Seasonal forecasts of Chesapeake Bay hypoxia

Modeling Workgroup Meeting
8 January 2019

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Seasonal forecasts of Chesapeake Bay hypoxia

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Chesapeake Bay's 'dead zone' expected to get bigger

John Aaron | @JohnAaronWTOP
June 13, 2019, 4:00 AM

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Large summer 'dead zone' forecast for Chesapeake Bay after wet winter and spring

Date: June 12, 2019

Source: University of Maryland Center for Environmental Science

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Chesapeake Bay 'dead zone' could be largest in decades, scientists say

Lucas Gonzalez, Salisbury Daily Times Published 6:00 a.m. ET June 20, 2019 | Updated 4:57 p.m. ET June 20, 2019

University of Michigan Chesapeake Bay hypoxia forecasting model

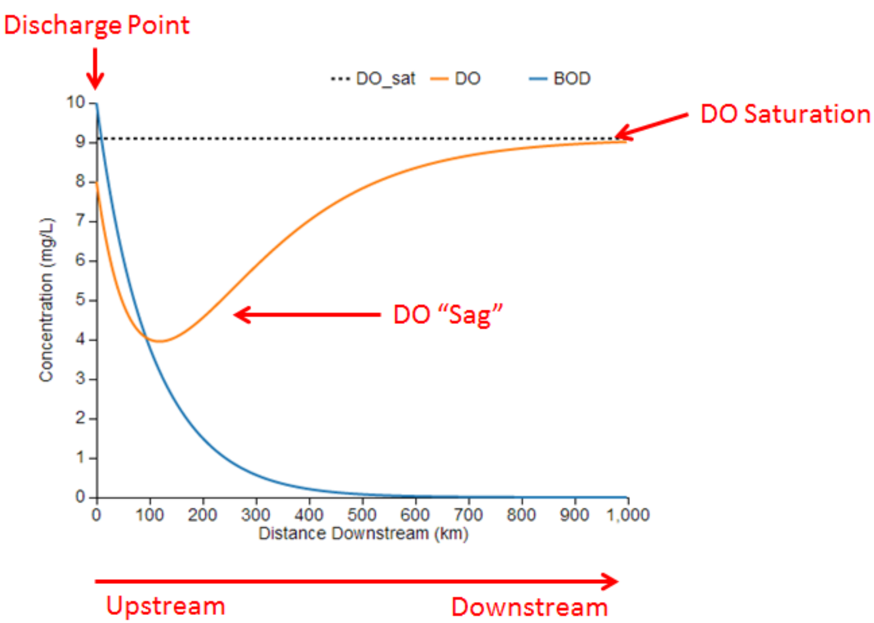
Streeter-Phelps Model

Biological Oxygen (BOD): Demand

$$\frac{dBOD}{dt} = -v * \frac{dBOD}{dx} - a * BOD$$

Dissolved Oxygen (*DO*):

$$\frac{dDO}{dt} = -v * \frac{dDO}{dx} + a * BOD - b * DO$$



t: time (d)

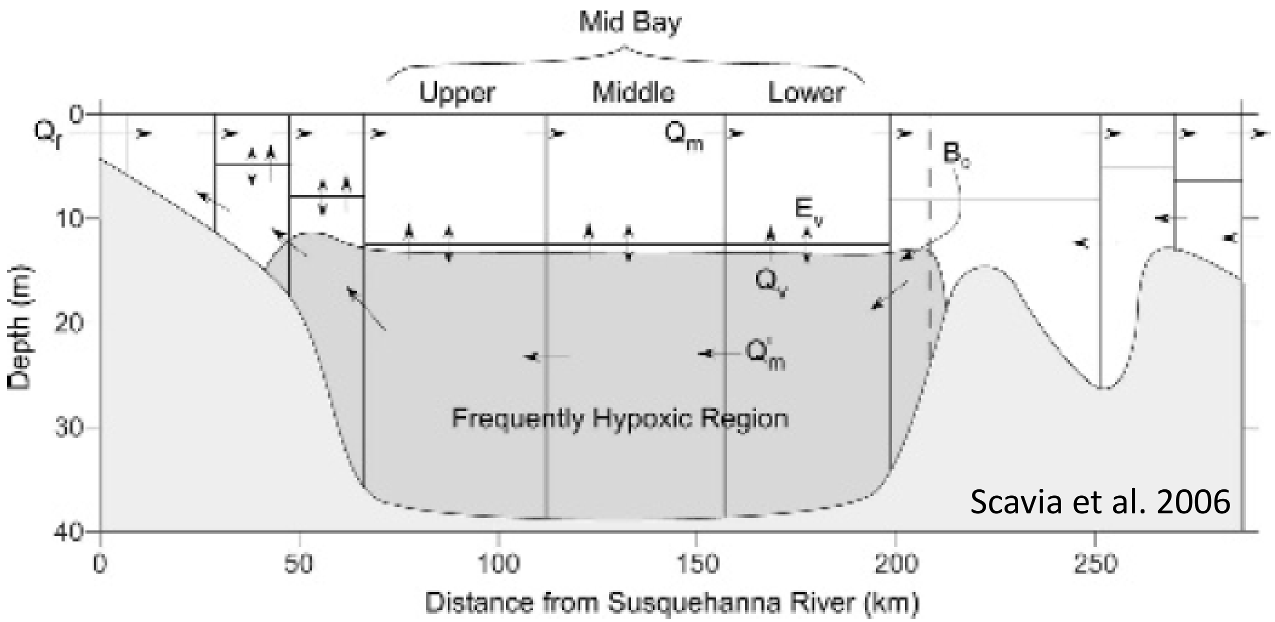
x: distance from source of *BOD* (km)

