James River Water Quality Model Refinement and Scenario Runs

Progress Report

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Virginia Institute of Marine Science

DEQ
Virginia Department of Environmental Quality

Outline

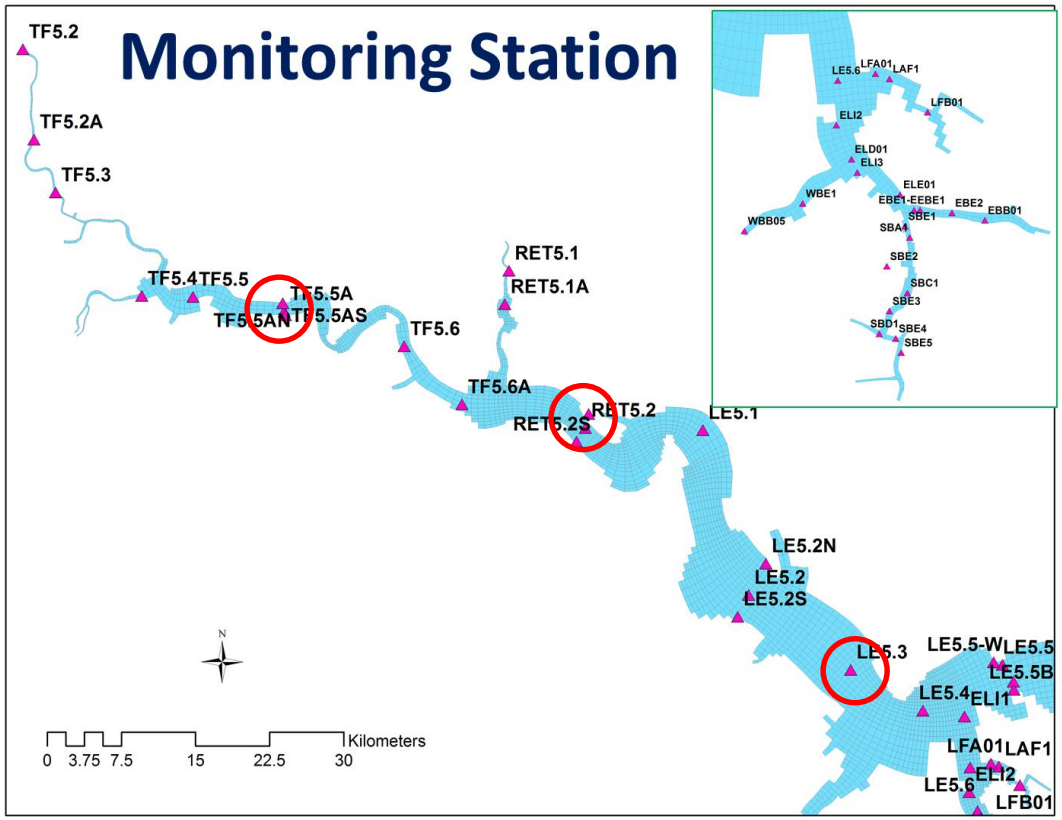
- Progress update
- Model calibration/verification results
- Model uncertainty
  - Model kinetic processes (model structure)
  - Parameter uncertainty
- Model response to load reduction
- Discussion

Progress Update

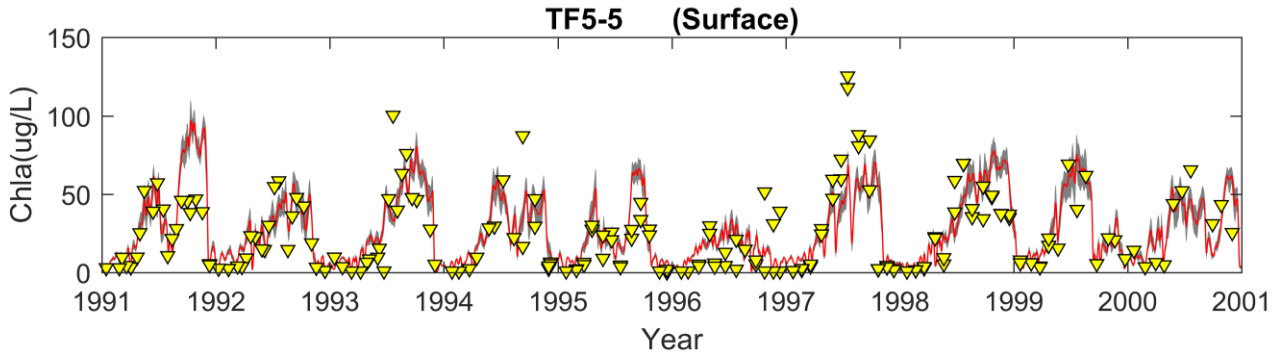
- Received data
  - Final Phase 6 watershed nonpoint source model results 1985-2014 (nonpoint/point, bank erosion, atmospheric deposition)
  - Results of scenario runs (loading and open boundary conditions)
    - WIP2 scenario
    - 2013 progress
    - E3
    - Non action
    - 1985 Progress
    - 1993 Progress
- Refined model calibration
- Conducted model scenario runs
- Sensitivity test for model response to load reduction

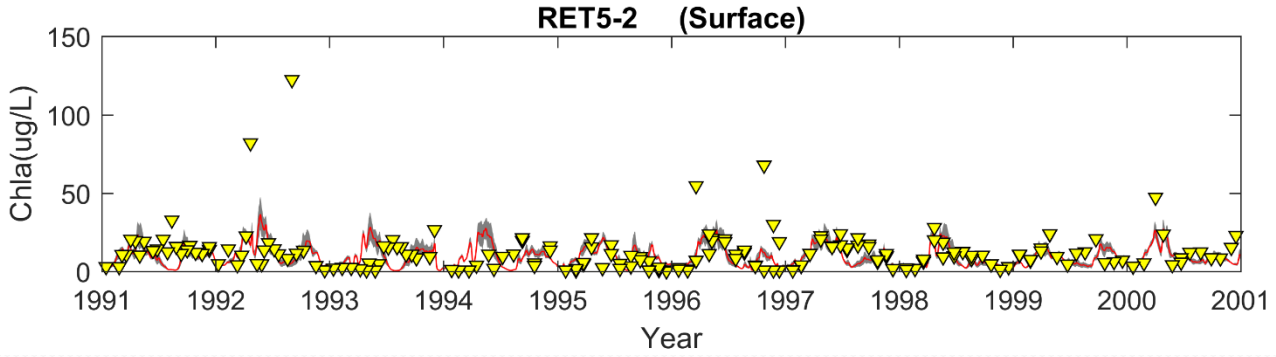
Examples of Model Calibration

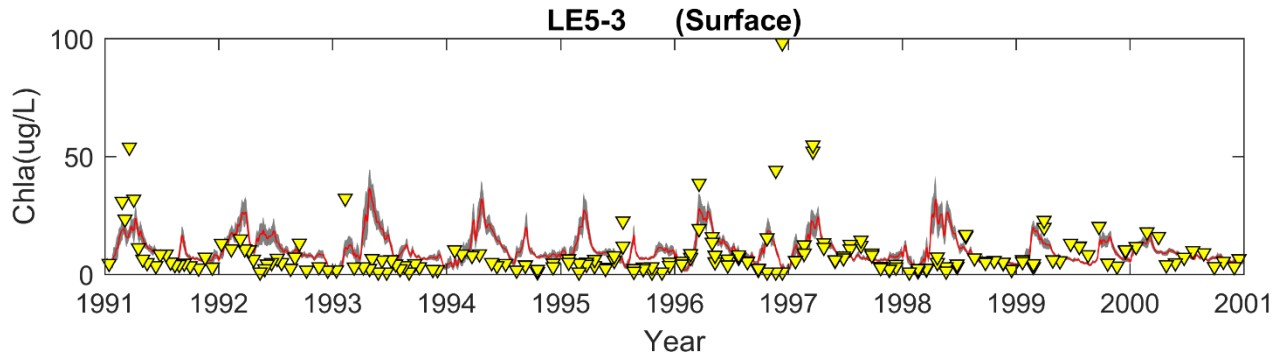
- Tidal freshwater (TF5-5)
- Oligohaline (RET5-2)
- Mesohaline (EL5-3)

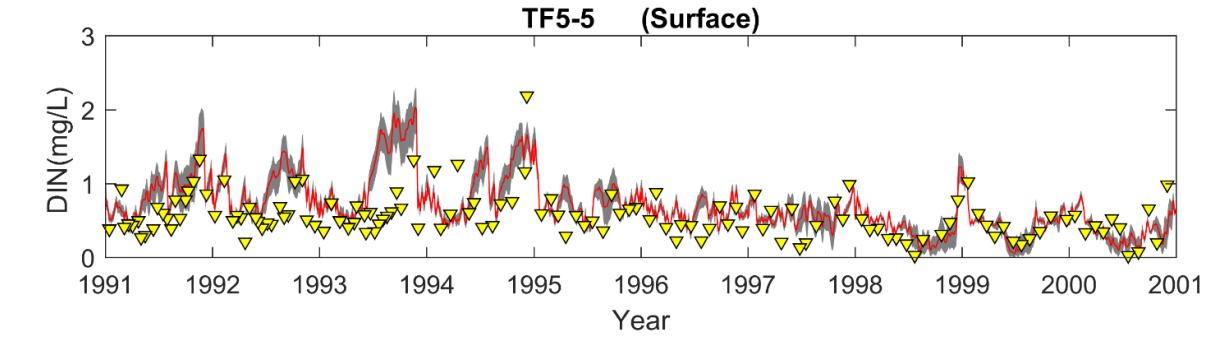


Model Calibration Results








TF5-5 (Surface)
DIN(mg/L)
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1
2
3
1991
1992
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1996
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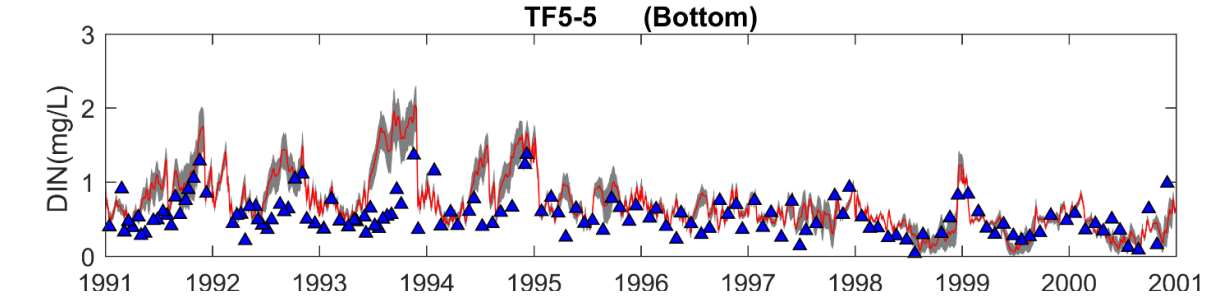
1999
2000
2001
Year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1993
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1996
1997
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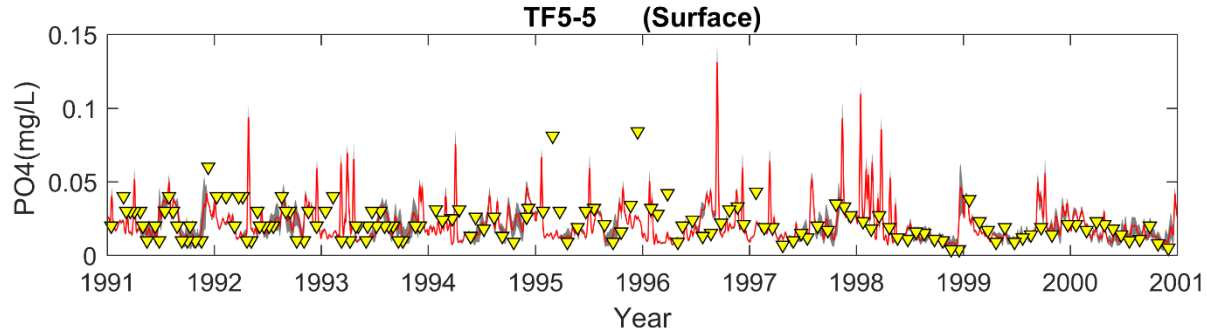
2001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PO4(mg/L)
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0.15
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1992
1993
1994
1995
1996
1997
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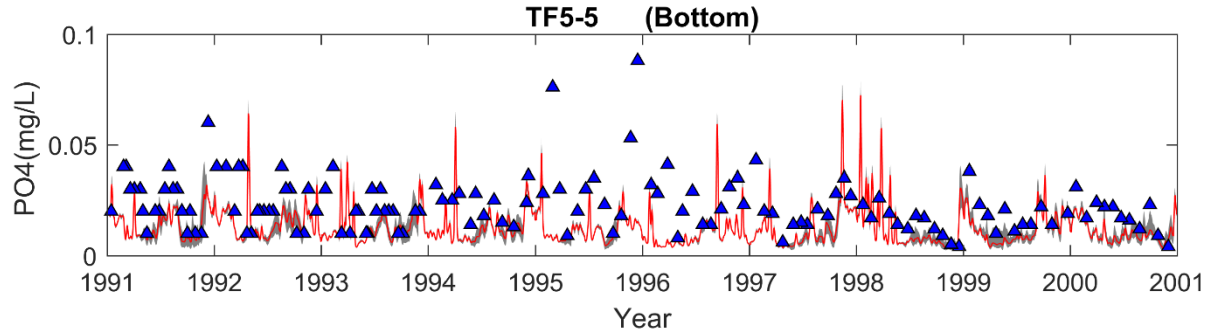
1999
2000
2001
Year


TF5-5 (Bottom)
PO4(mg/L)
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0.05
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1991
1992
1993
1994
1995
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1997
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1999
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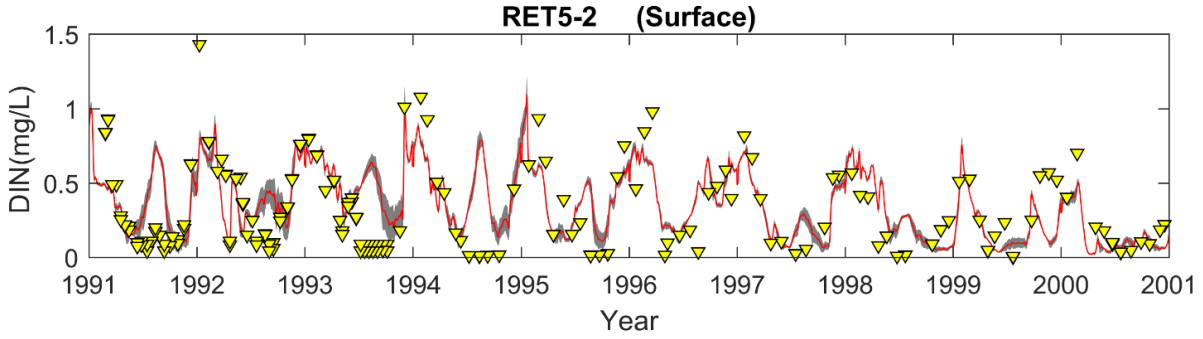
2001
Year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0.5
0
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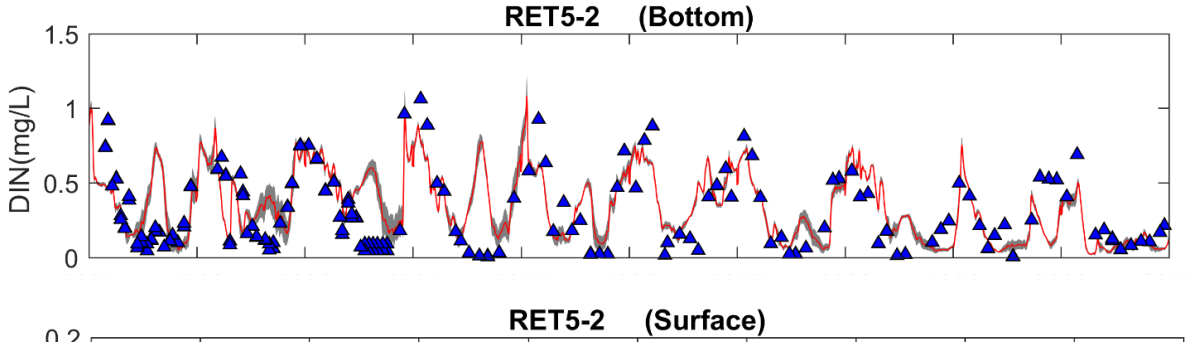
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
Year


RET5-2 (Bottom)
DIN(mg/L)
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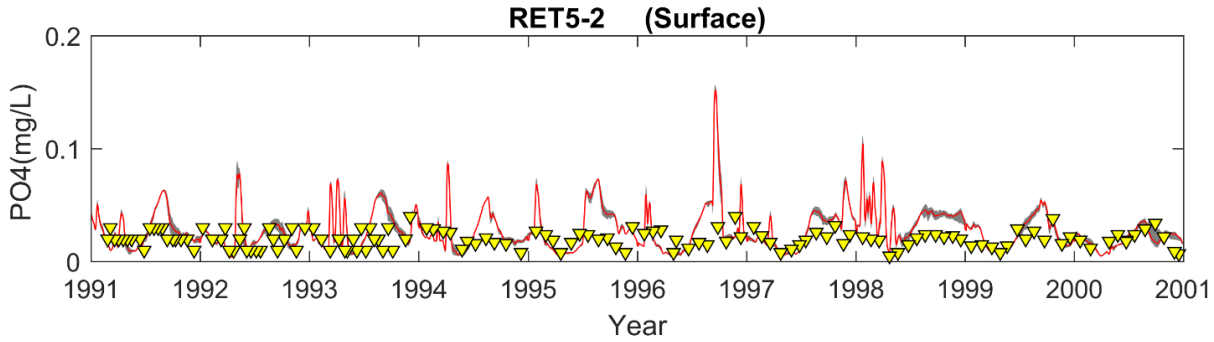
1
0.5
0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PO4(mg/L)
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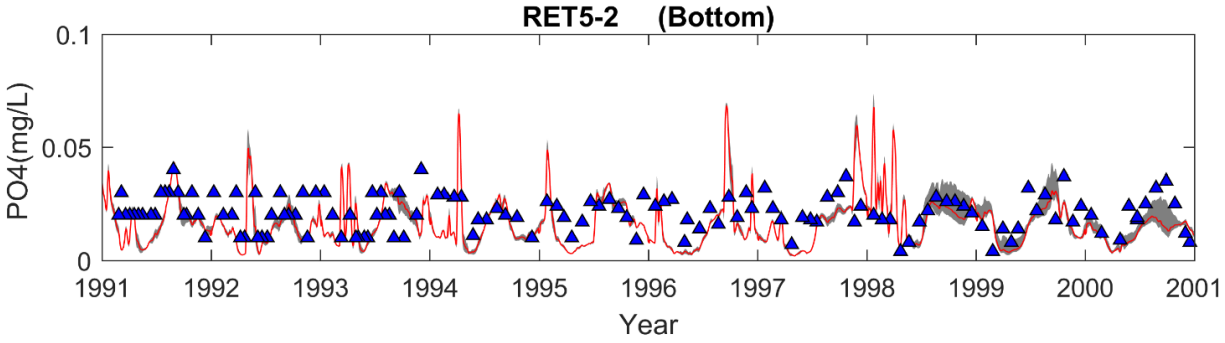
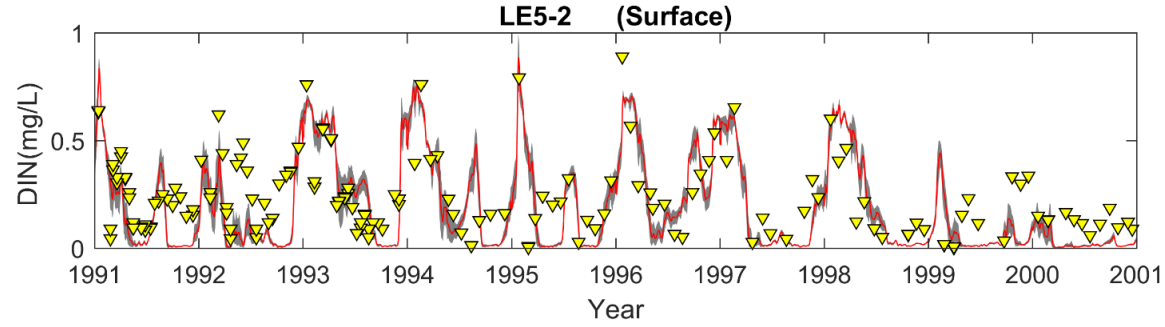
0.1
0
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
Year


