The competing impacts of climate change and nutrient reduction on dissolved oxygen in Chesapeake Bay

Ike Irby

CHAMP Meeting

August 2017

Evaluation of Climate Change Impacts

2050 Relative to 1993-1995

Temperature	Sea Level Rise	Precipitation
↑ 1.75°C	↑ 0.5m	↑ ~15% winter
↓ Oxygen Solubility	↑ Seawater intrusion	↑ River flow
↑ Biologic Rates	↑ Volume & Circulation	↑ Nutrient load

Evaluation of Climate Change Impacts

Climate Change Scenarios

Anoxia < 0.2 mg L^{-1}
Hypoxia < 2 mg L^{-1}
Low-DO < 5 mg L^{-1}

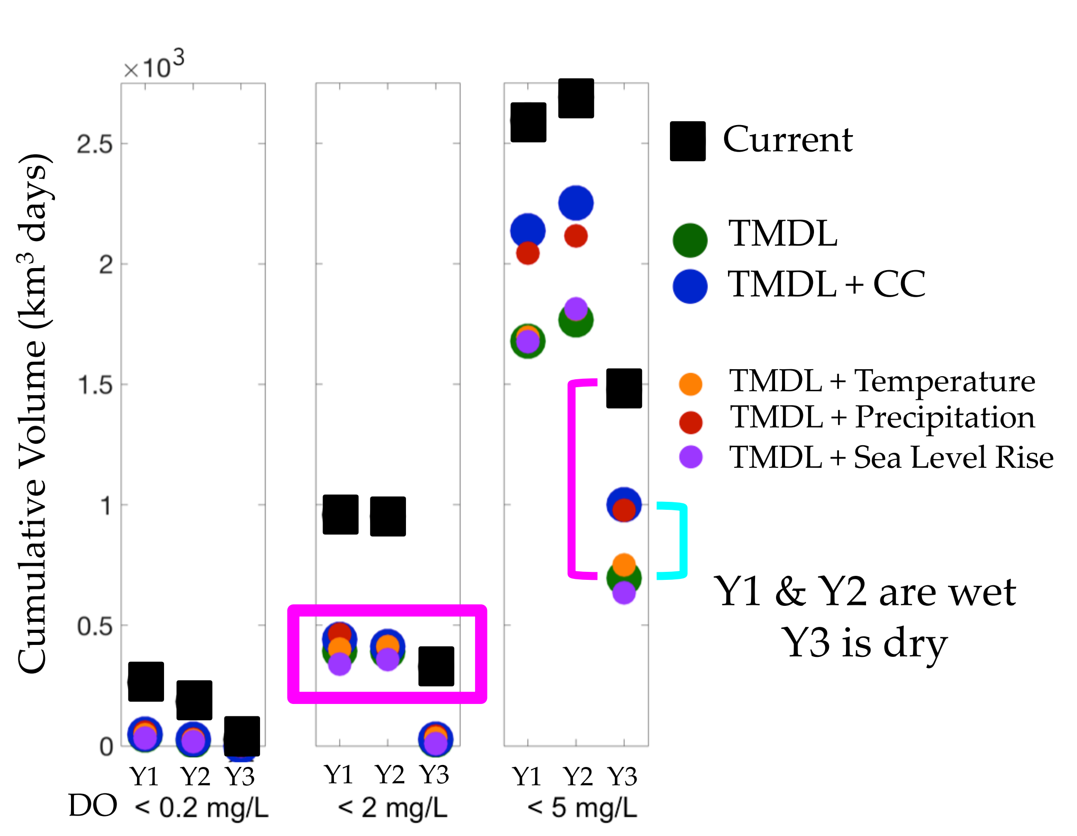
Current

TMDL

TMDL + Climate Change

- TMDL + Temperature
- TMDL + Precipitation
- TMDL + Sea Level Rise

