Report to the Water Quality Advisory Committee

DRBC Science and Water Quality Management
Namsoo Suk, Ph.D.
Thomas Amidon, BCES

April 27, 2022

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Outline

- Background (Namsoo Suk, DRBC)
- Model calibration results (Thomas Amidon, DRBC)
  - Discussion with Model Expert Panel (Vic Bierman, LimnoTech)
- Preview of Analysis of Attainability elements (Thomas Amidon, DRBC)
- Next Steps / Schedule (Namsoo Suk, DRBC)
- Q&A

DRBC Resolution 2017-04
Studies Required Before Rulemaking

Fish/DO Studies

- 6(a). Input on the **dissolved oxygen requirements of aquatic species**
- 6(b). Field studies of the occurrence, spatial and temporal distribution of the life stages of Estuary fish species
- 6(c). Input from consultations pursuant to the **Endangered Species Act** ("ESA")

Modeling Studies

- 6(d). Development and calibration of a **eutrophication model** for the Delaware River Estuary and Bay;
- 6(e). Determination of the nutrient **loadings from point and non-point sources** necessary to support key aquatic species;

Cost/Feasibility Studies

- 6(f). Evaluation of the **capital and operating costs for treatment** capable of achieving higher levels of dissolved oxygen;
- 6(g). Evaluation of the physical, chemical, biological, **social and economic factors affecting the attainment of uses**,

6. "Analysis of Attainability"

6(h).

Preparation of a **draft final report** containing findings and conclusions.

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Eutrophication Model Expert Panel Members

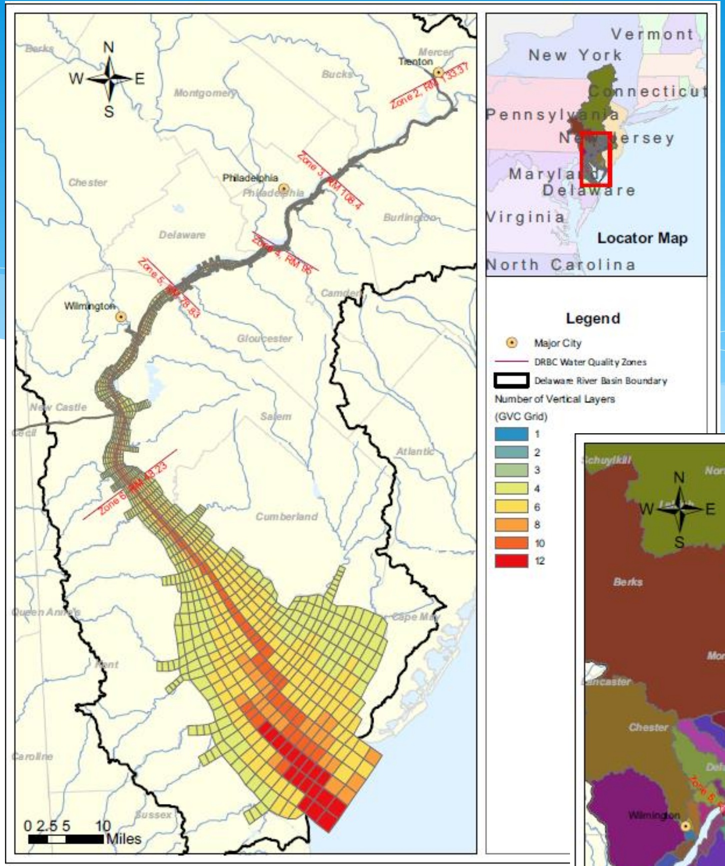
Name	Organization	Service
Carl Cerco	U.S. Army Corps of Engineers (Retired)	Panel Members
Bob Chant	Rutgers University	
Steve Chapra	Tuffs University	
Tim Wool	U.S. EPA Region 4 (Retired)	
Vic Bierman	LimnoTech Liaison to Model Expert Panel	Consultant to DRBC
Scott Hinz	LimnoTech Technical advisor to DRBC staff	

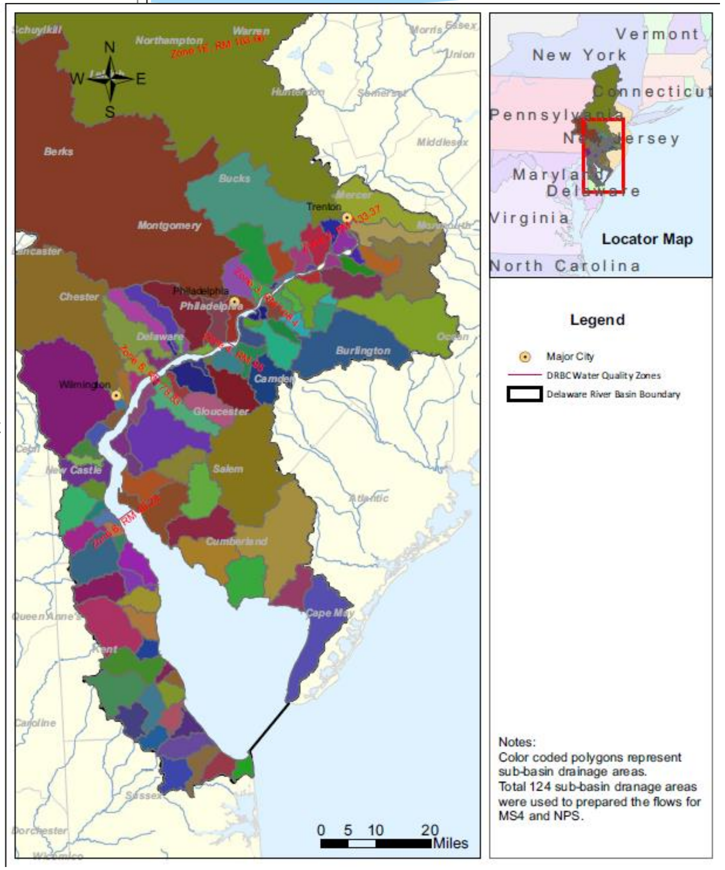
DRBC TEAM MEMBERS

Name	Title	Specialty and Responsibility
Kristen B. Kavanagh	Deputy Executive Director	Project management / multi-task
Thomas Amidon	Manager, Water Resource Modeling	Oversees modeling in general / data analysis
Sarah Beganskas	Water Resource Scientist	Modeling / data management
Jacob Bransky	Aquatic Biologist	Data collection / data analysis / Fish-DO relationship
Fanghui Chen	Senior Water Resource Engineer	Modeling / data retrieval / post processor
Vince DePaul	Hydrologist (USGS)	Modeling / NPS load / atmospheric deposition
Elaine Panuccio	Water Resource Scientist	Data collection / data management / load calculation
Namsoo Suk	Director, Science and WQ Management	Project management / multi-task / modeling
John Yagecic	Manager, Water Quality Assessment	Data analysis / post processor / affordability Assessment
Li Zheng	Senior Water Resource Engineer	Modeling / Data analysis

Purpose and Goal

- Purpose:
  - To determine ambient dissolved oxygen levels that would result from various pollutant reduction scenarios
- Goal:
  - To develop a eutrophication model for the Delaware River Estuary and Bay
    - technically sound
    - utilizing the current state of the science
    - within a timeframe established by the Commission





Modeling Approach

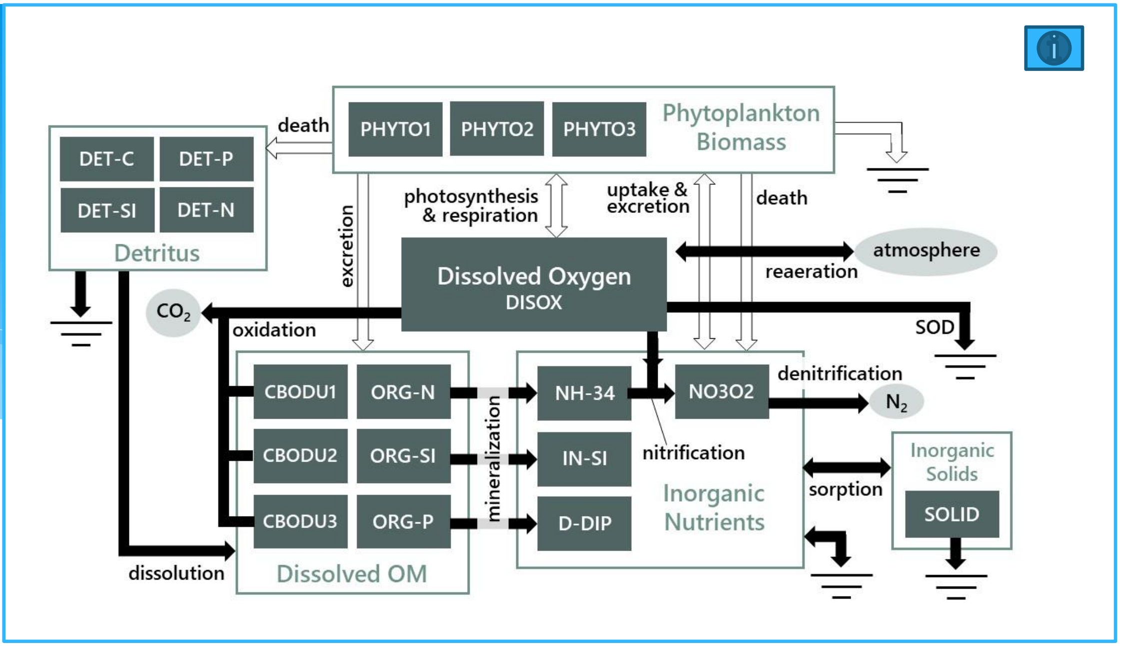
Develop linked hydrodynamic and water quality model

- Environmental Fluid Dynamics Code (EFDC)
- Water Quality Analysis Simulation Program (WASP8.x)

Develop flow and concentration inputs (boundary conditions)

- Intensive monitoring period 2018-2019
- Historical data, primarily 2012

Calibrate linked model



Delaware Estuary Eutrophication Model Kinetics

- Develop methodologies and submodels as needed to assign external loadings from point and nonpoint sources
- Test and select Delaware Estuary specific constants and coefficients

Conduct forecast simulations with calibrated model

- Develop baseline (design) conditions, future scenarios, and metrics for comparison
- Determine ambient dissolved oxygen levels associated w/ various pollutant reduction scenarios

State Variables and Processes Applied to Delaware Estuary Model

Dissolved Constituents

Gases
- **DISOX: dissolved oxygen**

Inorganic Nutrients
- NH-34: ammonia nitrogen
- NO3O2: nitrate nitrogen
- D-DIP: inorganic phosphate
- IN-SI: inorganic silica

Organic nutrients
- CBODU1: ultimate CBOD from stream
- CBODU2: ultimate CBOD from PS
- CBODU3: refractory CBOD
- ORG-N: dissolved organic nitrogen
- ORG-P: dissolved organic phosphorus
- ORG-SI: dissolved organic silica

Particulate Constituents

Phytoplankton Biomass
- PHYTO1: spring marine diatom community
- PHYTO2: summer freshwater diatom community
- PHYTO3: summer marine diatom community

Detritus
- DET-C: detrital carbon
- DET-N: detrital nitrogen
- DET-P: detrital phosphorus
- DET-SI: detrital silica

Other Solids
- TOTDE: particulate detrital organic material (dw)
- SOLID: inorganic solid

Major Processes Simulated

Chemical Processes
- **Oxidation of CBOD**
- **Nitrification of ammonia to nitrate**
- Dissolution and Mineralization
- **Sediment oxygen demand**

Physical Processes
- Settling
- **Reaeration (influx and efflux)**
- Sorption

Biological Processes
- **Photosynthesis**
- **Respiration**
- Phytoplankton growth and death
- Uptake

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Key Accomplishments since November 2021

- Finalized spatial assignments of benthic fluxes and sediment oxygen demand (SOD)
- Finalized kinetic constants / parameters / coefficients
- Identified key factors affecting dissolved oxygen and phytoplankton dynamics throughout the estuary
- Completed model calibration
  - Calibration report writing well underway
- 2012 test scenario developed to corroborate model performance
  - Likely will be used as basis for design condition

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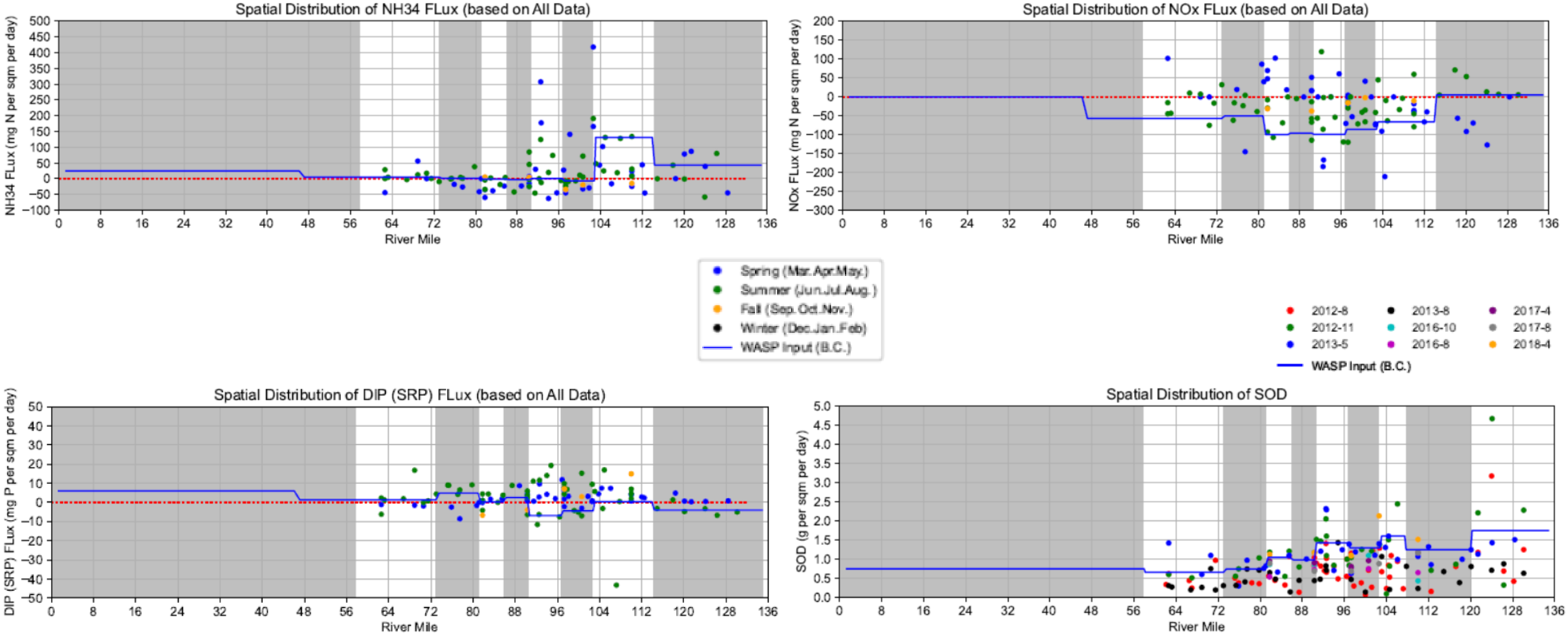
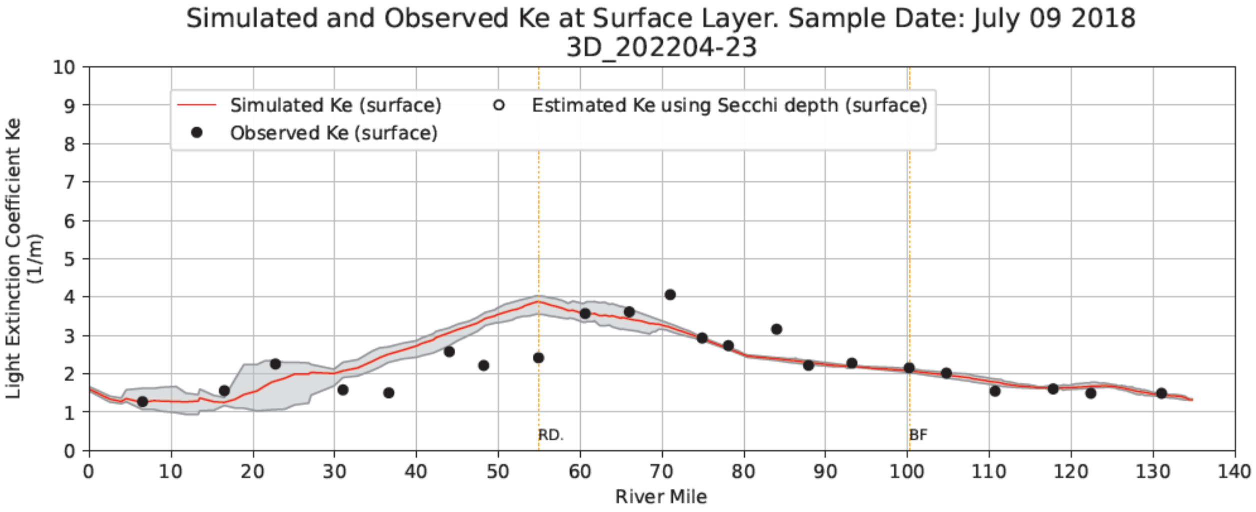
Overview

