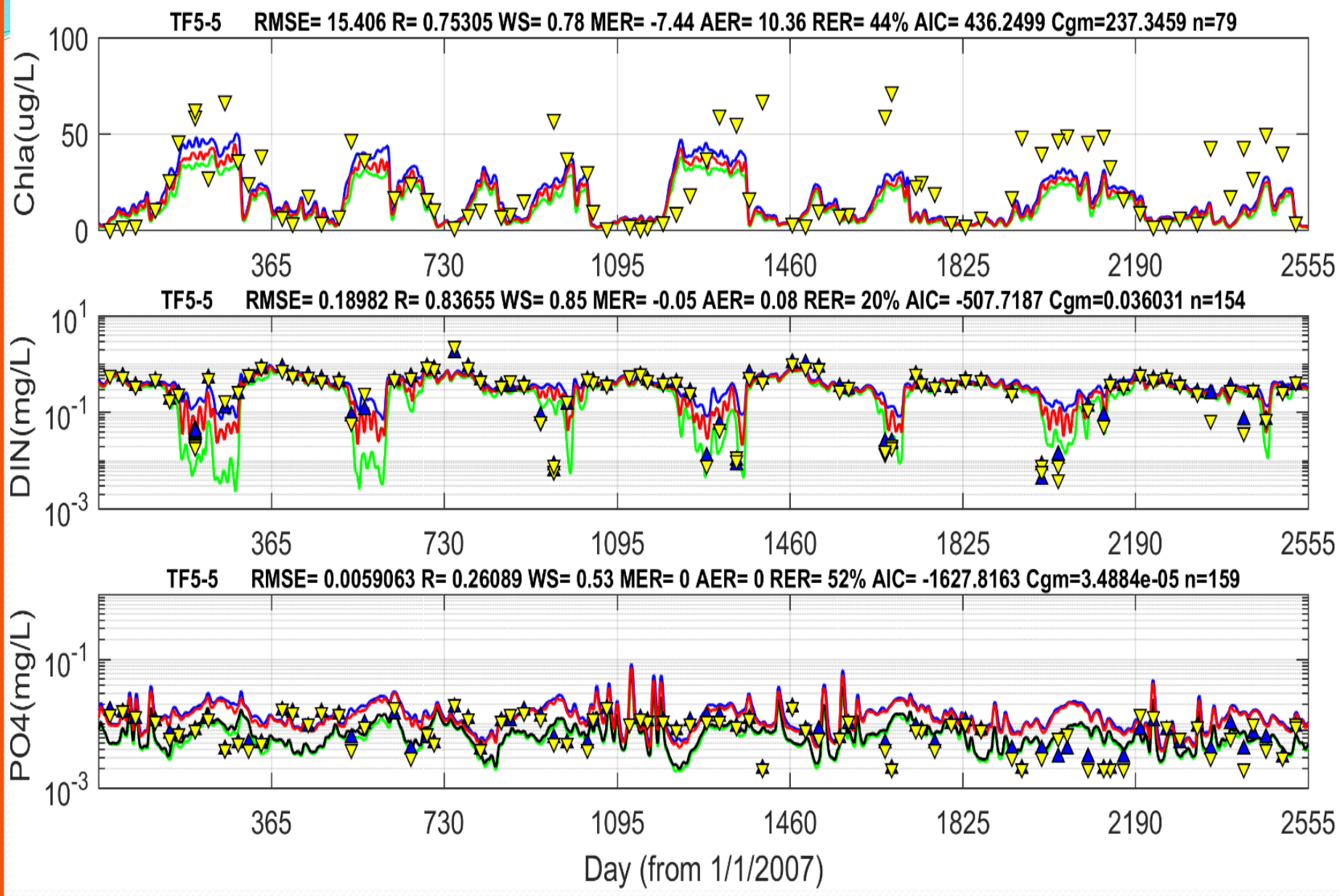


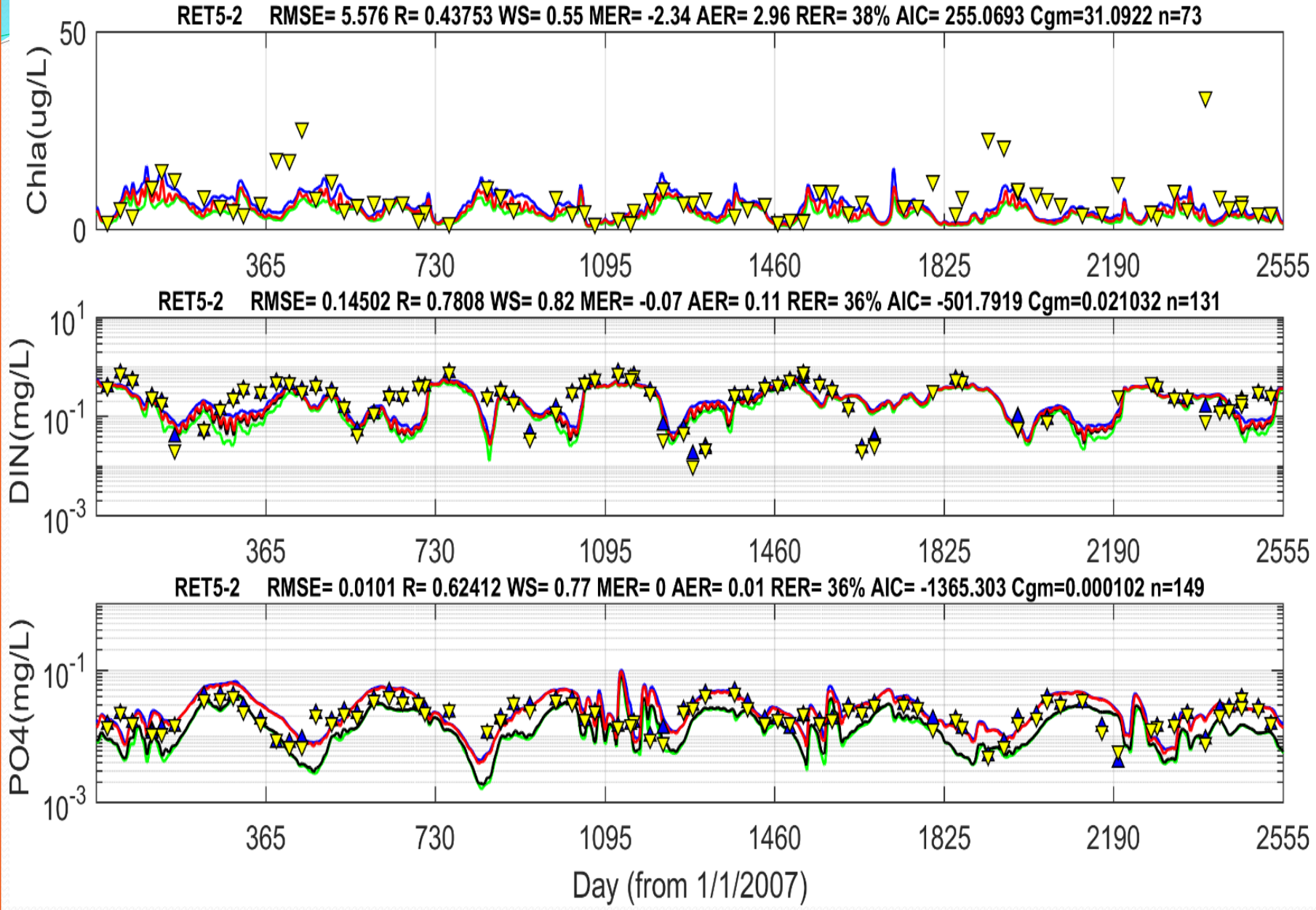

RET5-2
PO4(mg/L)
10^{-1}
10^{-3}
365
730
1095
1460
1825
2190
2555
RET5-2
DIN(mg/L)
10^{-1}
10^{-3}
365
730
1095
1460
1825
2190
2555
Year: 2007-2013

