What is this estuary-wide eutrophication model and why do we need it?

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Partnership for the Delaware Estuary Science and Environmental Summit

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Model Development Team

DRBC Personnel

Name	Title
Kristen B. Kavanagh	Deputy Executive Director
Thomas Amidon	Manager, Water Resource Modeling
Sarah Beganskas	Water Resource Scientist
Jacob Bransky	Aquatic Biologist
Fanghui Chen	Senior Water Resource Engineer
Vince DePaul	Hydrologist (USGS)
Elaine Panuccio	Water Resource Scientist
Namsoo Suk	Director, Science and WQ Management
John Yagecic	Manager, Water Quality Assessment
Li Zheng	Senior Water Resource Modeler

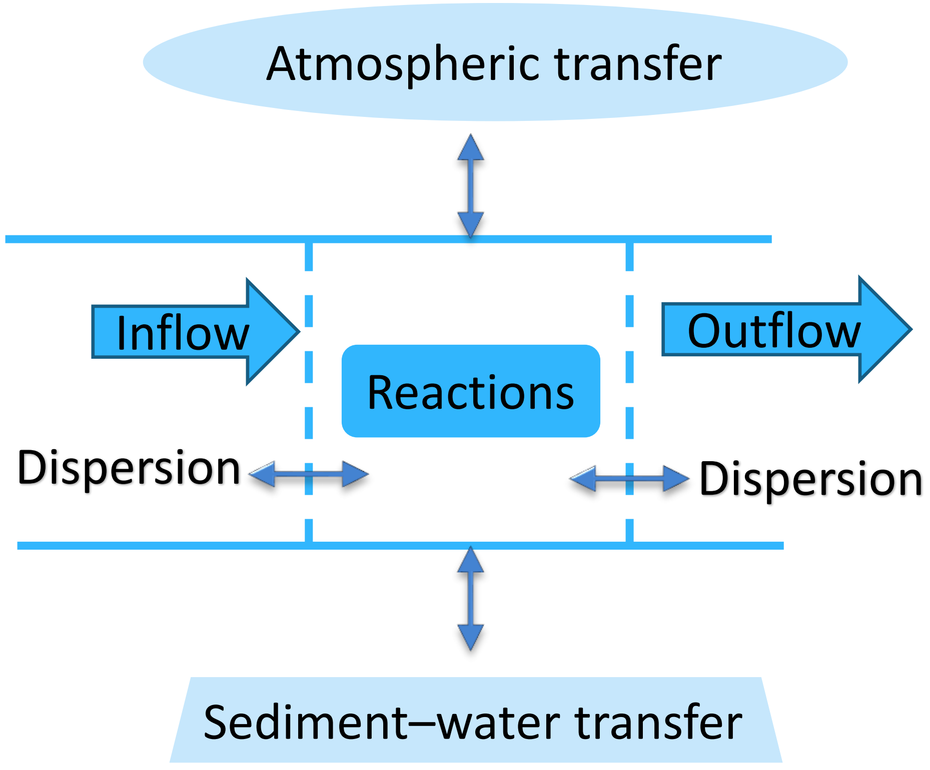
Expert Panel Members & Consultants

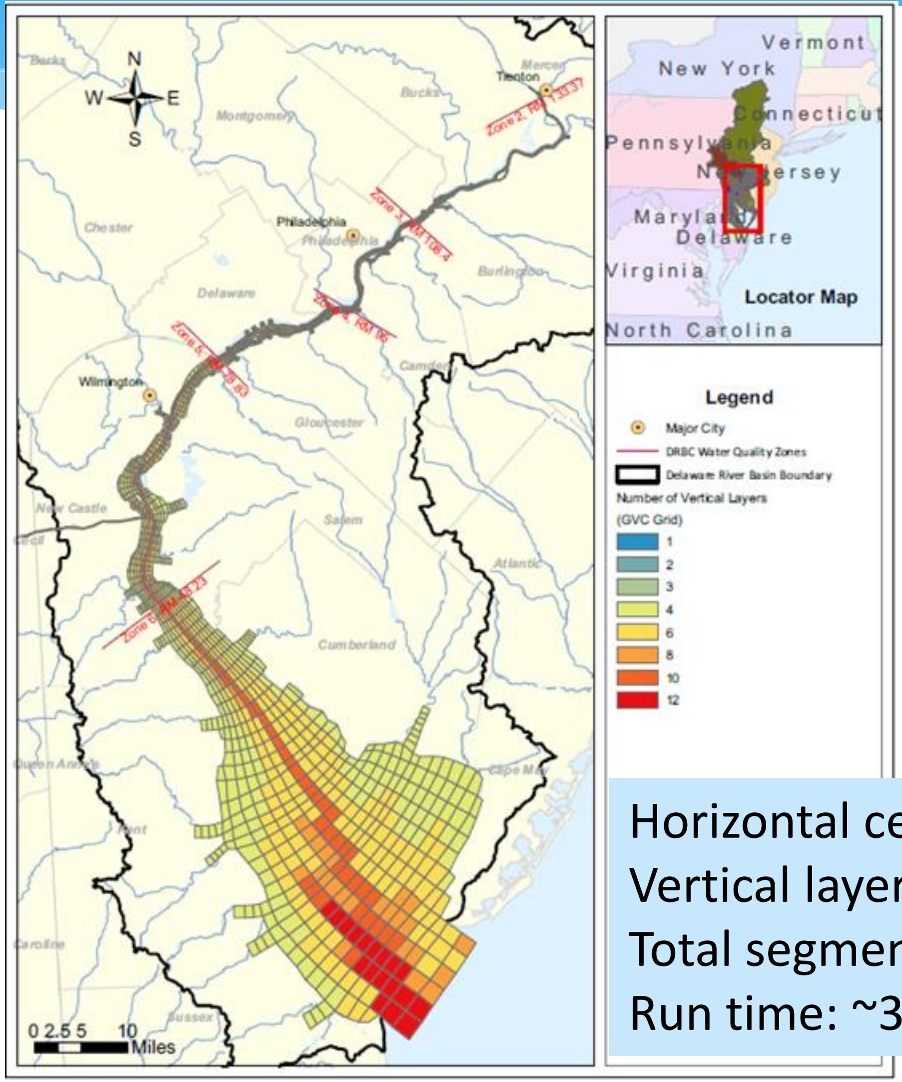
Name	Organization	Service
Carl Cerco	U.S. Army Corps of Engineers (Retired)	Panel Members
Bob Chant	Rutgers University	
Steve Chapra	Tuffs University	
Tim Wool	U.S. EPA Region 4 (Retired)	
Vic Bierman	LimnoTech	Consultant to DRBC
Scott Hinz	LimnoTech	