RET5-2 (Bottom)
PO4(mg/L)
0.1
0.05
0
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
Year


LE5-2 (Surface)
DIN(mg/L)
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0.5
0
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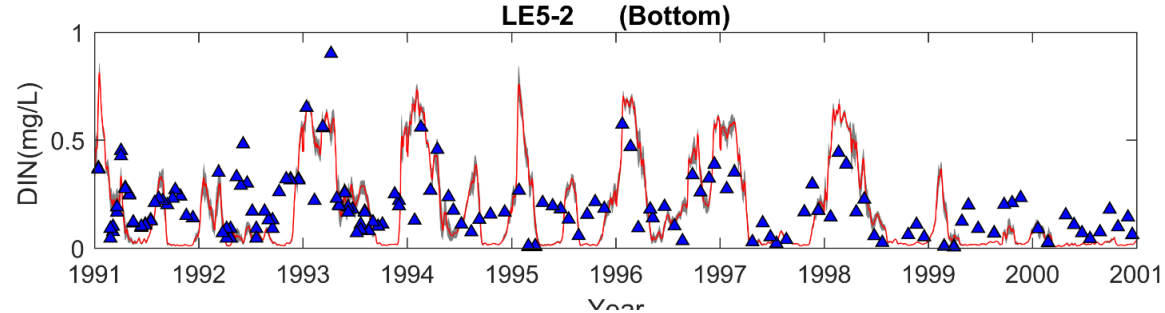
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
Year


LE5-2 (Bottom)
DIN(mg/L)
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0.5
0
1991
1992
1993
1994
1995
1996
1997
1998
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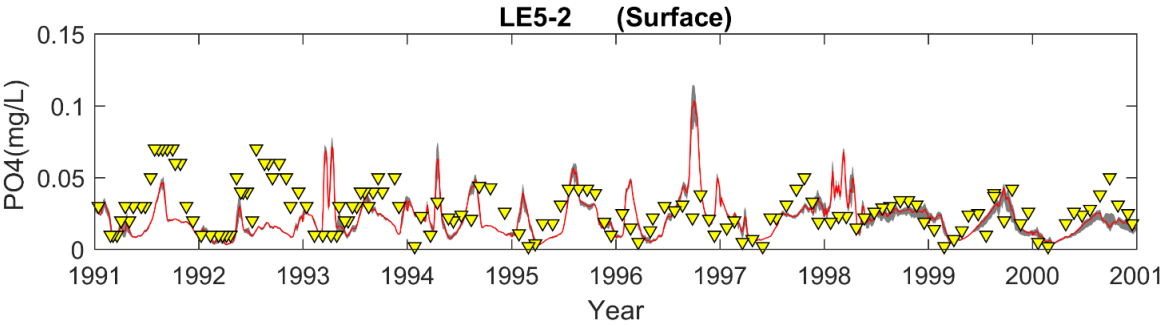
2000
2001


LE5-2 (Surface)
PO4(mg/L)
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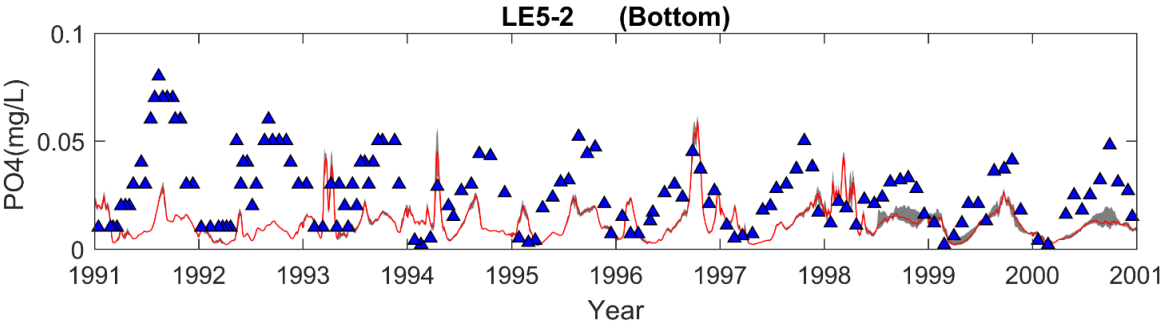
0.1
0.05
0
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
Year


LE5-2 (Bottom)
PO4(mg/L)
0.1
0.05
0
1991
1992
1993
1994
1995
1996
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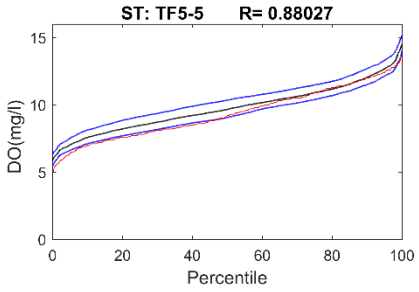
2001
Year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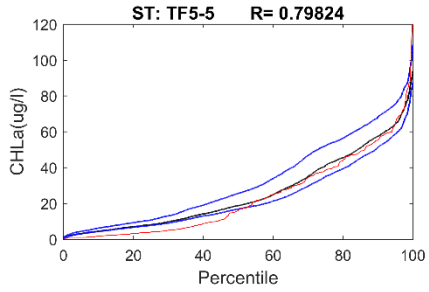
DO(mg/l)
Percentile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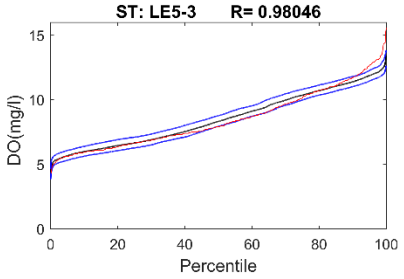
CHLa(ug/l)
Percentile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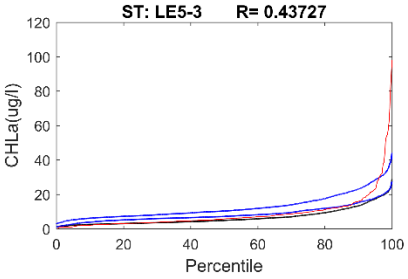
DO(mg/l)
Percentile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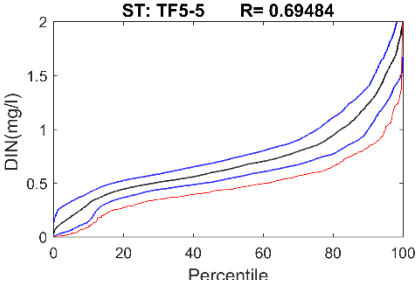
CHLa(ug/l)
Percentile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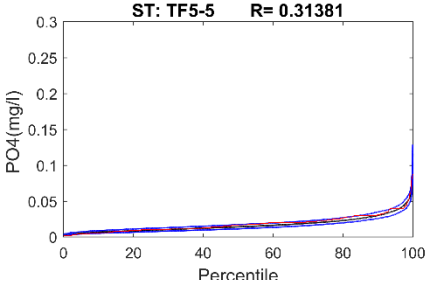
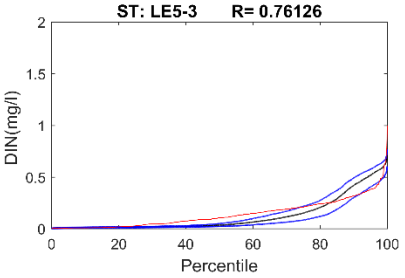
DIN(mg/l)
Percentile


ST: TF5-5 R= 0.31381
PO4(mg/l)
Percentile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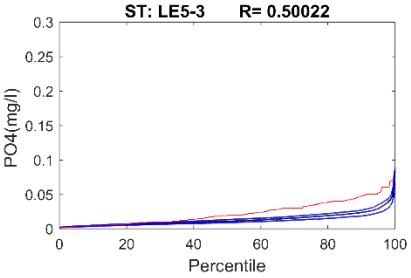
DIN(mg/l)
Percentile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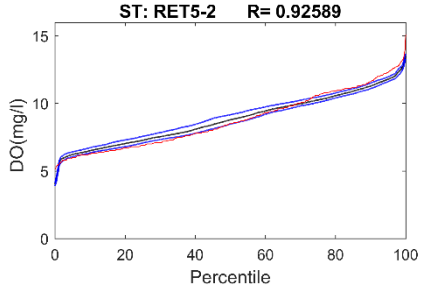
PO4(mg/l)
Percentile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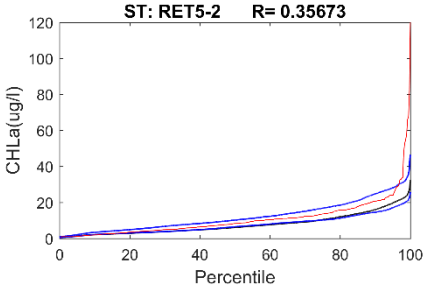
DO(mg/l)
Percentile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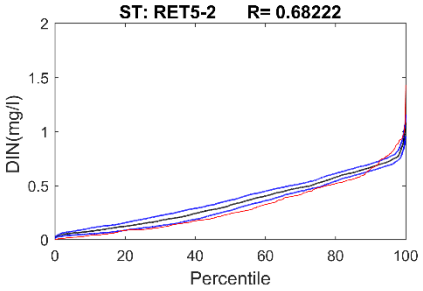
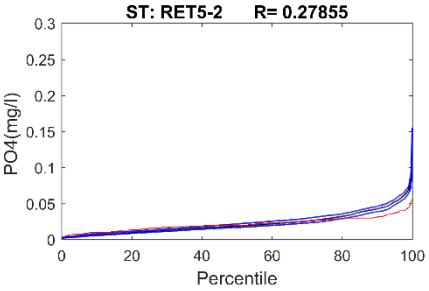
CHLa(ug/l)
Percentile


ST: RET5-2 R= 0.68222
DIN(mg/l)
Percentile


ST: RET5-2 R= 0.27855
PO4(mg/l)
Percentile

Statistical Summary

Chl a (TF5-5)

Station	RMSE	R	Mean Diff.	Abs. Diff.	Relative Diff. (%)	Obs. mean	Model mean	Obs. Std.	Model Std.	# of nata
TF5-2A	8.53	-0.08	-0.74	5.49	120.60	4.55	5.29	7.39	3.70	134
TF5-3	9.43	0.00	0.60	6.63	102.90	6.44	5.84	8.82	3.39	136
TF5-4	12.78	0.81	0.54	7.71	35.90	21.50	20.96	21.70	18.45	139
TF5-5	14.81	0.80	-2.70	9.62	38.90	24.71	27.42	23.78	21.85	139
TF5-5A	18.96	0.69	-0.70	10.60	40.10	26.43	27.13	26.27	17.60	137
TF5-6	12.59	0.27	-0.83	8.77	65.00	13.49	14.32	12.43	7.31	139
RET5-2	12.82	0.36	2.09	5.59	47.30	11.83	9.74	13.53	6.06	139
LE5-1	7.02	0.33	0.43	4.11	49.90	8.23	7.80	7.13	4.43	139
LE5-2	14.80	0.59	1.91	6.62	64.50	10.27	8.36	17.45	5.94	139
LE5-3	10.62	0.44	-0.23	4.75	54.20	8.75	8.97	11.82	5.81	138
LE5-4	4.82	0.70	-1.04	3.01	38.60	7.80	8.83	6.36	5.61	135
LE5-5	4.07	0.79	-0.69	2.73	27.70	9.87	10.56	6.50	5.85	95
Average	10.94	0.47	-0.11	6.30	57.13	12.82	12.94	13.60	8.83	134

DIN (TF5-5)

Station	RMSE	R	Mean Diff.	Abs. Diff.	Relative Diff. (%)	Obs. mean	Model mean	Obs. Std.	Model Std.	# of nata
TF5-2A	0.21	0.38	-0.02	0.14	36.80	0.39	0.41	0.12	0.23	132
TF5-3	0.22	0.51	-0.01	0.15	33.70	0.45	0.46	0.15	0.26	134
TF5-4	0.20	0.61	0.09	0.15	43.60	0.35	0.26	0.21	0.18	135
TF5-5	0.25	0.71	-0.10	0.17	30.10	0.56	0.66	0.29	0.30	137
TF5-5A	0.24	0.69	-0.02	0.16	29.60	0.54	0.56	0.32	0.28	136
TF5-6	0.22	0.66	0.01	0.15	30.40	0.49	0.48	0.28	0.24	137
RET5-2	0.21	0.69	-0.03	0.15	45.60	0.33	0.35	0.29	0.22	133
LE5-1	0.18	0.71	0.00	0.14	44.30	0.31	0.30	0.24	0.23	135
LE5-2	0.14	0.78	0.05	0.10	42.70	0.24	0.20	0.18	0.20	131
LE5-3	0.12	0.80	0.07	0.09	46.60	0.19	0.12	0.16	0.16	125
LE5-4	0.11	0.72	0.07	0.08	53.80	0.15	0.08	0.11	0.11	126
LE5-5	0.08	0.70	0.04	0.05	58.90	0.08	0.04	0.09	0.06	98
Average	0.18	0.66	0.01	0.13	41.34	0.34	0.33	0.20	0.21	130

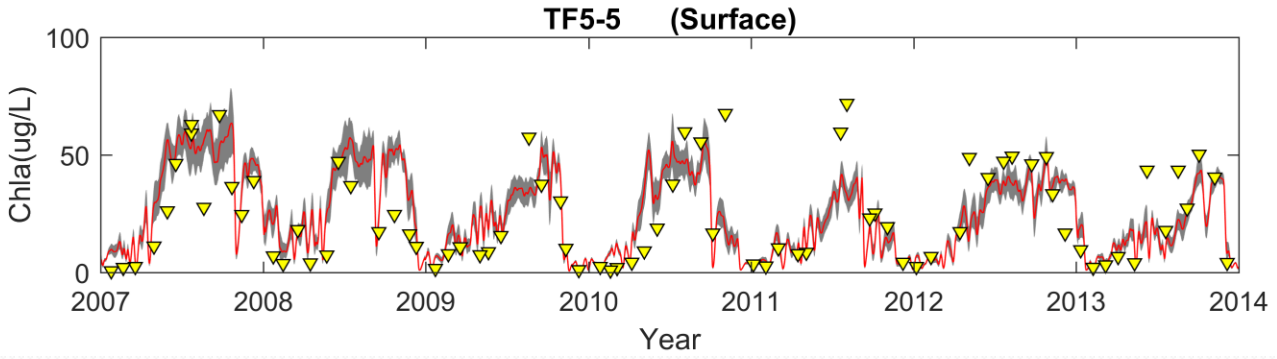
Station	RMSE	R	Mean Diff.	Abs. Diff.	Relative Diff. (%)	Obs. mean	Model mean	Obs. Std.	Model Std.	# of nata
TF5-2A	0.22	0.43	-0.02	0.15	37.00	0.39	0.42	0.14	0.23	130
TF5-3	0.22	0.54	-0.02	0.14	32.10	0.45	0.47	0.15	0.26	133
TF5-4	0.22	0.55	0.10	0.16	46.10	0.35	0.26	0.22	0.18	133
TF5-5	0.24	0.68	-0.12	0.16	30.30	0.54	0.66	0.25	0.28	135
TF5-5A	0.23	0.67	-0.02	0.15	29.20	0.53	0.55	0.29	0.28	134
TF5-6	0.21	0.64	0.00	0.14	29.80	0.47	0.48	0.26	0.24	135
RET5-2	0.19	0.68	-0.03	0.14	45.60	0.31	0.33	0.26	0.21	131
LE5-1	0.17	0.70	-0.01	0.13	44.70	0.28	0.29	0.21	0.22	132
LE5-2	0.15	0.64	0.03	0.11	57.80	0.19	0.17	0.14	0.19	129
LE5-3	0.11	0.69	0.05	0.08	52.80	0.15	0.10	0.11	0.13	125
LE5-4	0.11	0.37	0.06	0.08	65.70	0.12	0.06	0.08	0.08	126
LE5-5	0.04	0.37	0.02	0.03	53.80	0.06	0.03	0.04	0.02	99
Average	0.17	0.58	0.00	0.12	43.74	0.32	0.32	0.18	0.19	129

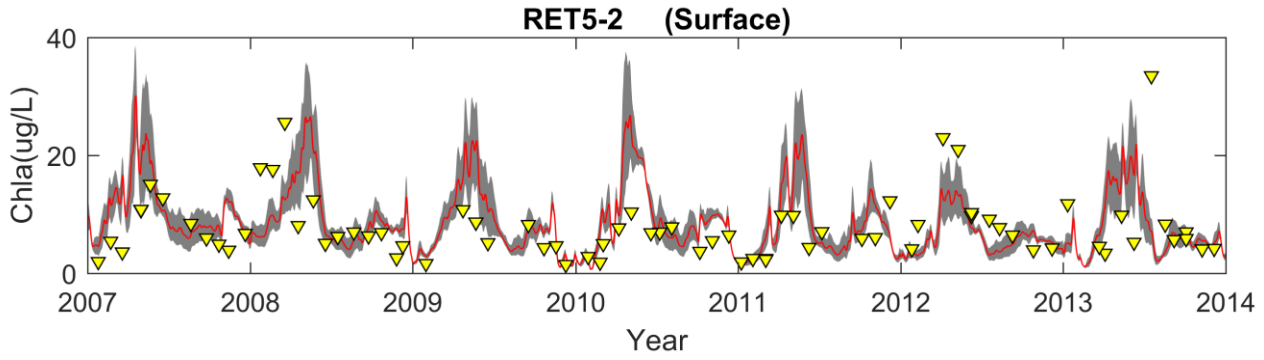
DIP (TF5-5)

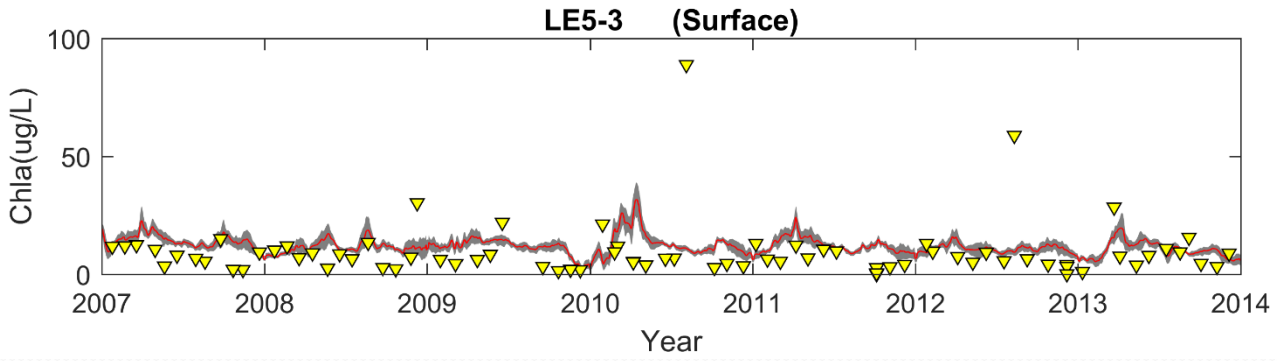
Station	RMSE	R	Mean Diff.	Abs. Diff.	Relative Diff. (%)	Obs. mean	Model mean	Obs. Std.	Model Std.	# of nata
TF5-2A	0.03	0.39	0.02	0.02	48.80	0.04	0.03	0.02	0.02	136
TF5-3	0.02	0.35	0.01	0.02	46.40	0.04	0.03	0.02	0.02	137
TF5-4	0.01	0.33	0.01	0.01	42.90	0.02	0.01	0.01	0.01	139
TF5-5	0.01	0.39	0.00	0.01	33.60	0.02	0.02	0.01	0.01	139
TF5-5A	0.01	0.46	0.00	0.01	34.30	0.02	0.02	0.01	0.01	139
TF5-6	0.01	0.21	0.00	0.01	42.80	0.02	0.02	0.01	0.01	139
RET5-2	0.02	0.30	-0.01	0.01	58.20	0.02	0.03	0.01	0.02	138
LE5-1	0.02	0.36	0.00	0.01	39.20	0.02	0.03	0.01	0.02	139
LE5-2	0.02	0.36	0.01	0.01	45.50	0.03	0.02	0.02	0.01	139
LE5-3	0.02	0.55	0.01	0.01	44.10	0.03	0.02	0.02	0.01	138
LE5-4	0.02	0.57	0.01	0.01	50.70	0.02	0.01	0.02	0.01	138
LE5-5	0.01	0.66	0.01	0.01	43.70	0.01	0.01	0.01	0.00	99
Average	0.02	0.41	0.00	0.01	44.18	0.02	0.02	0.01	0.01	135