EVALUATION OF CLIMATE CHANGE IMPACTS

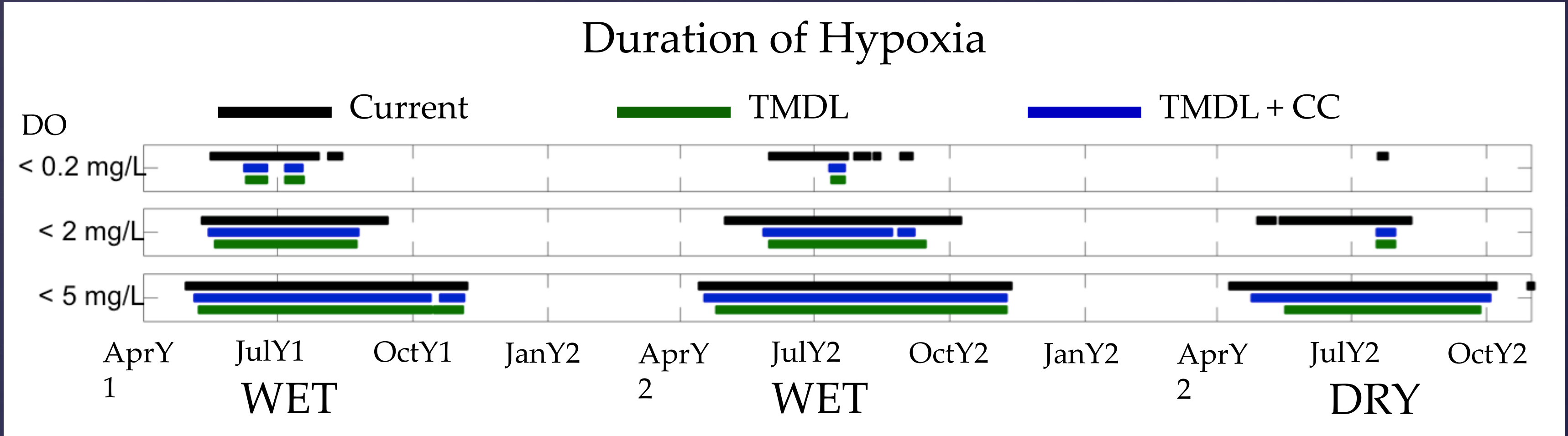


Impact of TMDL is greater than impact of climate change

Temperature is the biggest driver of climate change impact

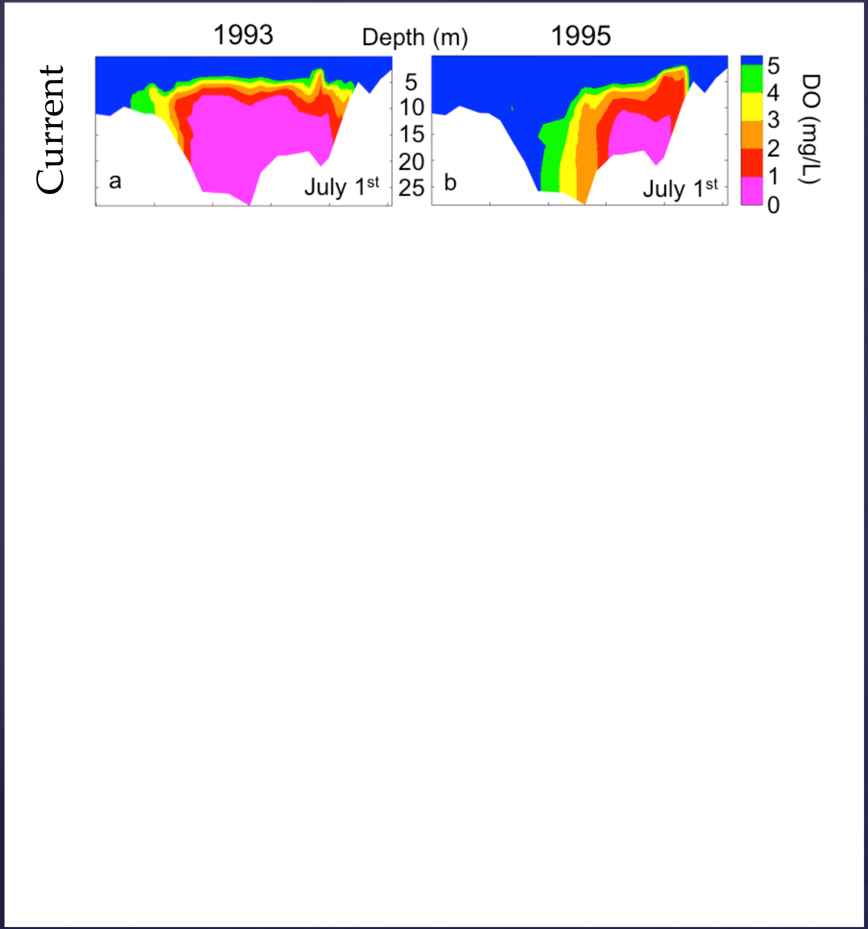
A TMDL wet year looks like a current dry year

Evaluation of Climate Change Impacts



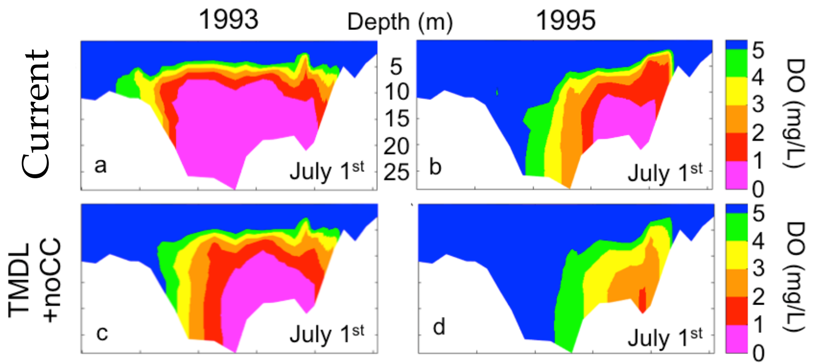
With impacts of climate change,
hypoxic conditions will start ~7 days earlier

Evaluation of Climate Change Impacts



- Large interannual variability

Evaluation of Climate Change Impacts



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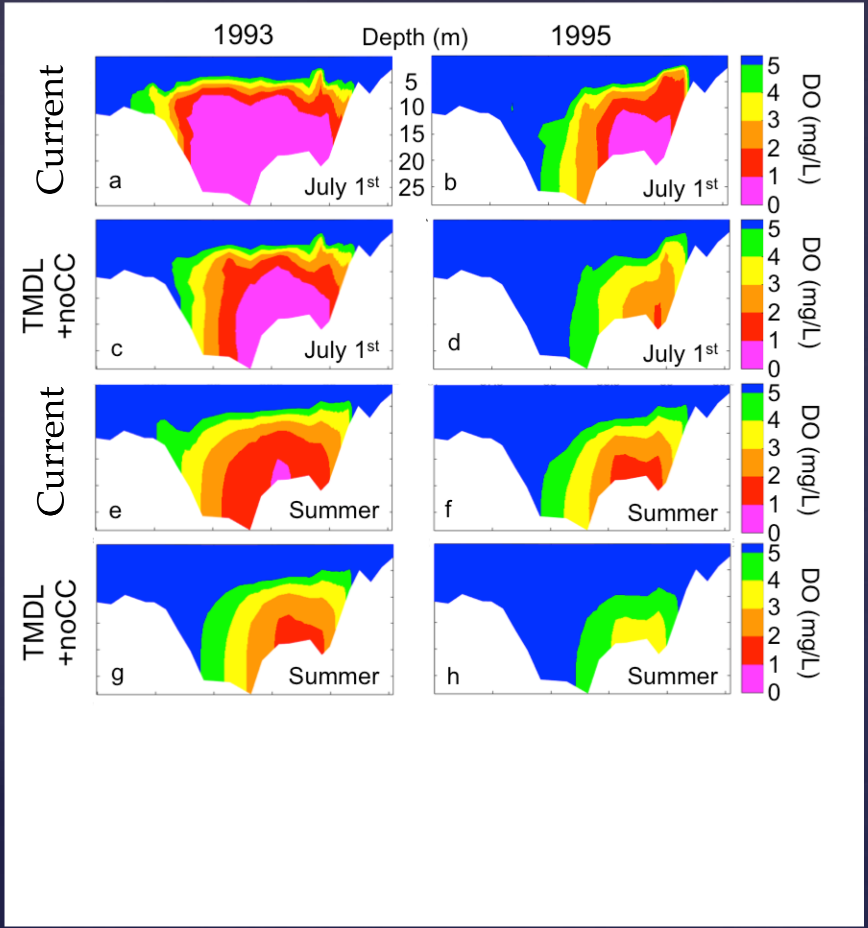