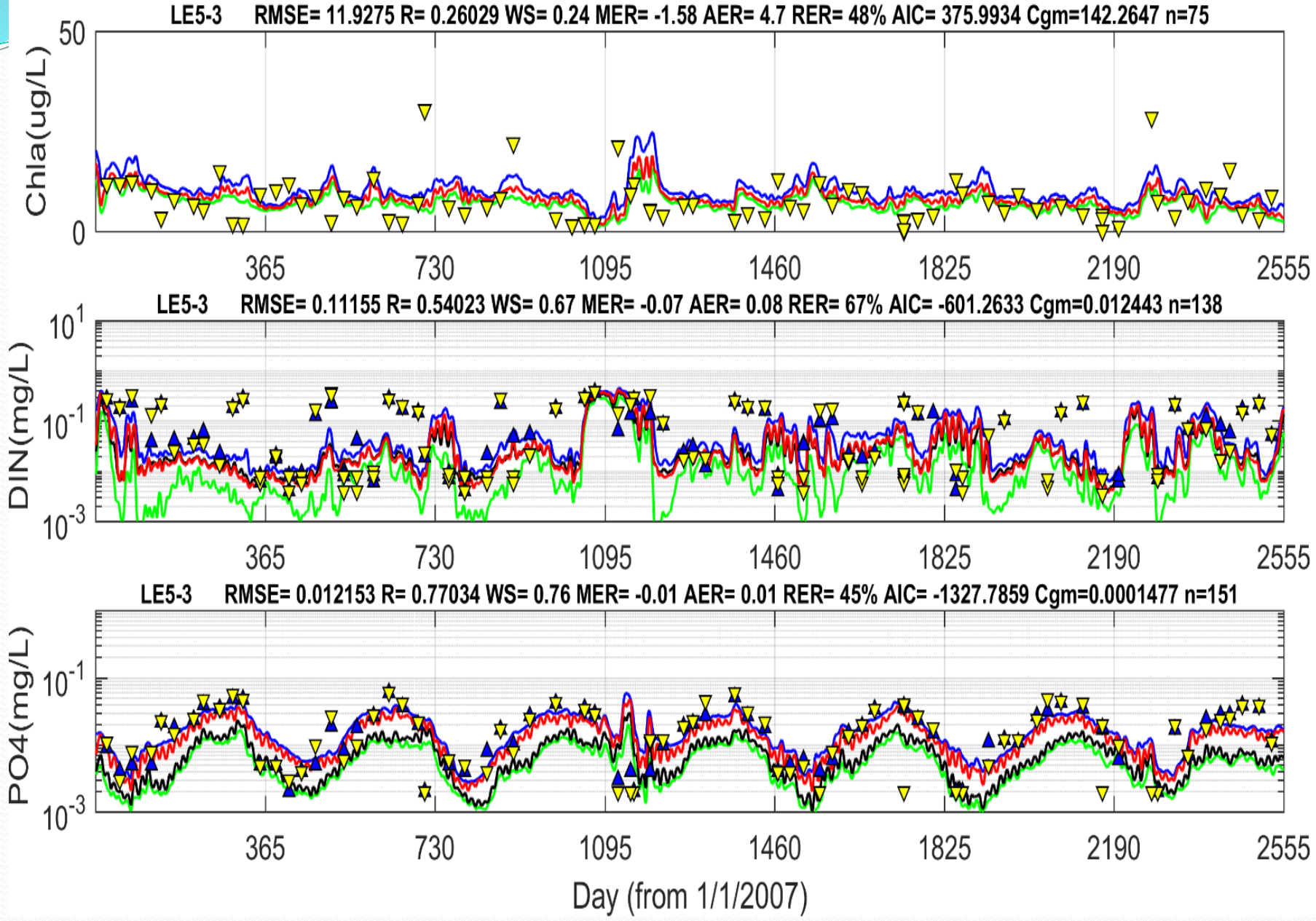

LE5-3
PO4(mg/L)
10^{-1}
10^{-3}
365
730
1095
1460
1825
2190
2555
LE5-3
DIN(mg/L)
10^{-1}
10^{-3}
365
730
1095
1460
1825
2190
2555
Year: 2007-2013