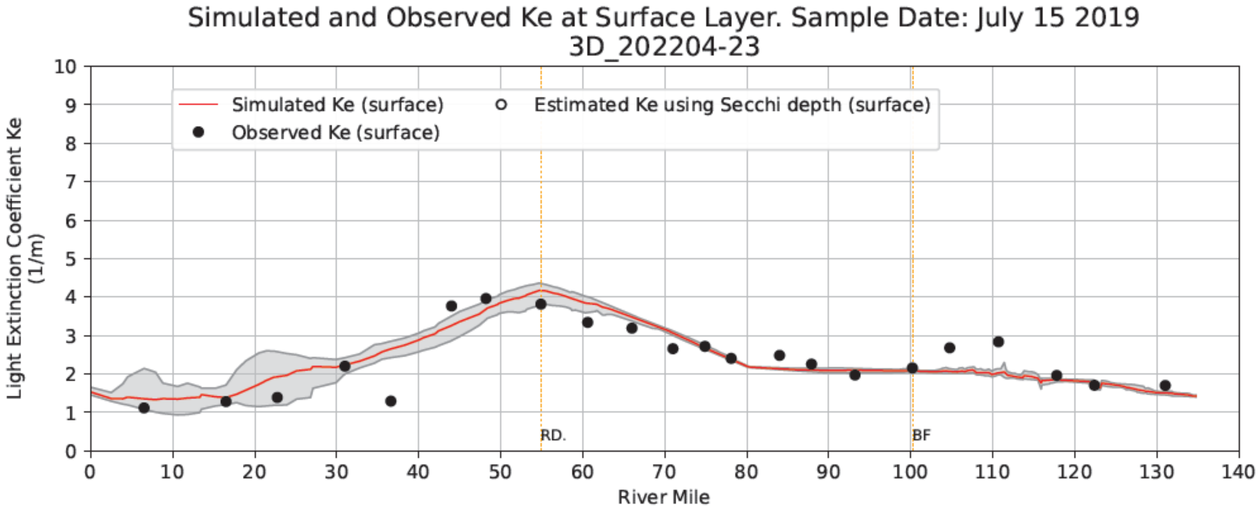
- Simulation years
  - 2018 and 2019 – calibration period
  - 2012 – hindcast based on much more limited dataset
- Benthic inputs
- Process Insights
  - Dissolved oxygen component evaluation
  - Algal growth limitation
- Results
  - Light extinction
  - Comparison with boat run
    - Dissolved organic carbon
    - Ammonia nitrogen
    - Total nitrogen
    - Total phosphorus
    - Dissolved oxygen
  - Phytoplankton trends
    - 2018-2019 2-yr against 10-yr trends
    - 2012 phyto boat run
  - Comparison with continuous data
- Zone 2 light sensitivity

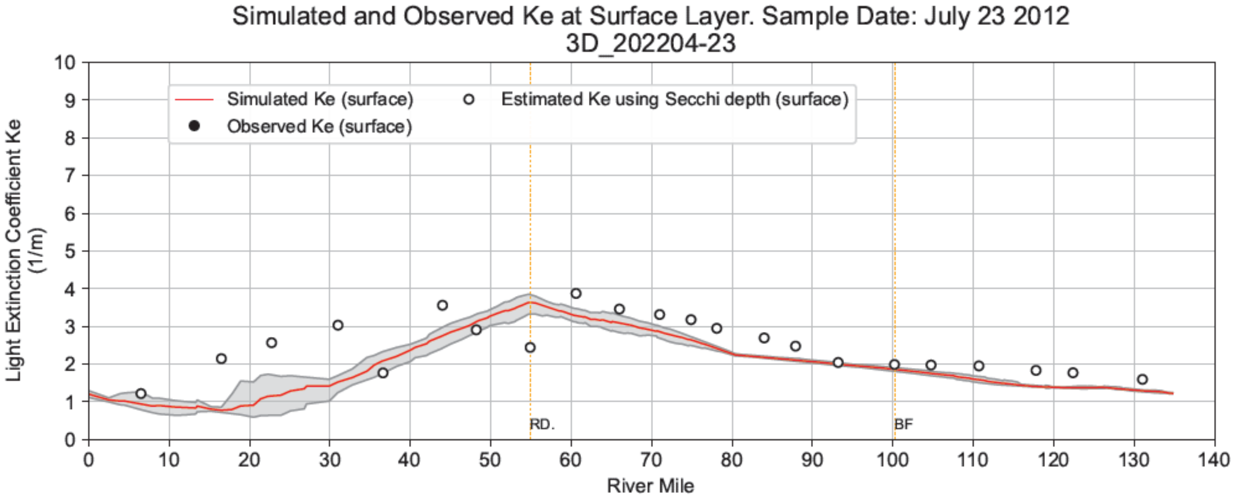
Spatial assignments of benthic fluxes and SOD



Light Extinction: July 2018, 2019 & 2012





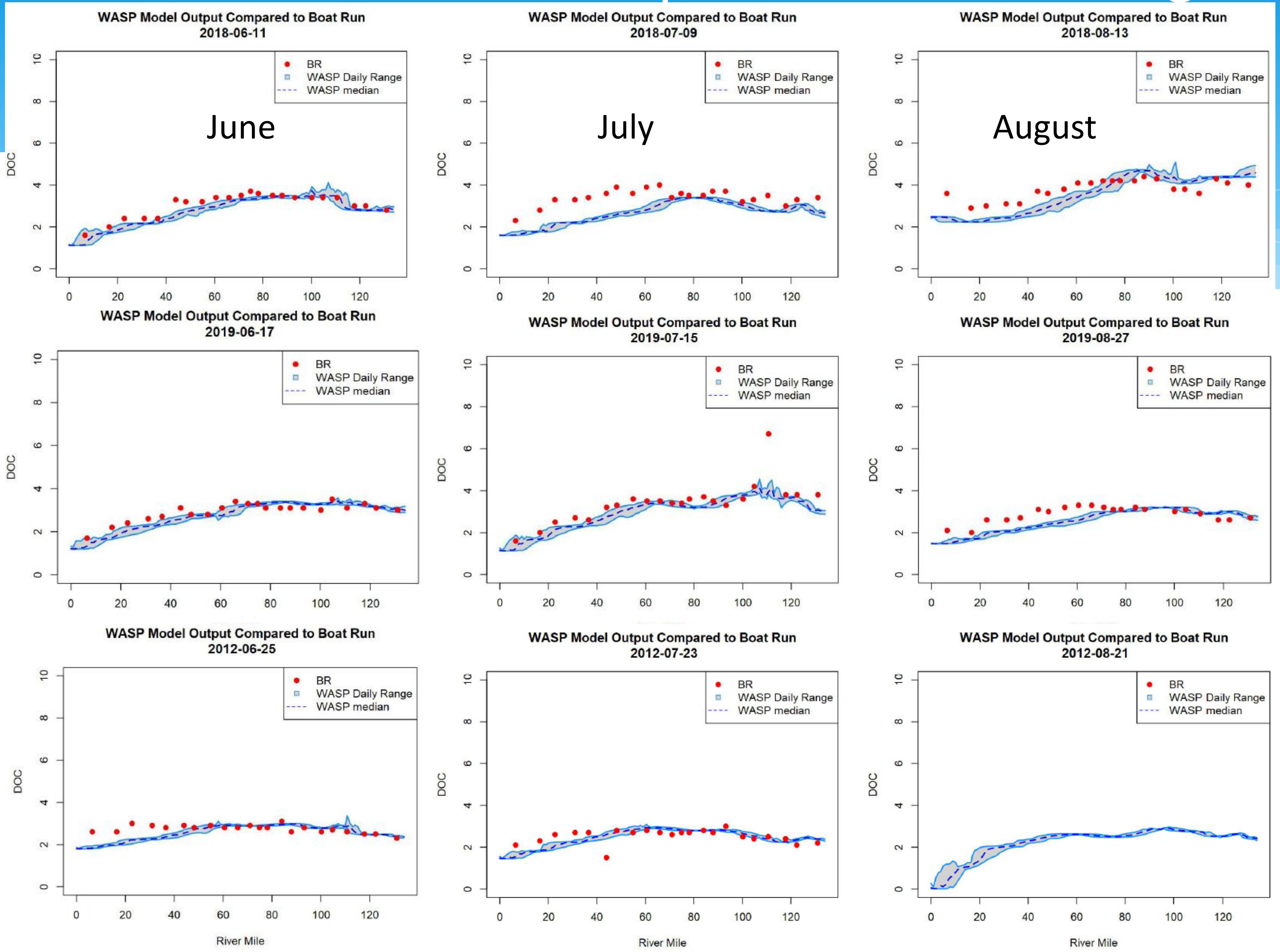


Model – Boat Run Data Comparison: DOC during Summer

2018

2019

2012



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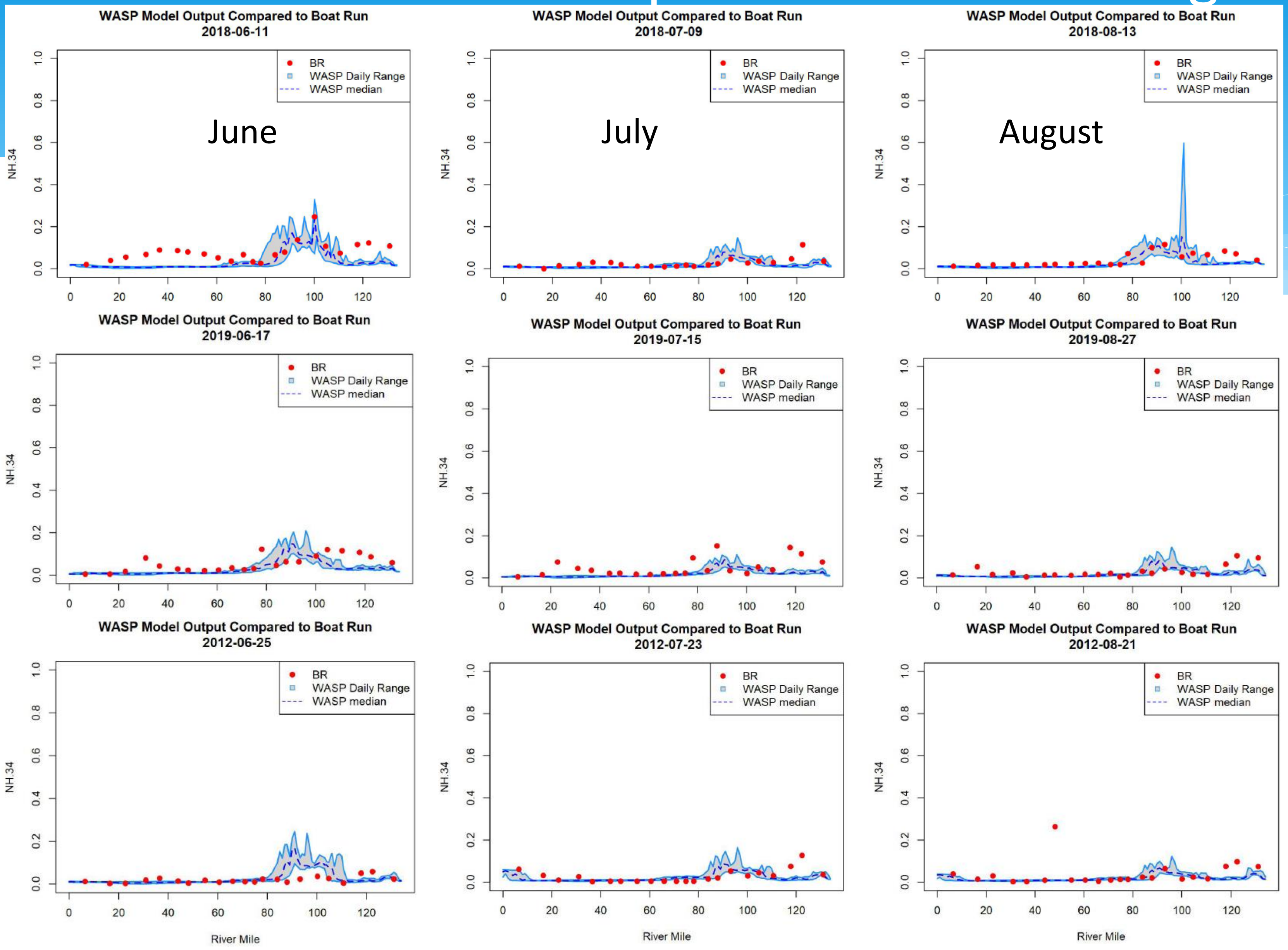
Model – Boat Run Data Comparison: NH34 during Summer