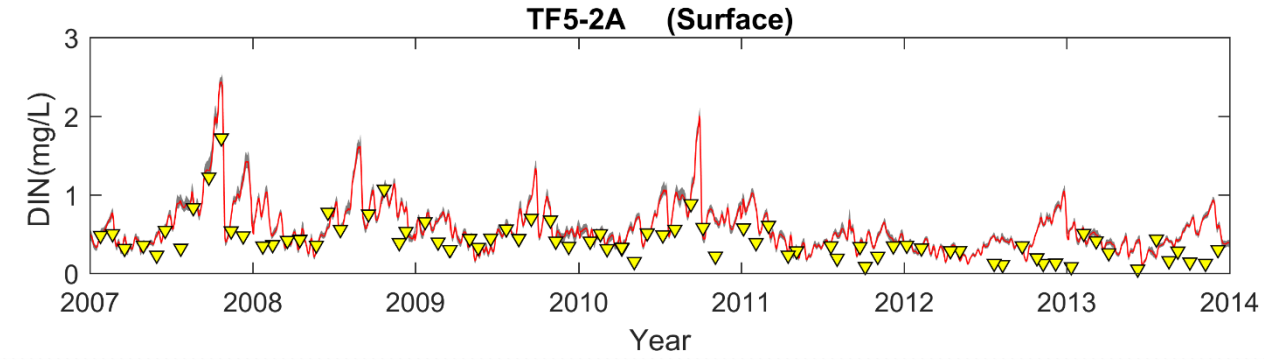
Station	RMSE	R	Mean Diff.	Abs. Diff.	Relative Diff. (%)	Obs. mean	Model mean	Obs. Std.	Model Std.	# of nata
TF5-2A	0.03	0.34	0.02	0.03	63.40	0.04	0.02	0.02	0.01	135
TF5-3	0.03	0.35	0.02	0.02	57.10	0.04	0.02	0.02	0.01	137
TF5-4	0.02	0.23	0.01	0.01	55.80	0.02	0.01	0.01	0.01	138
TF5-5	0.02	0.30	0.01	0.01	44.80	0.02	0.01	0.01	0.01	139
TF5-5A	0.01	0.35	0.01	0.01	45.40	0.02	0.01	0.01	0.01	138
TF5-6	0.01	0.13	0.01	0.01	45.80	0.02	0.01	0.01	0.01	139
RET5-2	0.01	0.38	0.00	0.01	37.80	0.02	0.02	0.01	0.01	137
LE5-1	0.02	0.34	0.01	0.01	47.70	0.03	0.02	0.01	0.01	138
LE5-2	0.02	0.41	0.02	0.02	60.00	0.03	0.01	0.02	0.01	138
LE5-3	0.02	0.49	0.01	0.01	60.50	0.02	0.01	0.02	0.01	137
LE5-4	0.02	0.52	0.01	0.01	65.30	0.02	0.01	0.02	0.00	138
LE5-5	0.01	0.57	0.01	0.01	72.80	0.02	0.00	0.01	0.00	98
Average	0.02	0.37	0.01	0.01	54.70	0.02	0.01	0.01	0.01	134

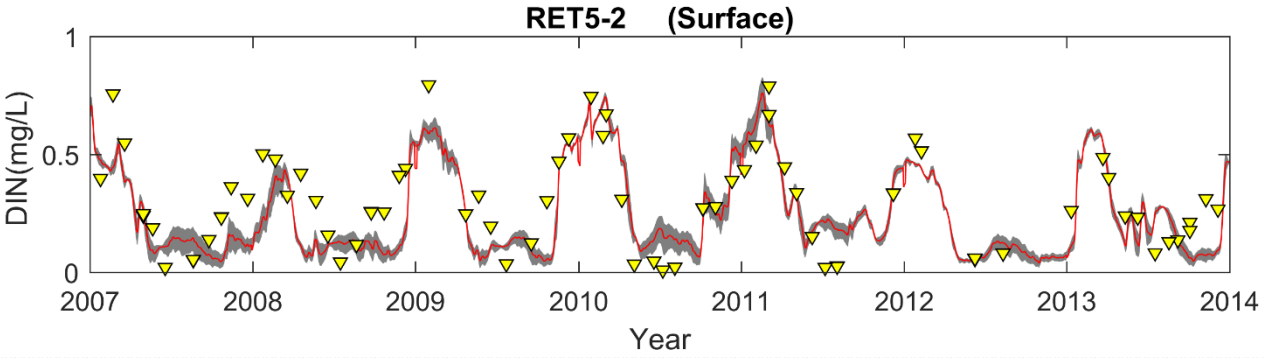
Model Verification Results








TF5-2A (Surface)
DIN(mg/L)
0
1
2
3
2007
2008
2009
2010
2011
2012
2013
2014
Year


RET5-2 (Surface)
DIN(mg/L)
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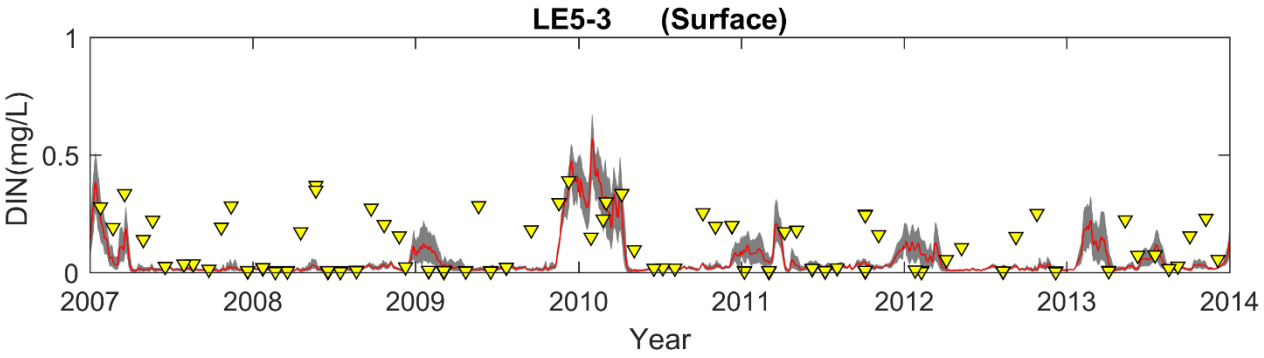
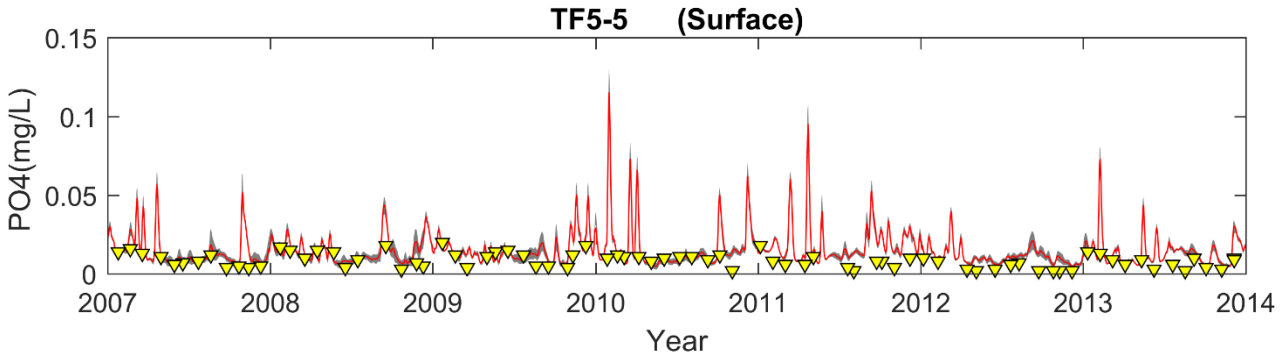
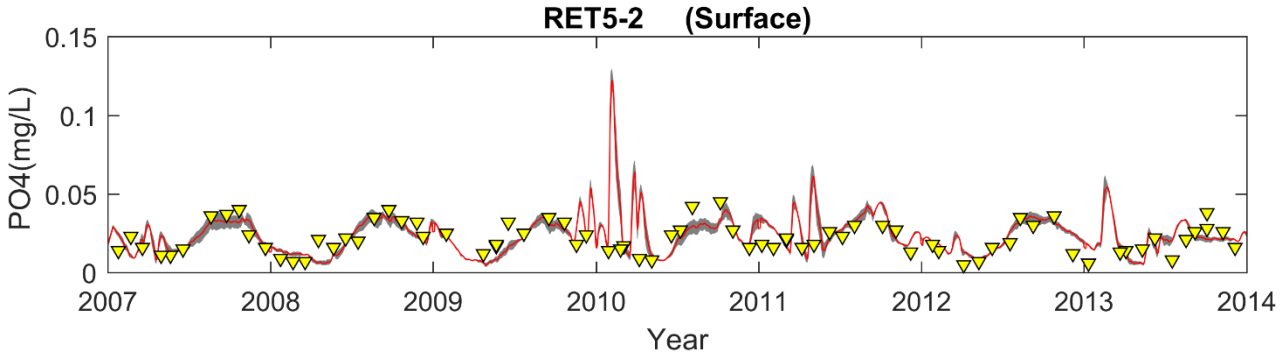
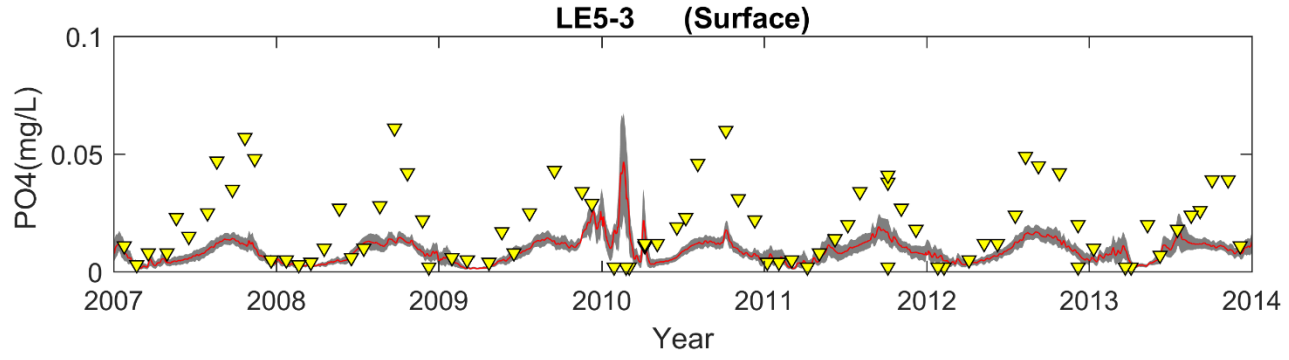
0.5
1
2007
2008
2009
2010
2011
2012
2013
2014
Year


LE5-3 (Surface)
DIN(mg/L)
0
0.5
1
2007
2008
2009
2010
2011
2012
2013
2014
Year


TF5-5 (Surface)
PO4(mg/L)
0.15
0.1
0.05
0
2007
2008
2009
2010
2011
2012
2013
2014
Year


RET5-2 (Surface)
PO4(mg/L)
0.15
0.1
0.05
0
2007
2008
2009
2010
2011
2012
2013
2014
Year


LE5-3 (Surface)
PO4(mg/L)
0.1
0.05
0
2007
2008
2009
2010
2011
2012
2013
2014
Year

Statistics

Chl a (surface)

Station	RMSE	R	Mean Diff.	Abs. Diff.	Relative Diff. (%)	Obs. mean	Model mean	Obs. Std.	Model Std.	# of nata
TF5-2A	9.24	-0.12	2.23	4.27	104.40	4.09	1.86	8.43	2.38	77
TF5-3	6.98	0.49	2.20	4.22	78.50	5.38	3.18	7.64	3.45	78
TF5-4	8.96	0.88	-2.07	6.36	33.60	18.94	21.00	18.54	16.40	73
TF5-5	10.66	0.85	-0.75	6.85	29.20	23.47	24.22	20.15	17.34	79
TF5-5A	12.07	0.69	-3.69	8.48	42.00	20.21	23.90	15.79	12.74	77
TF5-6	10.90	0.18	-5.40	8.39	106.50	7.88	13.28	7.66	7.16	78
RET5-2	4.20	0.67	0.07	2.43	31.10	7.80	7.74	5.66	3.72	73
LE5-1	19.23	0.34	2.49	4.96	53.50	9.27	6.79	19.97	2.87	72
LE5-2	25.65	0.30	4.37	8.78	68.00	12.92	8.55	26.41	4.38	74
LE5-3	11.19	0.42	1.06	4.32	44.00	9.82	8.76	12.30	3.98	75
LE5-4	5.78	0.60	0.20	2.72	28.30	9.59	9.39	7.26	4.53	76
LE5-5	4.62	0.91	-0.54	2.08	19.40	10.73	11.26	9.22	5.78	97
Average	10.79	0.52	0.01	5.32	53.21	11.67	11.66	13.25	7.06	77

DIN (surface)

Station	RMSE	R	Mean Diff.	Abs. Diff.	Relative Diff. (%)	Obs. mean	Model mean	Obs. Std.	Model Std.	# of nata
TF5-2A	0.25	0.74	-0.15	0.17	40.30	0.42	0.57	0.26	0.30	78
TF5-3	0.22	0.77	-0.14	0.17	36.70	0.45	0.60	0.25	0.26	79
TF5-4	0.16	0.79	0.06	0.10	30.10	0.34	0.28	0.25	0.18	72
TF5-5	0.20	0.80	-0.01	0.09	20.80	0.41	0.42	0.33	0.26	78
TF5-5A	0.10	0.93	0.00	0.06	17.90	0.36	0.35	0.28	0.26	77
TF5-6	0.19	0.80	0.09	0.13	29.30	0.43	0.34	0.27	0.22	75
RET5-2	0.12	0.85	0.04	0.09	28.80	0.30	0.27	0.20	0.19	67
LE5-1	0.13	0.79	0.06	0.10	36.50	0.27	0.22	0.18	0.19	66
LE5-2	0.14	0.63	0.08	0.10	55.90	0.18	0.10	0.14	0.13	69
LE5-3	0.11	0.61	0.06	0.07	63.50	0.12	0.06	0.12	0.08	70
LE5-4	0.05	0.85	0.03	0.03	38.70	0.09	0.06	0.08	0.06	68
LE5-5	0.01	0.99	0.00	0.01	12.20	0.05	0.05	0.06	0.06	97
Average	0.14	0.80	0.01	0.09	34.23	0.28	0.28	0.20	0.18	75

Model Uncertainty of Simulation of phytoplankton

The influence of light on phytoplankton production is represented by a chlorophyll-specific production equation (Jassby and Platt, 1976; Cerco and Noel, 2004):

$$P^B = P^Bm \frac{I}{\sqrt{I^2 + IK^2}} \quad (3\text{-}1)$$

where:

P^B = photosynthetic rate (g C g^{-1} Chl d^{-1})

P^Bm = maximum photosynthetic rate (g C g^{-1} Chl d^{-1})
I = irradiance (E m^{-2} d^{-1})

Parameter Ik is defined as the irradiance at which the initial slope of the production vs. irradiance relationship intersects the value of P^Bm:

$$IK = \frac{P^Bm}{\alpha} \quad (3\text{-}2)$$

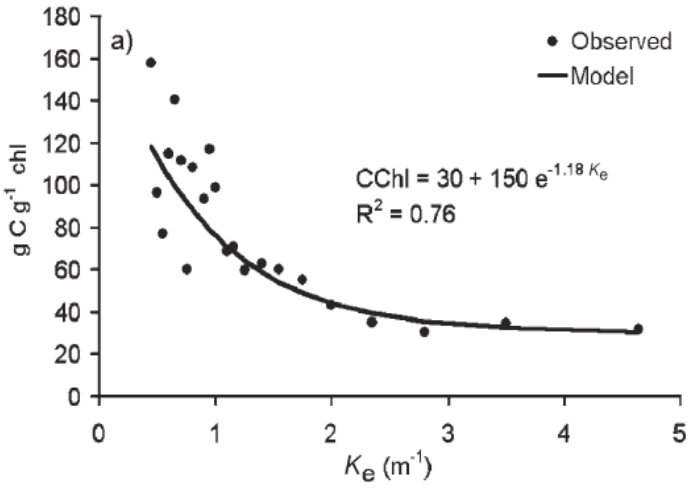
where: α = initial slope of production vs. irradiance relationship (g C g^{-1} Chl (E m^{-2})$^{-1}$)

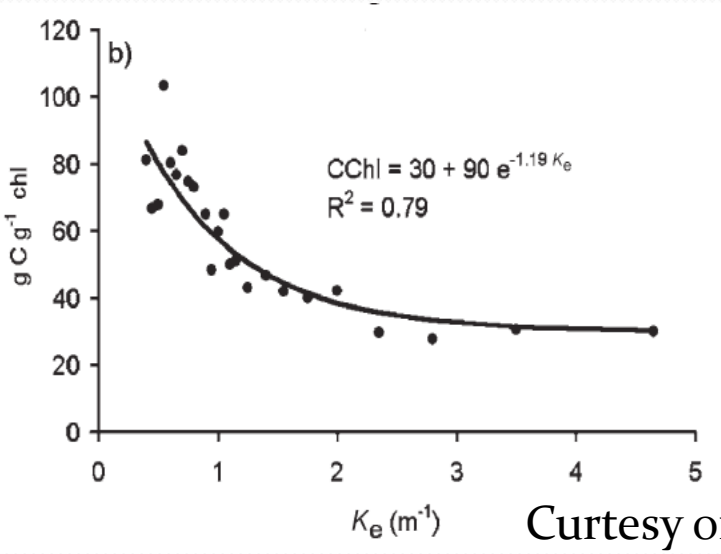
The chlorophyll-specific production rate is readily converted to the carbon-specific growth rate, through division by the carbon-to-chlorophyll ratio:

$$G = \frac{P^B}{CChl} \quad (3\text{-}3)$$

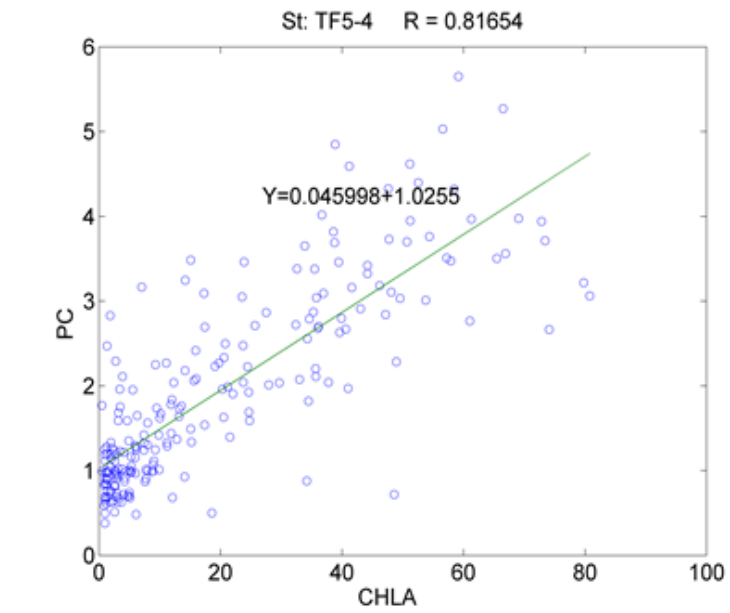
where: CChl = carbon-to-chlorophyll ratio (g C g^{-1} chlorophyll-a)