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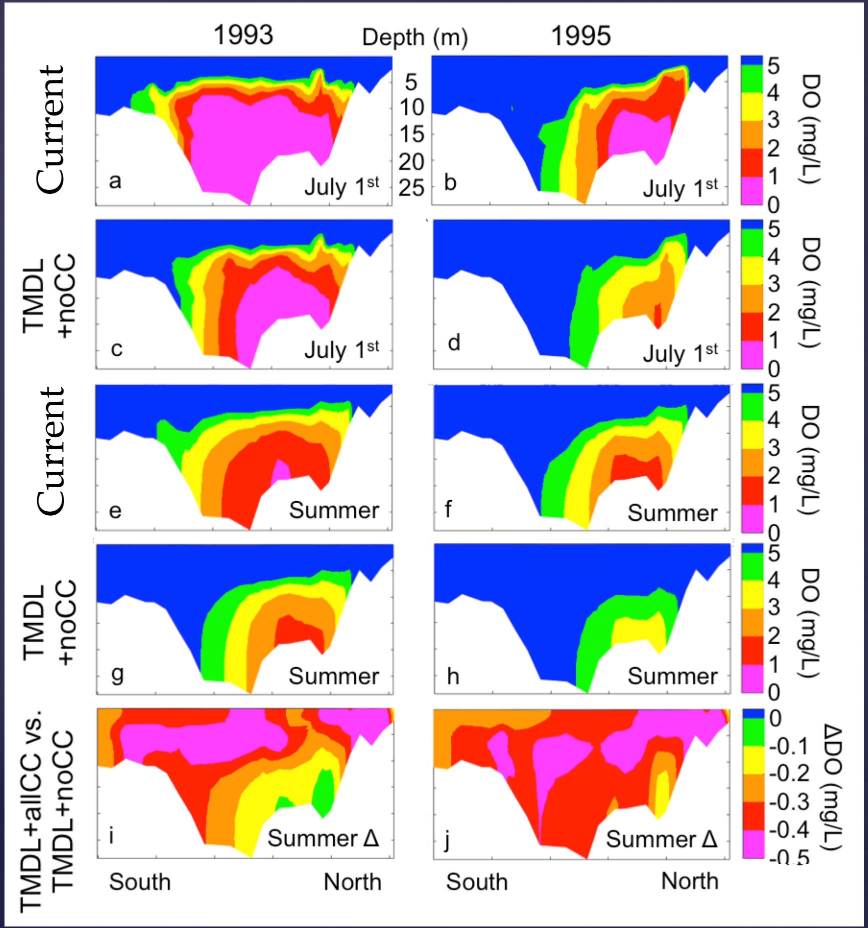


- Large interannual variability
- TMDL wet looks like Current dry
- Biggest impact due to climate change is at the periphery of low-DO waters

Evaluation of Climate Change Impacts

TMDL > Climate Change

Temp > Sea Level Rise & Precipitation

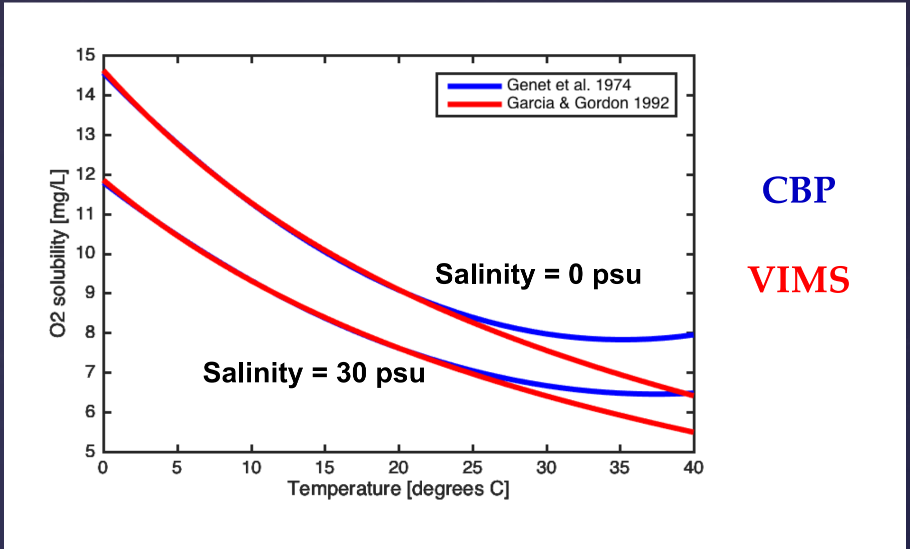
+ 7 Days Longer

Impact along periphery

Evaluation of Climate Change Impacts

Limitations & Future Directions

- Comparison with CBP
  - Temperature differences
  - SLR differences



Phytoplankton growth:
- CBP: Peak growth (multiple classes)
- VIMS: Exponential growth (one class)

Evaluation of Climate Change Impacts

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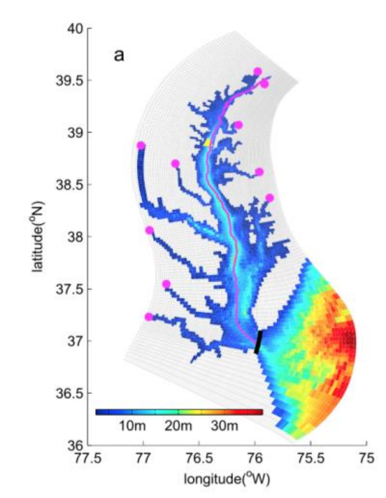
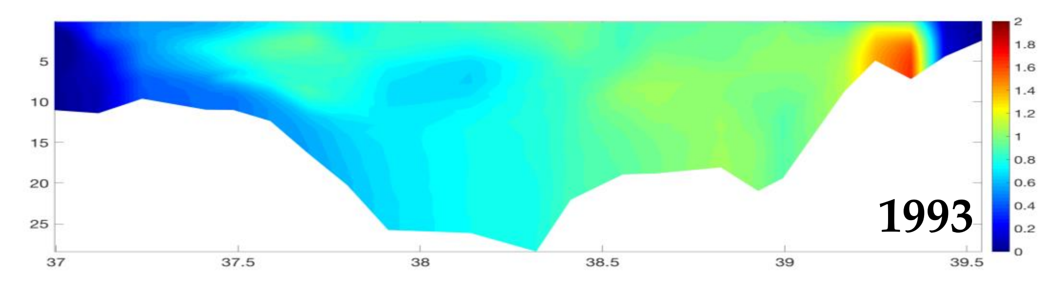