2018

2019

2012



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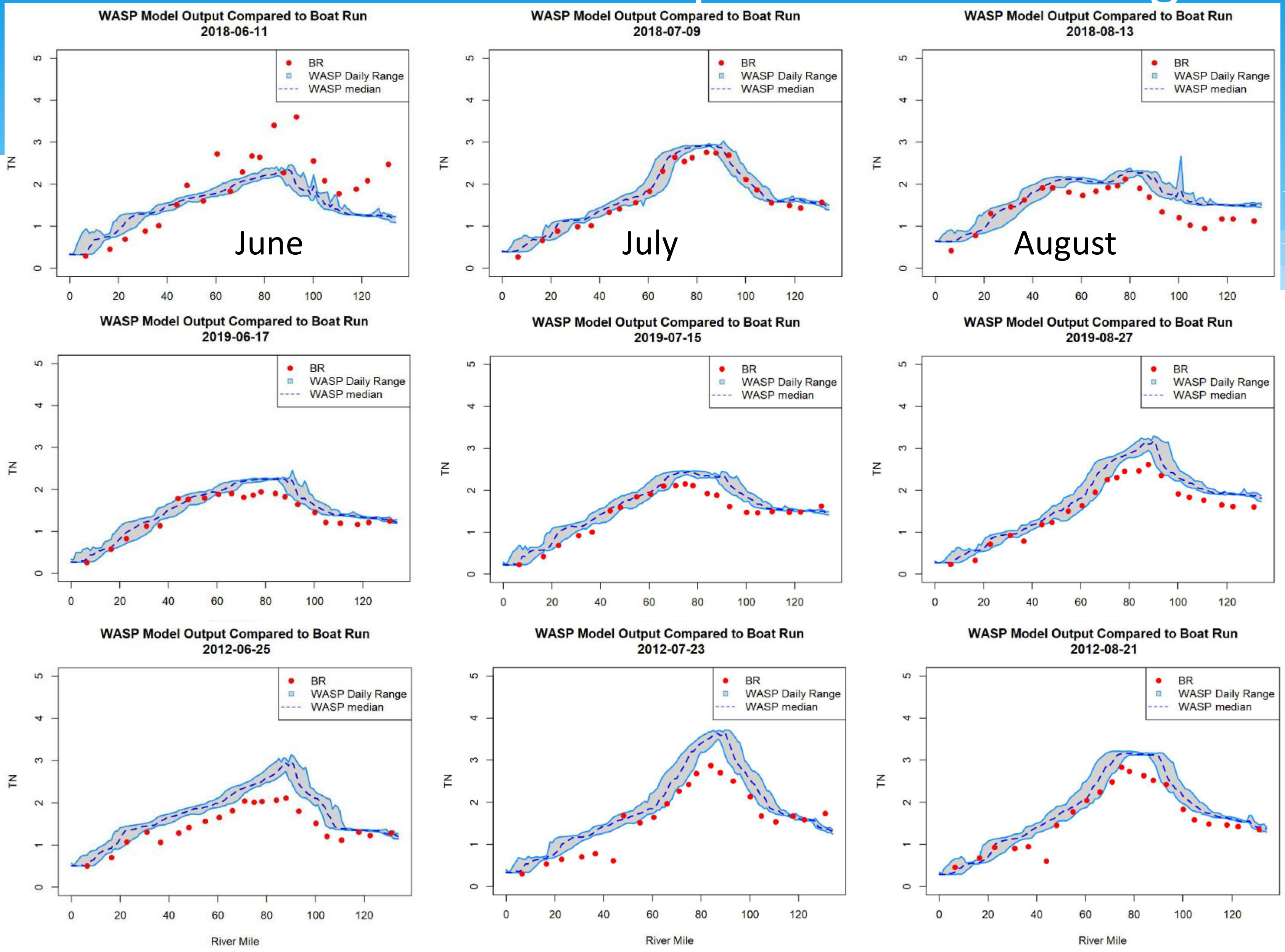
Model – Boat Run Data Comparison: TN during Summer

2018

2019

2012



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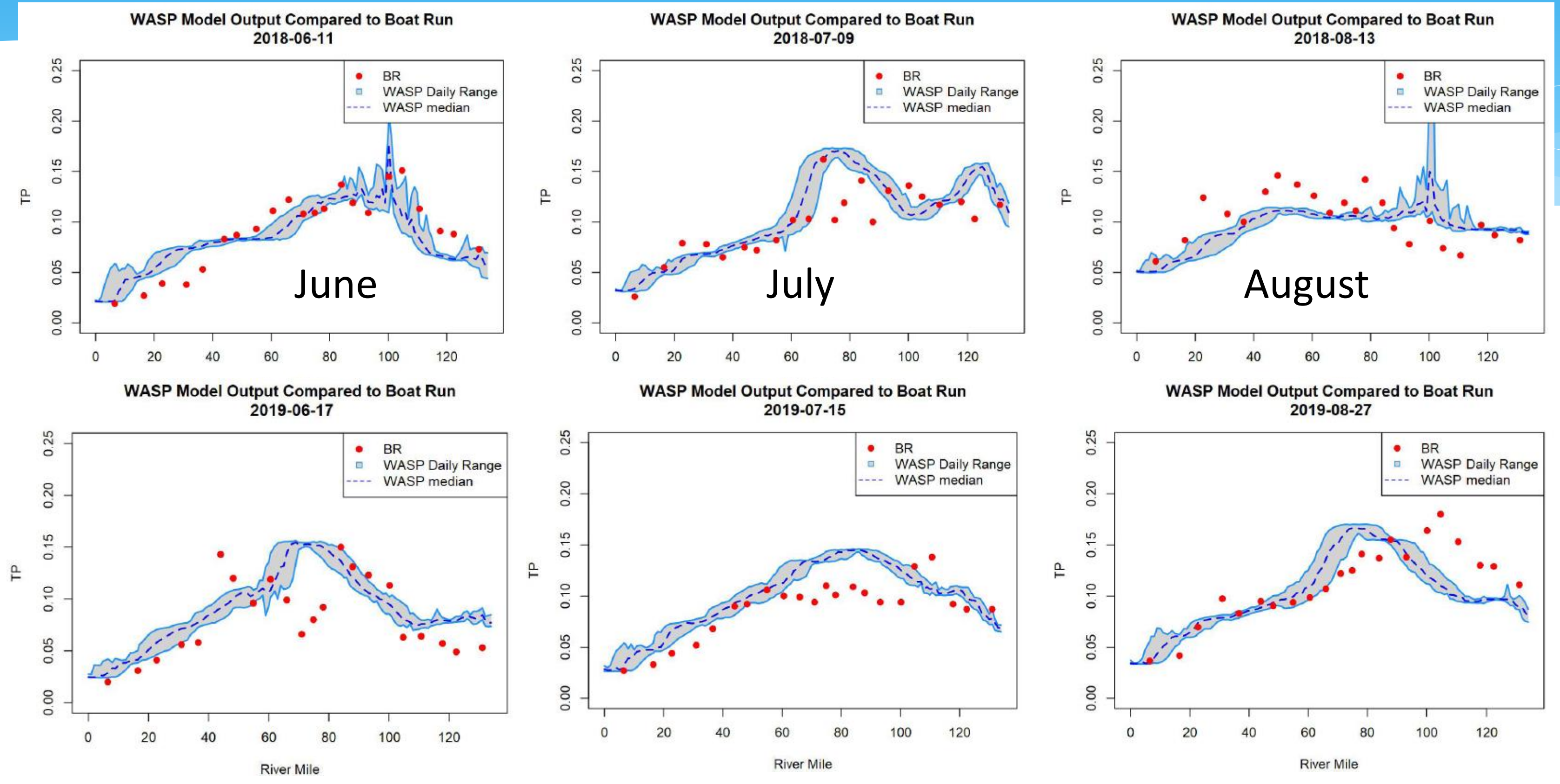
Model – Boat Run Data Comparison: TP during Summer

2018

2019



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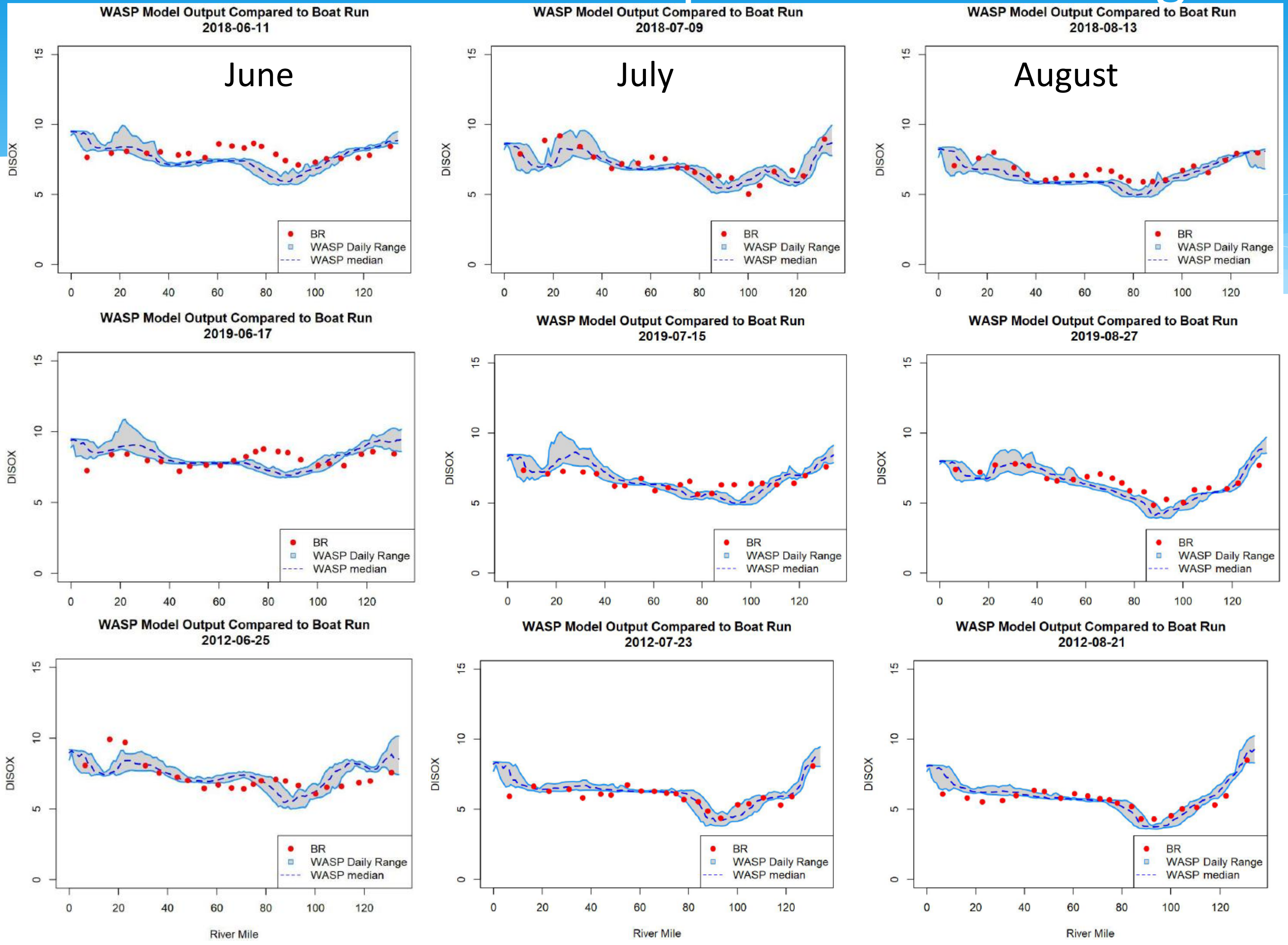
Model – Boat Run Data Comparison: DO during Summer

2018

2019

2012



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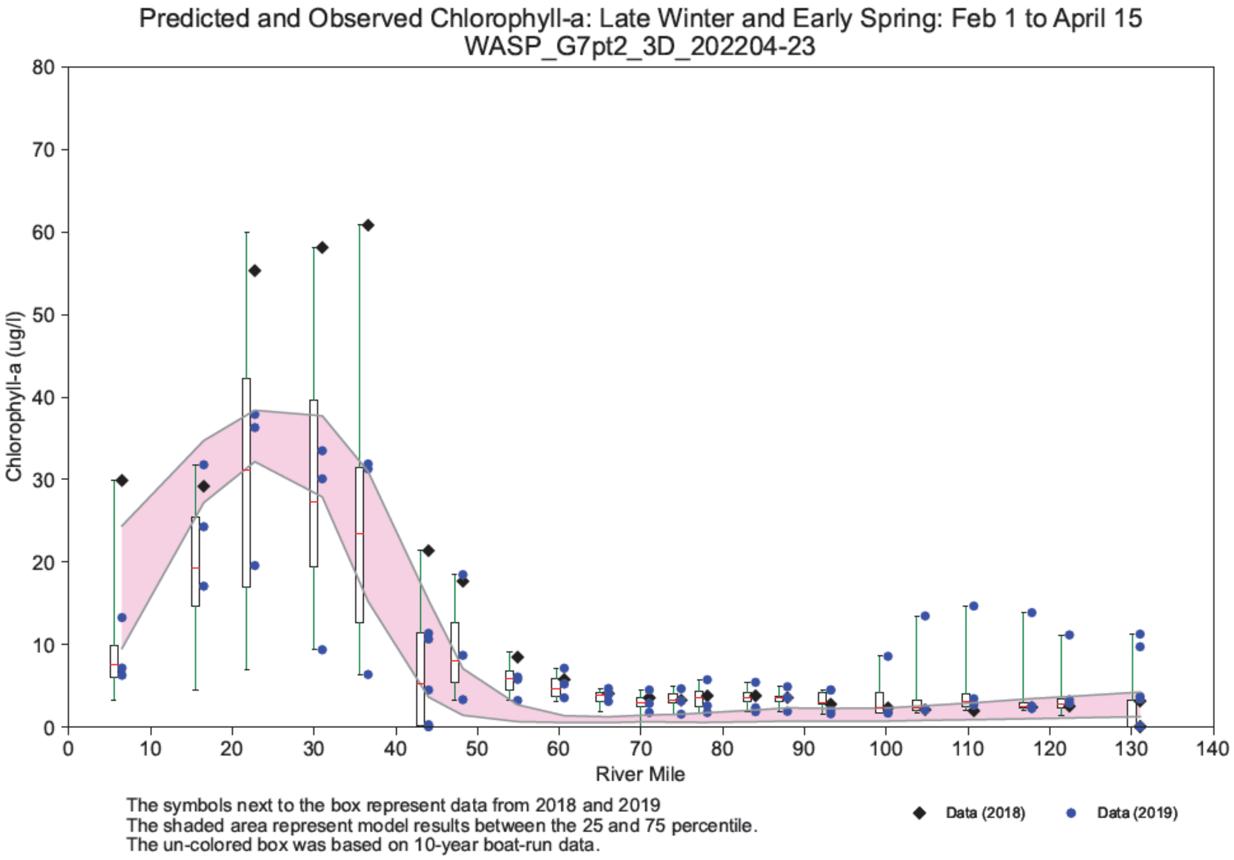
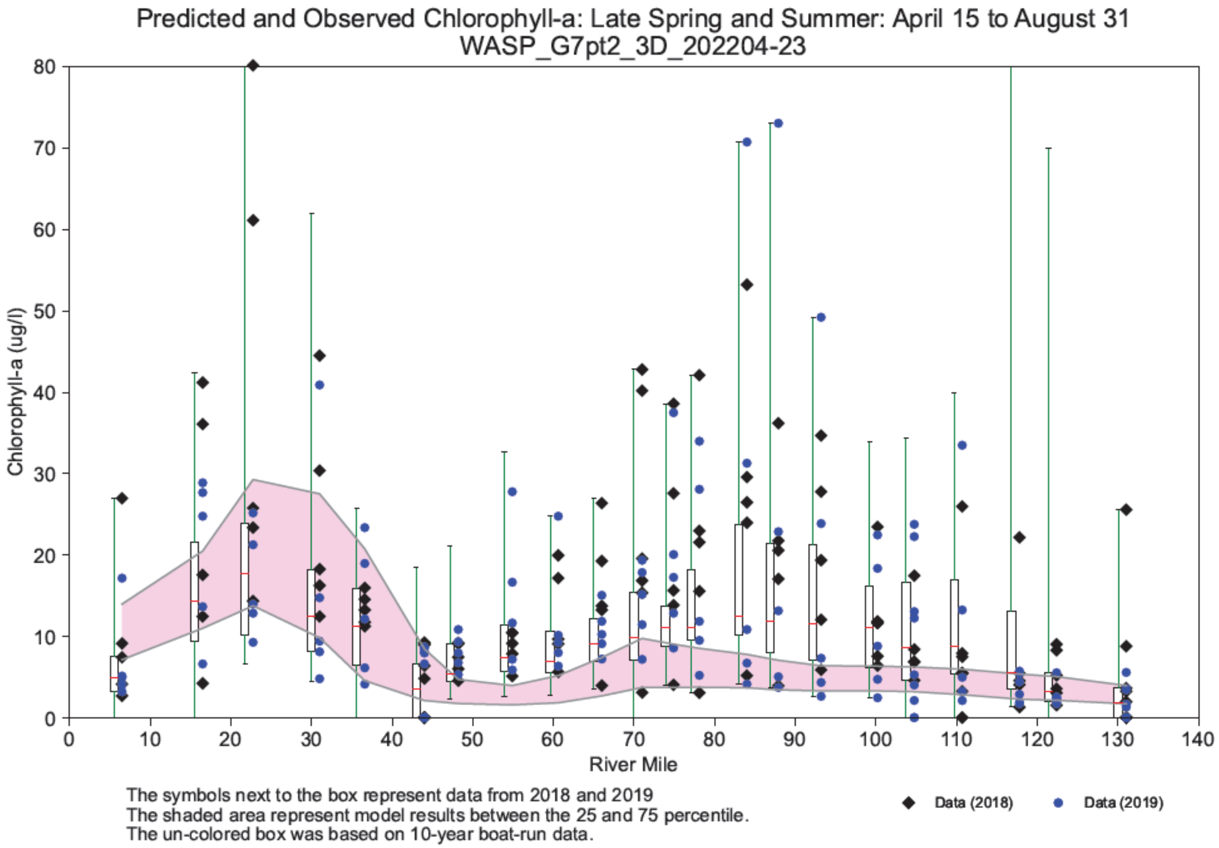
Phytoplankton: 2018 – 2019