Hydrodynamic and Eutrophication Models

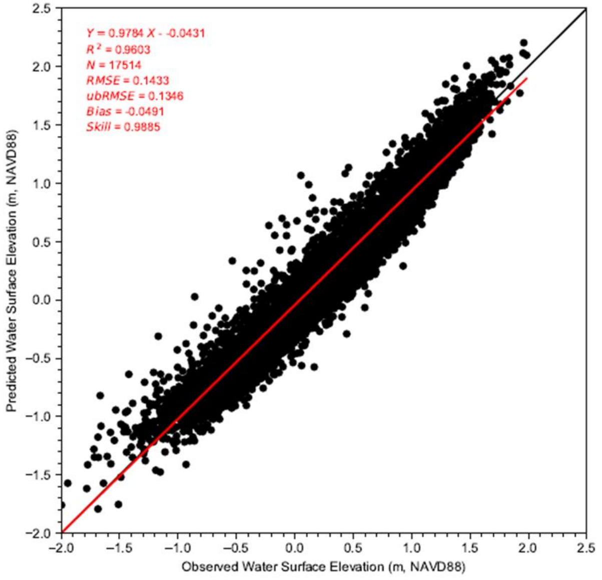
Purpose:

To determine ambient dissolved oxygen levels that would result from various pollutant reduction scenarios





Model–data comparison of water surface elevation at NOAA Philadelphia



Horizontal cell: 1876
Vertical layer: 10 in nav. Channel
Total segments: 11,490
Run time: ~32-hr in 3D

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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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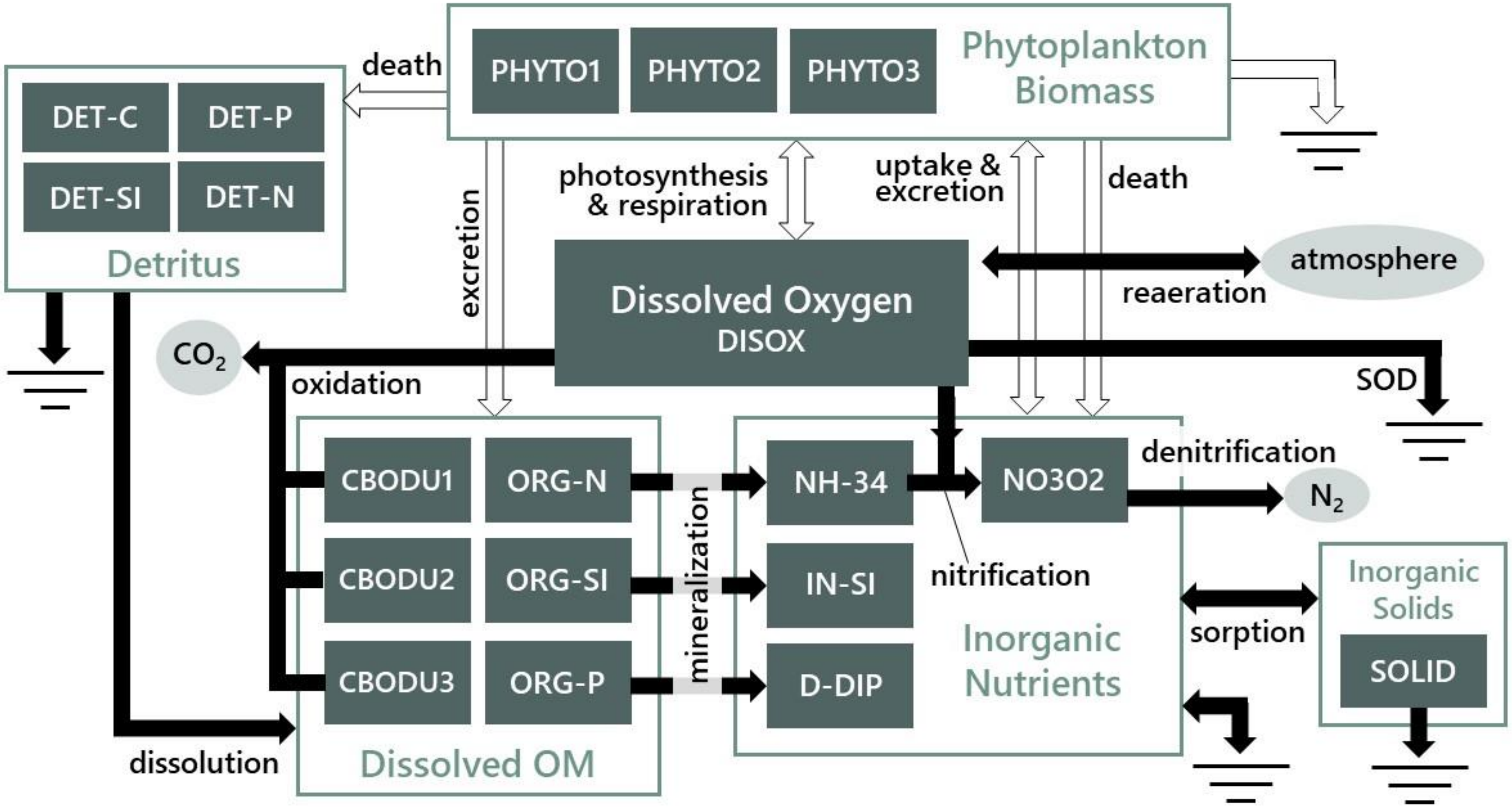
Delaware Estuary Eutrophication Model Kinetics