a: *BOD* decomposition rate (d^{-1})

b: *DO* re-aeration rate (d^{-1})

v: downstream advection (km d^{-1})

University of Michigan Chesapeake Bay hypoxia forecasting model



Model driver: Jan-May average **TN load from Susquehanna** at Conowingo

TN → C through Redfield Ratio (5.67 gC/gN)

F: fraction of C assumed to settle below the pycnocline

C → BOD through respiration ratio (2.4 gO_2/gC)

University of Michigan Chesapeake Bay hypoxia forecasting model

Driver:

Jan-May average
Susquehanna TN load

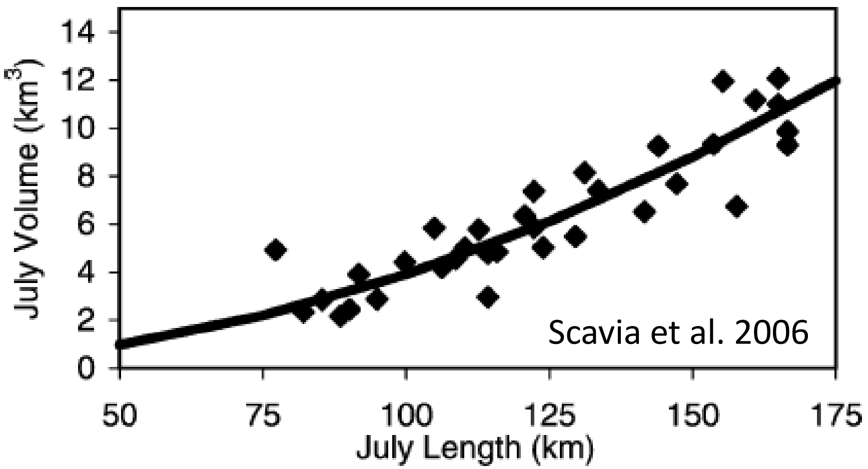
Calibration target:

Mean July hypoxic volume (HV)
([DO] < 2 mg/L)

Model output:

Average subpycnocline [DO] as a function of distance from TN source

V-L relationship



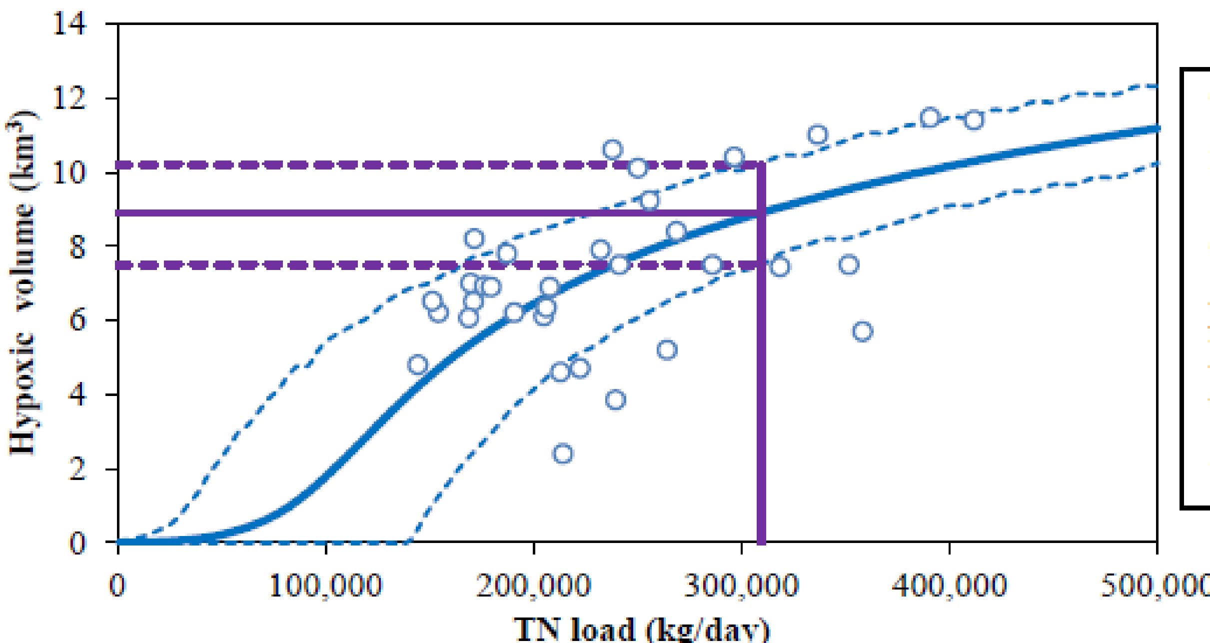
Hypoxic length = sum of all segments with [DO] < 2 mg/L