Prediction against 10-year trend

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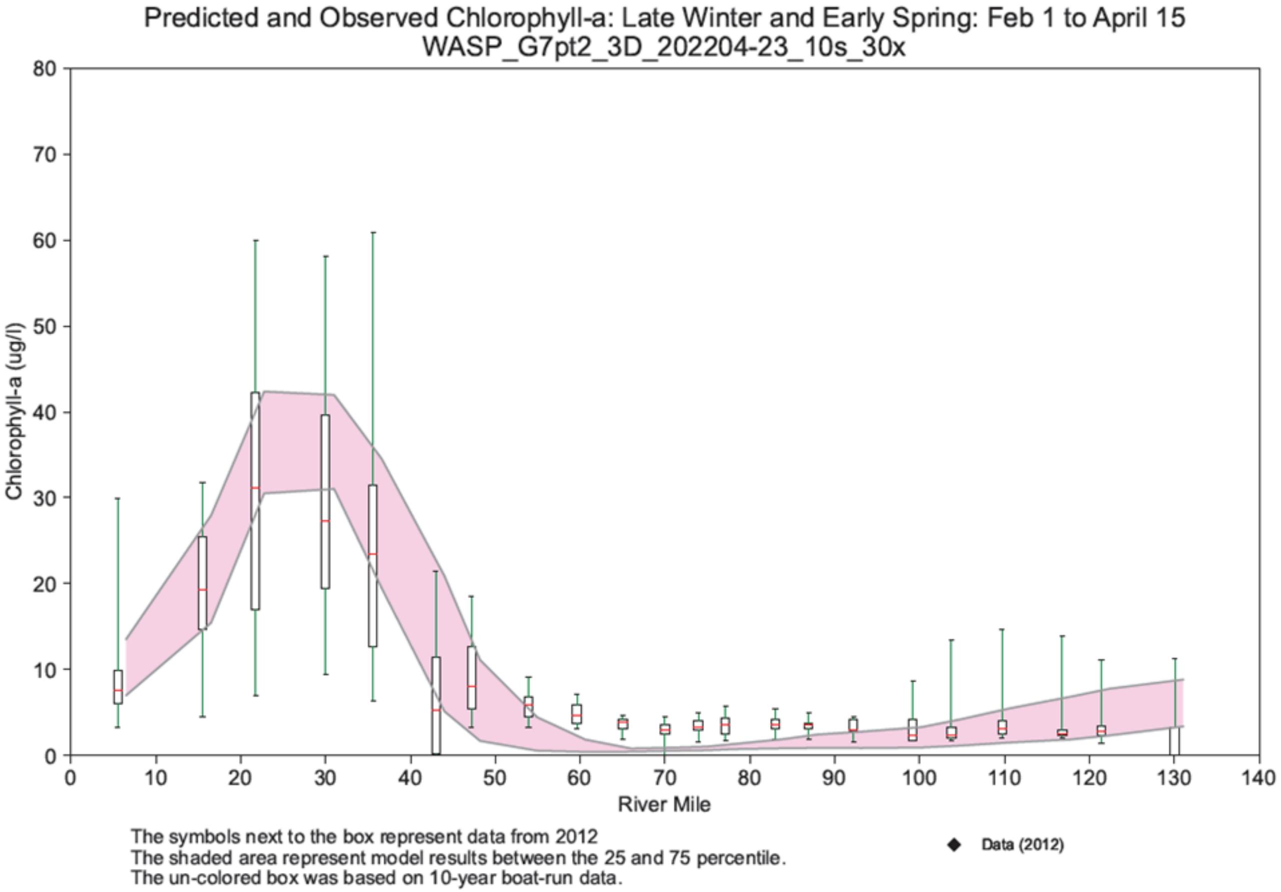
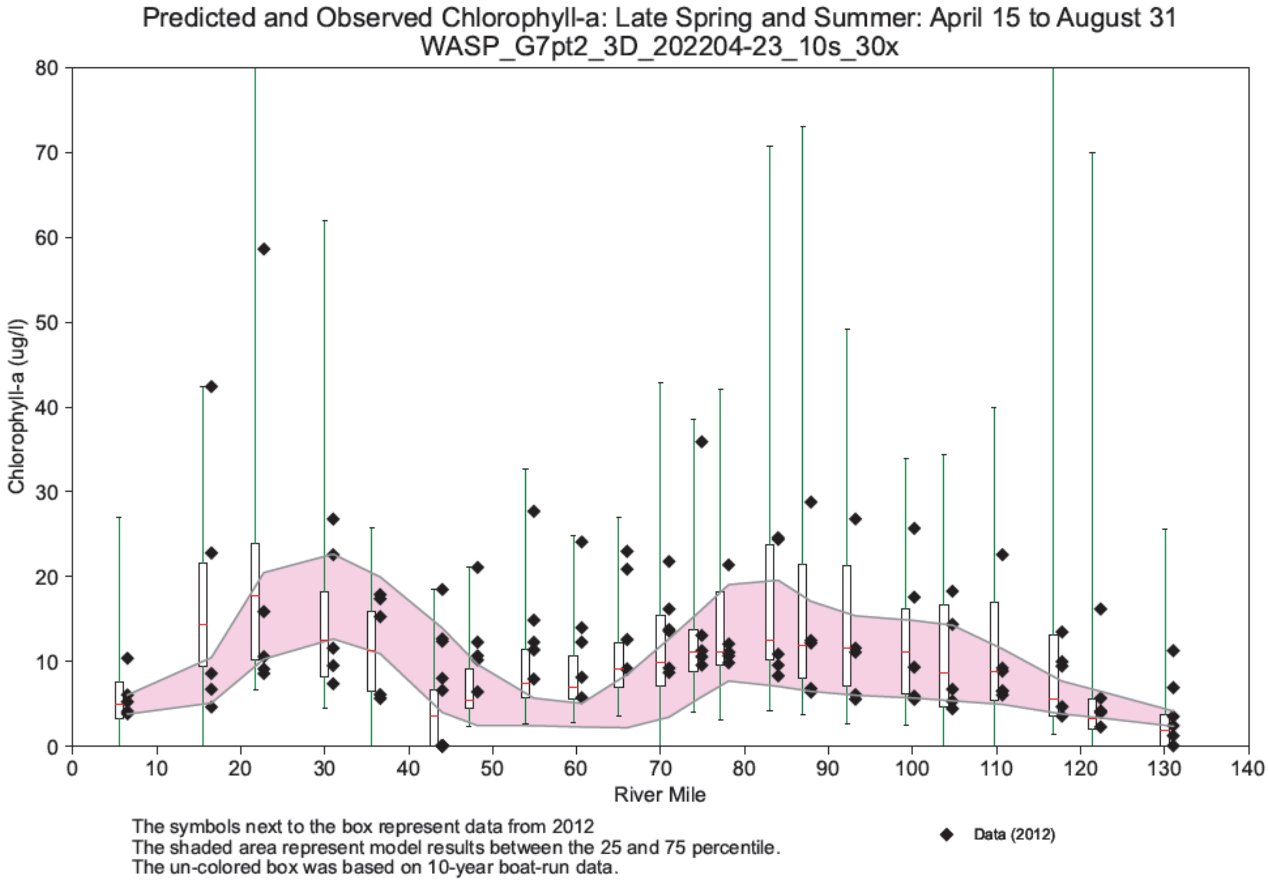
Phytoplankton: 2012





Prediction against 10-year trend

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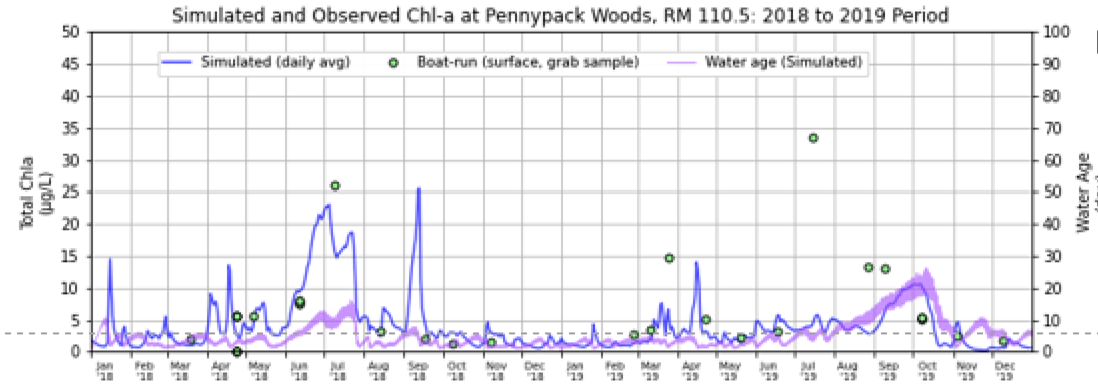
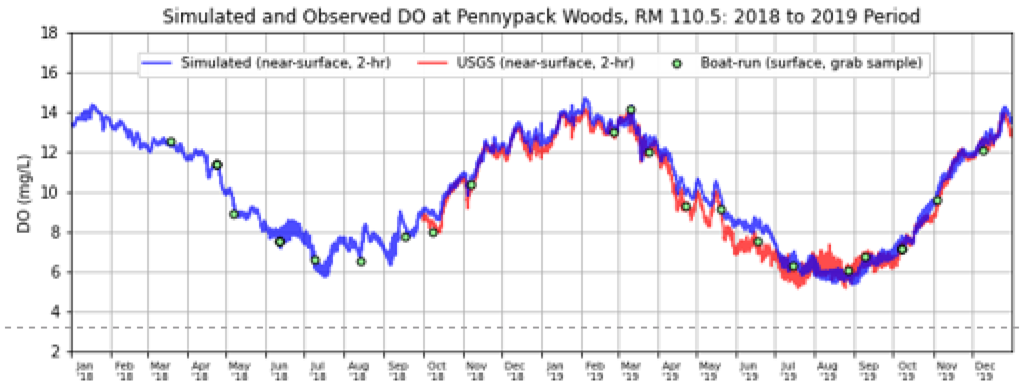
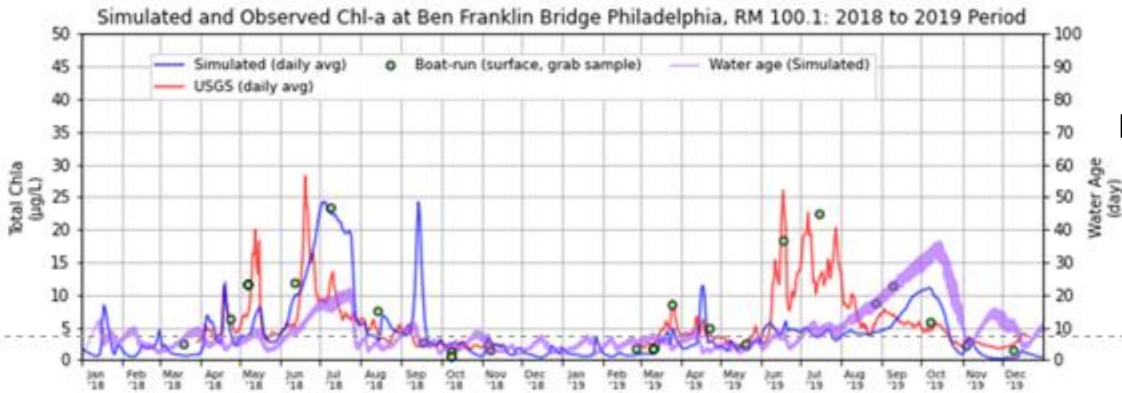
In-Situ Continuous Phyto and DO: 2018 – 2019