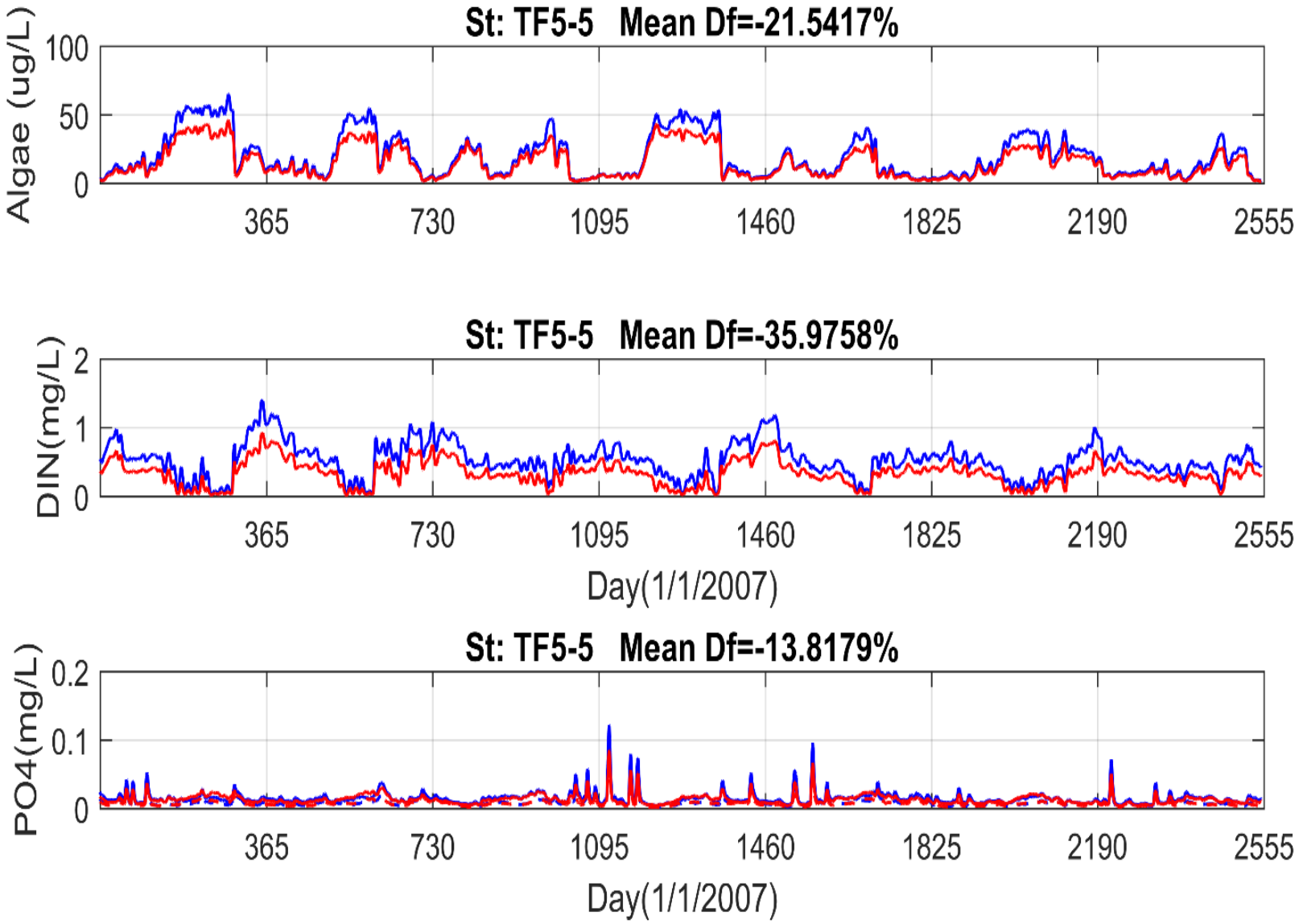
Model Response to Nutrient Reduction

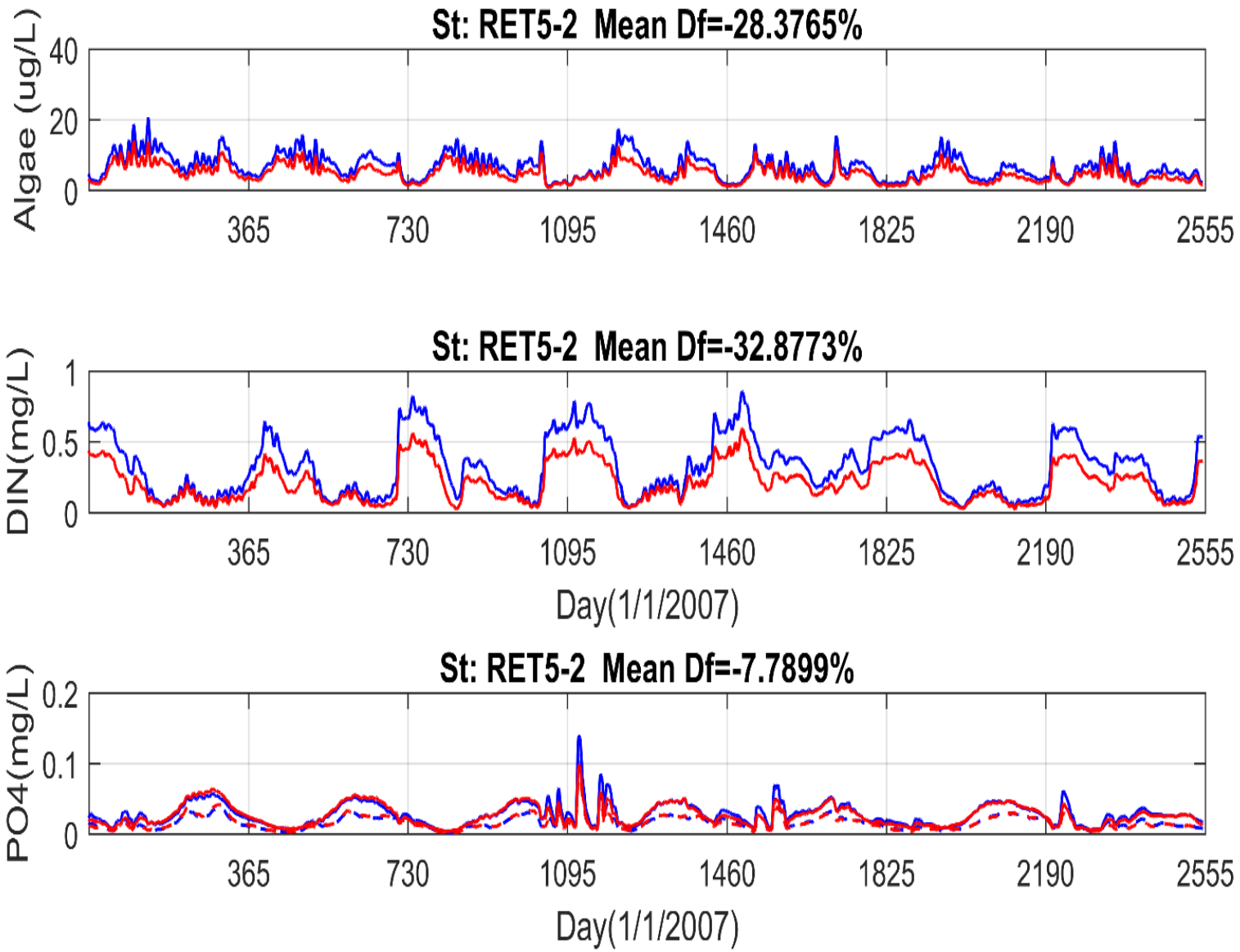
- Conduct a sensitivity test for reduction of N and P by 30% everywhere
- No reduction of phytoplankton from fall-line
- No change of boundary condition