Difference in average salinity after 0.5m SLR

Wet Year

ChesROMS-ECB



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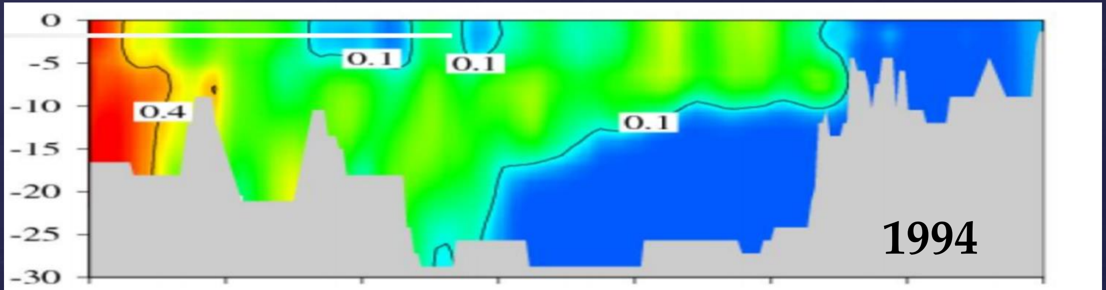

Evaluation of Climate Change Impacts

Limitations & Future Directions

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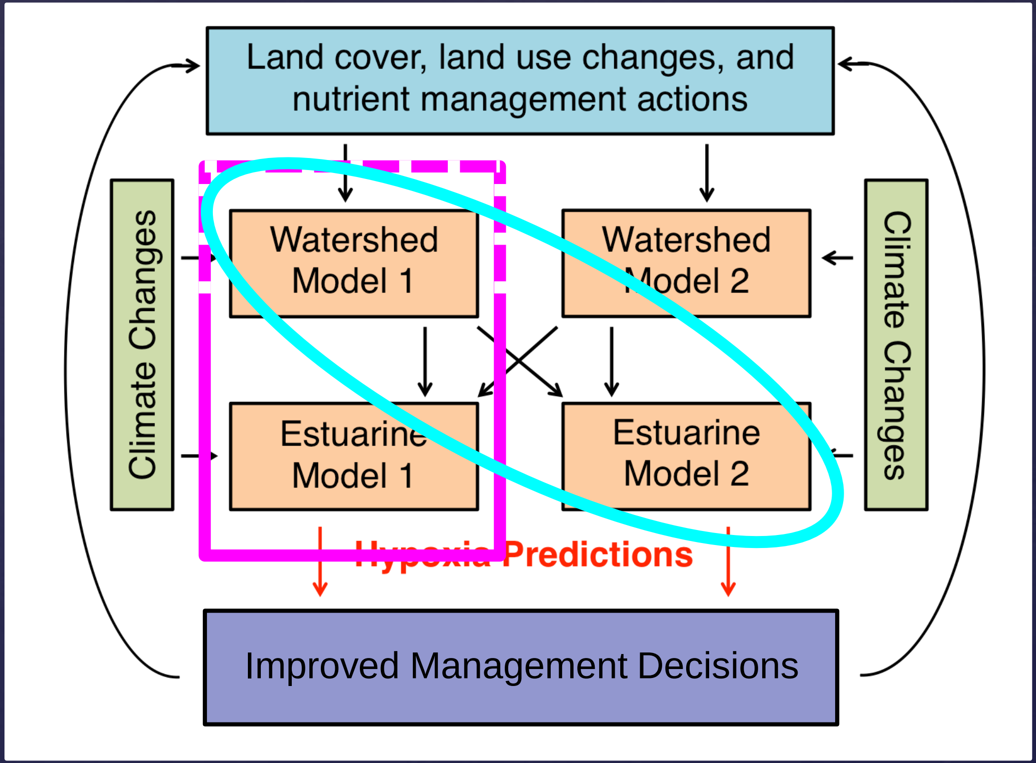
- Single watershed & estuarine models



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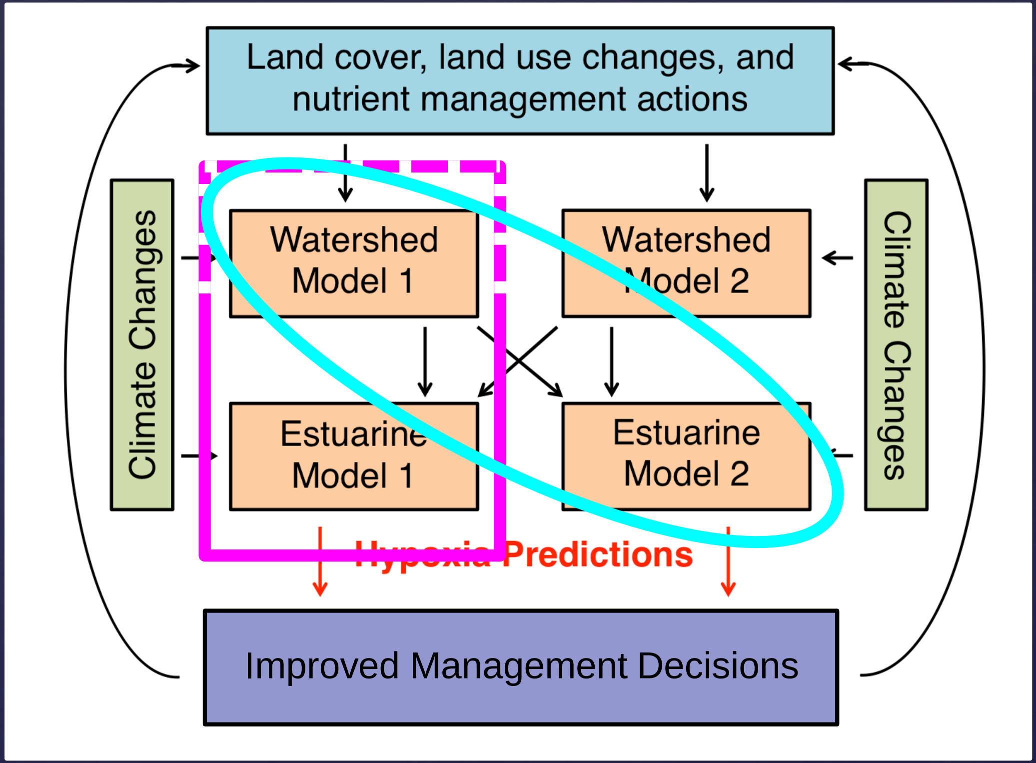
- Sensitivity tests