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Advancements to State-of-the-Art

Model Improvements

- Integration of hydrodynamic (EFDC) and eutrophication (WASP) models
  - Code modification
  - Model correction
- **Light extinction**
- **Reaeration**

Implementation

- Statistical sub-models for boundary assignments
  - Flows
  - Concentrations
- Input and output processing tools

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Light Extinction Simulation

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- Light extinction (Ke) refers to how quickly light is attenuated in the water column
  - Ke for salinity fitted using data downstream of ETM Zone
  - Ke for chl-a, and DOC fitted using data outside ETM Zone
- Used expression of intercept as f(RM) to calculate intercepts along the entire estuary

$$Ke = Ke_{Int} + (0.014 \times Chla) + (0.345 \times DOC) - (0.097 \times Salinity)$$

Where:

$$Ke_{Int} \ as \ f(RM) = 3.5944 \times e^{(-0.016*RM)} + Max[0, (1.7549 - 0.069 \times ABS(54.9 - RM))]$$

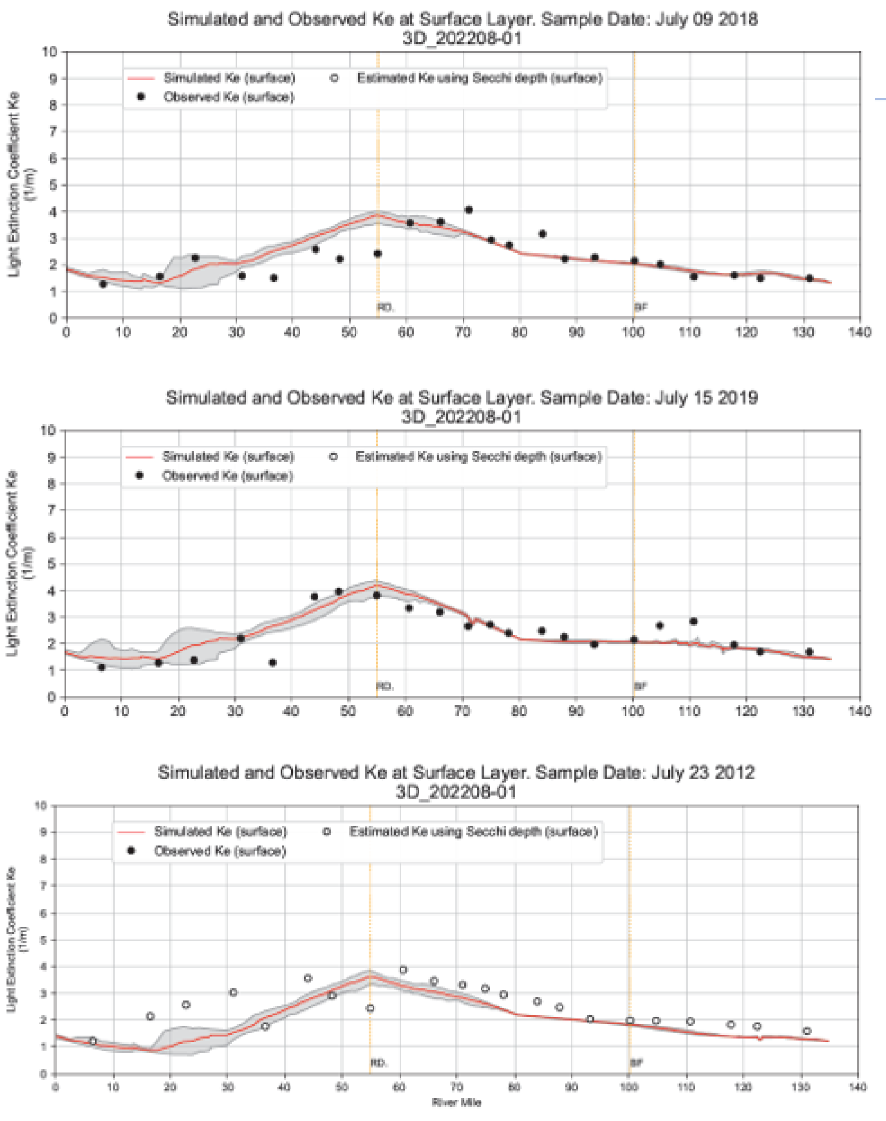
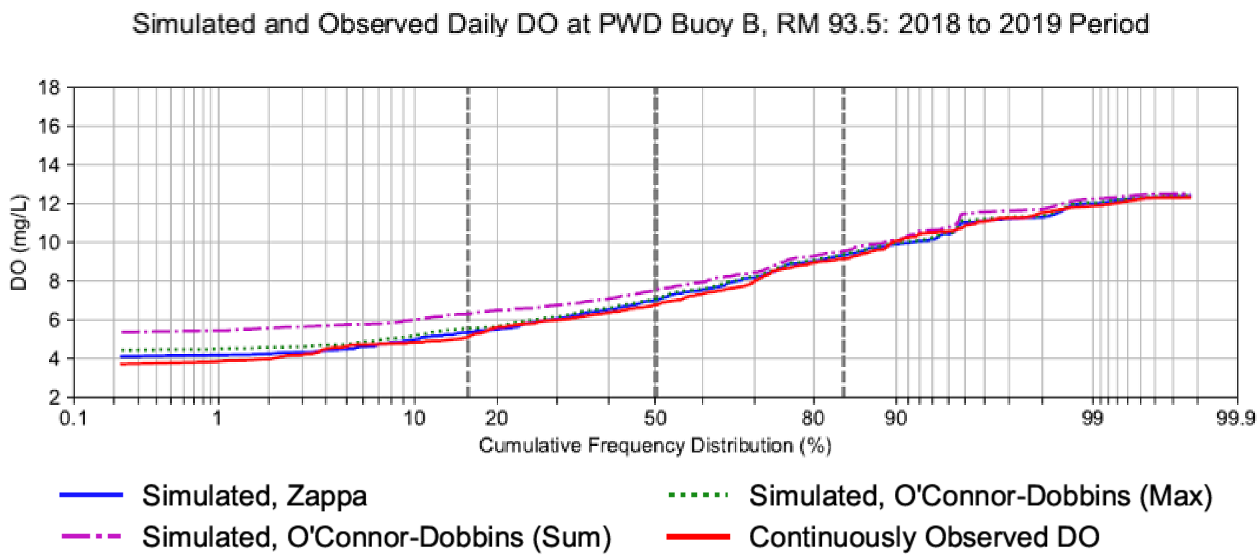