Hypoxic length → **hypoxic volume** through empirical V-L relationship

University of Michigan Chesapeake Bay hypoxia forecasting model

Seasonal forecast

The 2019 Forecast **- Given the average January-May 2019 total nitrogen load of 309,403 kg/day, this summer's hypoxia volume forecast is 8.9 km^3, the 4th largest in the past 20 years.**



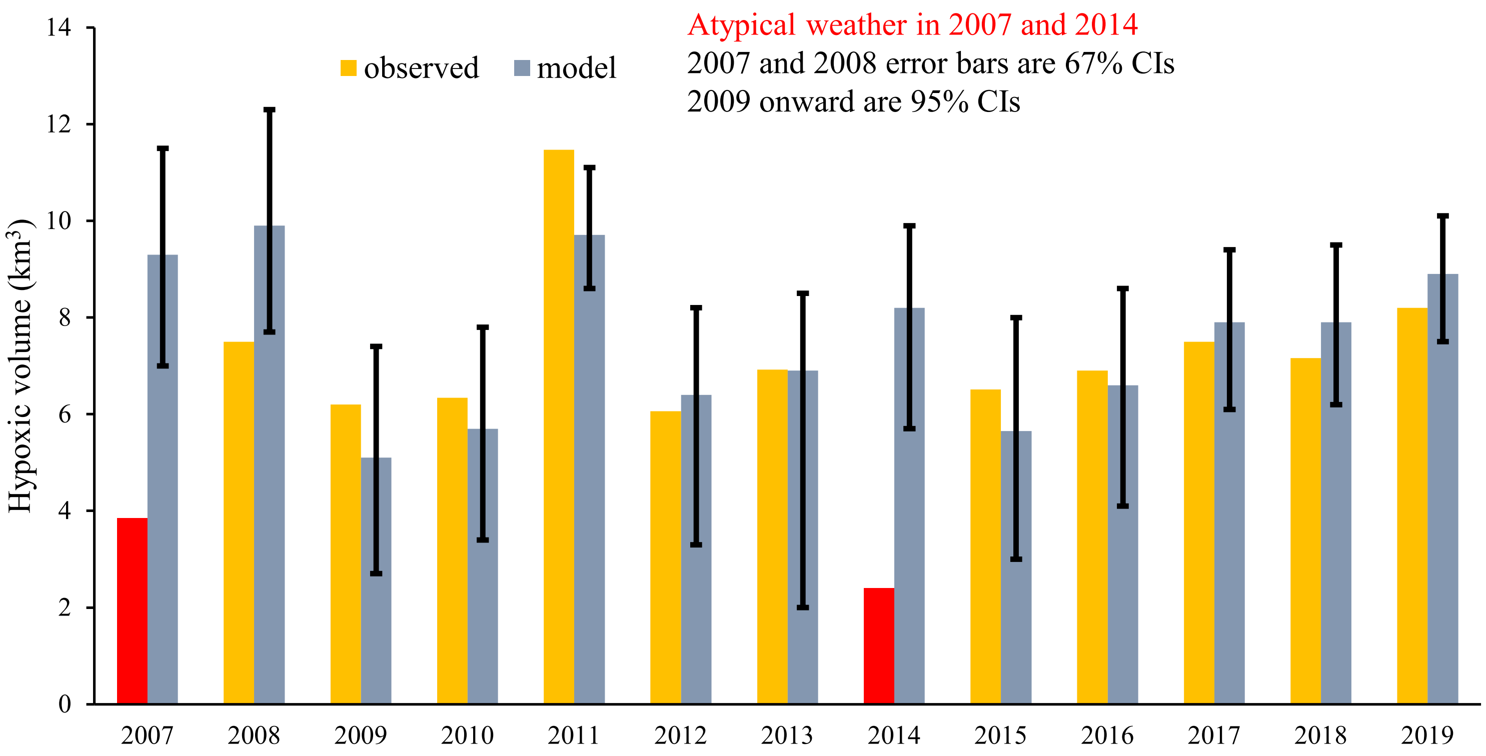
The average 2019 forecast is 8.9 km^3.