Evaluation of Climate Change Impacts

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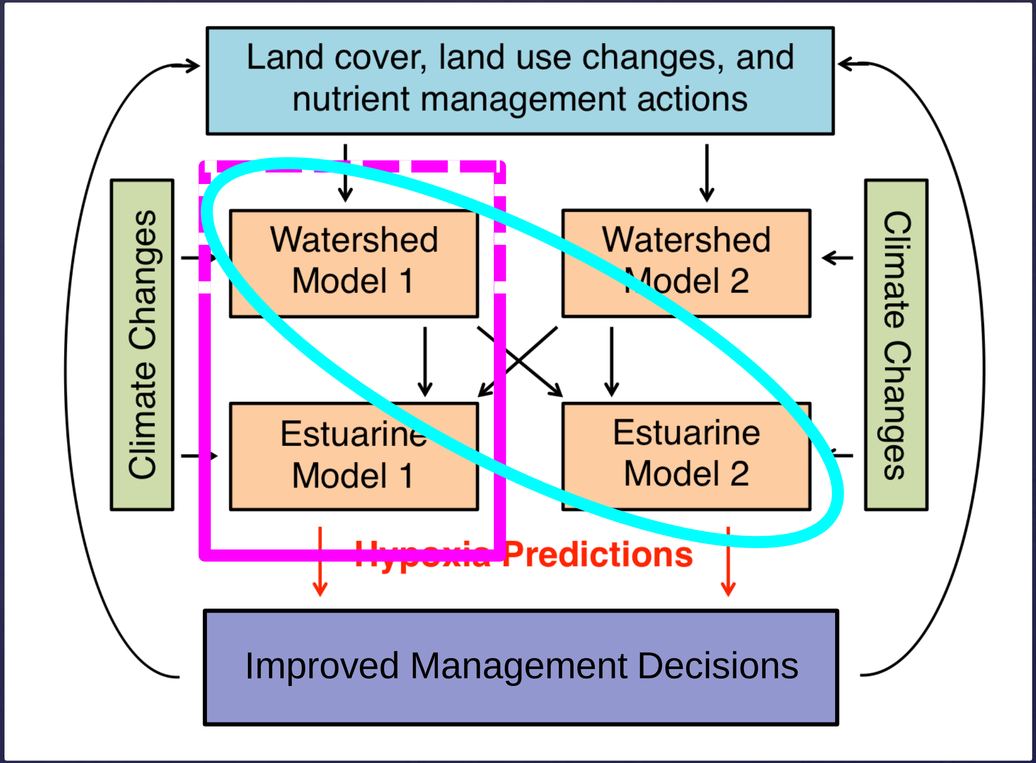
- Contemporaneous nutrient reduction & climate change



EVALUATION OF CLIMATE CHANGE IMPACTS

Limitations & Future Directions

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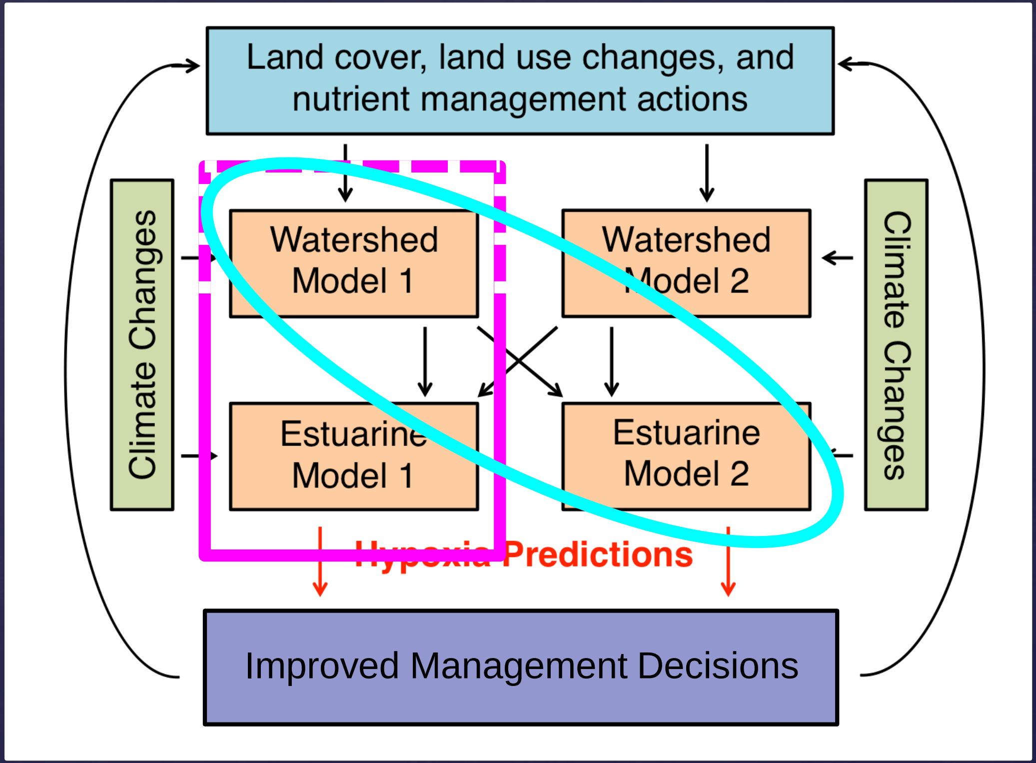
- Contemporaneous nutrient reduction & climate change
- Assessment of water quality standards