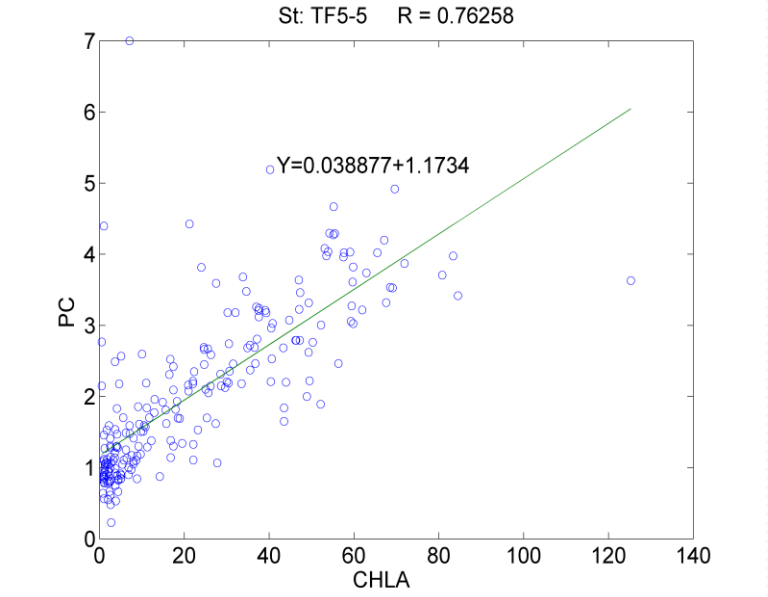
Two Approach: Fix CChl and vary CChl





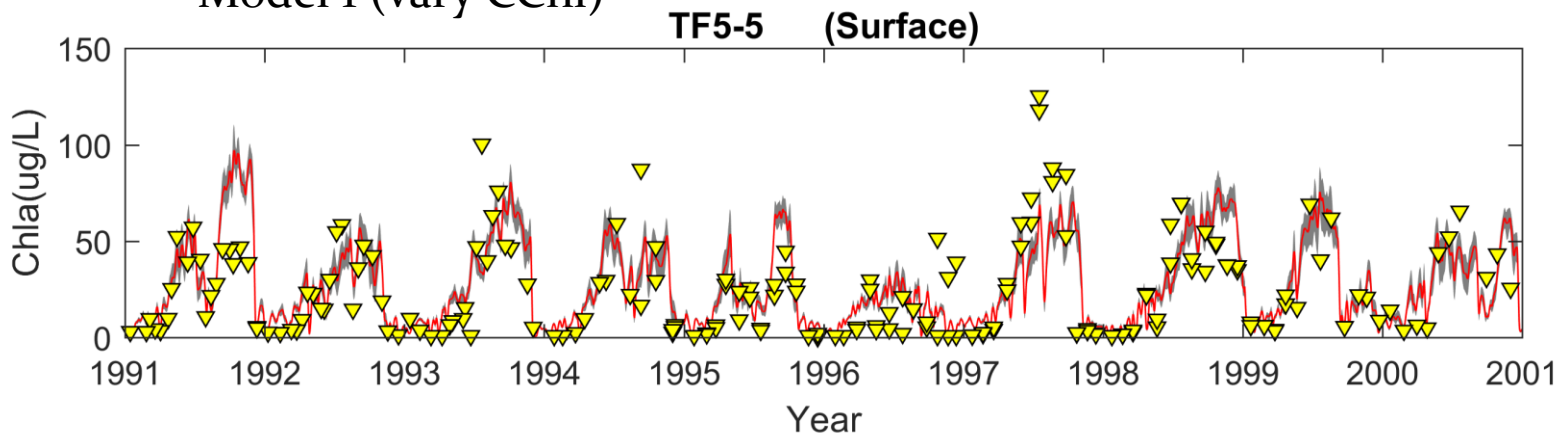
Curtesy of Cerco and Noel. 2004)



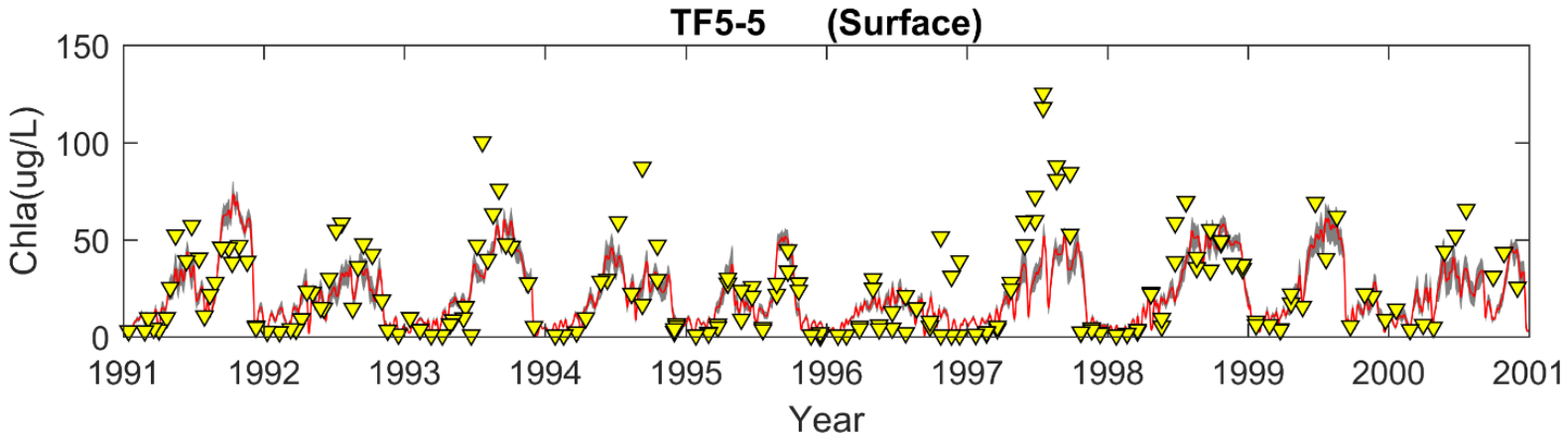


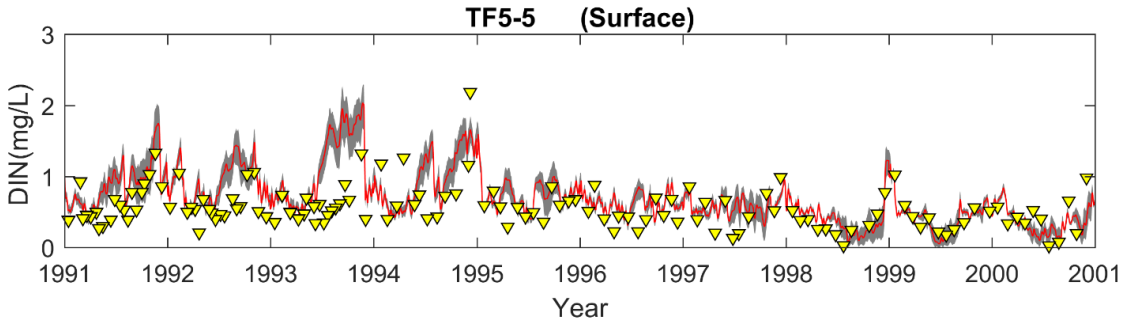
Comparison of model results

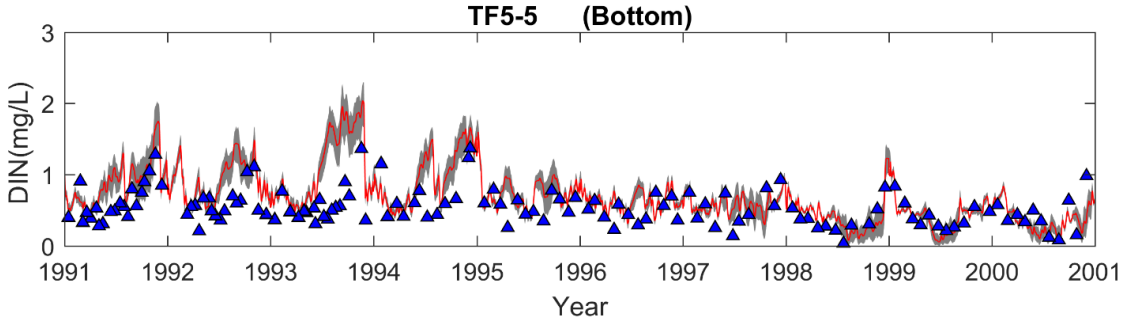
Model 1 (vary CChl)

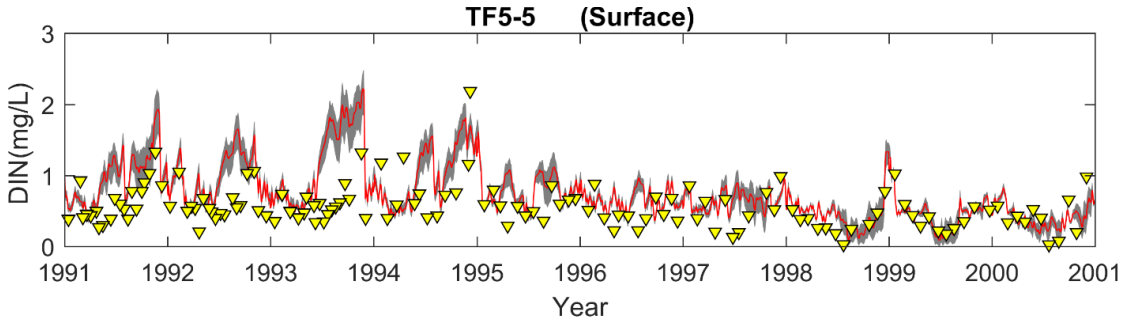


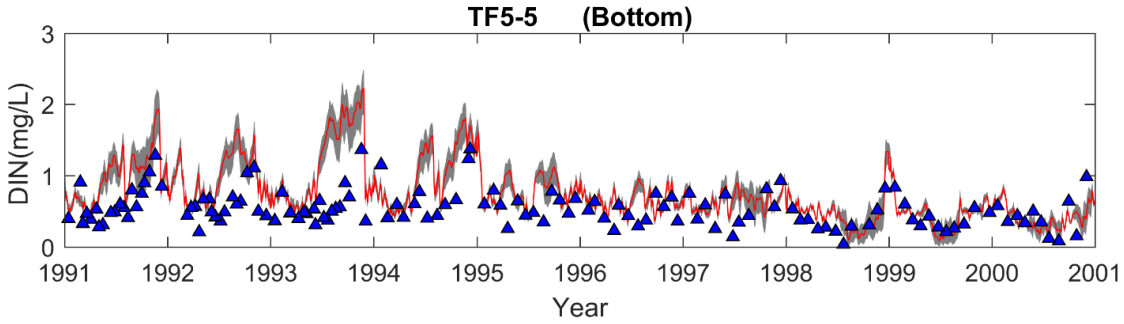
Model 2 (Fixed CChl)



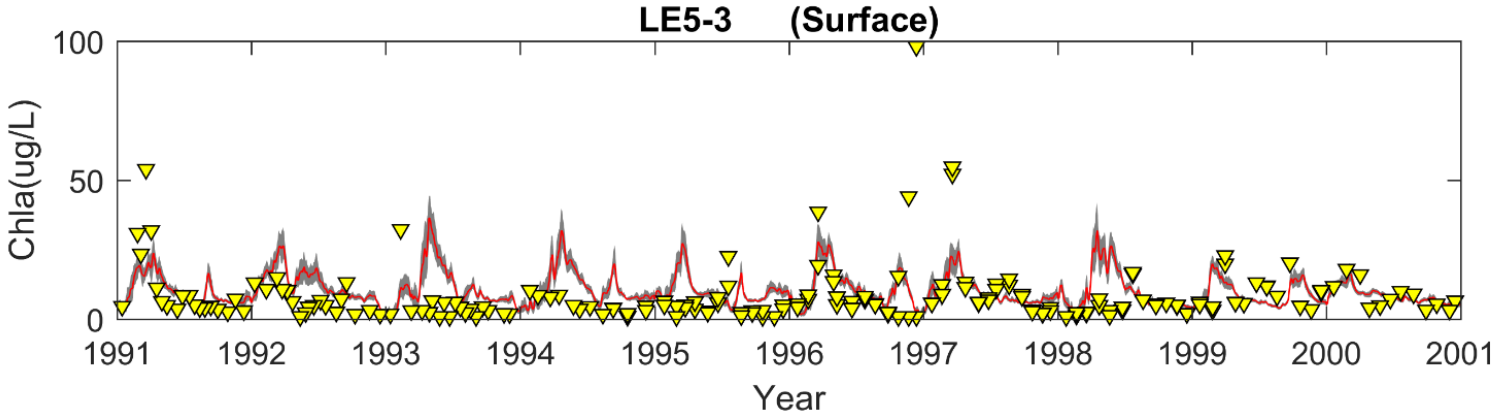

TF5-5 (Surface)
DIN(mg/L)
0
1
2
3
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
Year


TF5-5 (Bottom)
DIN(mg/L)
0
1
2
3
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
Year

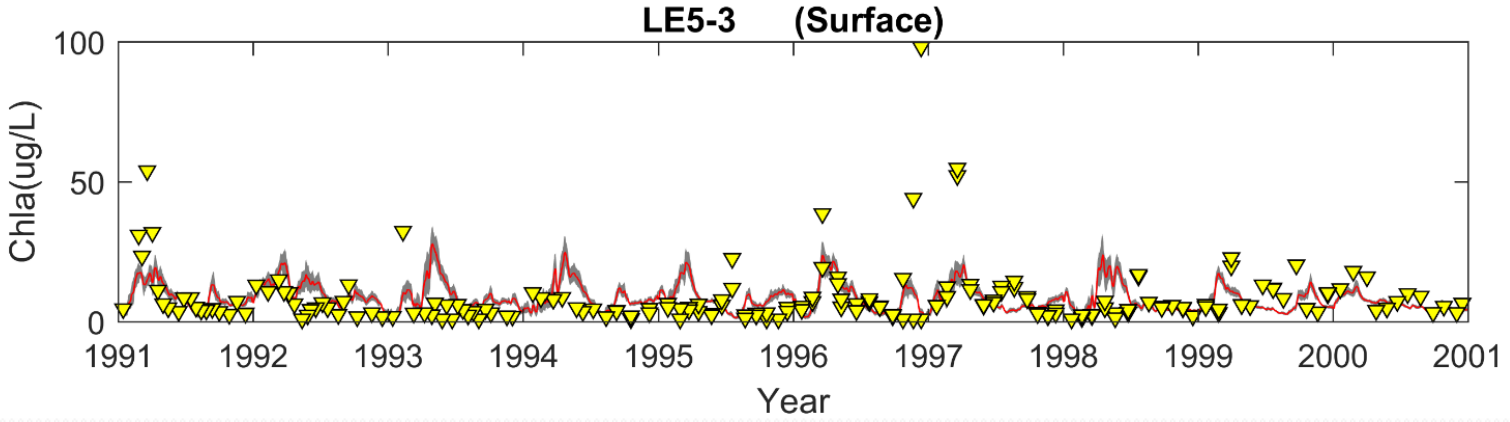

TF5-5 (Surface)
DIN(mg/L)
0
1
2
3
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
Year


TF5-5 (Bottom)
DIN(mg/L)
0
1
2
3
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
Year

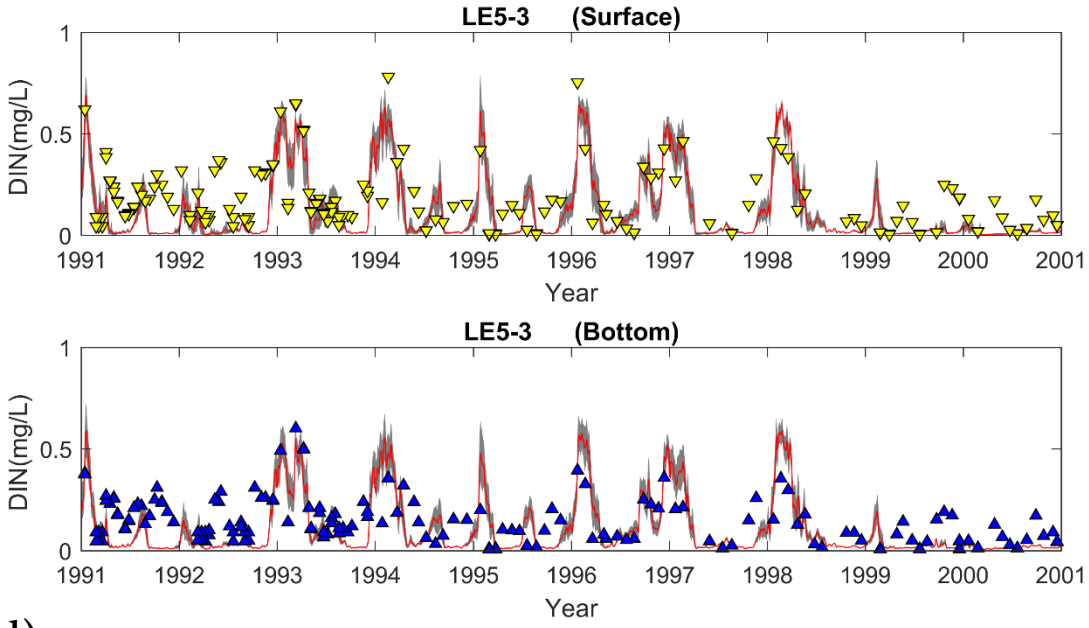
Model 1 (vary CChl)



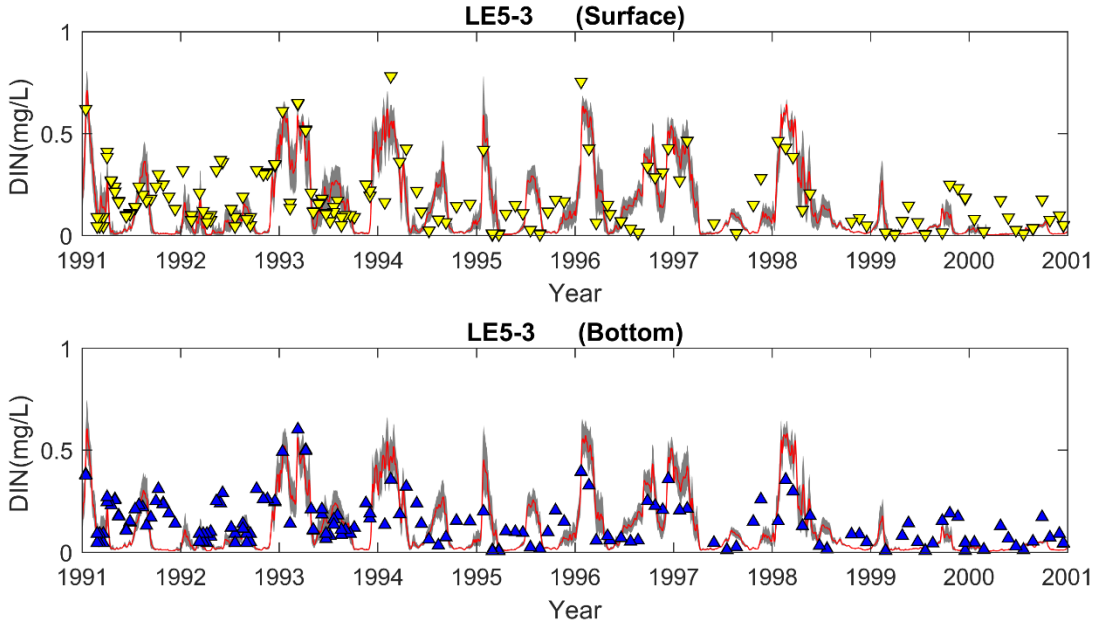
Model 2 (Fixed CChl)