There is a 95% probability that hypoxic volume will be between 7.5 and 10.2 km^3.

http://scavia.seas.umich.edu

University of Michigan Chesapeake Bay hypoxia forecasting model

Forecasting track record



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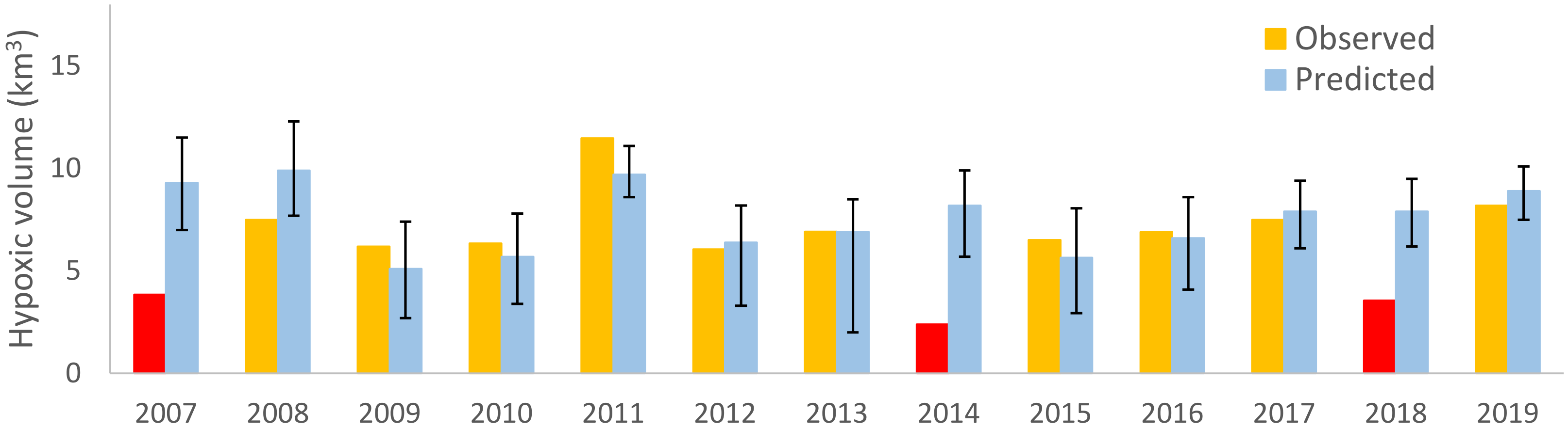
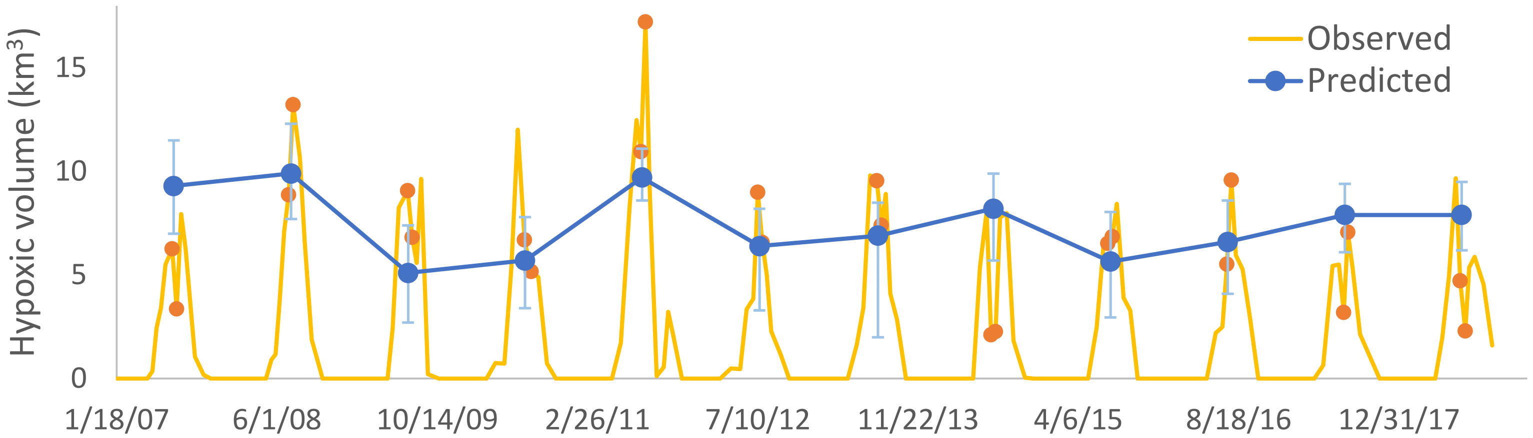
Lessons learned from model track record and other analyses