Evaluation of Climate Change Impacts

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Impact along periphery

Future comparisons of Water Quality Standard attainment

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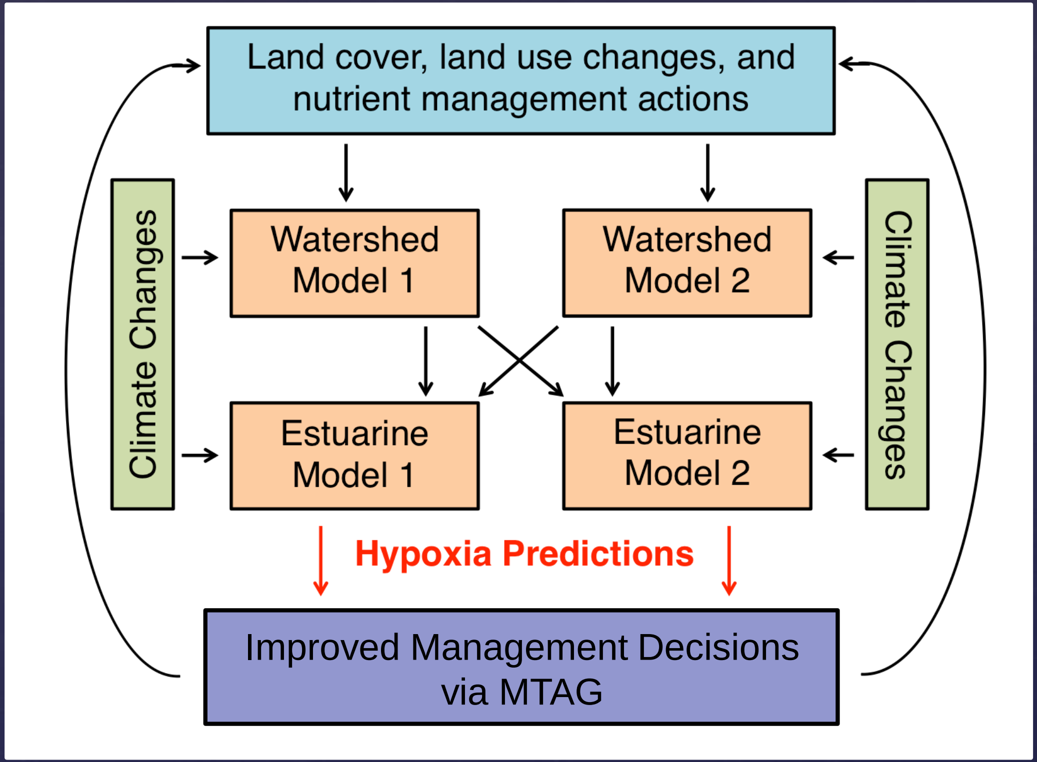
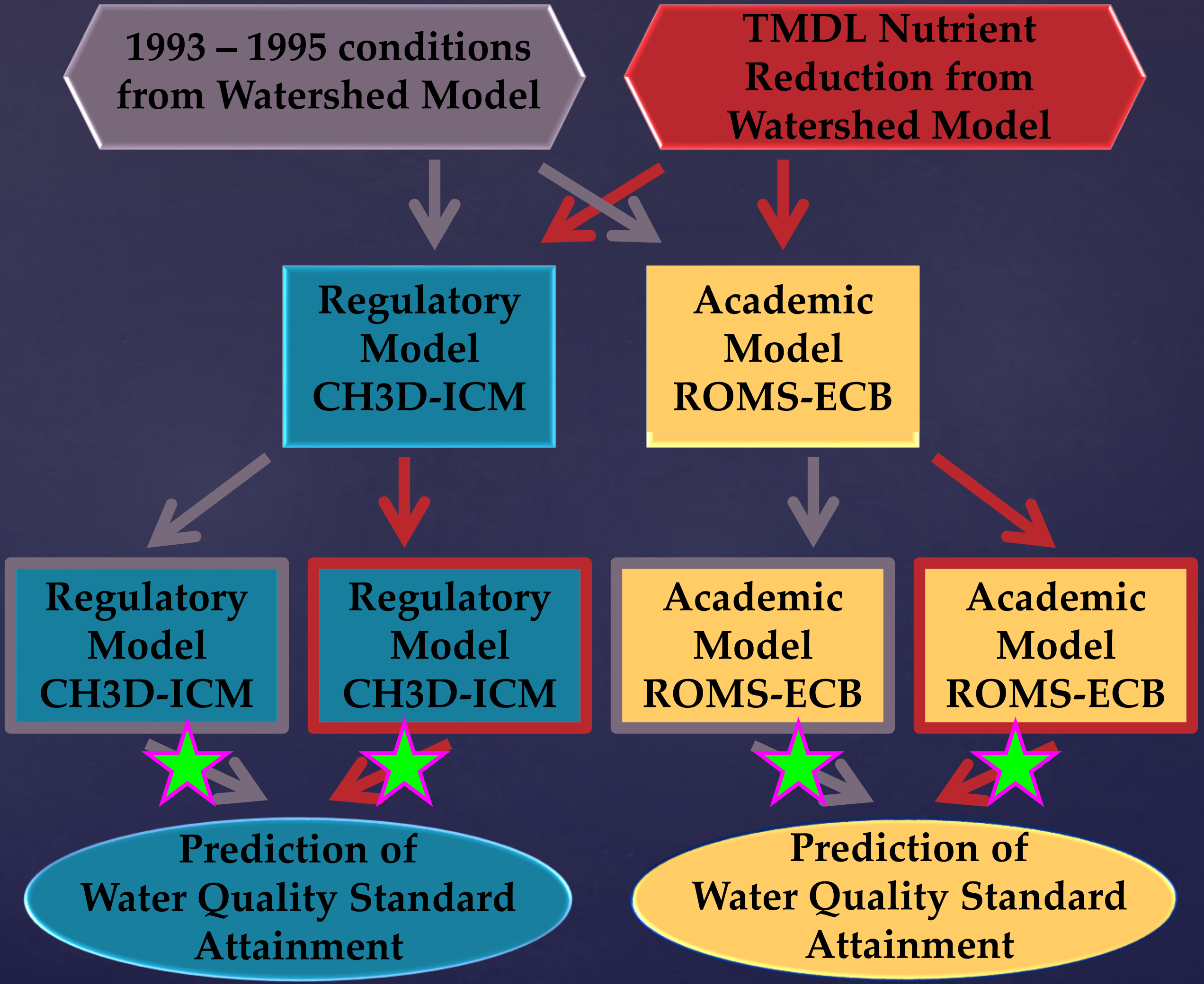