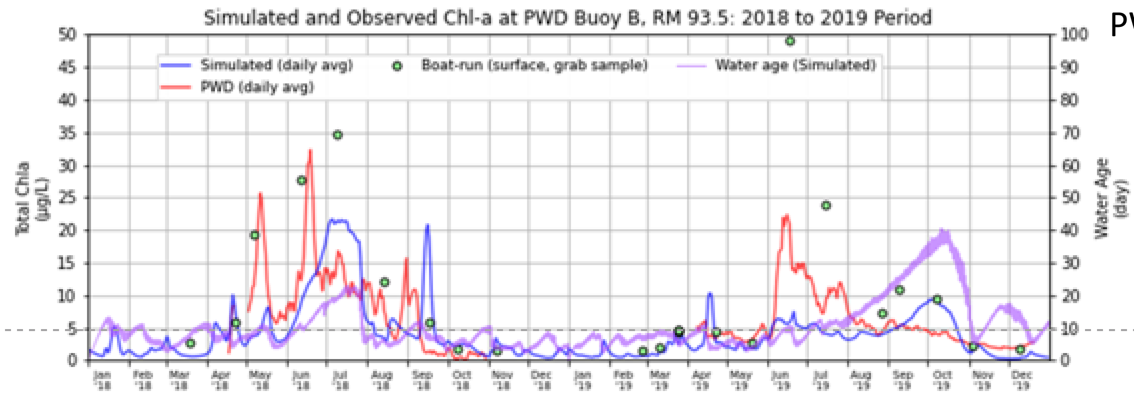


Pennypack Woods RM 110.5

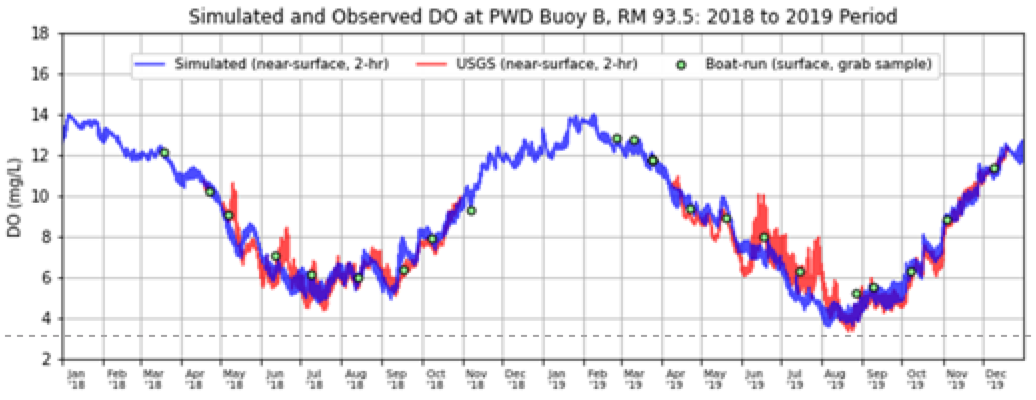




Ben Franklin RM 100.1

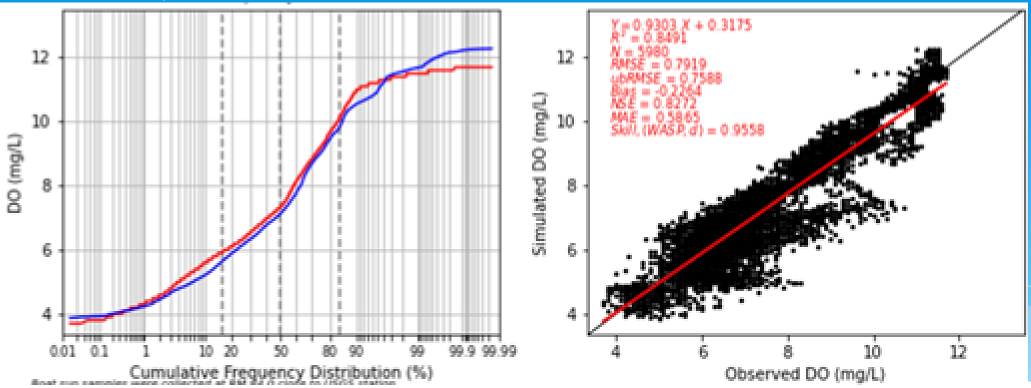


PWD Buoy B RM 93.5



Model-Data Comparison for Continuous DO

Chester, RM 83.6



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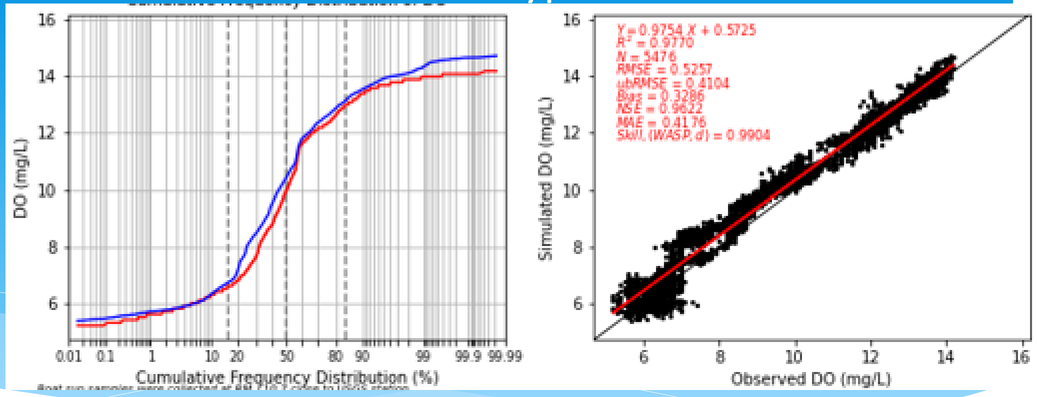
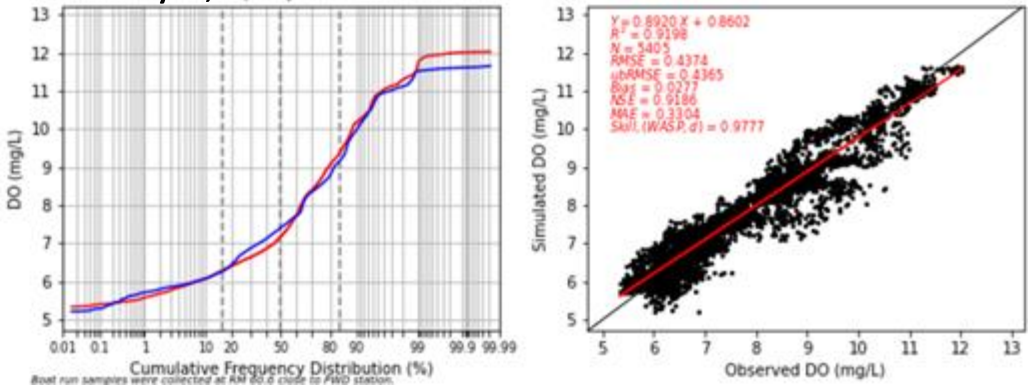
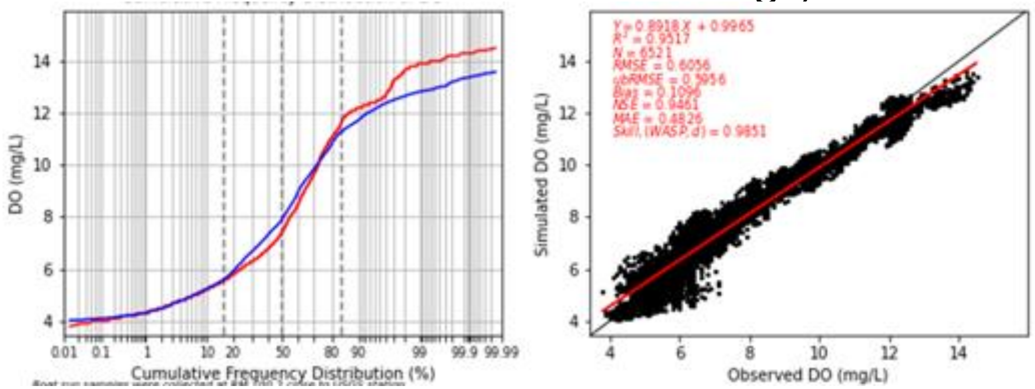


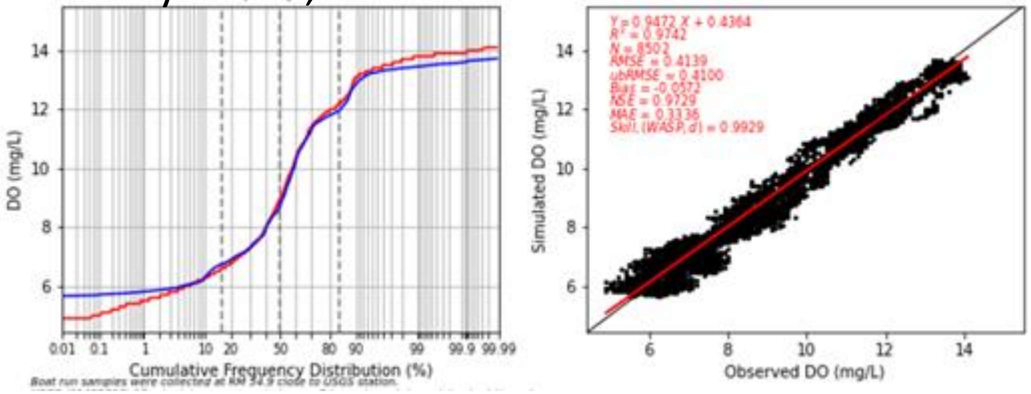
Buoy P, RM 62.0



Ben Franklin Bridge, RM 100.1



Reedy Island, RM 54.1



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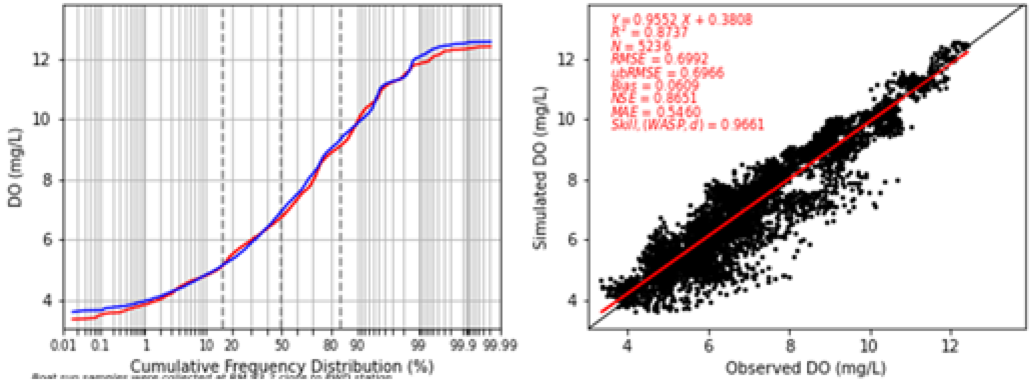

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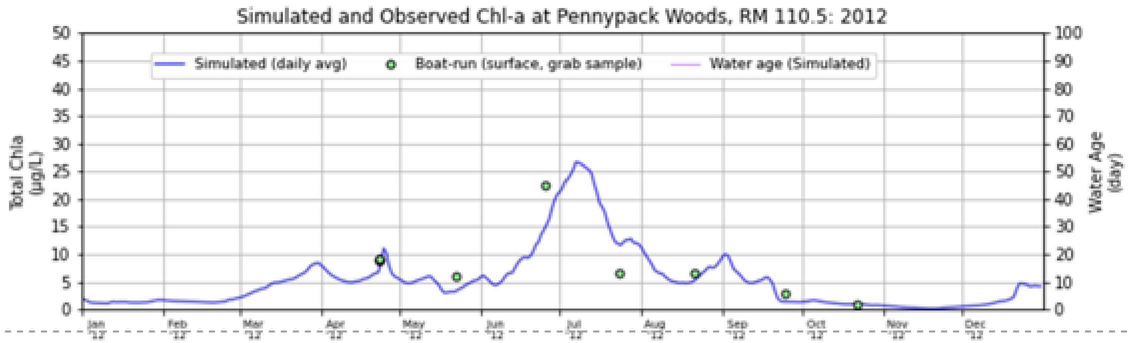
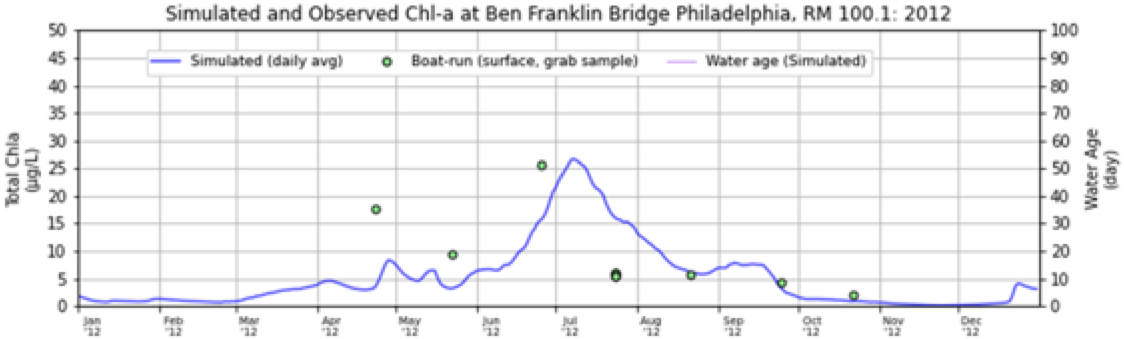
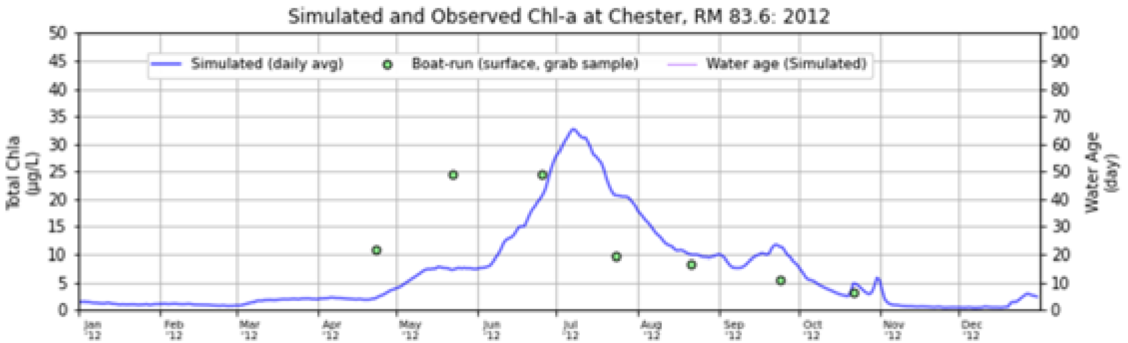
In-Situ Continuous Phyto and DO: 2012







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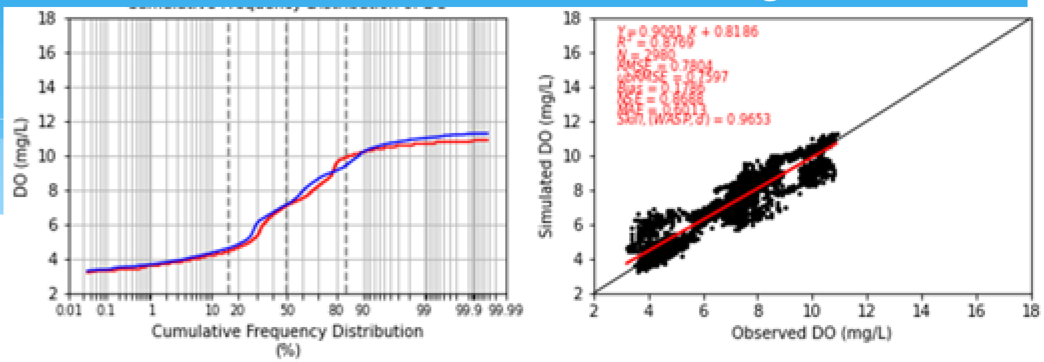

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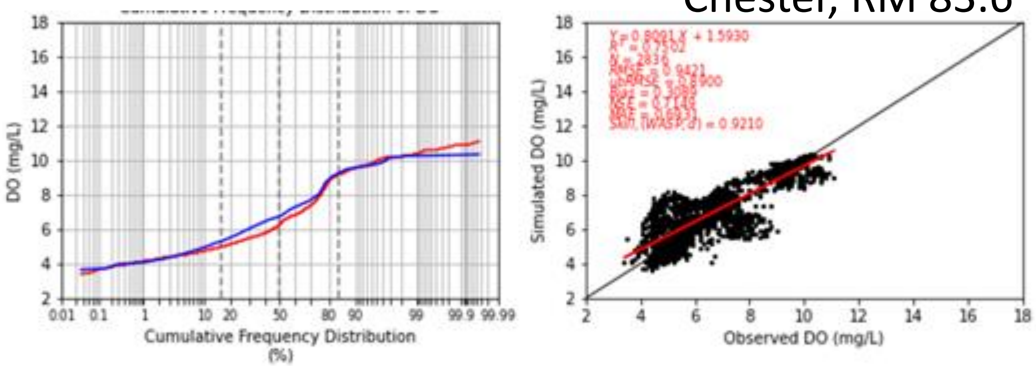