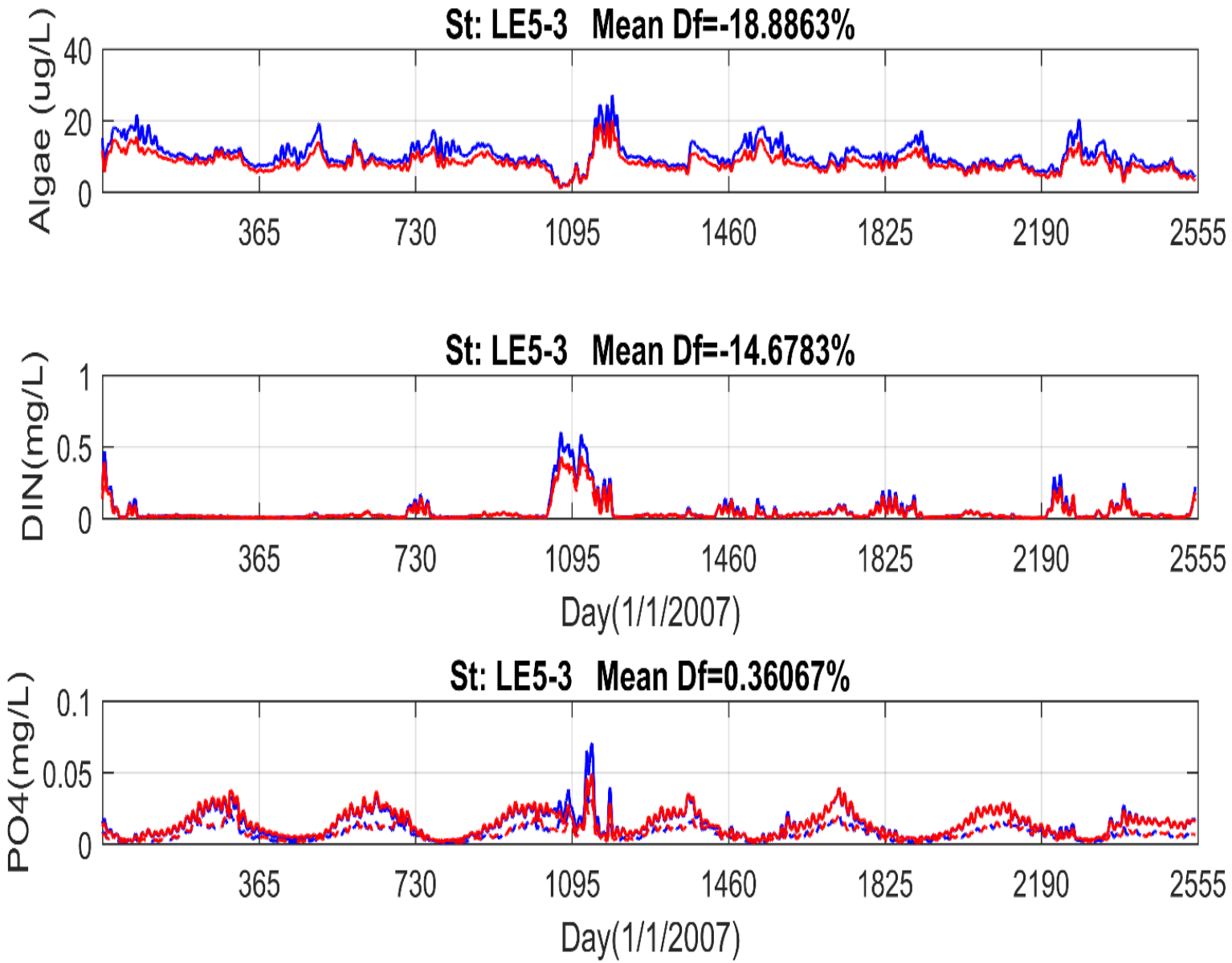

TF5-5 RMSE= 15.406 R= 0.75305 WS= 0.78 MER= -7.44 AER= 10.36 RER= 44% AIC= 436.2499 Cgm=237.3459 n=79
Chla(ug/L)
100
50
0
365
730
1095
1460
1825
2190
2555
TF5-5 RMSE= 0.18982 R= 0.83655 WS= 0.85 MER= -0.05 AER= 0.08 RER= 20% AIC= -507.7187 Cgm=0.036031 n=154
DIN(mg/L)
10^{1}
10^{-1}
10^{-3}
365
730
1095
1460
1825
2190
2555
TF5-5 RMSE= 0.0059063 R= 0.26089 WS= 0.53 MER= 0 AER= 0 RER= 52% AIC= -1627.8163 Cgm=3.4884e-05 n=159
PO4(mg/L)
10^{-1}
10^{-3}
365
730
1095
1460
1825
2190
2555
Day (from 1/1/2007)


RET5-2 RMSE= 5.576 R= 0.43753 WS= 0.55 MER= -2.34 AER= 2.96 RER= 38% AIC= 255.0693 Cgm=31.0922 n=73
Chla(ug/L)
50
0
365
730
1095
1460
1825
2190
2555
RET5-2 RMSE= 0.14502 R= 0.7808 WS= 0.82 MER= -0.07 AER= 0.11 RER= 36% AIC= -501.7919 Cgm=0.021032 n=131
DIN(mg/L)
10^{1}
10^{-1}
10^{-3}
365
730
1095
1460
1825
2190
2555
RET5-2 RMSE= 0.0101 R= 0.62412 WS= 0.77 MER= 0 AER= 0.01 RER= 36% AIC= -1365.303 Cgm=0.000102 n=149
PO4(mg/L)
10^{-1}
10^{-3}
365
730
1095
1460
1825
2190
2555
Day (from 1/1/2007)