Land cover, land use changes, and nutrient management actions
Climate Changes
Watershed Model 1
Watershed Model 2
Climate Changes
Estuarine Model 1
Estuarine Model 2
Hypoxia Predictions
Improved Management Decisions via MTAG


1993 – 1995 conditions from Watershed Model
TMDL Nutrient Reduction from Watershed Model
Regulatory Model CH3D-ICM
Academic Model ROMS-ECB
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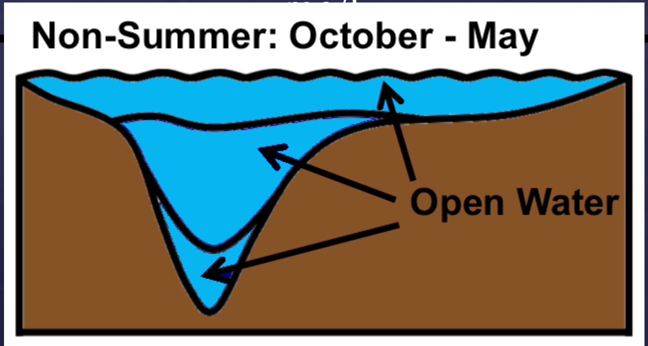
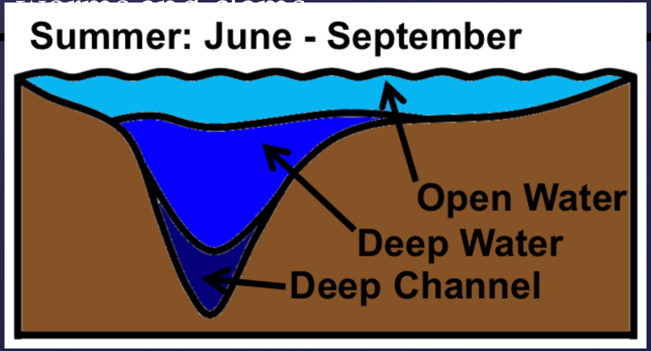
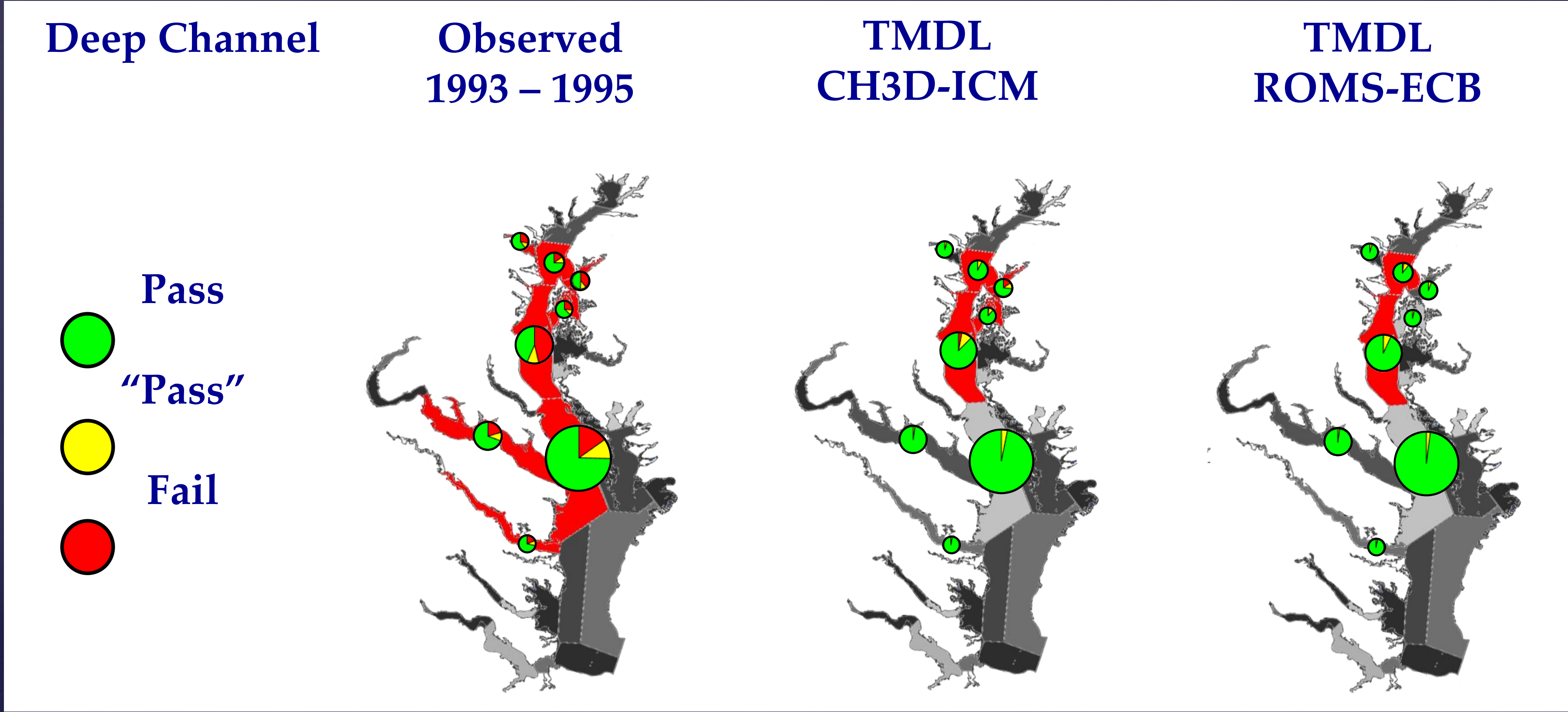
Prediction of Water Quality Standard Attainment
Prediction of Water Quality Standard Attainment