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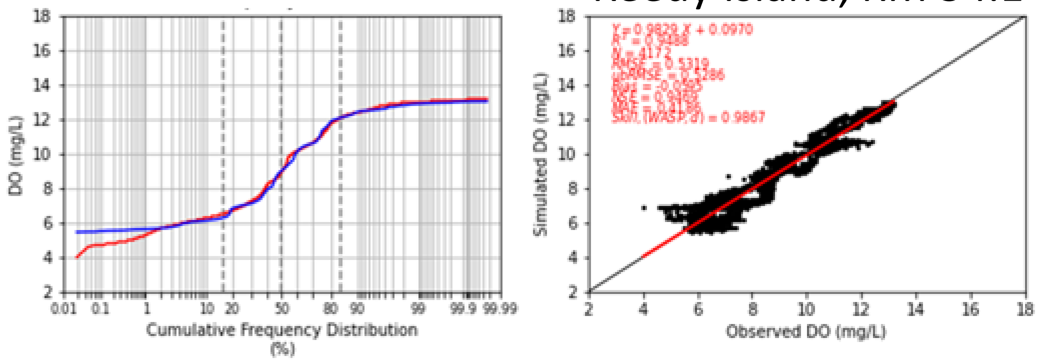

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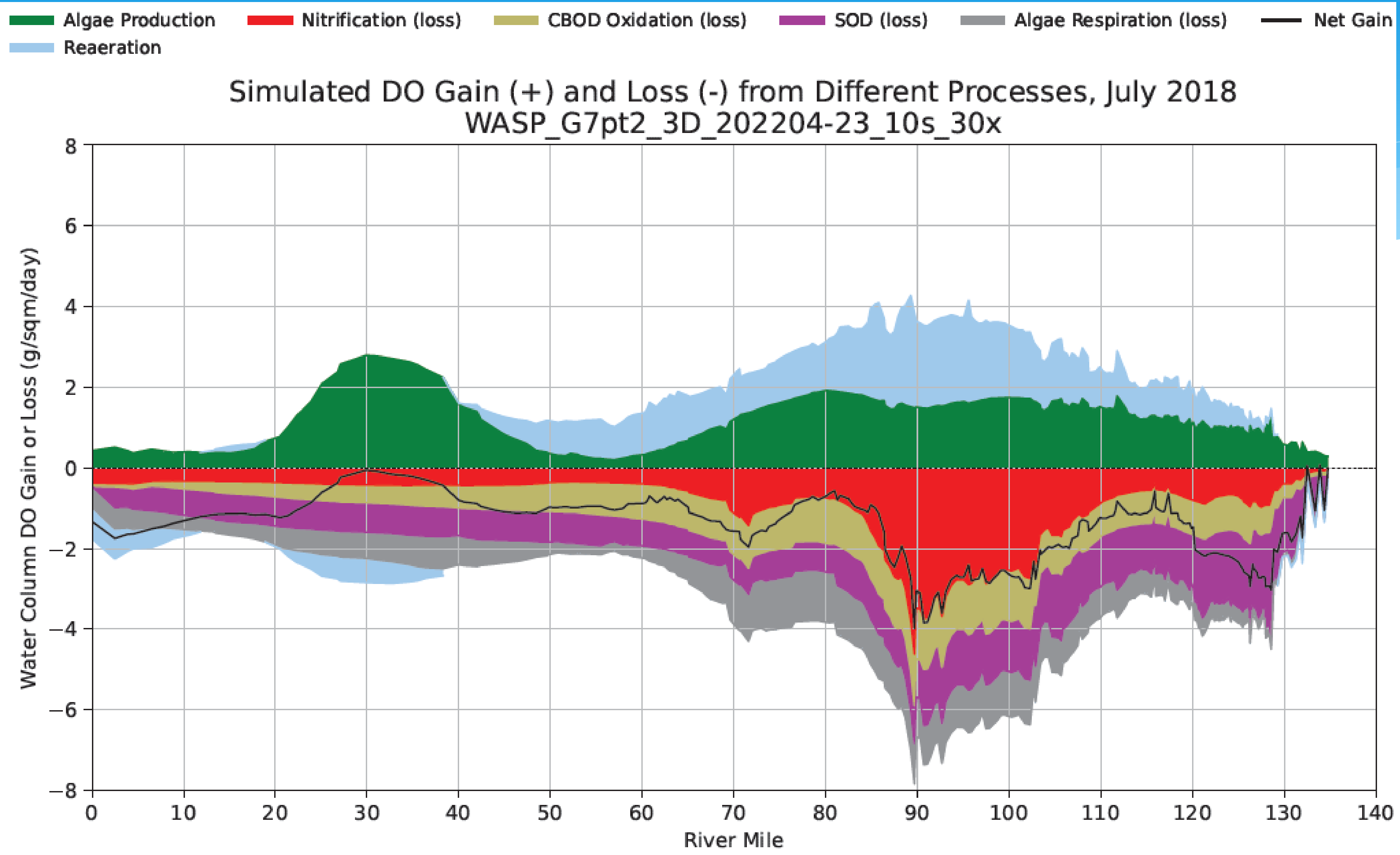
Dissolved Oxygen Components: July 2018



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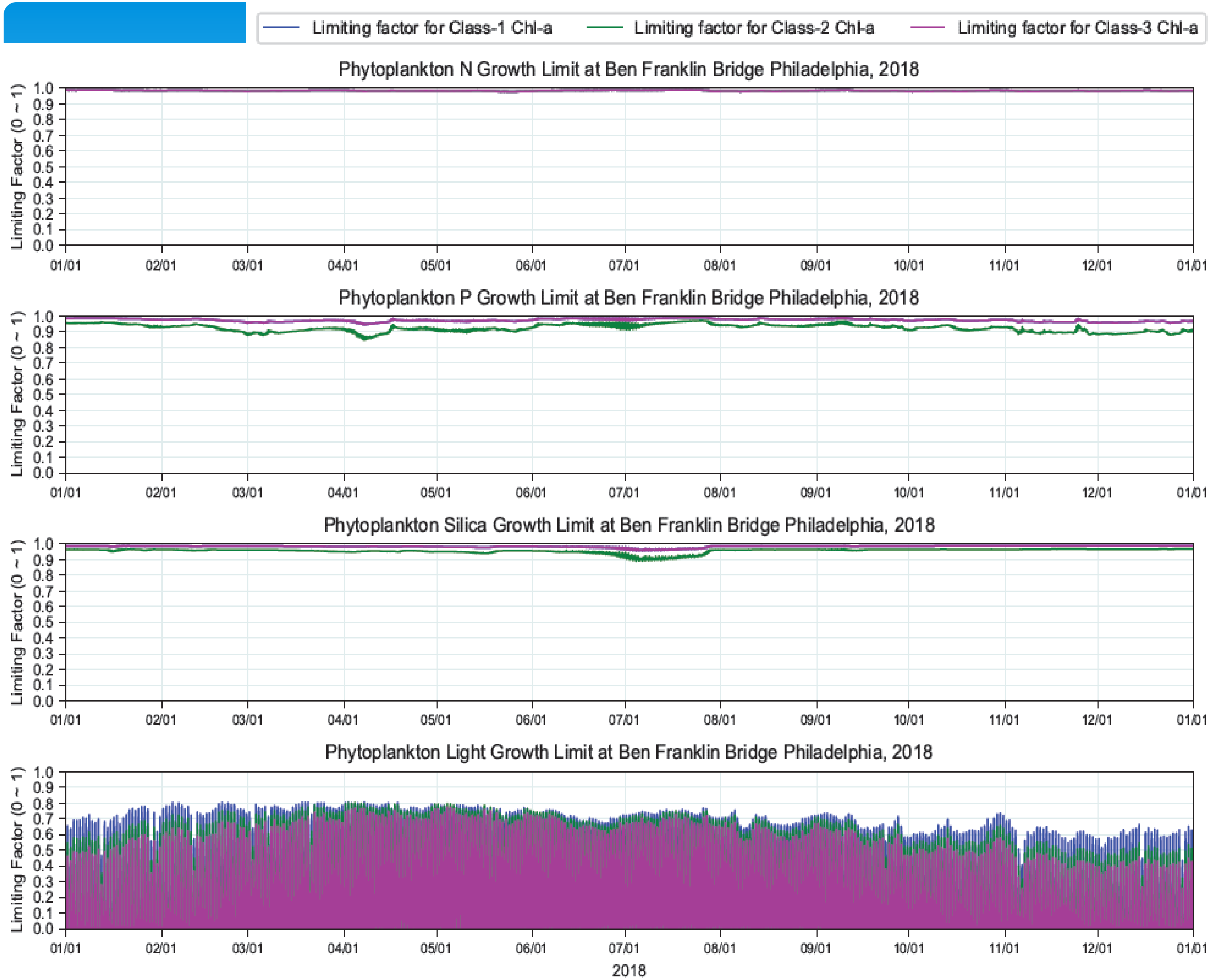
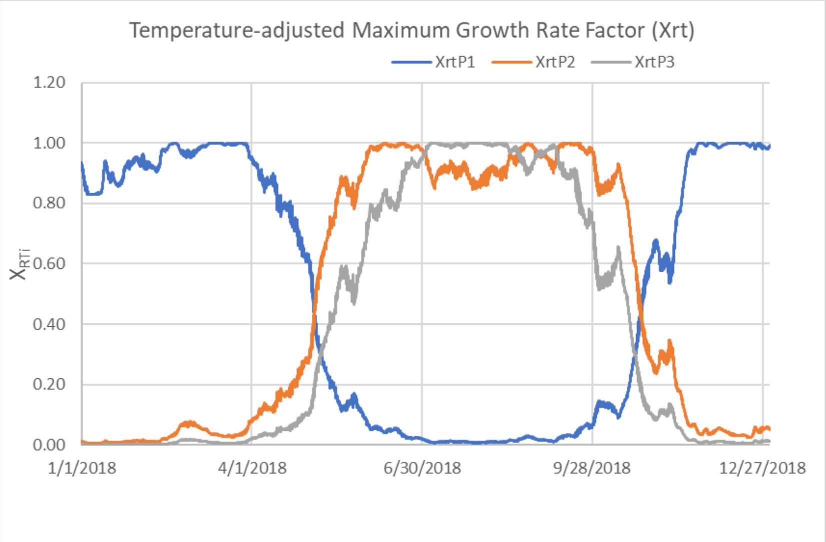
Algal Growth Limitation Factors: 2018



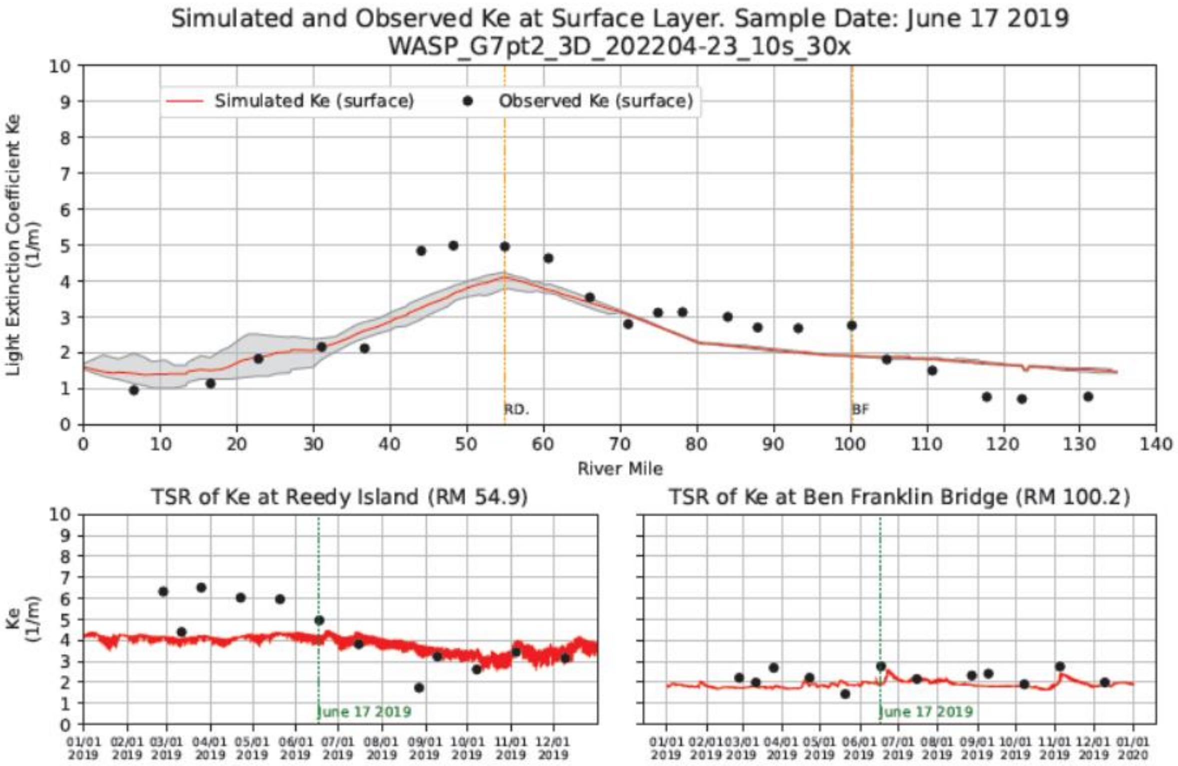


Zone 2 light sensitivity demonstration

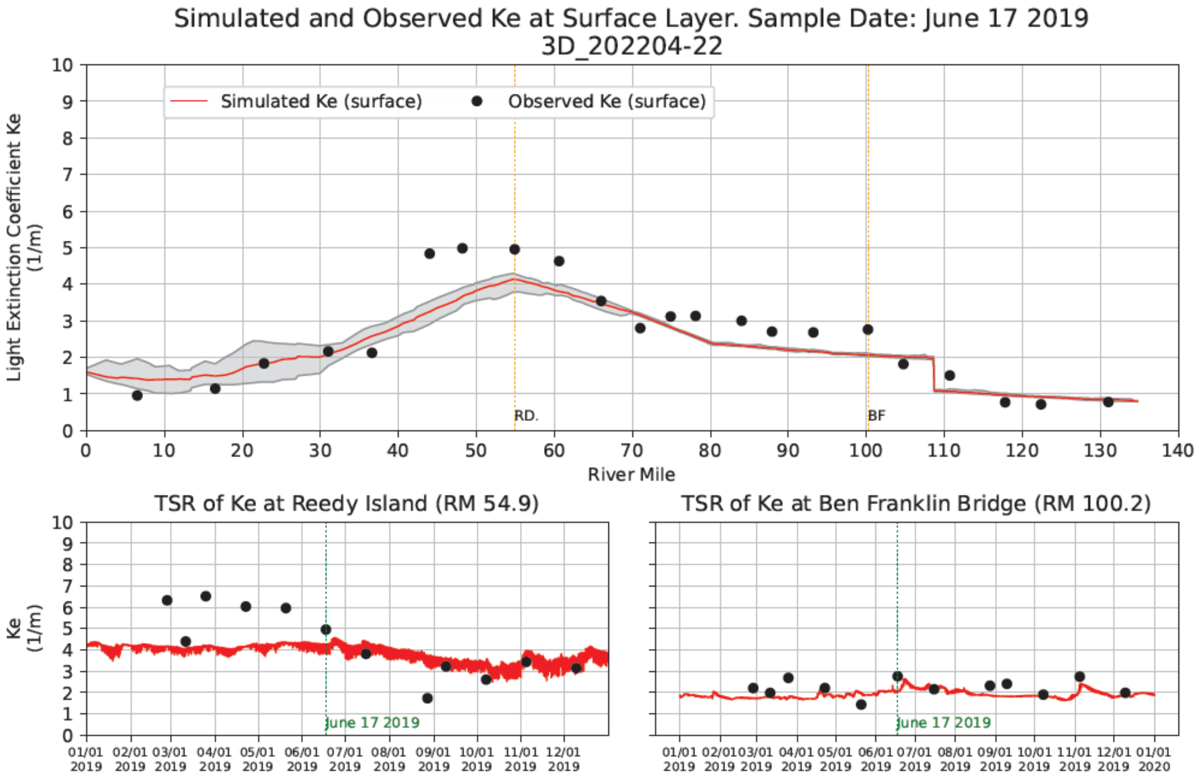
- Performed to understand why the model was not capturing phytoplankton bloom in urban estuary from early June through July of 2019
- What is NOT causing the underprediction
  - Temperature sensitivity
  - Boundary loads of DO or chl-a
  - Kinetic specifications
  - Stormwater flushing in accumulated phytoplankton
  - Hydrodynamics
- So … what is it?
  - Periods of higher water clarity during the growing season in the upper tidal river result in transient blooms that propagate downstream and affect phytoplankton throughout the tidal river.