Model 1 (vary CChl)



Model 2 (Fixed CChl)



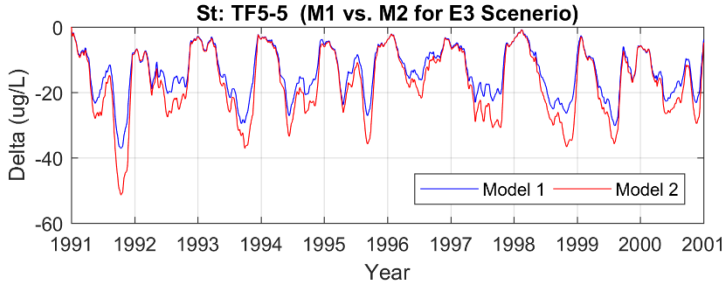
Chl a (Surface)

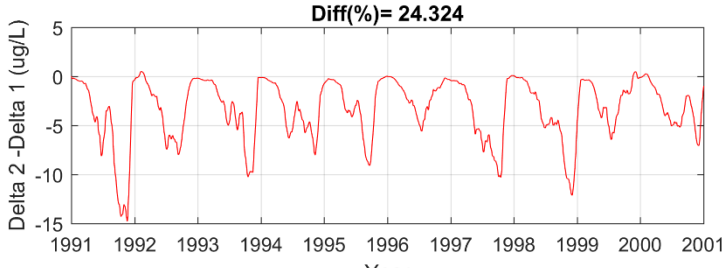
	M-2	M-1	M-2	M-1	M-2	M-1	M-2	M-1
Station	RMSE		R		Mean Difference		Relative Difference (%)	
TF5-2A	8.27	8.53	-0.10	-0.08	0.04	-0.74	112.40	120.60
TF5-3	9.49	9.43	-0.05	0.00	1.41	0.60	99.20	102.90
TF5-4	13.09	12.78	0.80	0.81	1.56	0.54	37.20	35.90
TF5-5	14.43	14.81	0.80	0.80	2.05	-2.70	36.10	38.90
TF5-5A	19.35	18.96	0.69	0.69	2.67	-0.70	38.50	40.10
TF5-6	10.90	12.59	0.48	0.27	0.43	-0.83	52.30	65.00
RET5-2	13.92	12.82	0.30	0.36	5.33	2.09	54.70	47.30
LE5-1	7.67	7.02	0.21	0.33	2.87	0.43	56.10	49.90
LE5-2	15.94	14.80	0.50	0.59	3.28	1.91	67.10	64.50
LE5-3	10.77	10.62	0.41	0.44	0.38	-0.23	58.90	54.20
LE5-4	5.15	4.82	0.61	0.70	-1.03	-1.04	44.20	38.60
LE5-5	4.78	4.07	0.67	0.79	0.13	-0.69	29.00	27.70
Average	11.15	10.94	0.45	0.47	1.59	-0.11	57.14	57.13

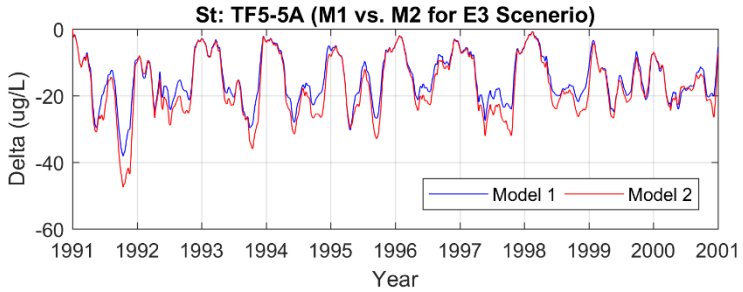
DIN (surface)

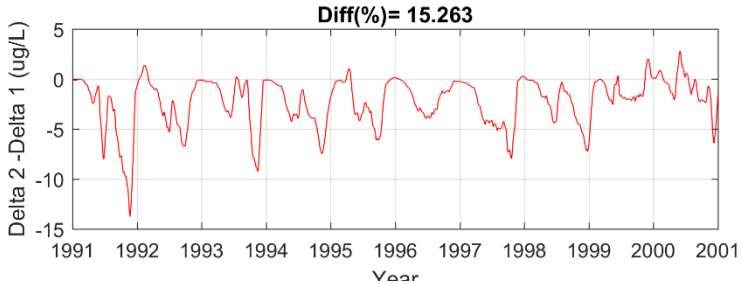
	M-2	M-1	M-2	M-1	M-2	M-1	M-2	M-1
Station	RMSE		R		Mean Difference		Relative Difference (%)	
TF5-2A	0.22	0.22	0.38	0.43	-0.03	-1.38	37.10	-0.02
TF5-3	0.23	0.22	0.50	0.54	-0.03	-0.02	34.40	32.10
TF5-4	0.20	0.22	0.62	0.55	0.08	0.10	42.60	46.10
TF5-5	0.29	0.24	0.66	0.68	-0.14	-0.12	35.80	30.30
TF5-5A	0.26	0.23	0.64	0.67	-0.06	-0.02	33.80	29.20
TF5-6	0.23	0.21	0.63	0.64	-0.02	0.00	32.20	29.80
RET5-2	0.26	0.19	0.56	0.68	-0.10	-0.03	60.80	45.60
LE5-1	0.22	0.17	0.58	0.70	-0.07	-0.01	54.60	44.70
LE5-2	0.13	0.15	0.74	0.64	0.00	0.03	42.80	57.80
LE5-3	0.12	0.11	0.78	0.69	0.05	0.05	43.80	52.80
LE5-4	0.10	0.11	0.71	0.37	0.06	0.06	48.80	65.70
LE5-5	0.08	0.04	0.68	0.37	0.04	0.02	59.80	53.80
Average	0.19	0.17	0.62	0.58	-0.02	-0.11	43.88	40.66

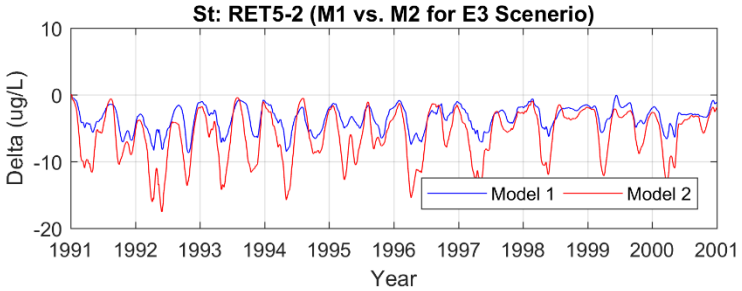
Sensitivity of Reduction (E3 scenario)

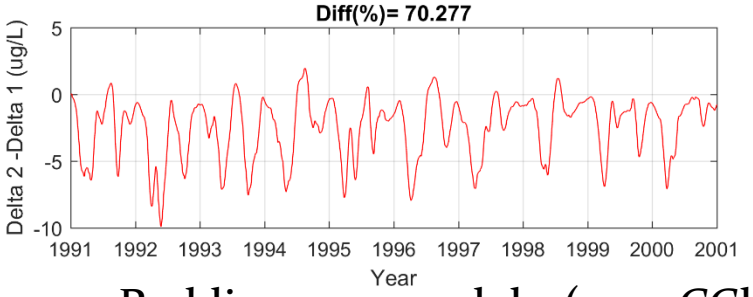


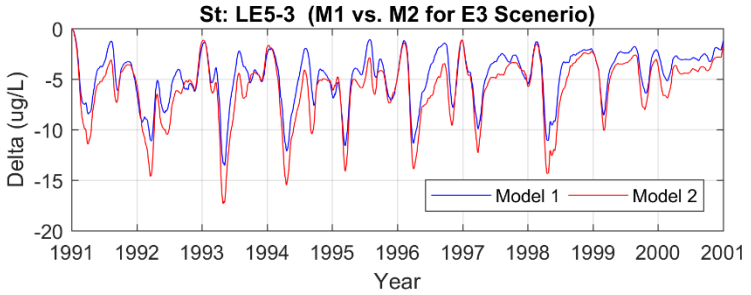


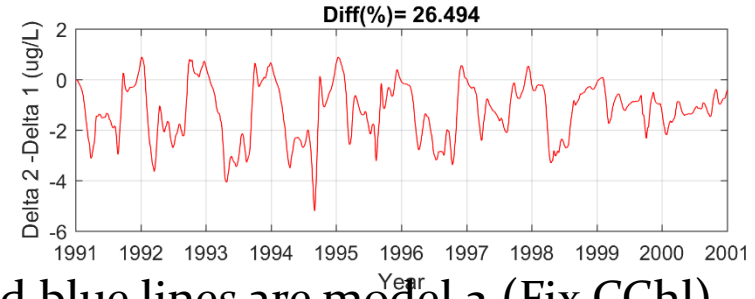






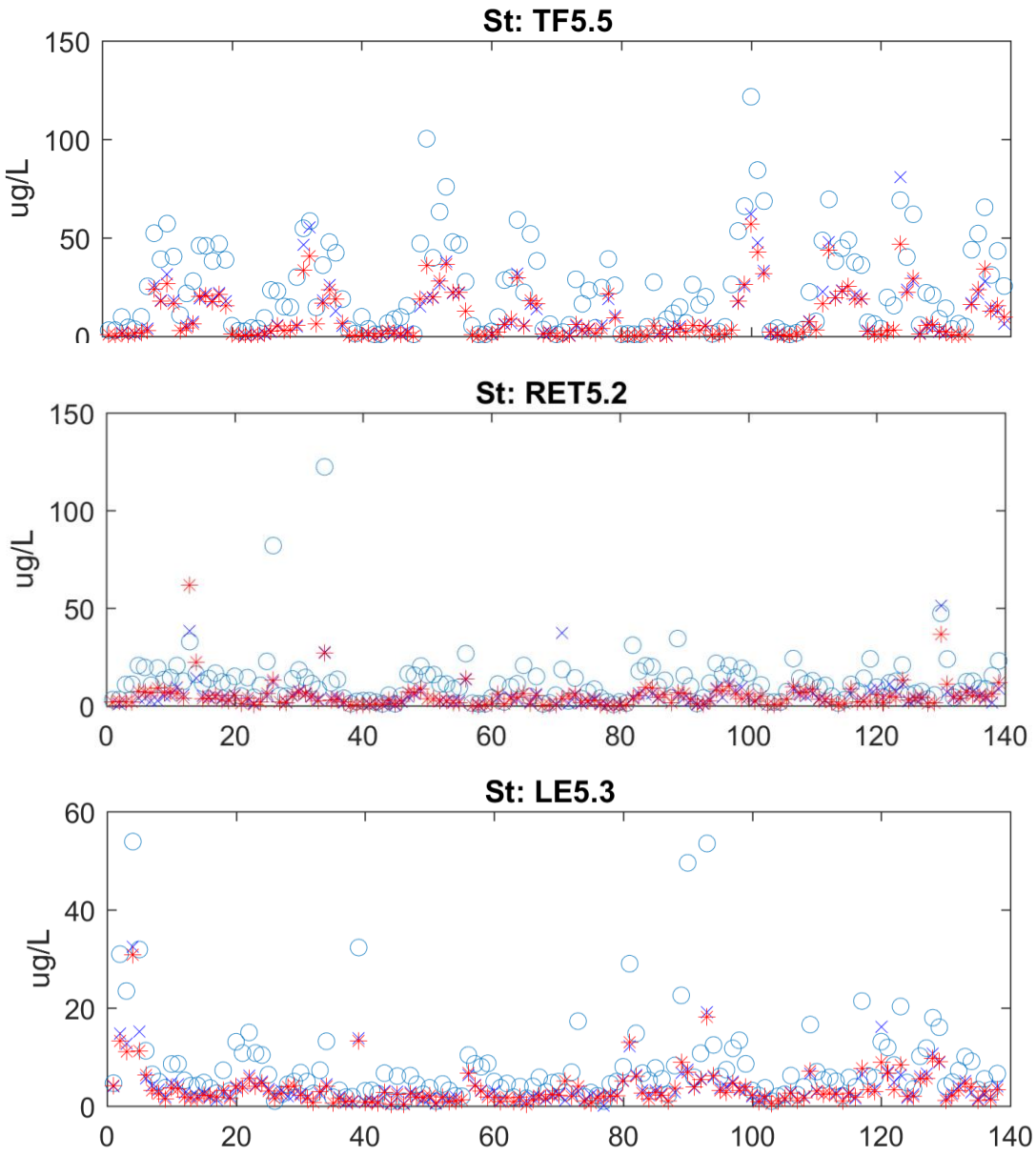






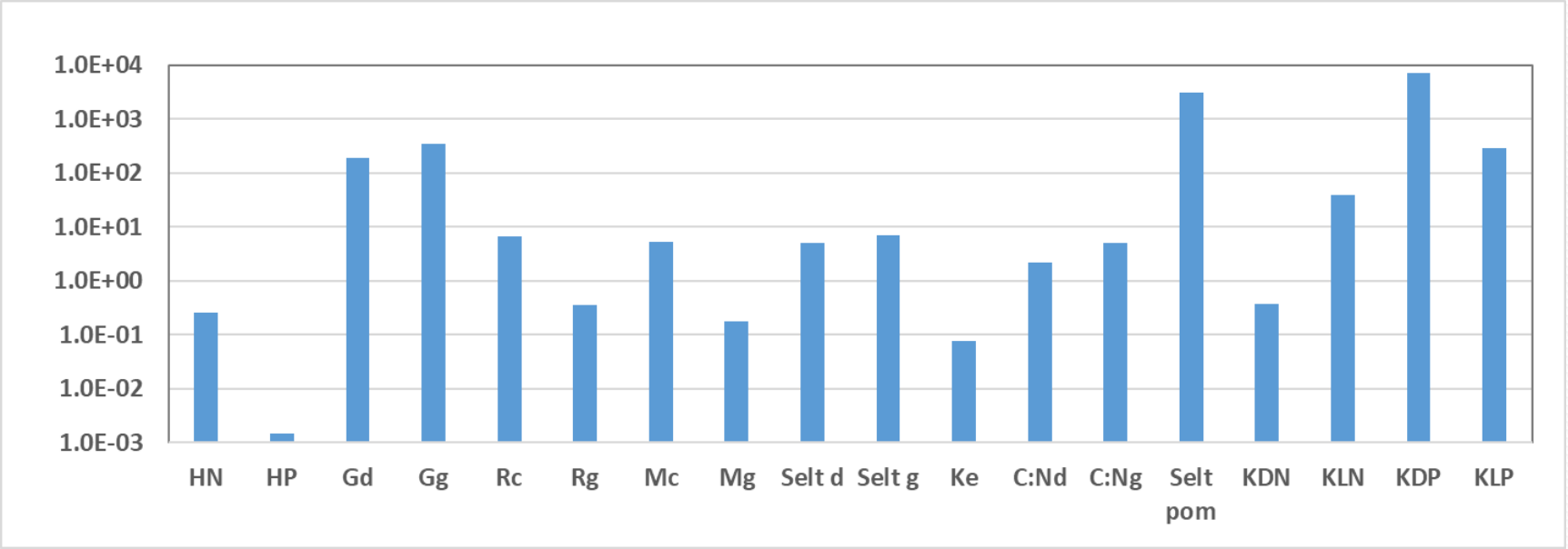
Red lines are model 1 (vary CChl) and blue lines are model 2 (Fix CChl).

Correction of observation



Parameter Uncertainty

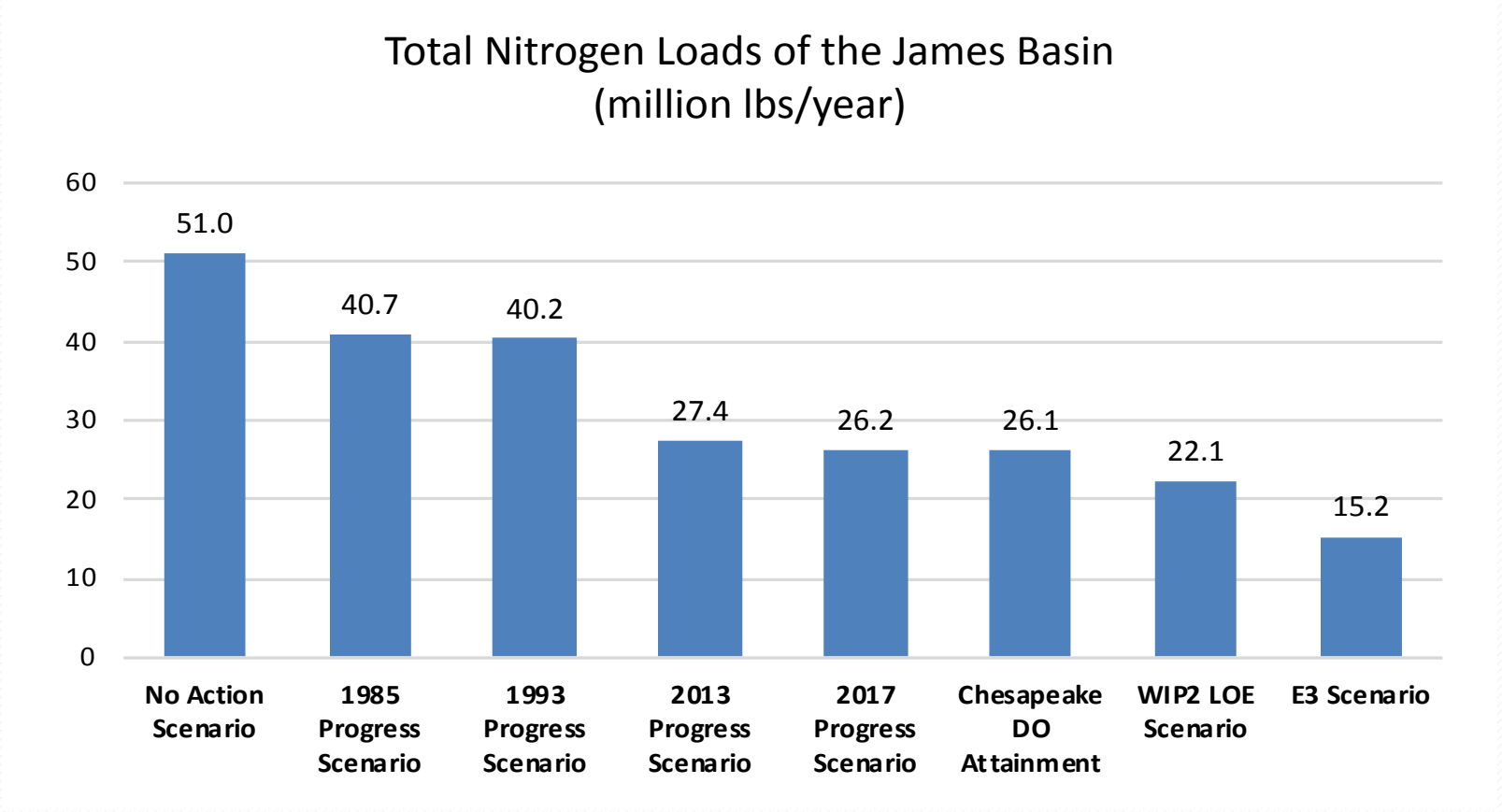
- Conduct model experiments with 5% perturbation of model kinetic parameters. Compute sensitivity matrix and model uncertainty (inverse of sensitivity matrix)