Figure 3-32: Light extinction – July 2018, 2019, and 2012

Reaeration Simulation Enhancements

- Reaeration: rate of DO transfer at the air-water interface
- Mass Transfer Coefficient
  - Existing WASP model options
    - Hydraulic-driven reaeration for river & stream
    - Wind-driven reaeration for lake or bay
  - Utilize turbulent energy dissipation rate at air-water interface (Zappa et al. 2007)
    - Include the effects of both hydraulic and wind-induced

Figure 3-1c: Model–Data Comparisons of Daily DO during 2018–2019 at PWD Buoy B



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Calibration Strategy

- Calibration period: 2018 and 2019
- Corroboration period: 2012
- Principal data used for comparison with model predictions
  - DRBC monthly boat-run survey with grab samples
  - USGS & PWD continuous measurement
- Approach
  - Spatial plots, time series plots, 1-1 plots, cumulative frequency distributions, target diagrams, and statistical metrics used to compare predicted and observed
  - Phytoplankton output compared based on growth seasons of three communities

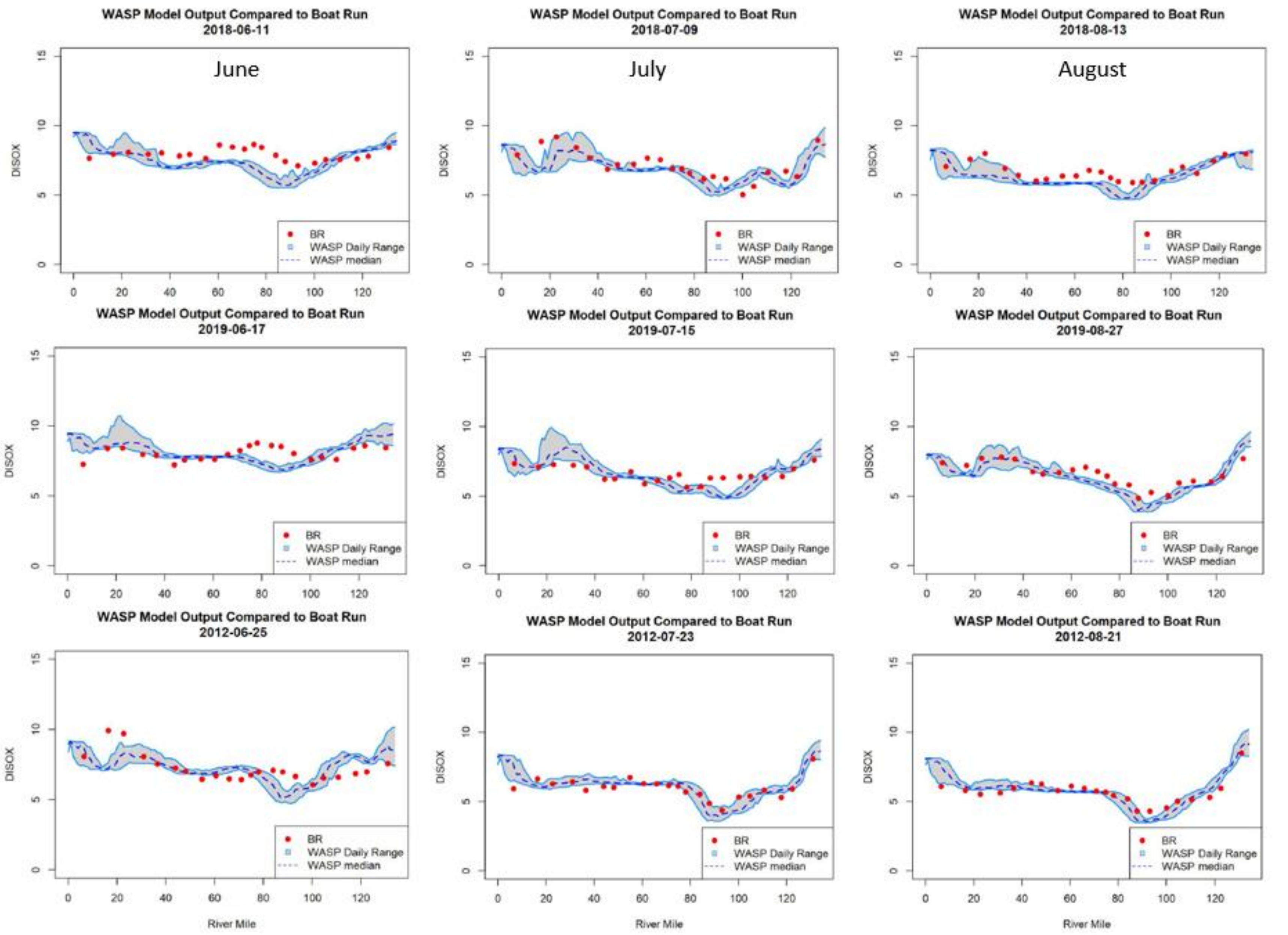
Calibration data locations

Model – Boat Run Data Comparison: DO during Summer

calibration 2018

calibration 2019

Corroboration 2012



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In-Situ Continuous DO: 2018 – 2019