Light Extinction seasonal modification in Zone 2

Calibrated Model



Seasonal adjustment: multiply light extinction coef. by 0.55 for the period of 5/1 ~ 7/15



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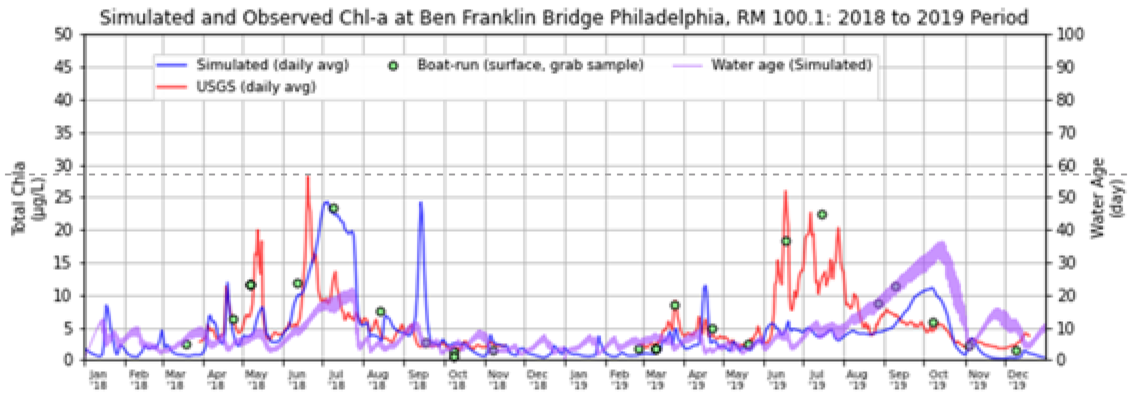
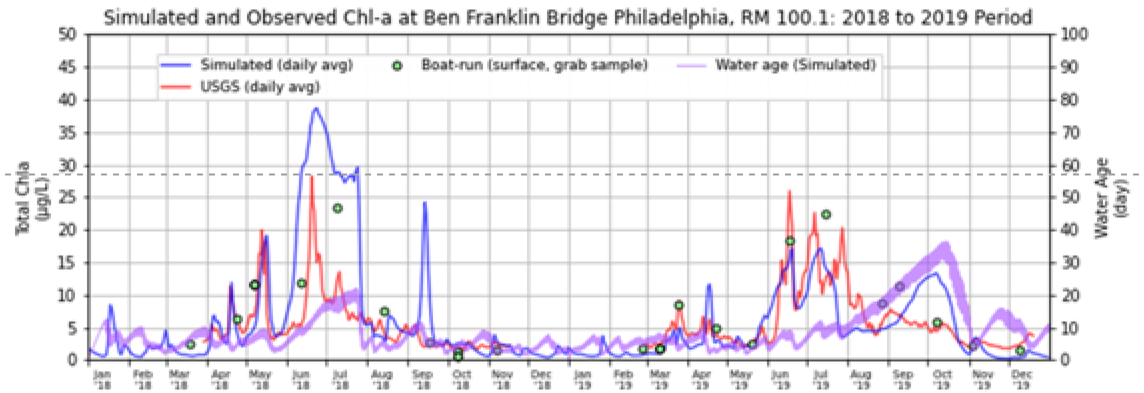
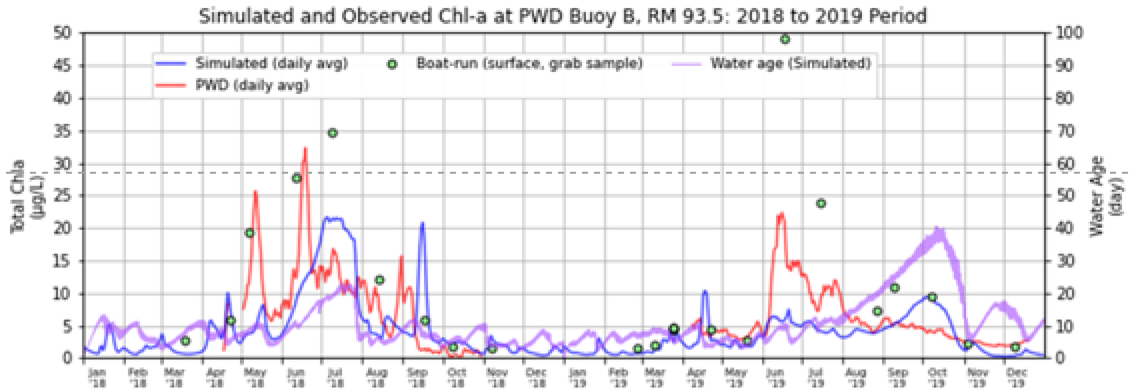
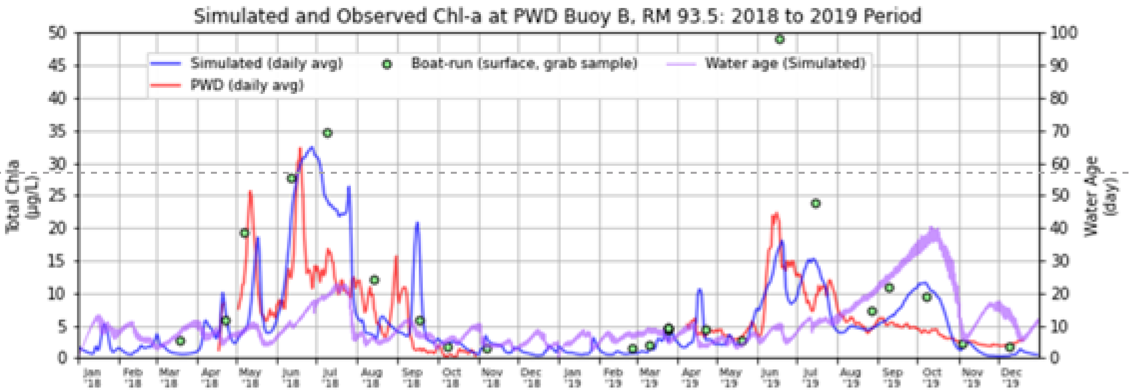
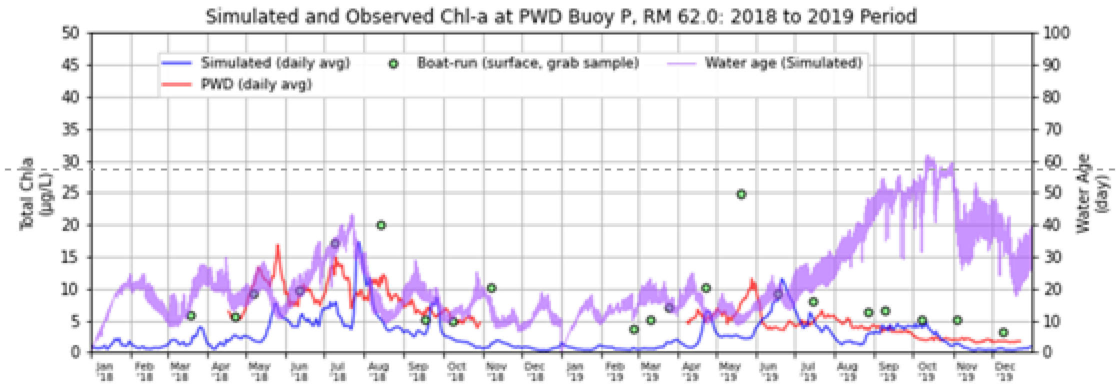
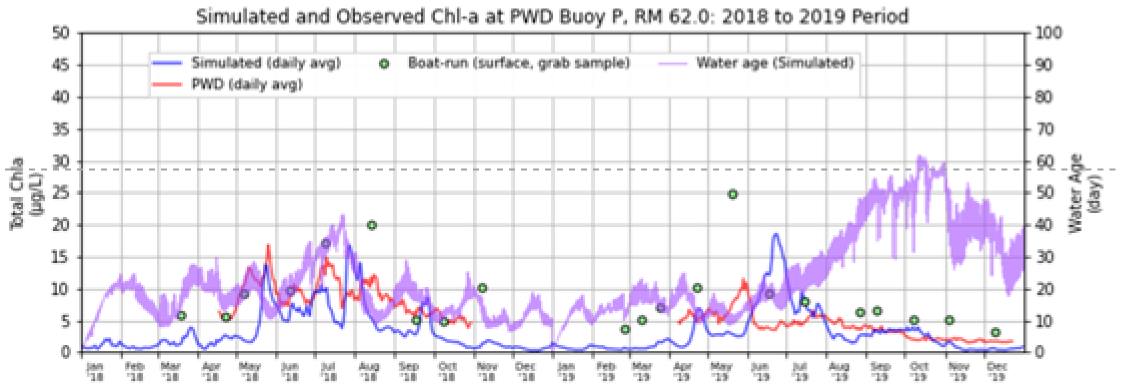










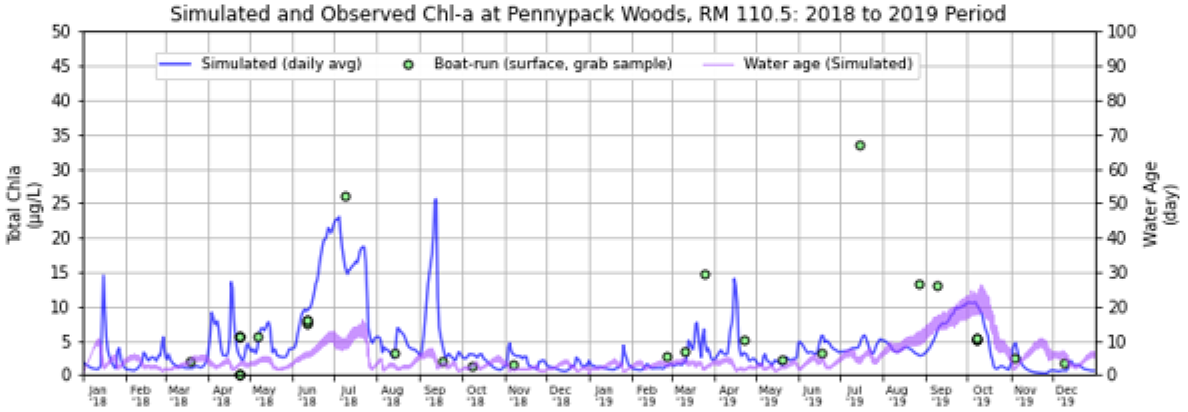


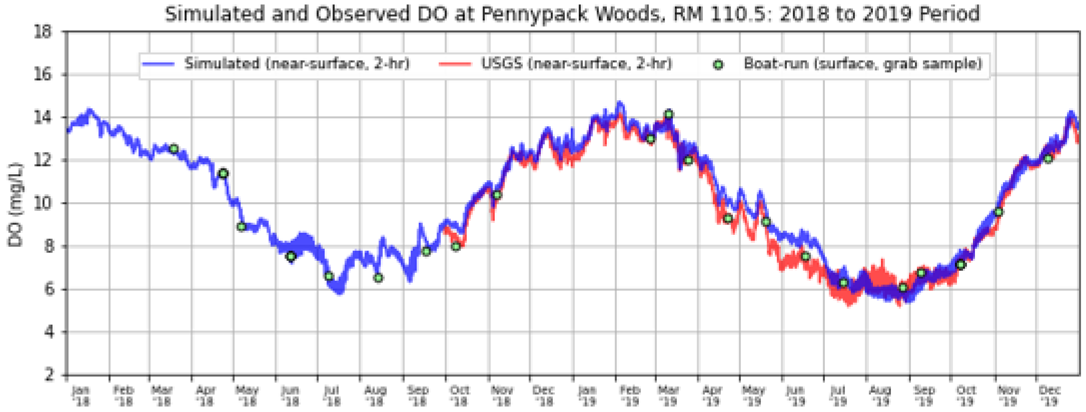
Sensitivity of DO and phytoplankton to Zone 2 light