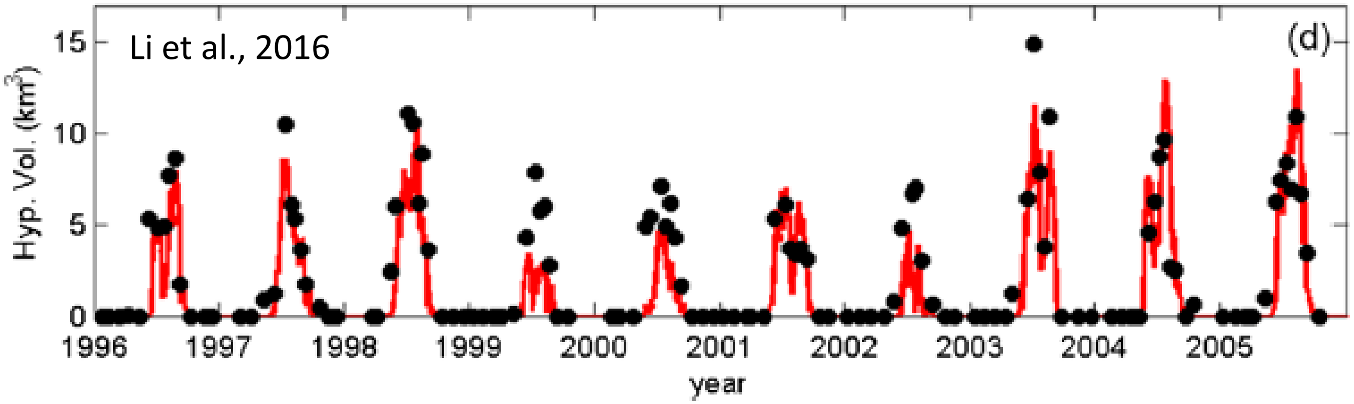
Average July HV somewhat "arbitrary" metric and highly sensitive to transitory weather disruptions