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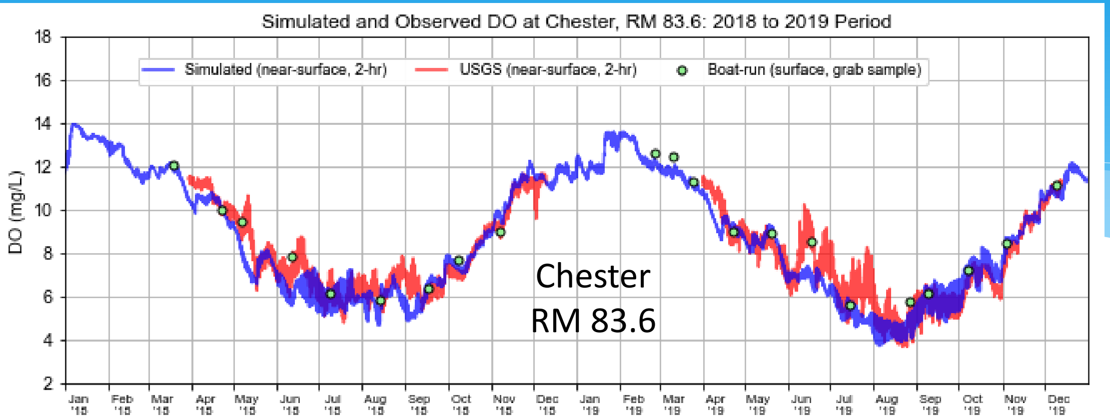
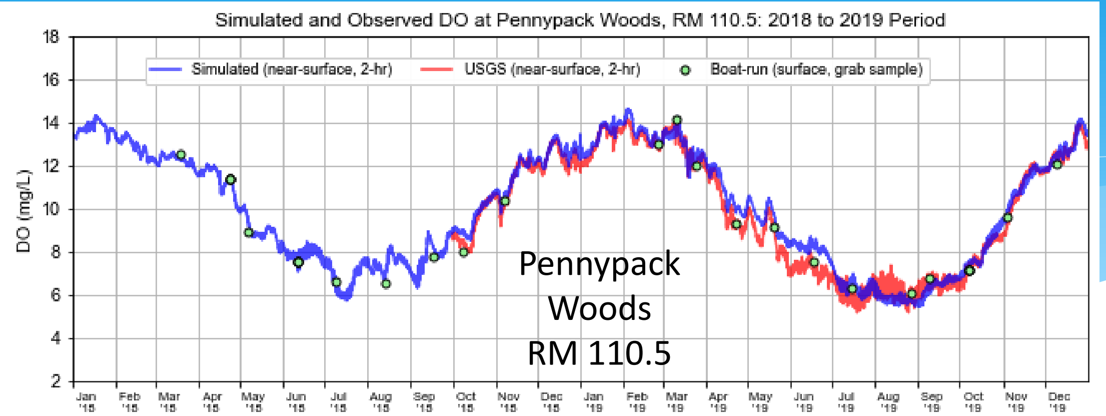