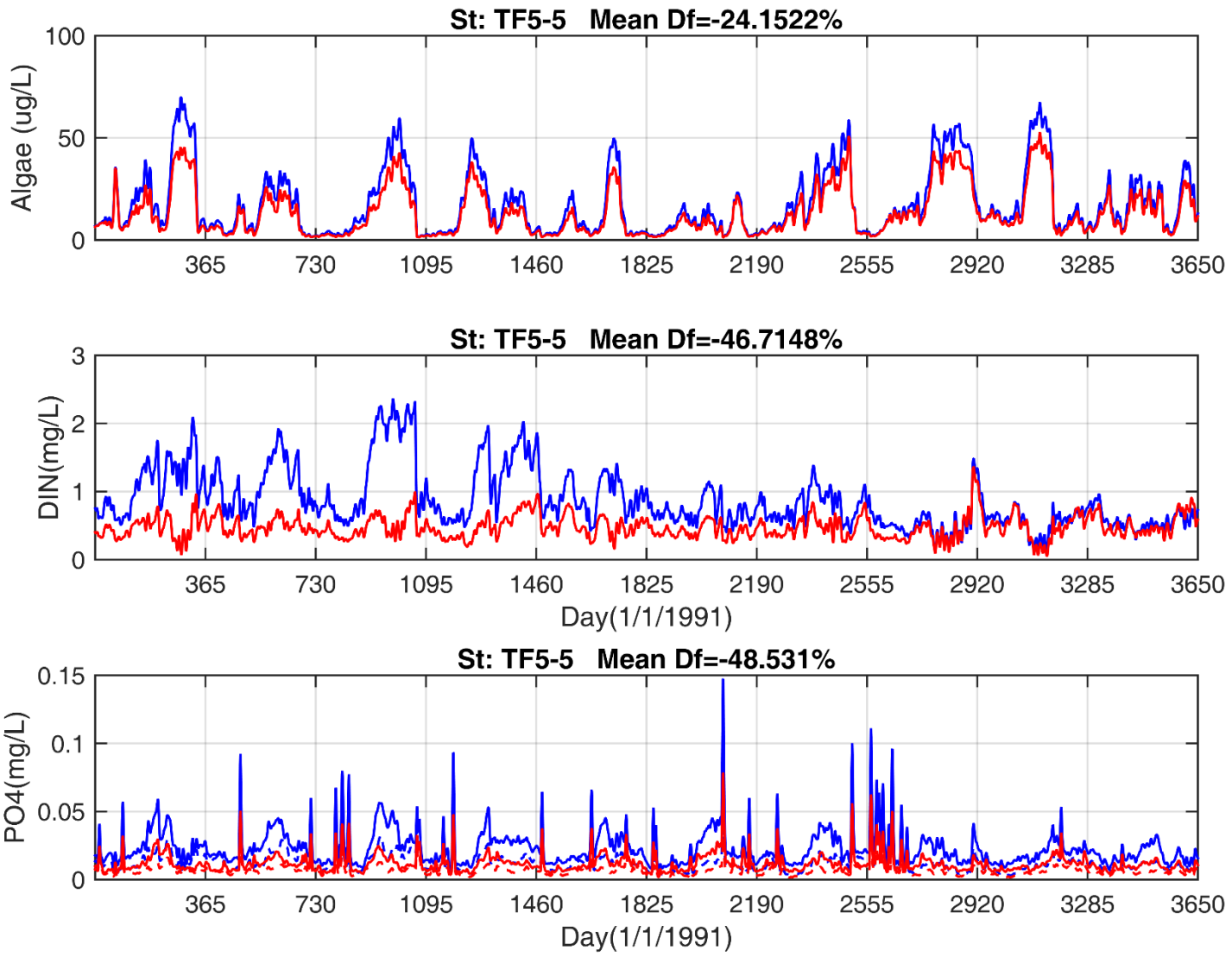

LE5-3 RMSE= 11.9275 R= 0.26029 WS= 0.24 MER= -1.58 AER= 4.7 RER= 48% AIC= 375.9934 Cgm=142.2647 n=75
Chla(ug/L)
50
0
365
730
1095
1460
1825
2190
2555
LE5-3 RMSE= 0.11155 R= 0.54023 WS= 0.67 MER= -0.07 AER= 0.08 RER= 67% AIC= -601.2633 Cgm=0.012443 n=138
DIN(mg/L)
10^{1}
10^{-1}
10^{-3}
365
730
1095
1460
1825
2190
2555
LE5-3 RMSE= 0.012153 R= 0.77034 WS= 0.76 MER= -0.01 AER= 0.01 RER= 45% AIC= -1327.7859 Cgm=0.0001477 n=151
PO4(mg/L)
10^{-1}
10^{-3}
365
730
1095
1460
1825
2190
2555
Day (from 1/1/2007)