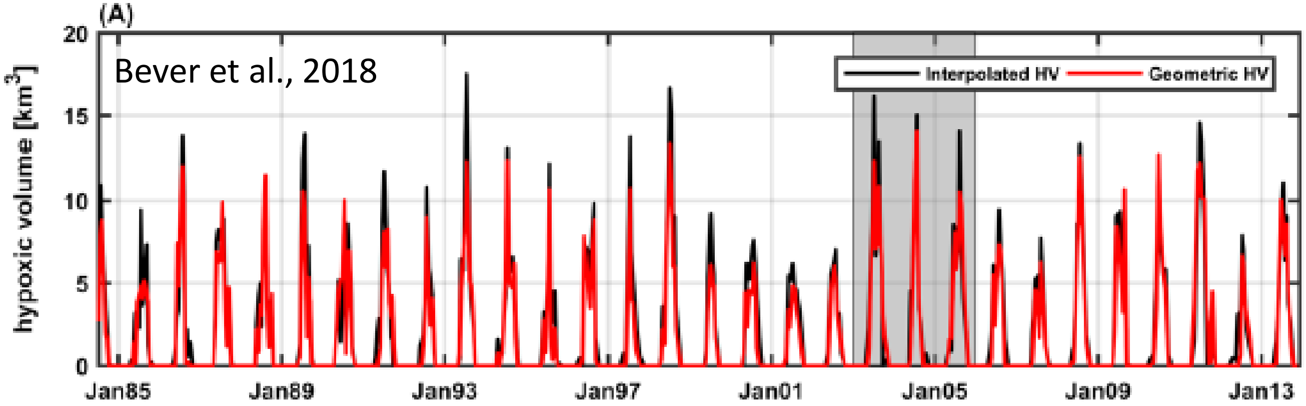




Lessons learned from model track record and other analyses

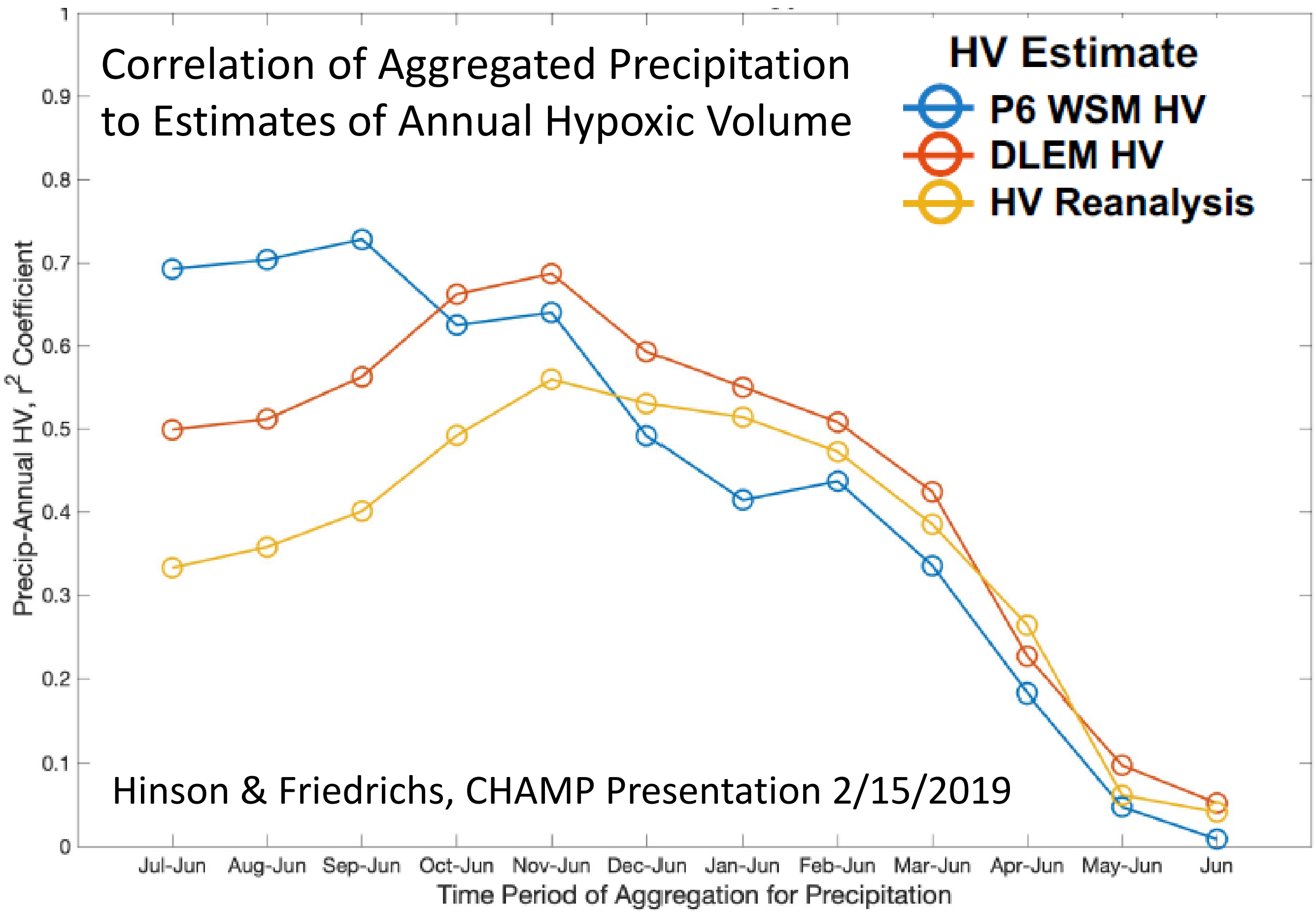
Multiple estimates of HV now available, both from observations and 3D models – Opportunity to incorporate multiple sources of information during Bayesian calibration





Lessons learned from model track record and other analyses

Preliminary analyses from CHAMP group suggest that loading periods other than Jan-May might be relevant to total annual hypoxia



Lessons learned from model track record and other analyses

Susquehanna works as a reasonable proxy for total load, but including other sources may improve model performance

Relative contribution* of different geobasins to hypoxia as estimated by the CBP model

Geobasin	N	P	Total
JmsA	0.9%	0.4%	1.3%
PotA	16.3%	1.9%	18.2%
PxtA	0.5%	0.1%	0.6%
RapA	0.9%	0.2%	1.1%
Susq	45.0%	4.4%	49.4%
YrkA	0.3%	0.1%	0.4%
EshLow	3.3%	0.5%	3.8%
EshMid	1.8%	0.6%	2.4%
EshUpp	2.2%	0.5%	2.7%
EshVA	0.8%	0.1%	0.9%
JmsB	1.3%	0.3%	1.6%
PotB	6.7%	1.1%	7.8%
PxtB	0.9%	0.2%	1.1%
RapB	1.2%	0.2%	1.3%
Wsh	5.4%	1.2%	6.5%
YrkB	0.6%	0.1%	0.7%
Total	88.1%	11.9%	100.0%

*Based on the effect of N and P loads from each basin on the 25th percentile of summer DO concentrations below the surface mixed layer

Planned short-term revisions to the University of Michigan Chesapeake Bay hypoxia forecasting model – before 2020 forecast

Re-calibrate model to different sets of HV estimates, HV metrics, loading periods and load sources

HV estimates:

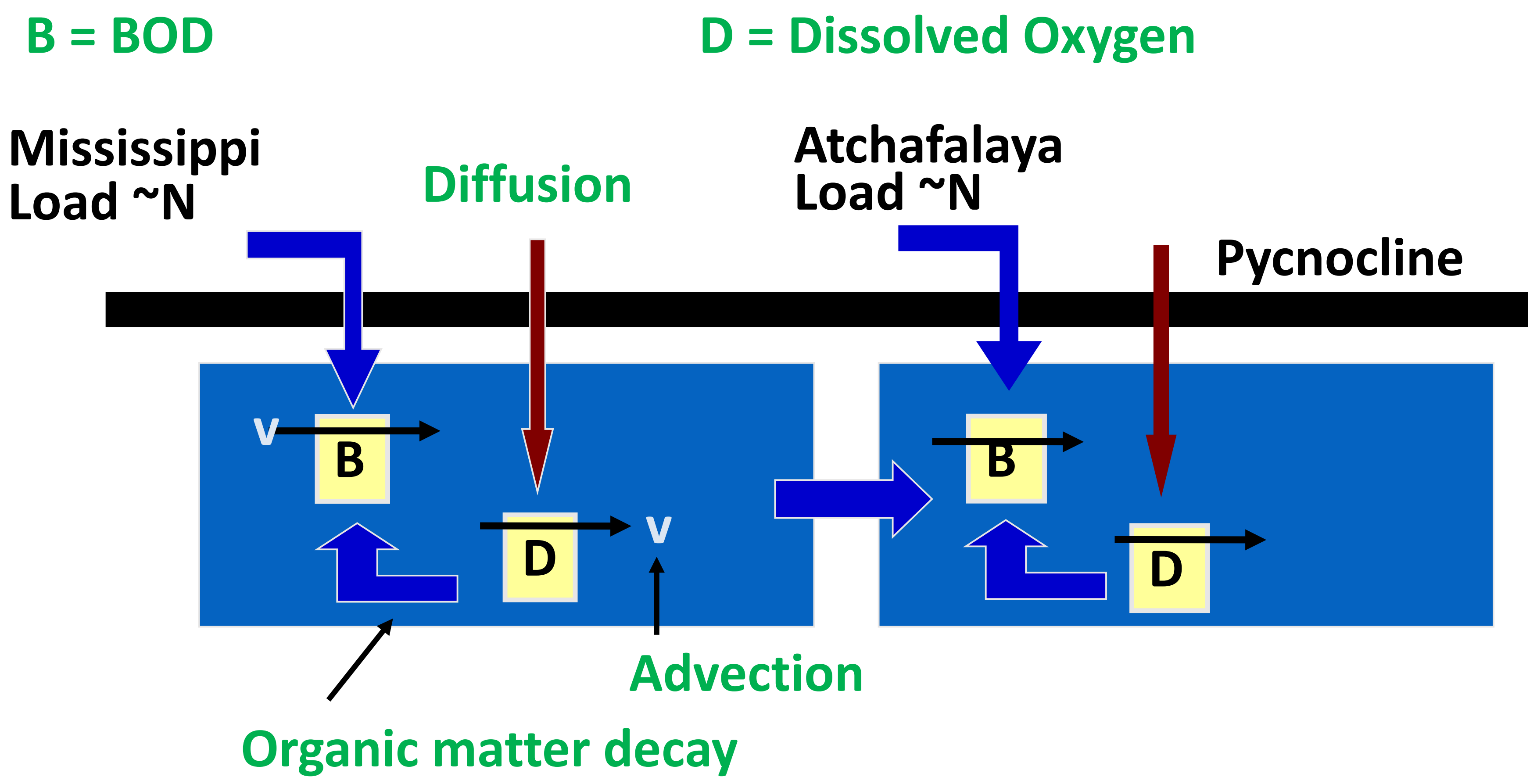
- HV estimated through interpolation of cruise data
- Simulated HV from 3D models (e.g., VIMS, UMCES)

HV metrics: average July, average summer, total annual, monthly

Load sources: consider major load sources other than Susquehanna (e.g., Potomac, Rappahannock, cumulative point sources)

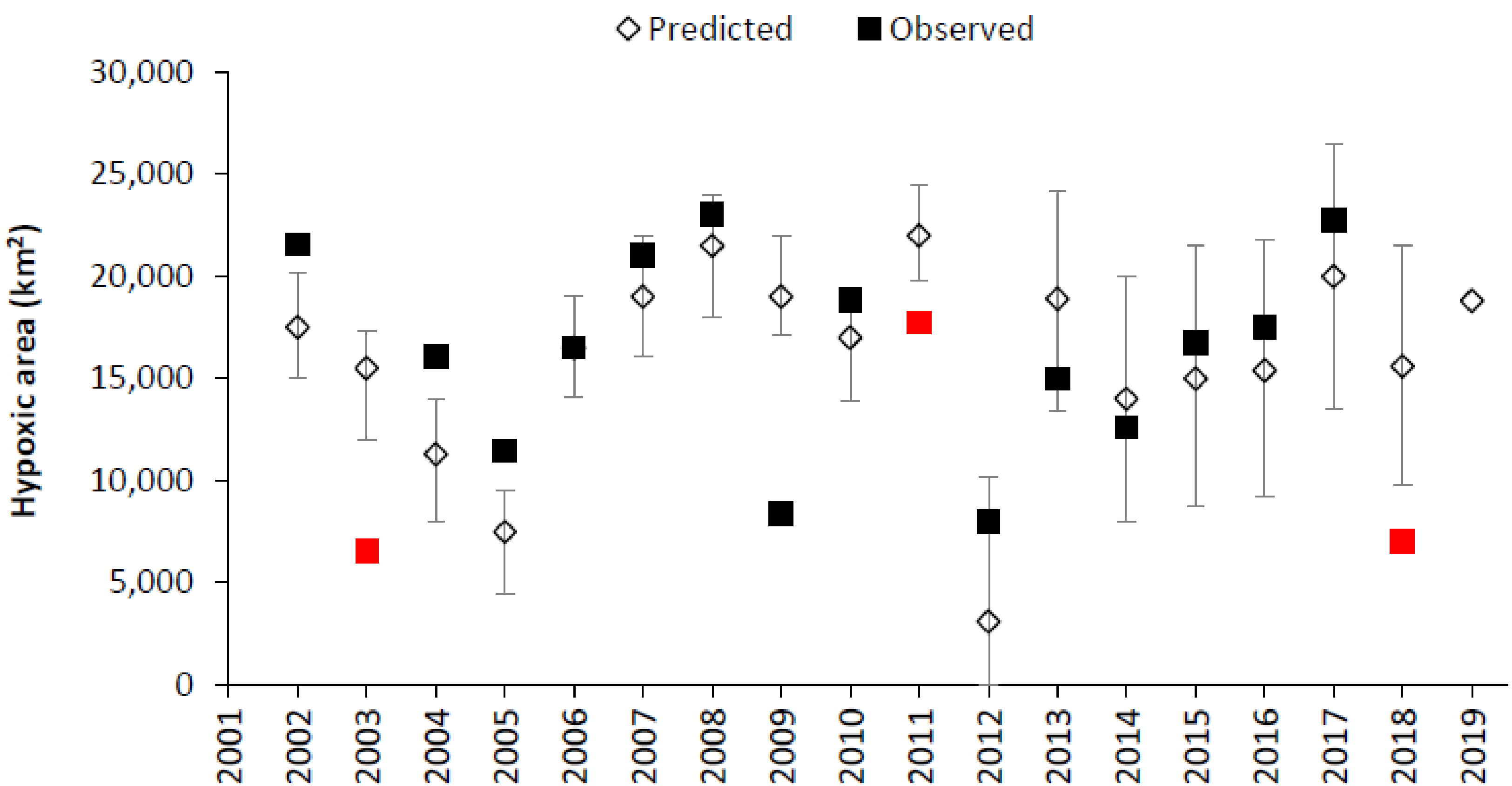
Compare model skill and track record (e.g. through blind forecasting) and uncertainty across different calibration versions