Phytoplankton Chl-a

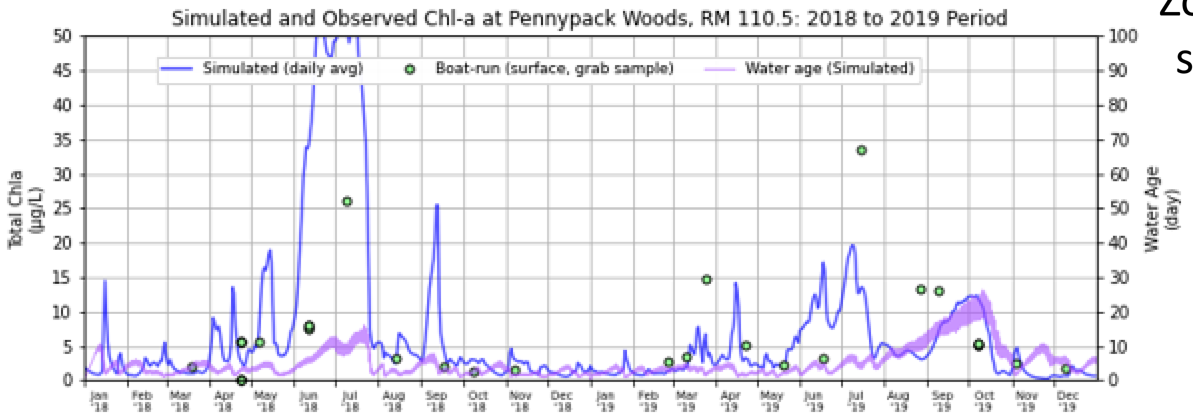
Dissolved Oxygen

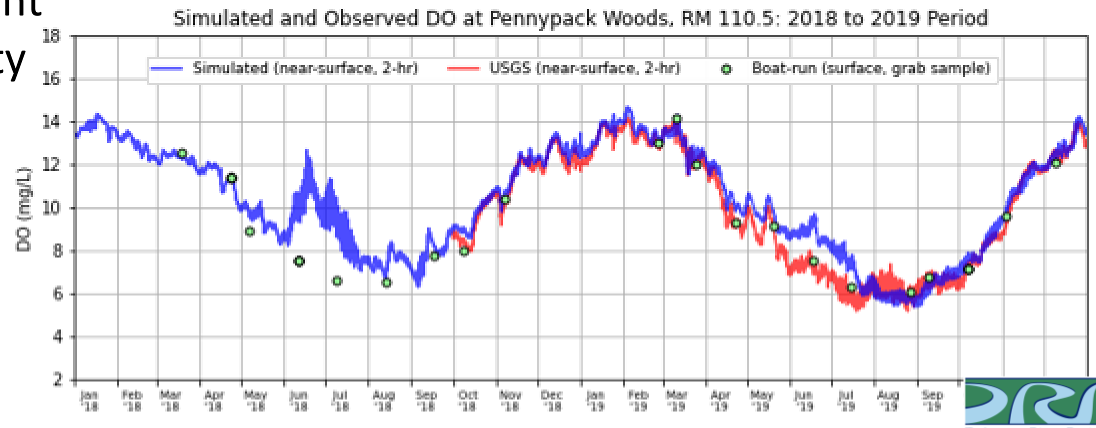
Base Case





Zone 2 light sensitivity





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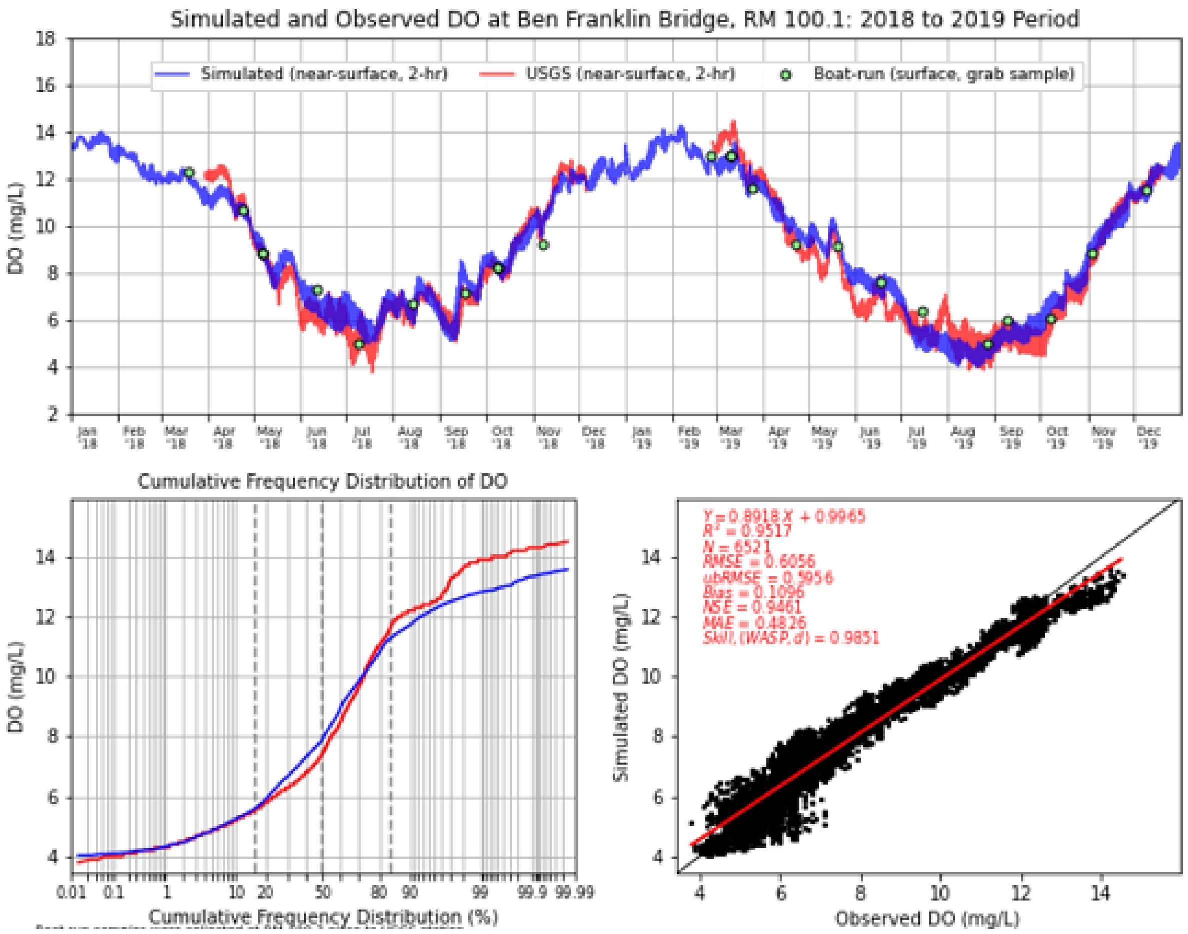
Sensitivity of DO at Ben Franklin to Zone 2 light

Calibrated Model



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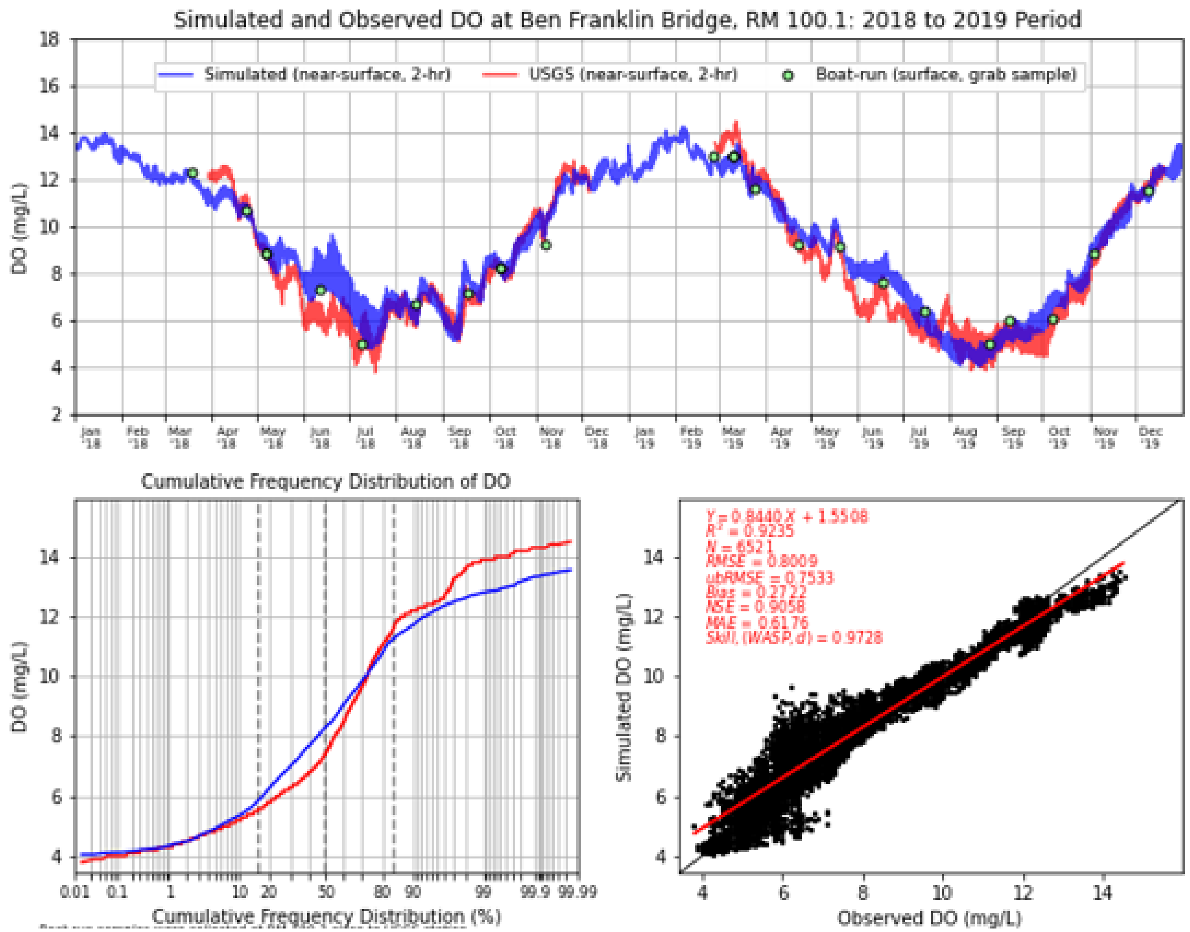

Summary of Findings
What we have learned from all this modeling?

- Major processes controlling dissolved oxygen
  - Production: reaeration and photosynthesis
  - Consumption: nitrification, followed by SOD, CBOD oxidation, and respiration
- Drivers of low dissolved oxygen in the urban estuary
  - Nitrification is the most important driver and is centered in the urban estuary
  - Low flows and high temperatures, as expected, exacerbate low DO
  - Photosynthesis from phytoplankton tempers low DO events
- Processes controlling phytoplankton
  - Light and temperature
  - Autochthonous growth during summer periods of high clarity in Zone 2 can impact entire estuary

Eutrophication Model Expert Panel Discussion

Dr. Vic Bierman, LimnoTech – liaison to Model Expert Panel

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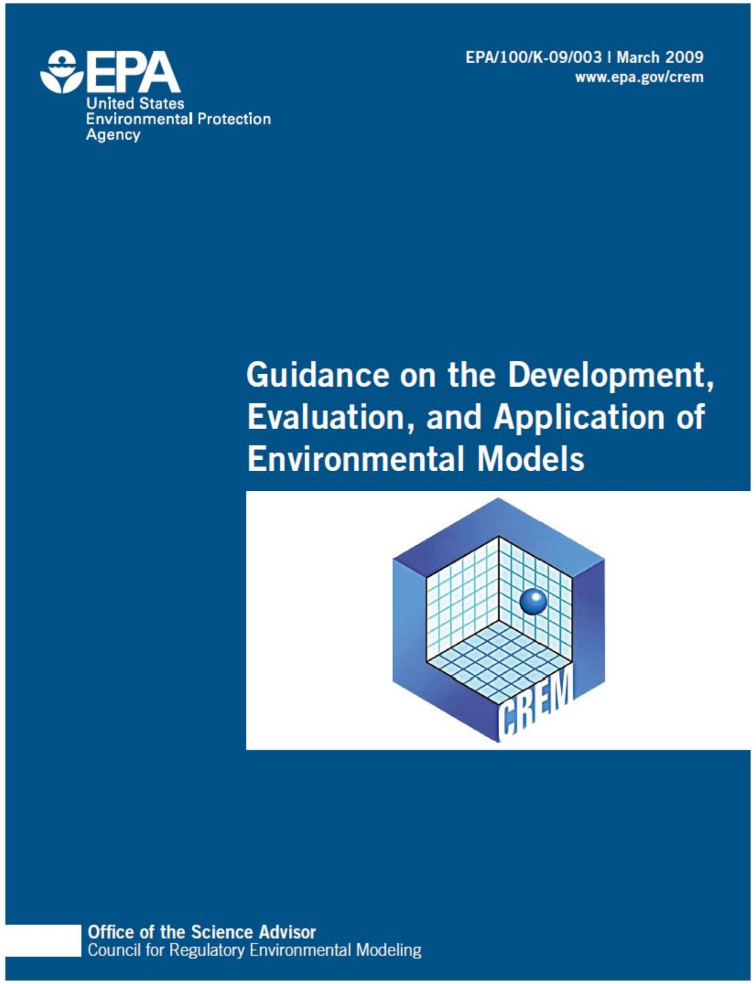
How good is the model?


EPA United States Environmental Protection Agency

EPA/100/K-09/003 I March 2009
www.epa.gov/crem

Guidance on the Development, Evaluation, and Application of Environmental Models

Office of the Science Advisor
Council for Regulatory Environmental Modeling

Corroboration: Quantitative and qualitative methods for evaluating the degree to which a model corresponds to reality.

In some disciplines, this process has been referred to as validation.

In general, the term “corroboration” is preferred because it implies a claim of usefulness and not truth.

Model is Corroborated for Intended Use

- Model well-calibrated to intensive project dataset for 2018-2019
  - High flows in 2018 and medium flows in 2019
  - Moderately low DO in both years
- Model successfully hindcasted historical conditions in 2012
  - Flows, boundary conditions, forcing functions based on available 2012 data
  - Model coefficients unchanged from 2018-2019 calibration
  - Low flows and low DO
- Model is quantitatively consistent with observed data across a range of flow and DO conditions

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Conclusions

1. Model is scientifically defensible over a wide range of environmental conditions in the Delaware Estuary

2. Model is appropriate for its intended use
   - To determine the improvement in dissolved oxygen condition that would result from specific reductions to point and nonpoint source loadings

Discussion with Model Expert Panel members

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Analysis of Attainability

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Analysis of Attainability Methodology preview

Elements

- For discussion at WQAC on May 18
  - Design condition
  - Test Scenarios
  - Metrics to compare scenarios
- Subsequent elements for future discussion
  - Selection of candidate scenarios
  - Characterization of costs and benefits
  - Affordability evaluation

Initial Design Condition Ideas

- 2012 hydrology and climate
  - With shipping channel dredged
  - Compare with and without
  - Benthic/SOD fluxes and kinetics remain same
- Boundary flows based on estimate of actual flows for 2012
  - Difference between actual and permitted flow capacity will not affect hydrodynamics
- Point source concentrations
  - 90th percentile of seasonal values from intensive monitoring period
  - LTAs associated with existing permit AMLs

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Scenarios and Metrics

Initial Scenario Ideas

- Four levels of point source reductions
  - NH_3 = 10, 5, 1.5 mg/L → adjust NO_3 accordingly
  - TN = 4 mg/L
  - Applied to: Tier 1 only, Tier 1 + 2, all
    - Individual WWTP sensitivity
  - DO = 100% saturation
- Natural condition sensitivity
  - Groundwater concentrations used as surrogate for natural condition
  - Applied to: tributaries/MS4, WWTPs, both

Initial Ideas for Metrics

- Spatial graphs of summer 1st percentile DO
- Define bins within Zones as needed to capture critical areas
- Compare incremental dissolved oxygen changes

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Scheduled Next WQAC Meetings

- May 18
  - Analysis of attainability design conditions
  - Draft affordability study
- June 14
  - Analysis of attainability (AA) design conditions
  - Preliminary results of selected AA design condition simulations
- July 14
  - Preliminary results of selected AA design condition simulations
  - Finalize analysis of attainability (AA) design conditions
- August 18
  - Preliminary results of final AA design condition simulations linking with cost, benefit, affordability
- September 13
  - Preliminary results of final AA design condition simulations linking with cost, benefit, affordability, levels of fish protection
- October 12

TENTATIVE SCHEDULE

Task	Target Date
Draft Hydrodynamic Model Report	January 2022
Draft Water Quality Model Report	May 2022
2nd Draft Aquatic Life Protection Levels and Dissolved Oxygen	May/June 2022
Draft Affordability Assessment	June/July 2022
Procedure for Analysis of Attainability – WQAC process	July 2022
Final Draft Analysis of Attainability	September 2022