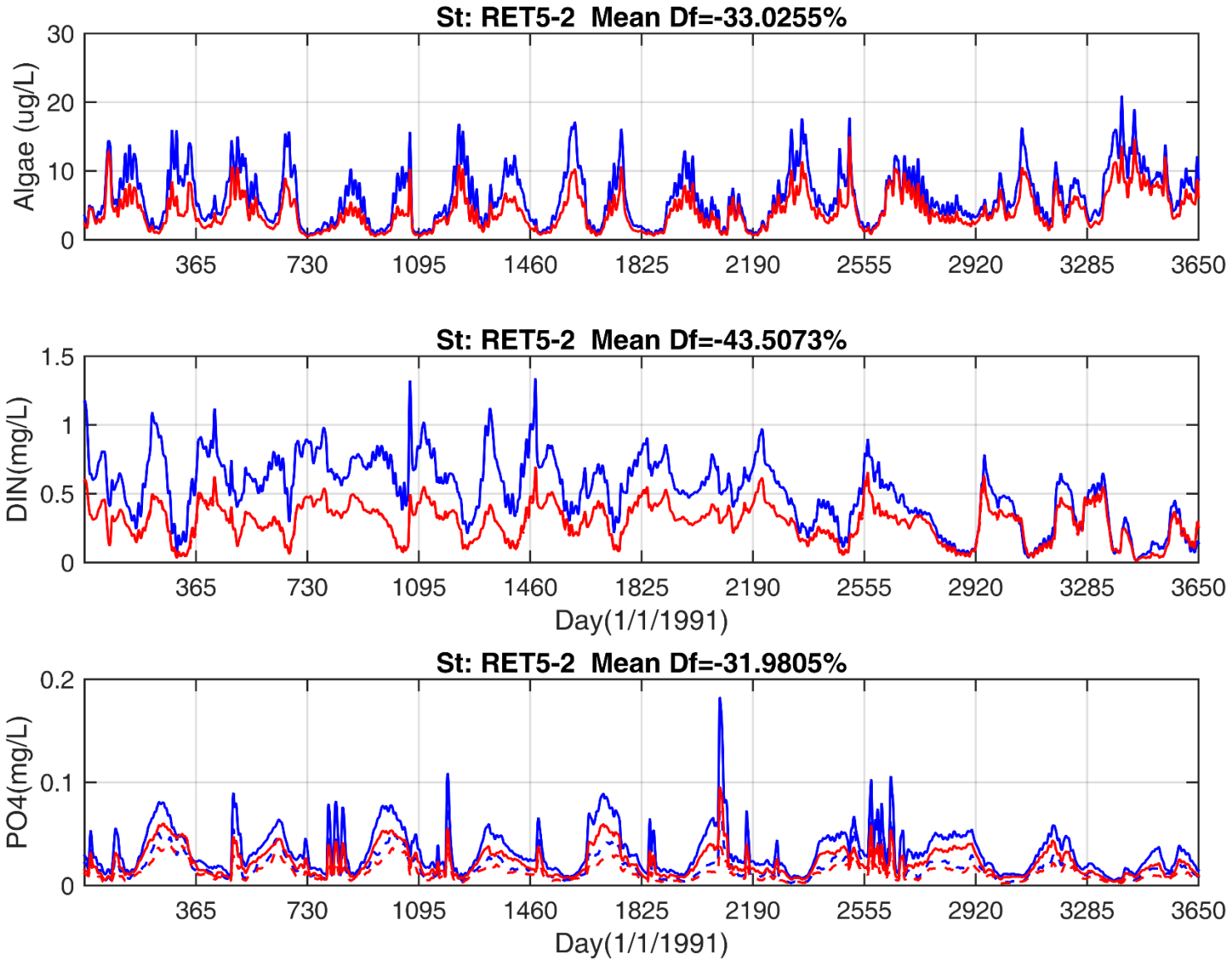

St: TF5-5 Mean Df=-21.5417%
Algae (ug/L)
100
50
0
365
730
1095
1460
1825
2190
2555
St: TF5-5 Mean Df=-35.9758%
DIN(mg/L)
2
1
0
365
730
1095
1460
1825
2190
2555
Day(1/1/2007)
St: TF5-5 Mean Df=-13.8179%
PO4(mg/L)
0.2
0.1
0
365
730
1095
1460
1825
2190
2555
Day(1/1/2007)