Application to Gulf Hypoxia



University of Michigan Gulf of Mexico hypoxia forecasting model

Forecasting track record



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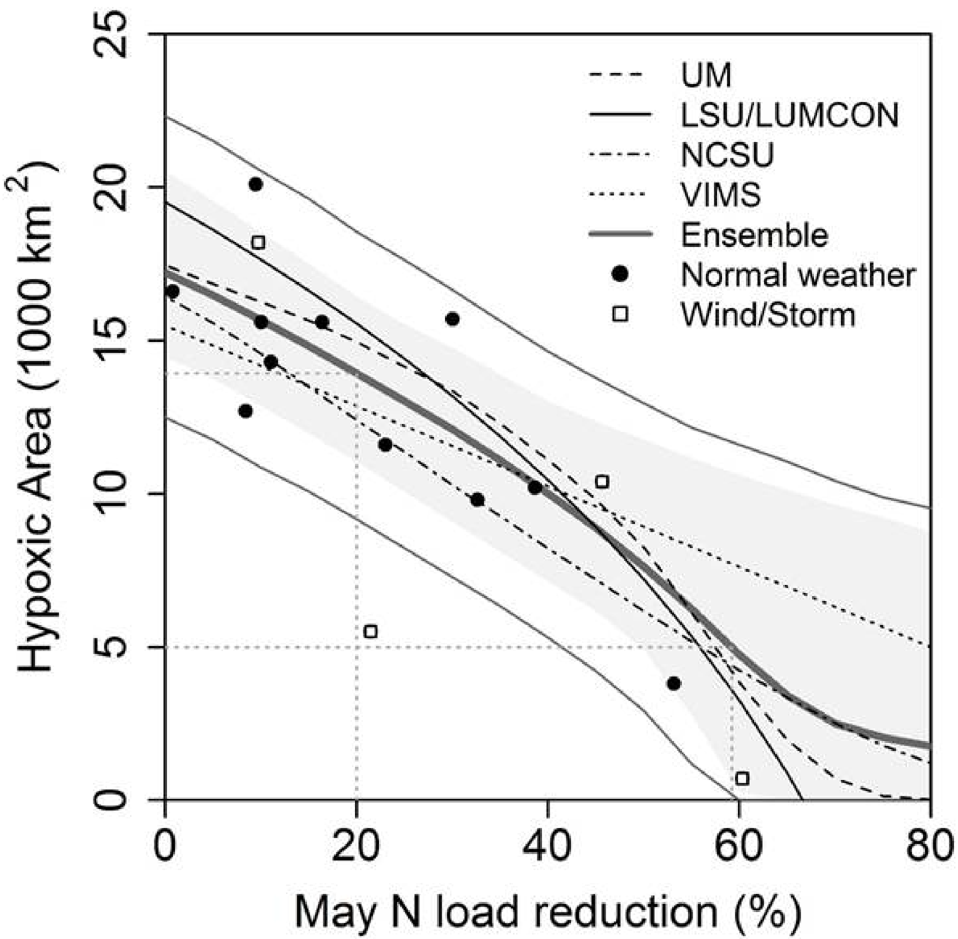
University of Michigan Gulf of Mexico hypoxia forecasting model

Management application – Ensemble of four models



Scavia et al. 2017