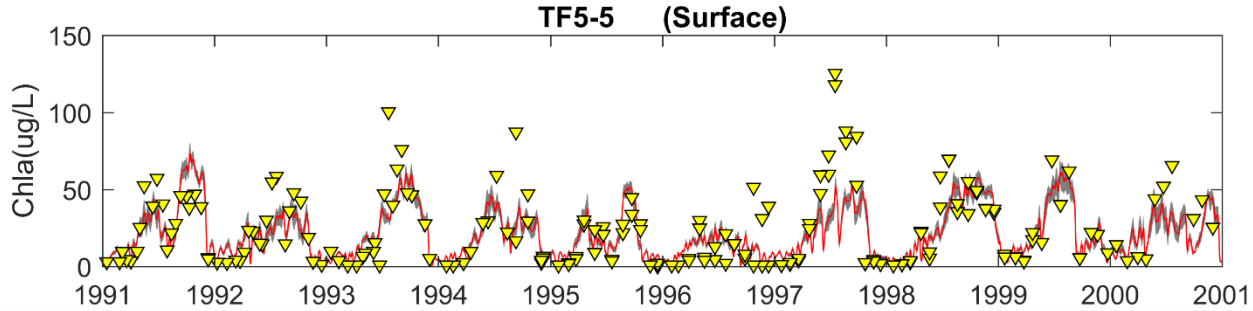
Correlation among parameters

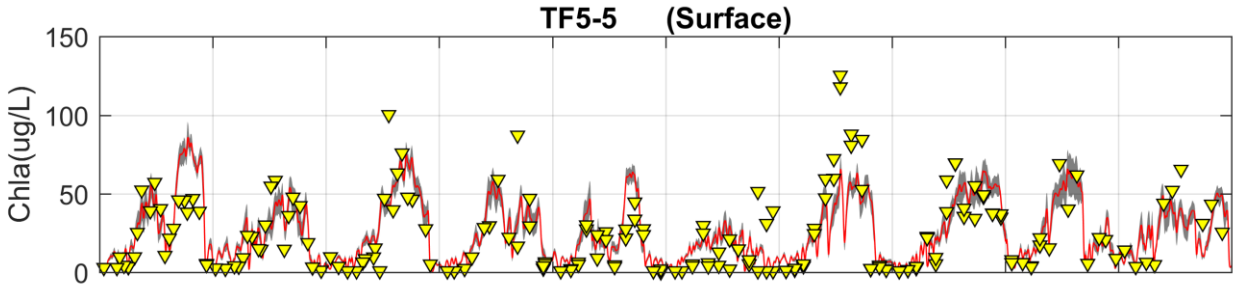
Param.	HN	HP	Gd	Gg	Rc	Rg	Mc	Mg	Selt d	Selt g	Ke	C:Nd	C:Ng	Selt pom	KDN	KLN	KDP	KLP
HN	1	0.38	0.16	0.75	0.76	0.41	0.76	0.03	0.26	0.74	0.67	0.62	0.81	0.30	0.47	0.89	0.33	0.58
HP		1	0.81	0.52	0.29	0.28	0.42	0.55	0.15	0.50	0.69	0.31	0.14	0.39	0.62	0.33	0.34	0.13
Gd			1	0.22	0.13	0.64	0.05	0.77	0.54	0.18	0.47	0.27	0.39	0.23	0.60	0.03	0.43	0.11
Gg				1	0.90	0.50	0.95	0.24	0.41	0.99	0.95	0.14	0.59	0.16	0.61	0.91	0.50	0.88
Rc					1	0.70	0.98	0.13	0.65	0.92	0.76	0.22	0.75	0.04	0.40	0.90	0.56	0.81
Rg						1	0.59	0.63	0.47	0.50	0.31	0.41	0.72	0.13	0.30	0.54	0.52	0.69
Mc							1	0.03	0.59	0.97	0.85	0.15	0.68	0.08	0.53	0.92	0.51	0.81
Mg								1	0.23	0.19	0.39	0.33	0.34	0.01	0.79	0.10	0.06	0.12
Selt d									1	0.49	0.15	0.01	0.54	0.27	0.26	0.55	0.63	0.45
Selt g										1	0.92	0.13	0.62	0.13	0.60	0.92	0.48	0.83
Ke											1	0.02	0.36	0.34	0.64	0.77	0.30	0.76
C:Nd												1	0.78	0.63	0.16	0.43	0.23	0.20
C:Ng													1	0.47	0.13	0.83	0.58	0.62
Selt pom														1	0.18	0.21	0.31	0.12
KDN															1	0.58	0.31	0.39
KLN																1	0.57	0.80
KDP																	1	0.78
KLP																		1

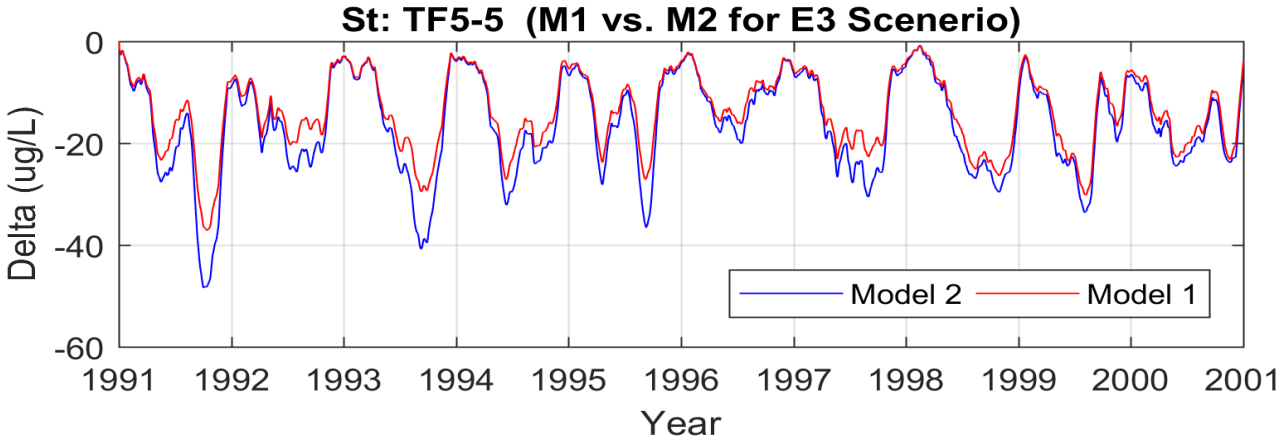
Comparison of Reduction Scenarios

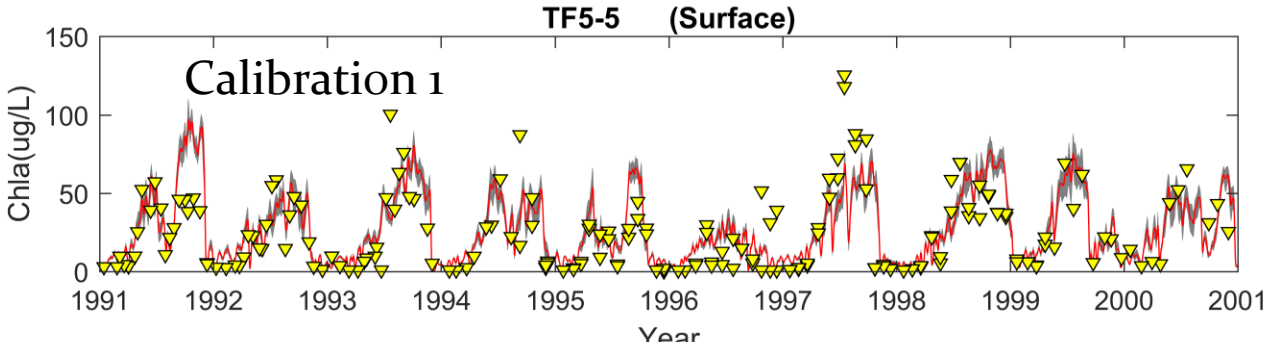


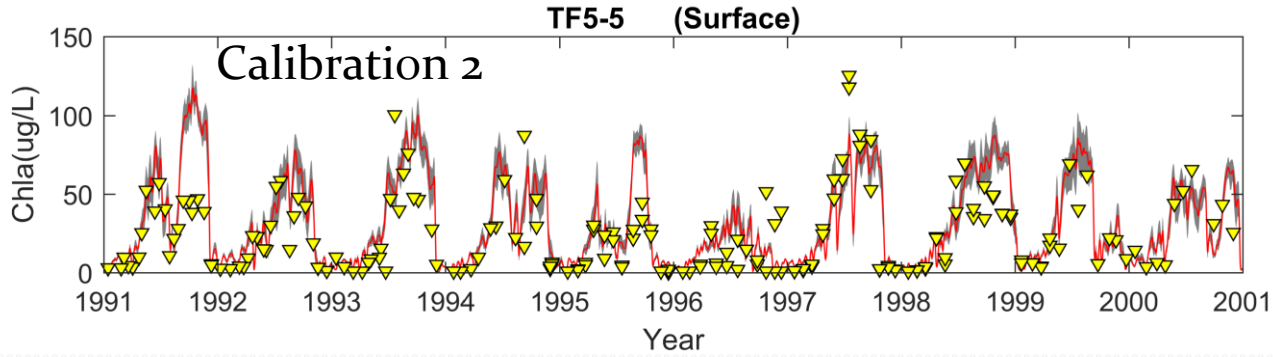
Calibration of model to match high Chl-a concentratio

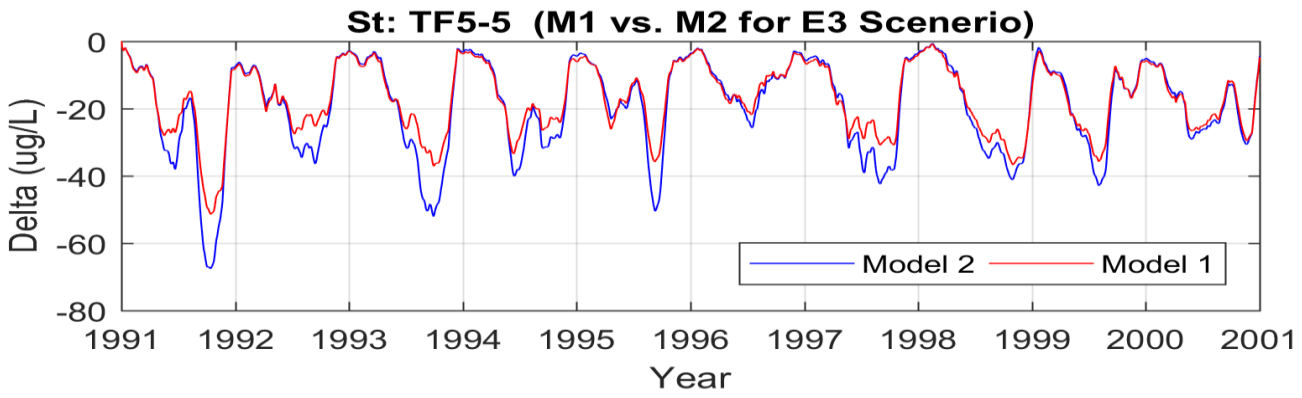




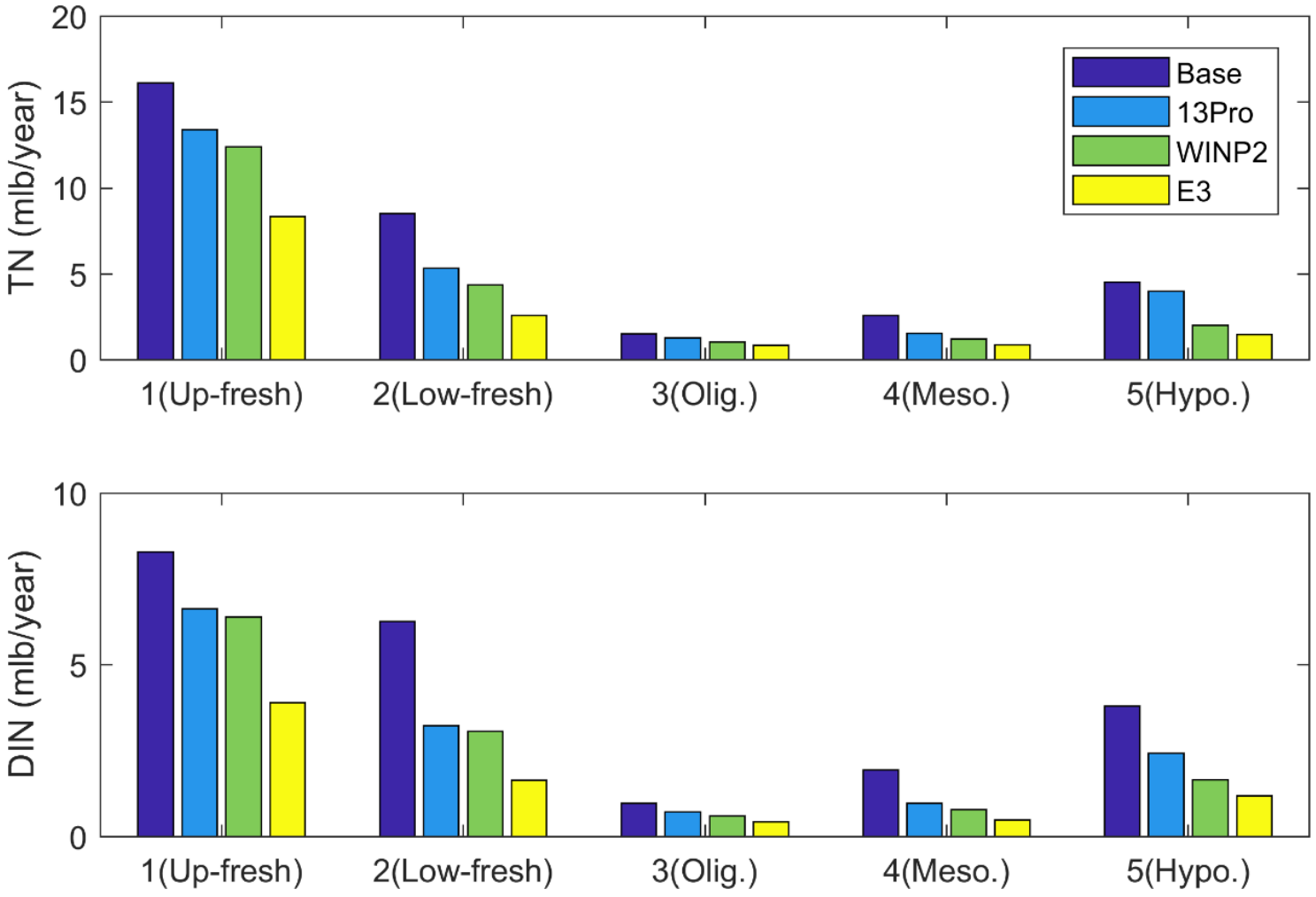



TF5-5 (Surface)
Calibration 1
Chla(ug/L)
150
100
50
0
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
Year

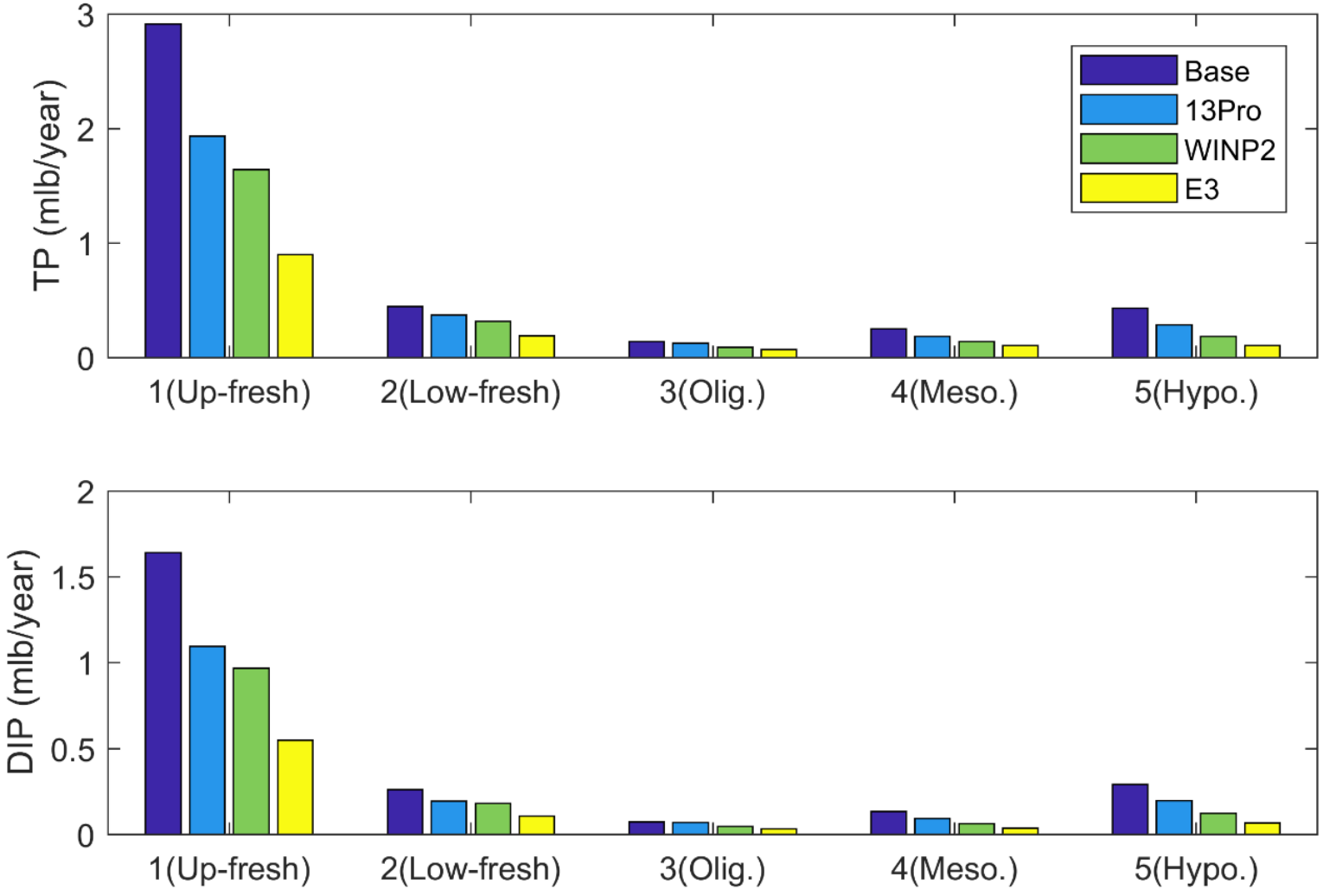

TF5-5 (Surface)
Calibration 2
Chla(ug/L)
150
100
50
0
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
Year


St: TF5-5 (M1 vs. M2 for E3 Scenerio)
Delta (ug/L)
0
-20
-40
-60
-80
Model 2
Model 1
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
Year