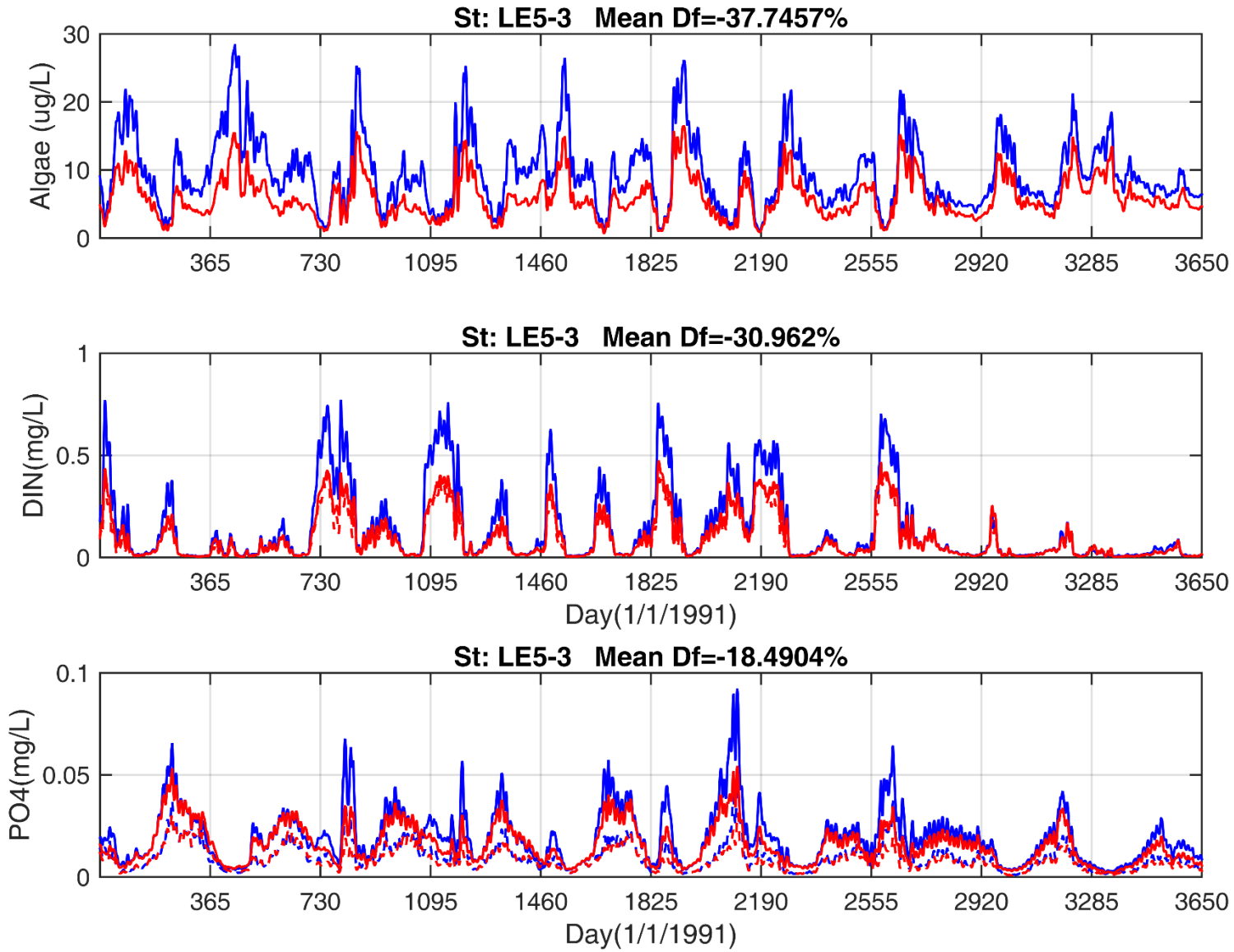

St: RET5-2 Mean Df=-28.3765%
Algae (ug/L)
40
20
0
365
730
1095
1460
1825
2190
2555
St: RET5-2 Mean Df=-32.8773%
DIN(mg/L)
1
0.5
0
365
730
1095
1460
1825
2190
2555
Day(1/1/2007)
St: RET5-2 Mean Df=-7.7899%
PO4(mg/L)
0.2
0.1
0
365
730
1095
1460
1825
2190
2555
Day(1/1/2007)


St: LE5-3 Mean Df=-18.8863%
Algae (ug/L)
40
20
0
365
730
1095
1460
1825
2190
2555
St: LE5-3 Mean Df=-14.6783%
DIN(mg/L)
1
0.5
0
365
730
1095
1460
1825
2190
2555
Day(1/1/2007)
St: LE5-3 Mean Df=0.36067%
PO4(mg/L)
0.1
0.05
0
365
730
1095
1460
1825
2190
2555
Day(1/1/2007)

Test Draft WIP2 scenario 1985-2000




St: RET5-2 Mean Df=-33.0255%
Algae (ug/L)
30
20
10
0
365
730
1095
1460
1825
2190
2555
2920
3285
3650
St: RET5-2 Mean Df=-43.5073%
DIN(mg/L)
1.5
1
0.5
0
365
730
1095
1460
1825
2190
2555
2920
3285
3650
Day(1/1/1991)
St: RET5-2 Mean Df=-31.9805%
PO4(mg/L)
0.2
0.1
0
365
730
1095
1460
1825
2190
2555
2920
3285
3650
Day(1/1/1991)


St: LE5-3 Mean Df=-37.7457%
Algae (ug/L)
30
20
10
0
365
730
1095
1460
1825
2190
2555
2920
3285
3650
St: LE5-3 Mean Df=-30.962%
DIN(mg/L)
1
0.5
0
365
730
1095
1460
1825
2190
2555
2920
3285
3650
Day(1/1/1991)
St: LE5-3 Mean Df=-18.4904%
PO4(mg/L)
0.1
0.05
0
365
730
1095
1460
1825
2190
2555
2920
3285
3650
Day(1/1/1991)

Conclusions

- Calibration of model parameters depends on the dynamic condition.
- For a nutrient limited estuary, one can use different model parameters to calibrate model for different loadings.
- The response of model to loading reduction depends on transport time. A model with a short transport time is more sensitive to load reduction than a model with longer transport time.
- The model sensitivity test of response to load reduction shows that the change of phytoplankton concentration is less than change of nitrogen concentration.
- The model is not very sensitive to phosphorus reduction, which needs to be further investigated.