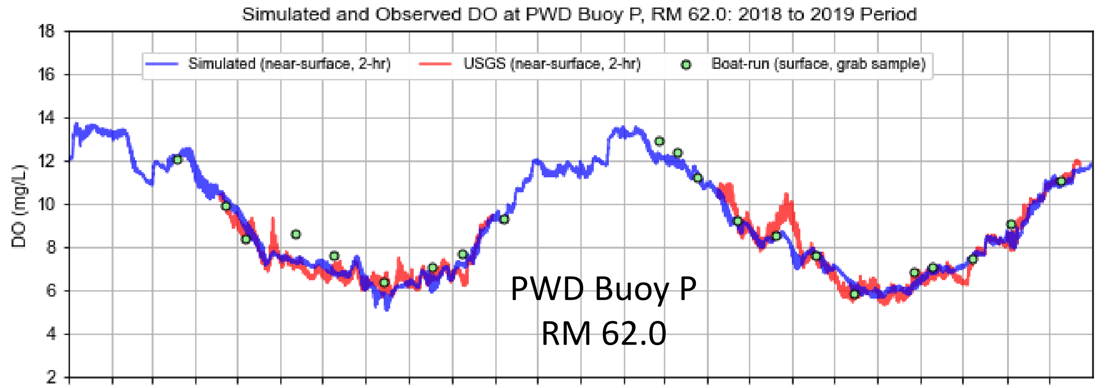
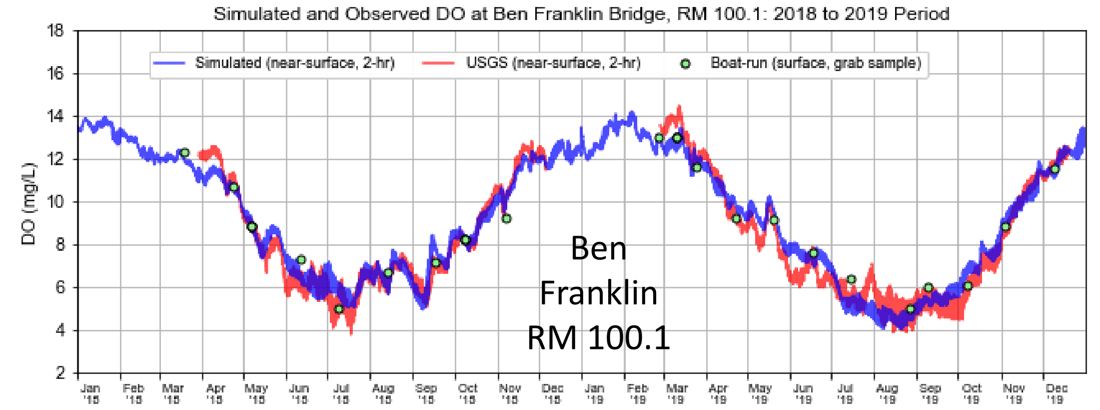
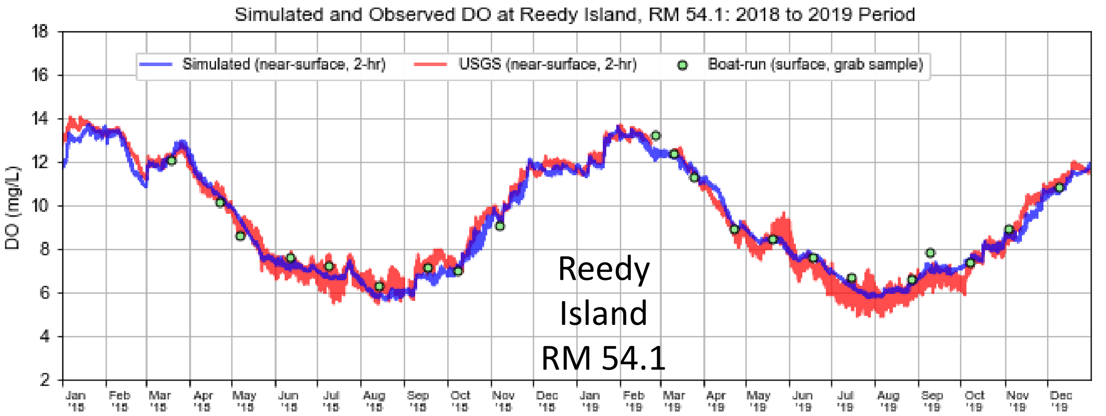
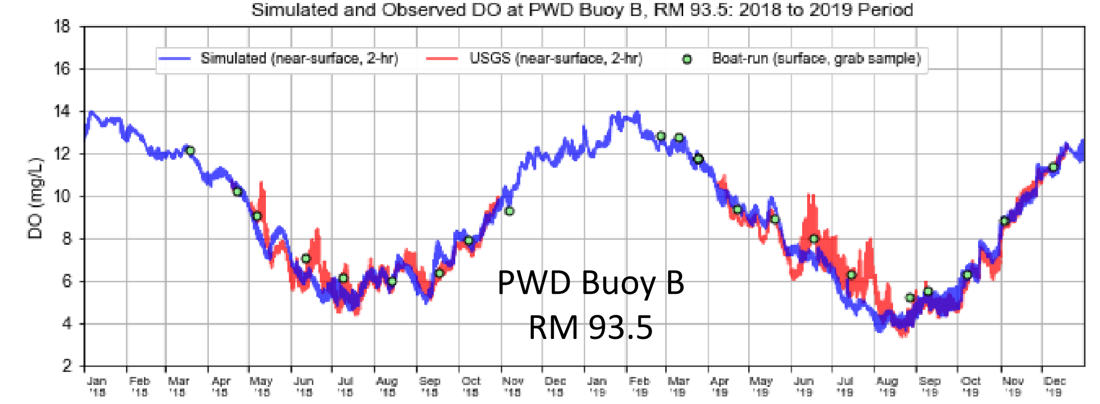