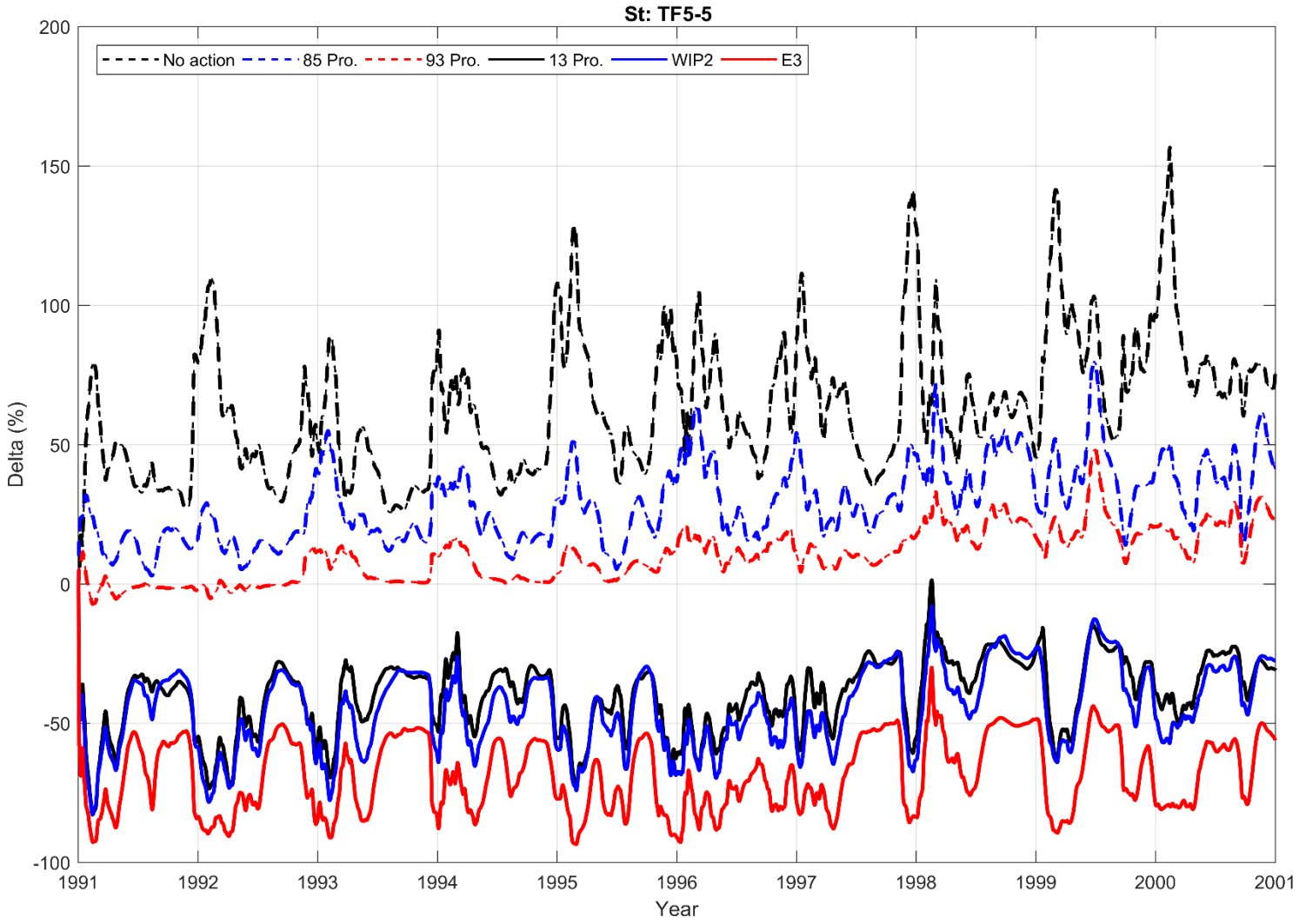
Loading Distribution (1991-2000)



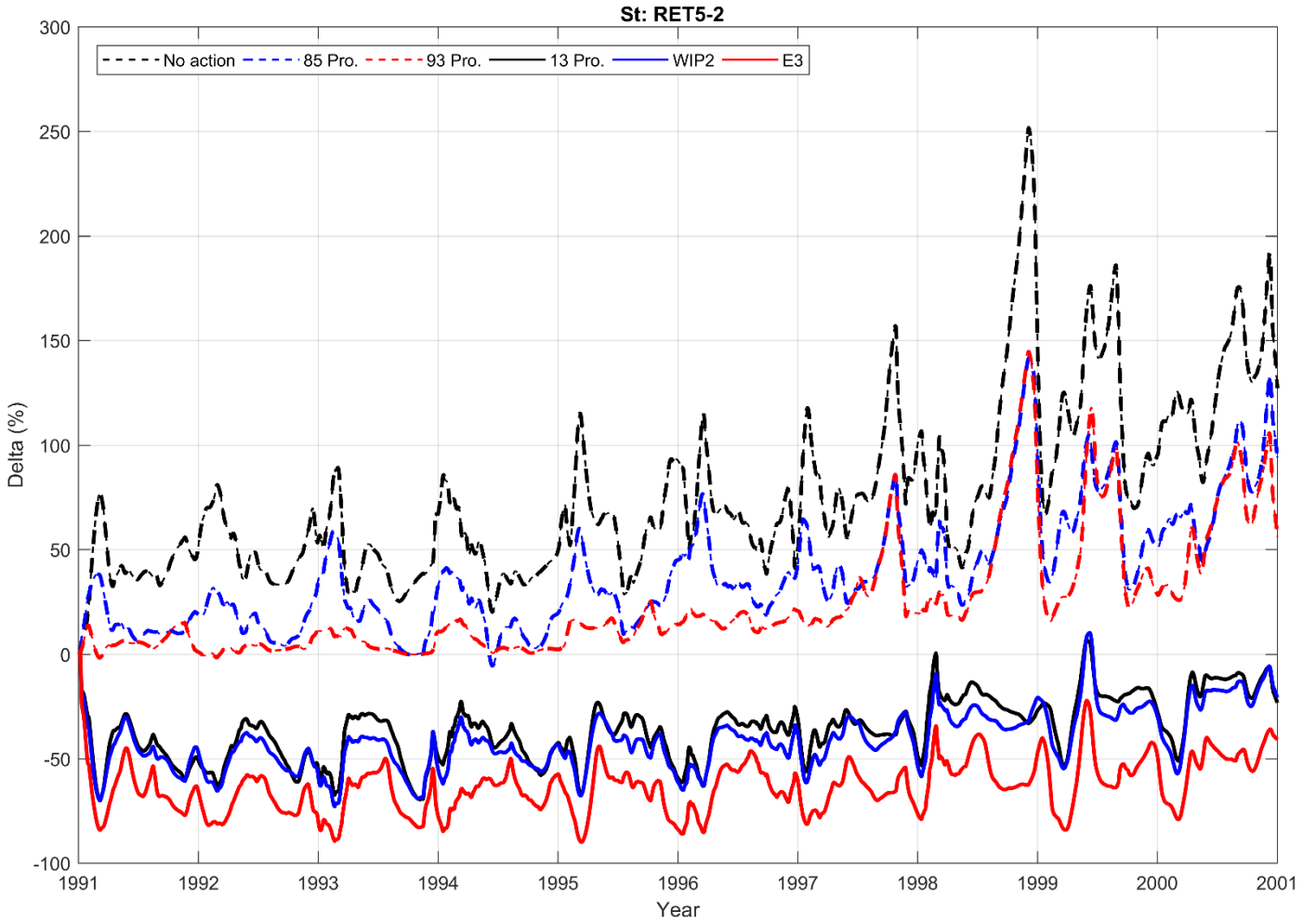
Loading Distribution (1991-2000)



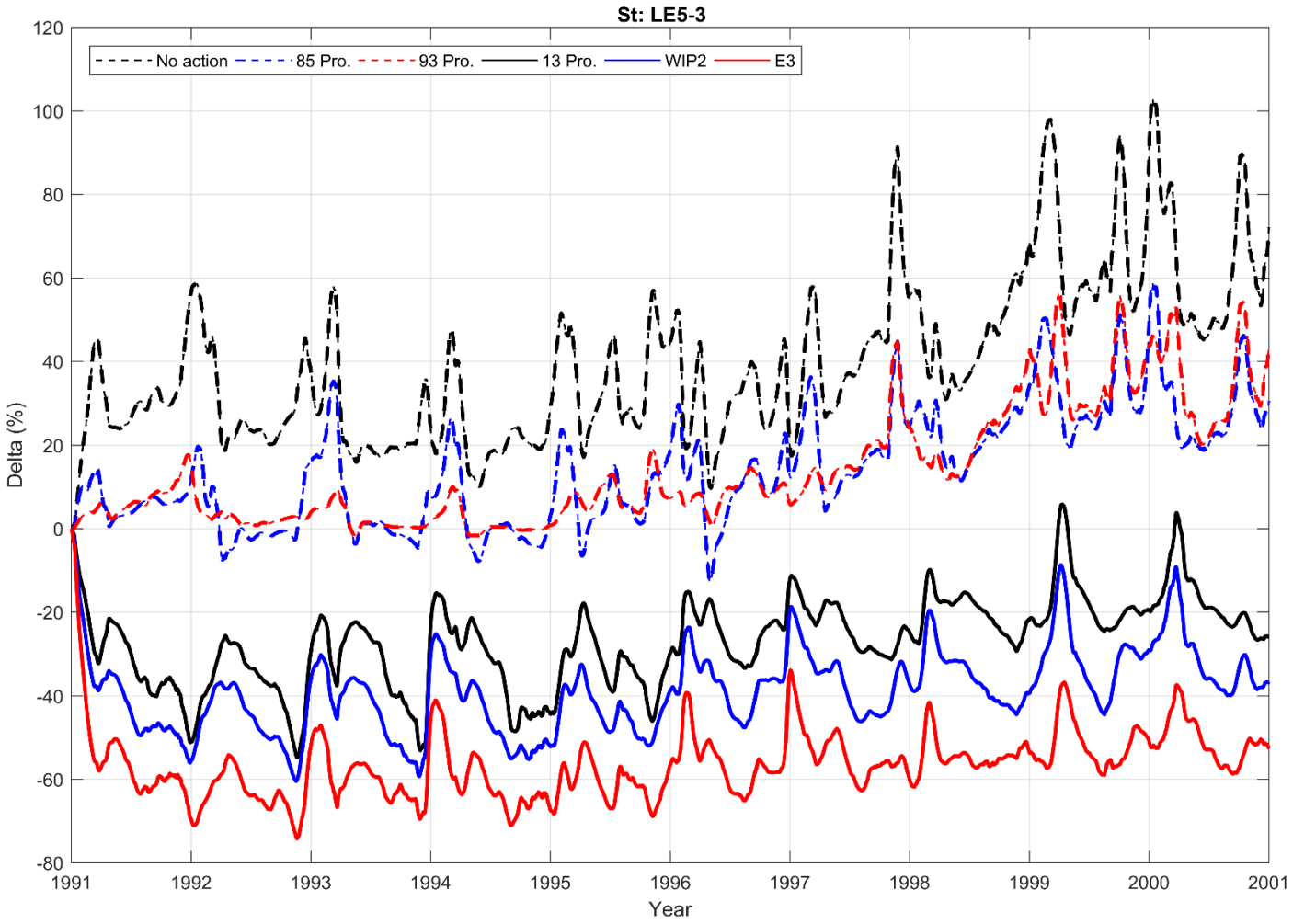
Change of Phytoplankton (%)



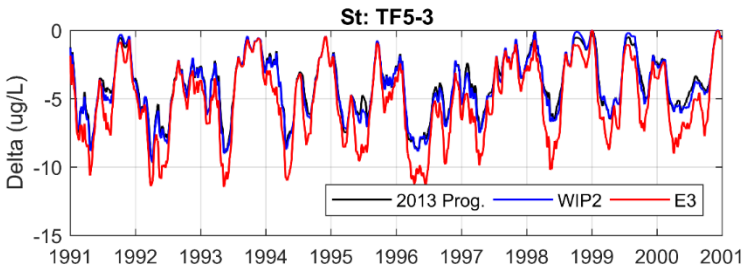
Change of Phytoplankton (%)



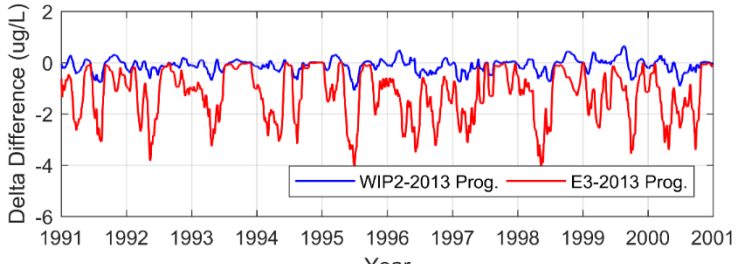
Change of Phytoplankton (%)

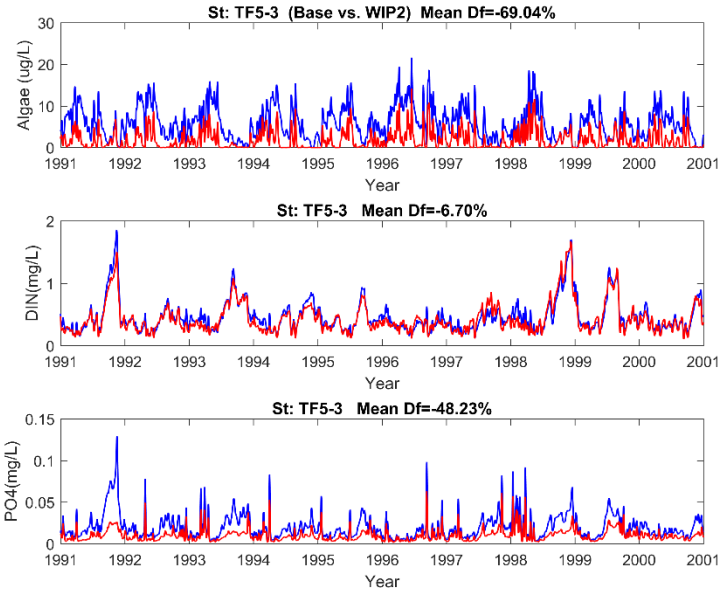


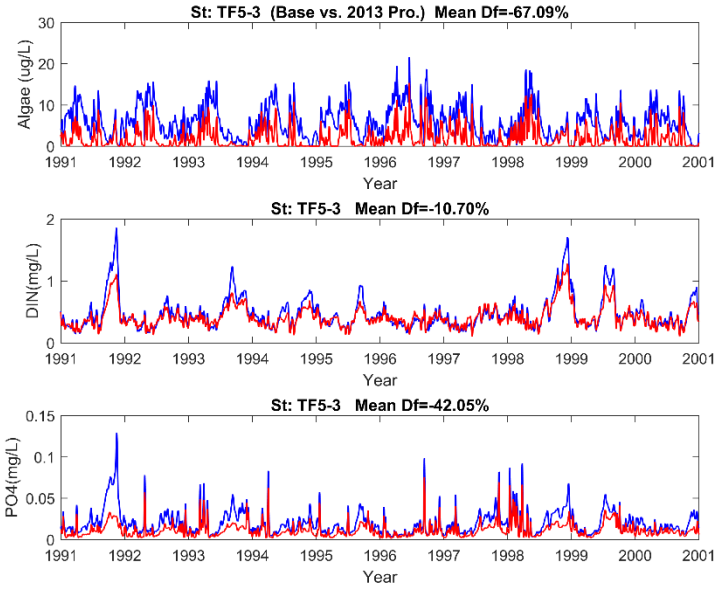
Comparison of Delta (Tidal freshwater)

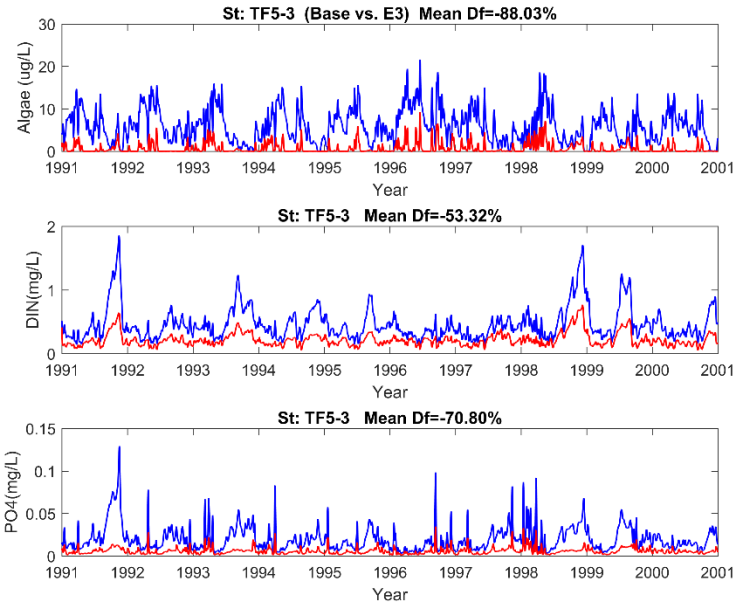


(30-day moving average)

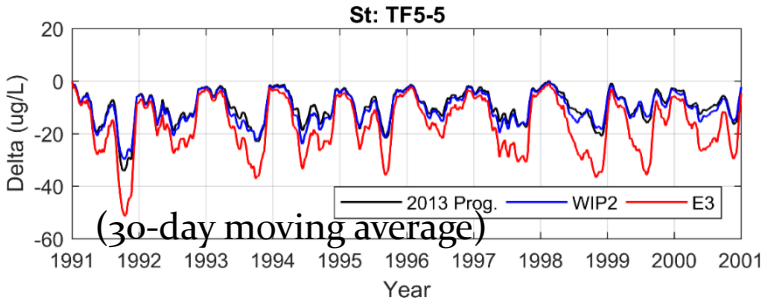


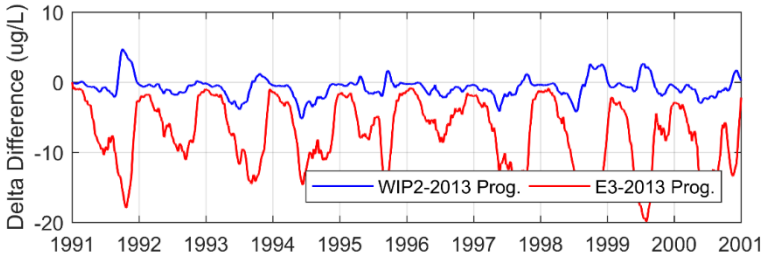


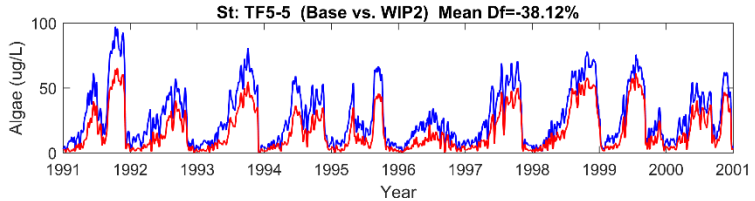


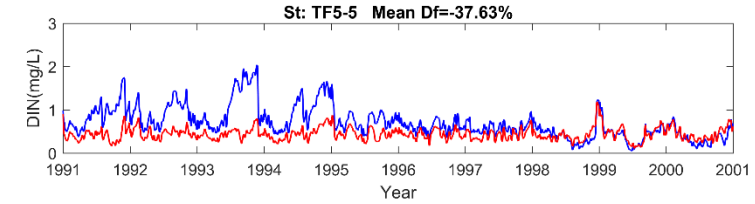


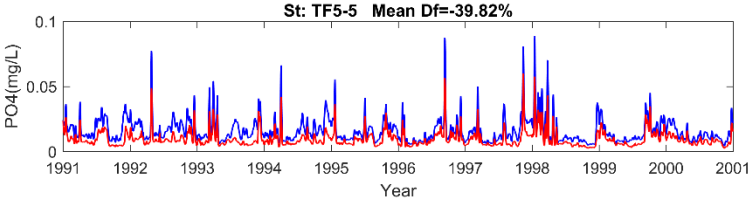
Comparison of Delta (Tidal freshwater)

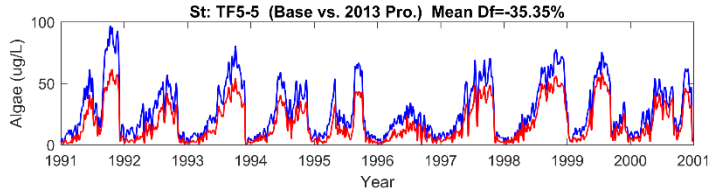


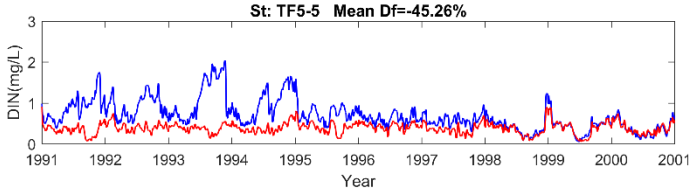


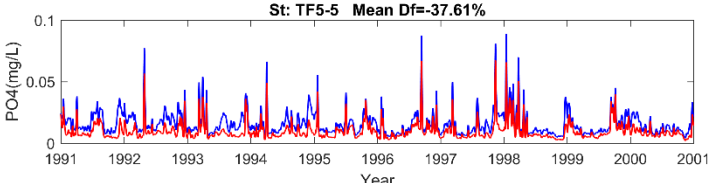


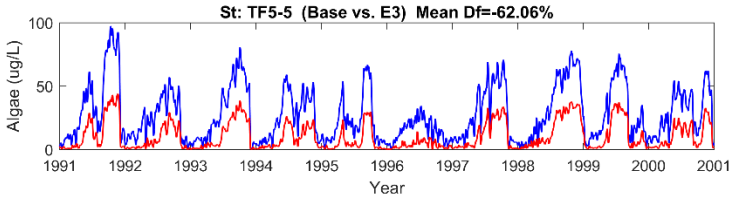


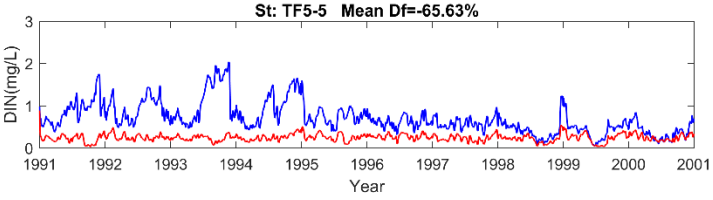


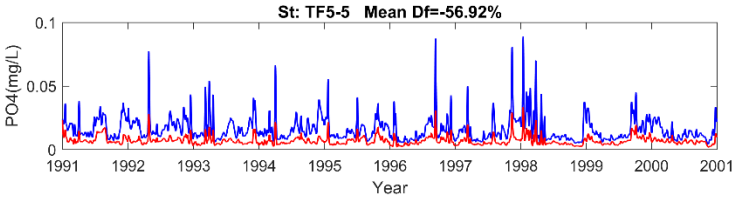




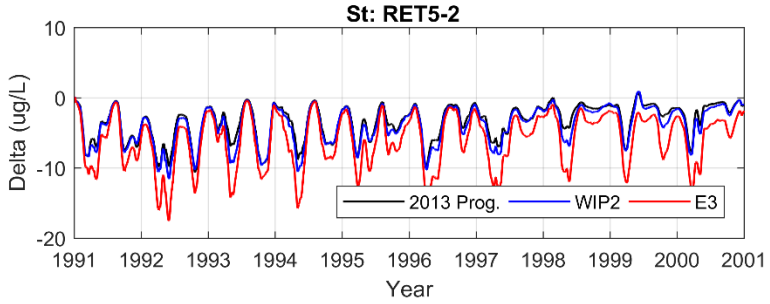


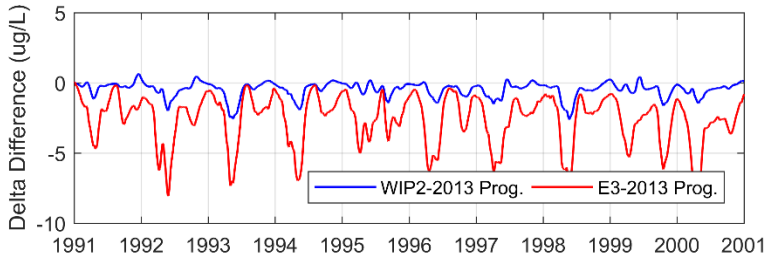


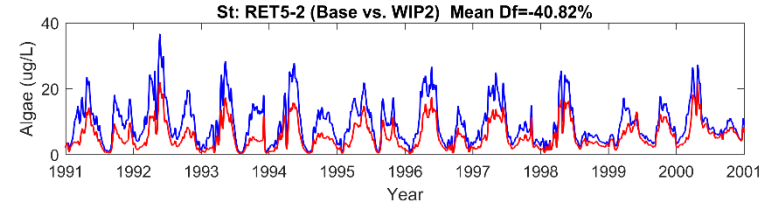


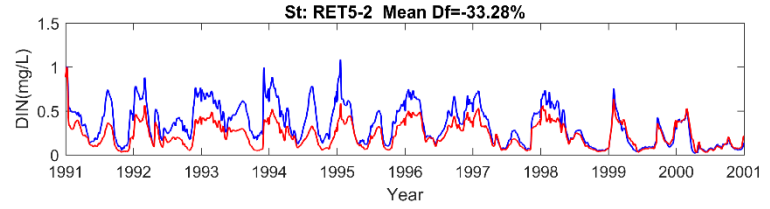


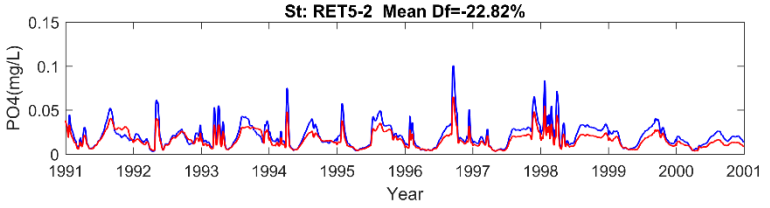
Comparison of Delta (oligo. and mesohaline)

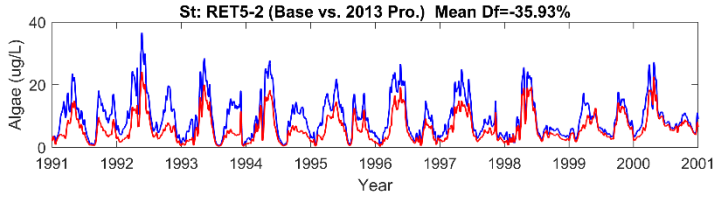


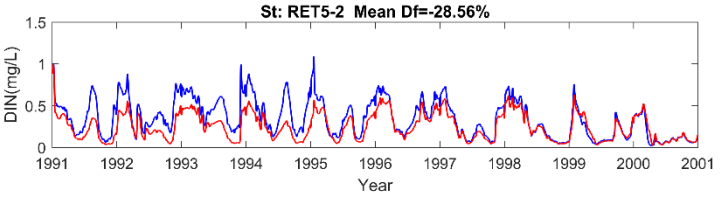


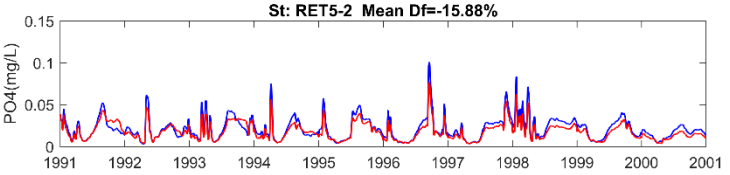


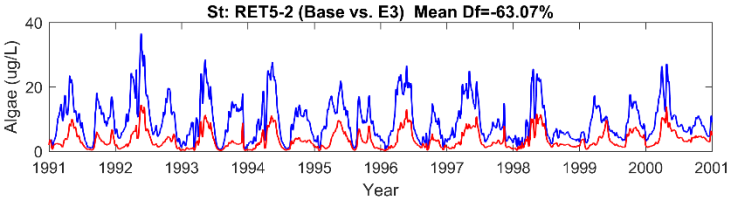


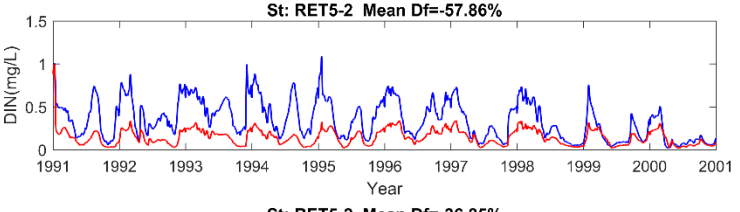


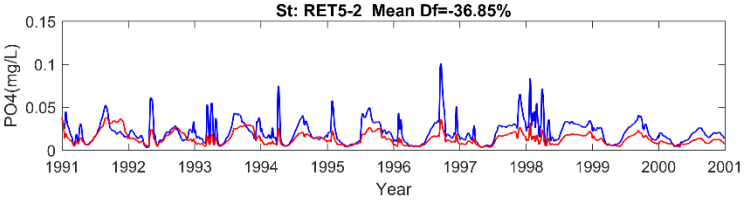




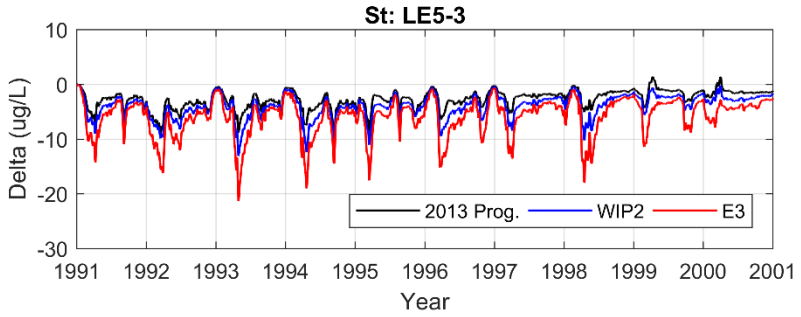


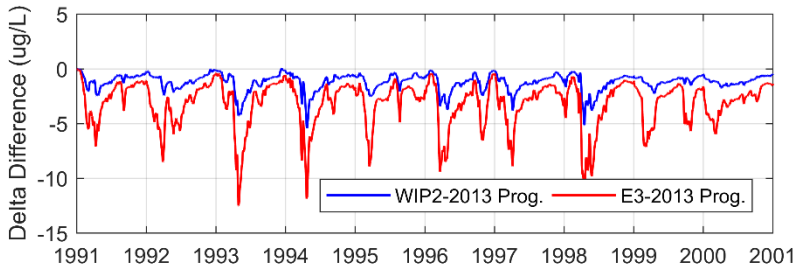


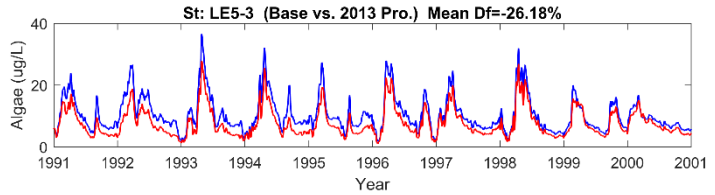


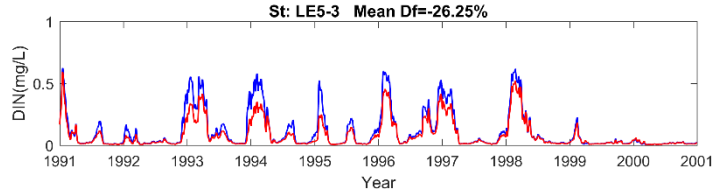


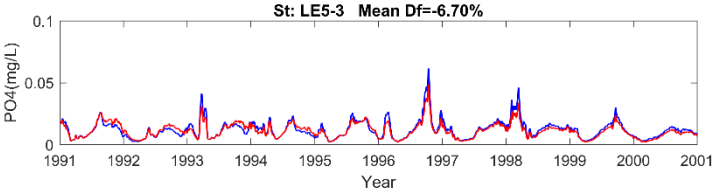
Comparison of Delta (mesohaline)

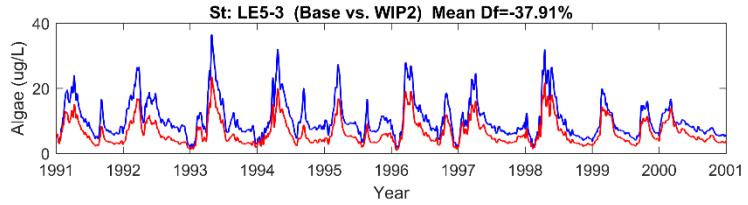


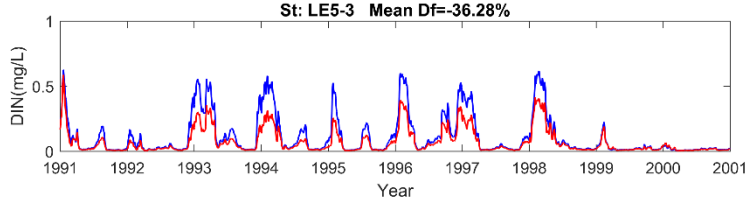


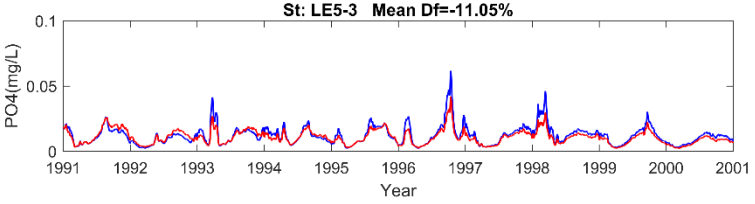


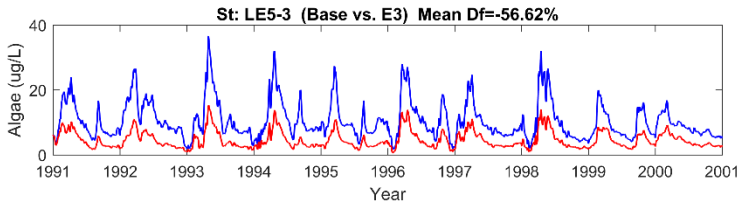


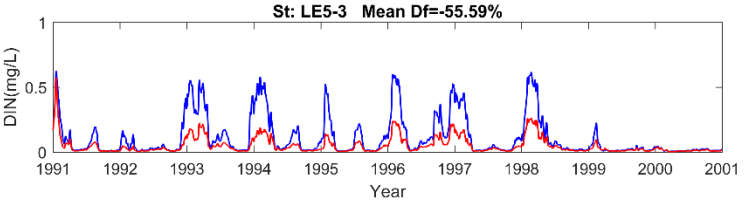


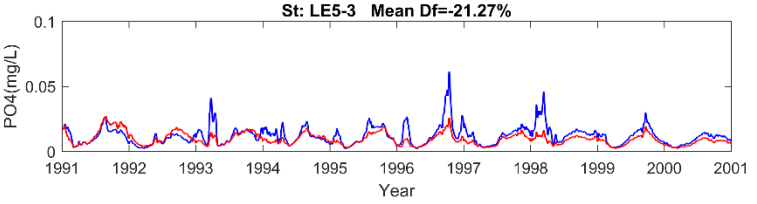




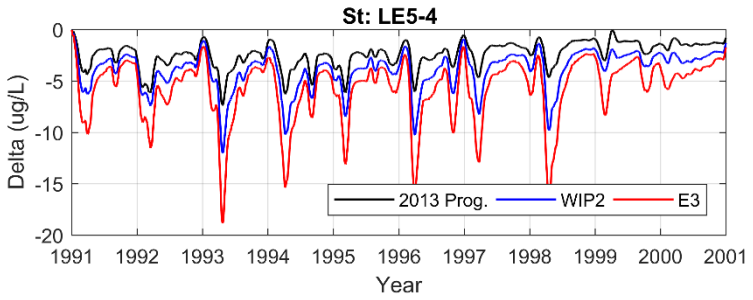


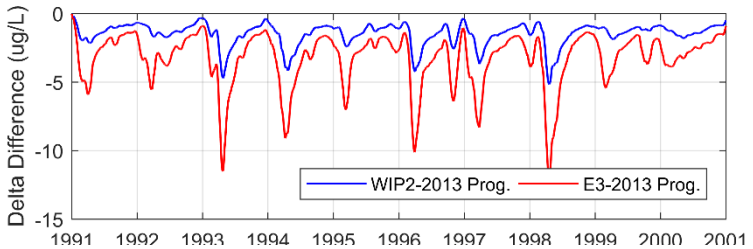


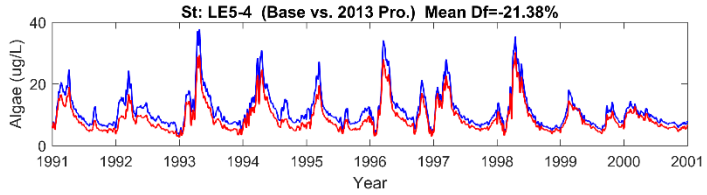


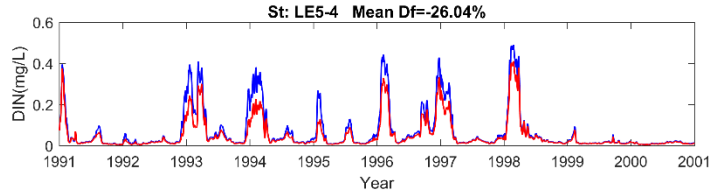


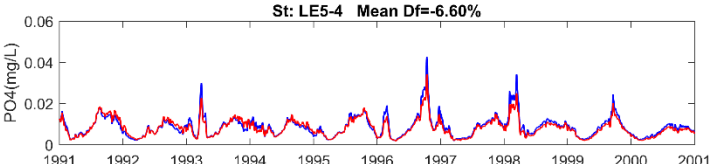
Comparison of Delta (hypohaline)

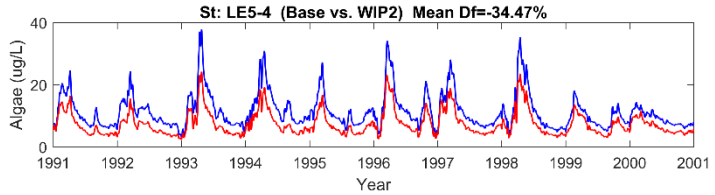


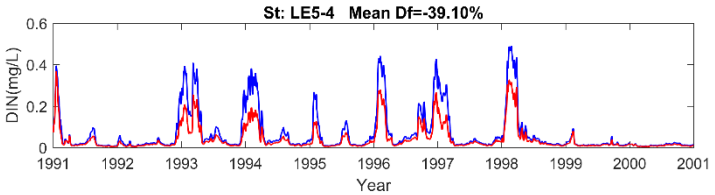


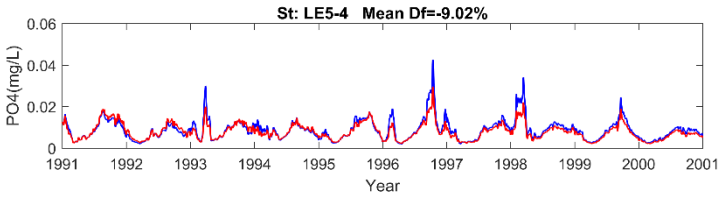


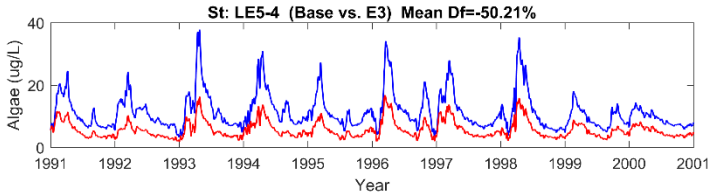


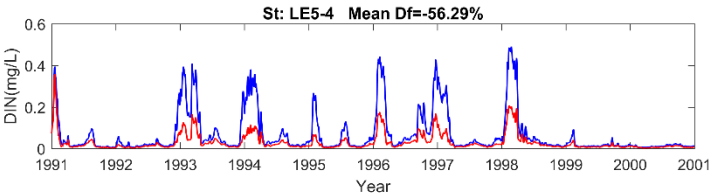


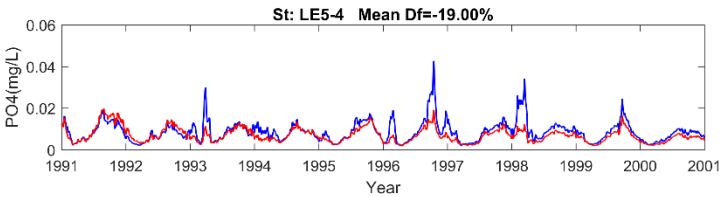












Discussion and Summary

- The model uncertainty analysis, including using different kinetic model of phytoplankton and model parameter sensitivity analysis, indicates that model is reliable.
- Model calibration can affect the model response to loading reduction. Model calibration to high Chl-a values can result in more reduction although there is no significant difference statistically for the model calibration.
- Model uncertainty needs to be considered for water quality assessment.
- Model response to nitrogen reduction is reasonable and there is a high reduction corresponding to low Chl-a concentration.