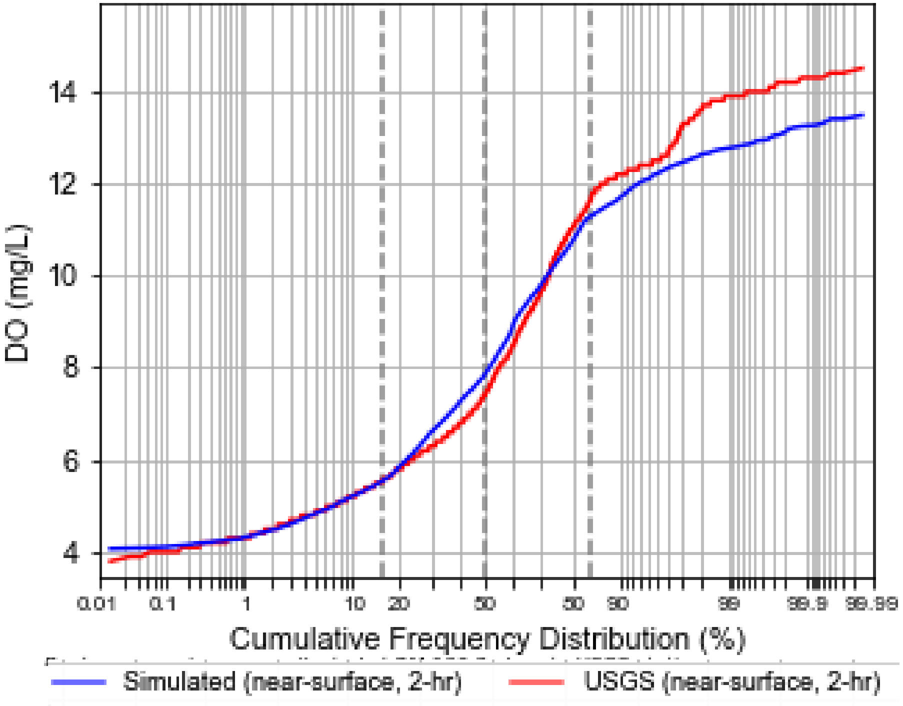


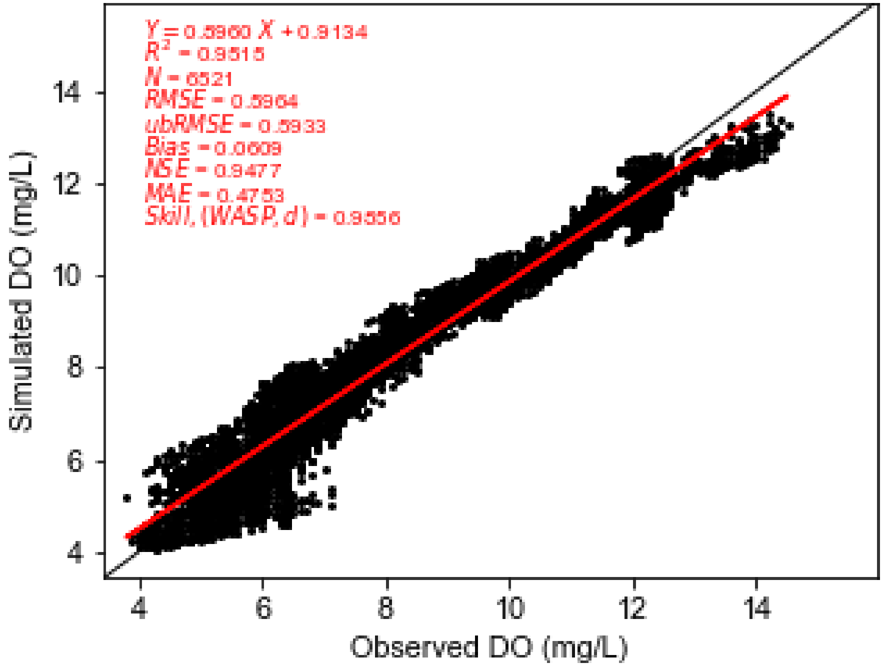




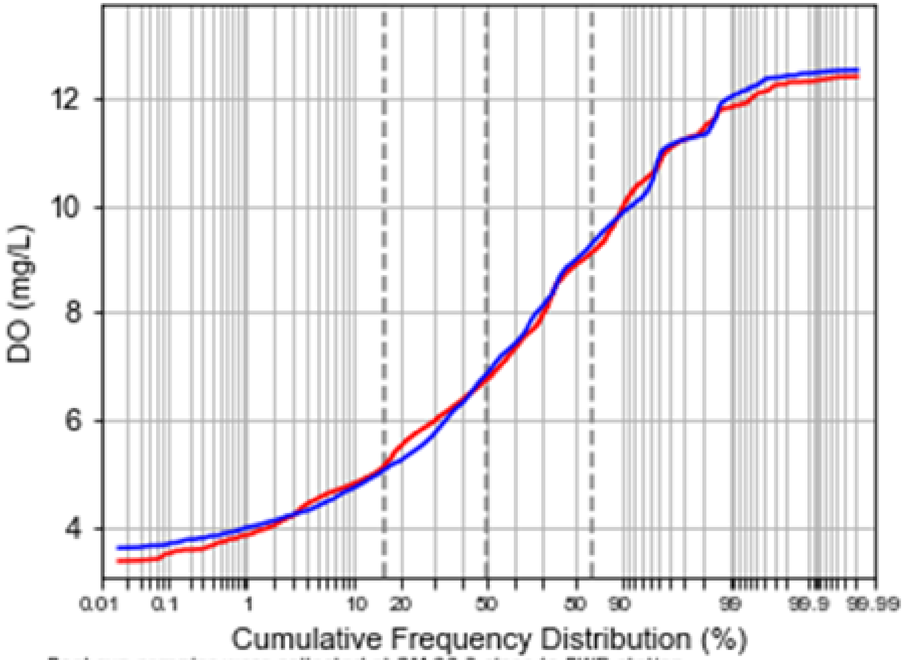
In-Situ Continuous DO: 2018 – 2019

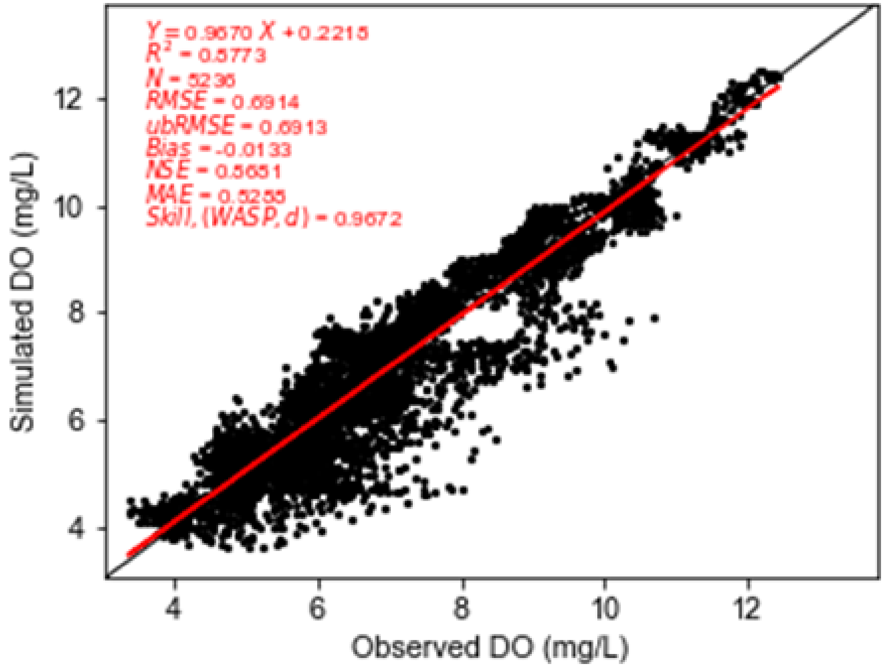
Ben Franklin Bridge, RM 100.1





Buoy B, RM 93.5





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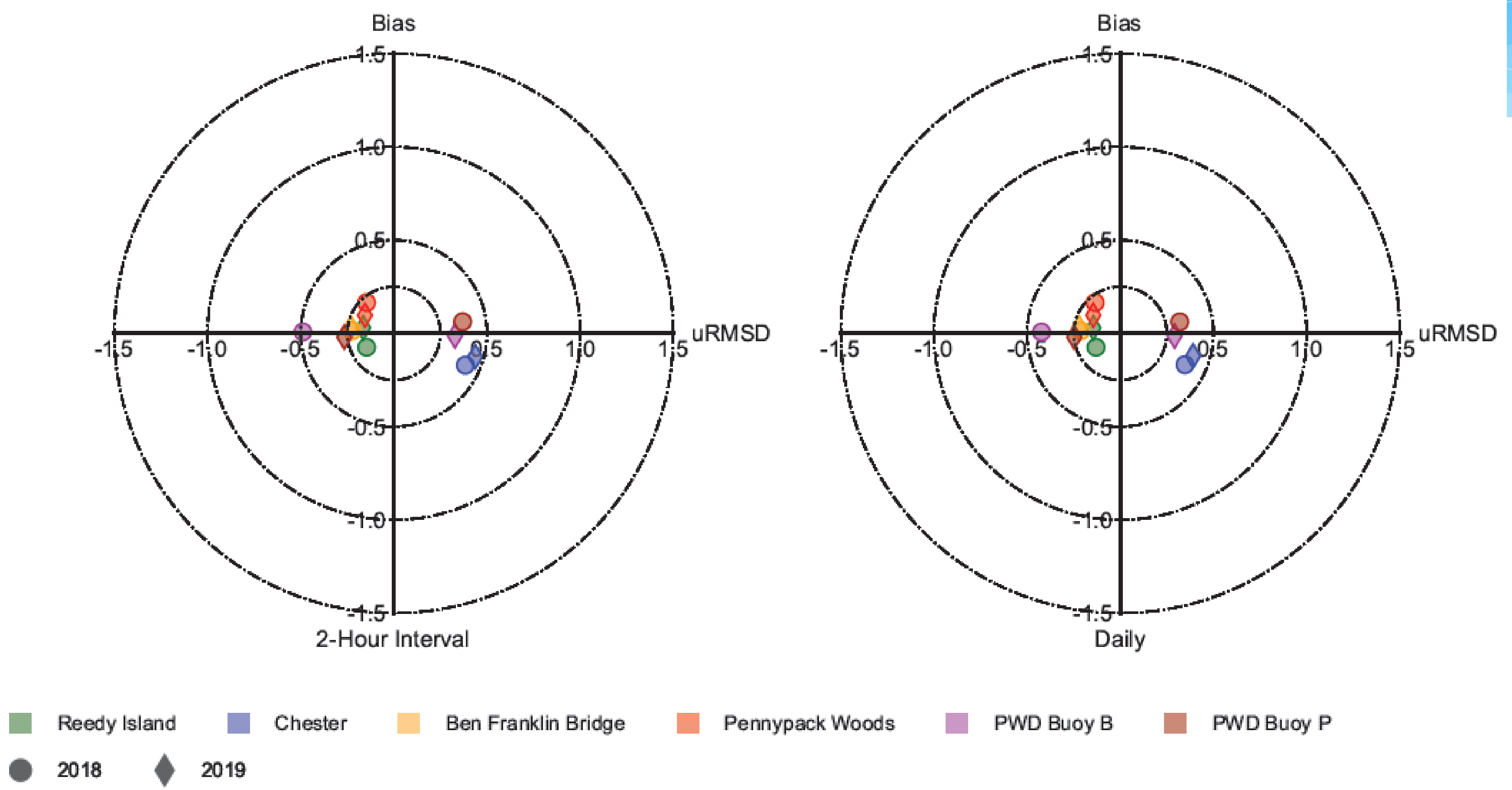
In-Situ Continuous DO: 2018 – 2019

Target Diagram for Predicted Dissolved Oxygen



Normalized Bias and Unbiased RMSD (ubRMSD) are shown.
Nomalization was based on the standard deviation of the data

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Conclusions

DRBC technical staff and Expert Panel Members

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

Improving Dissolved Oxygen and Aquatic Life Uses in the Delaware River Estuary

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Topic	Presenter
Why are we here?	Steve Tambini
How did DRBC address low dissolved oxygen in the Delaware Estuary - then and now?	Namsoo Suk
Where do ammonia and other nutrients in the Delaware Estuary originate, and how do we know?	John Yagecic
What is this estuary-wide eutrophication model and why do we need it?	Li Zheng
What matters and what doesn't with regard to low dissolved oxygen events in the Delaware Estuary?	**Fanghui Chen**
What combination of wastewater improvements will achieve the best dissolved oxygen outcome in the Delaware Estuary?	Sarah Beganskas
What is the highest attainable dissolved oxygen condition in the Delaware Estuary, and what will it mean for aquatic life uses?	Thomas Amidon
Q&A Panel: Enhancing support for aquatic life uses in the Delaware Estuary	**All**