Habitat	Dissolved Oxygen Rules	Rationale	Timeframe
Open Water	30-day mean ≥ 5.0 mg/L (tidal habitats with salinity ≥ 0.5 PSU)	Protects growth of larval, juvenile, and adult fish and shellfish as well as threatened/endangered species	All year round
	Instantaneous minimum ≥ 3.2 mg/L	Protects survival of threatened/endangered sturgeon species	
Deep Water	30-day mean ≥ 3.0 mg/L	Protects survival and recruitment of Bay anchovy eggs and larvae	June 1 – September 30
	Instantaneous minimum ≥ 1.7 mg/L	Protects survival of Bay anchovy eggs and larvae	
Deep Channel	Instantaneous minimum ≥ 1.0	Protects survival of bottom-dwelling	June 1 – September 30



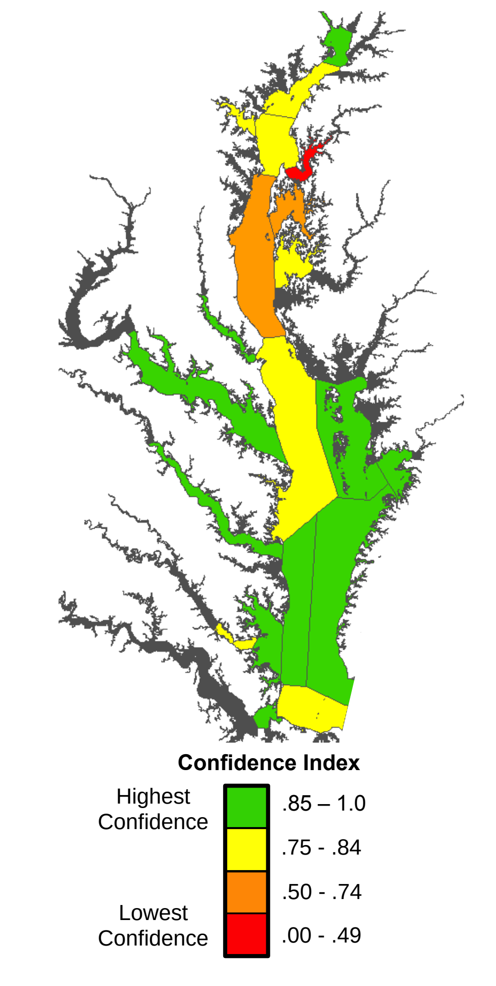


Are dissolved oxygen standards attained with nutrient reduction?



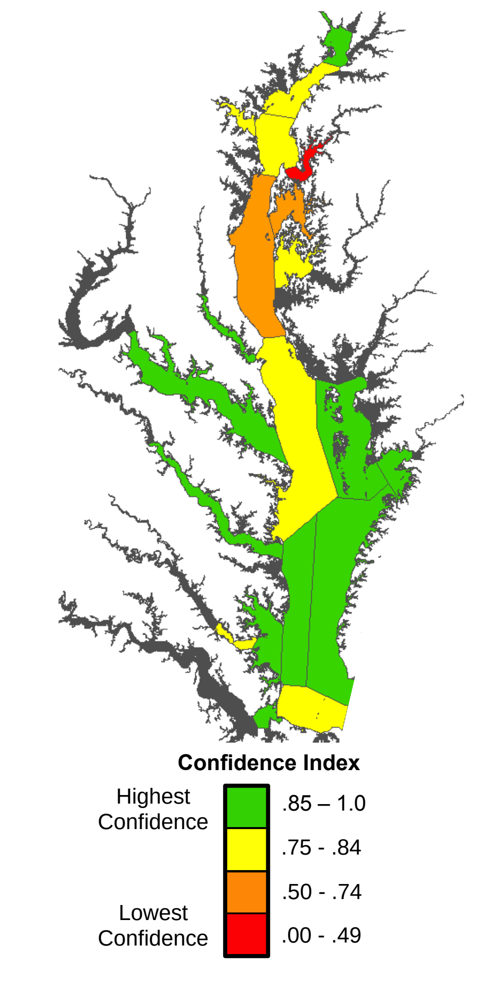
Confidence Index

- Across habitats
  - How similar are the model results for open water, deep water, and deep trench?
- Across years
  - How similar are the model results for 1993, 1994, 1995?
- Across methodology
  - How similar are the intermediate results of the models?



Ways to Evaluate Water Quality with CHAMP

- Traditional TMDL Water Quality Standard Attainment



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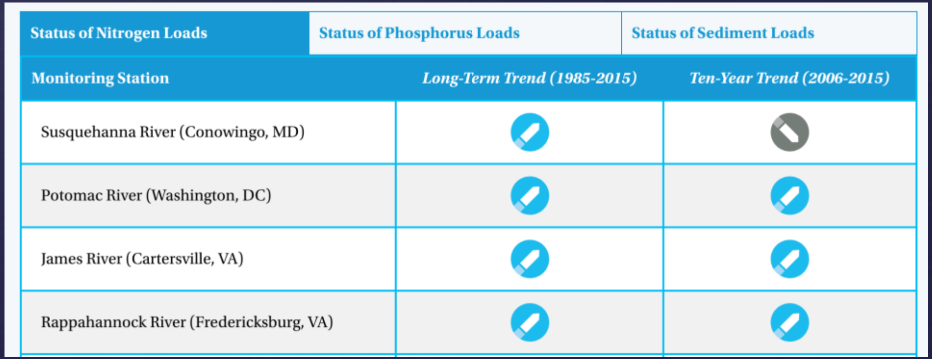

Status of Nitrogen Loads | Status of Phosphorus Loads | Status of Sediment Loads

Monitoring Station	*Long-Term Trend (1985-2015)*	*Ten-Year Trend (2006-2015)*
Susquehanna River (Conowingo, MD)		
Potomac River (Washington, DC)		
James River (Cartersville, VA)		
Rappahannock River (Fredericksburg, VA)		

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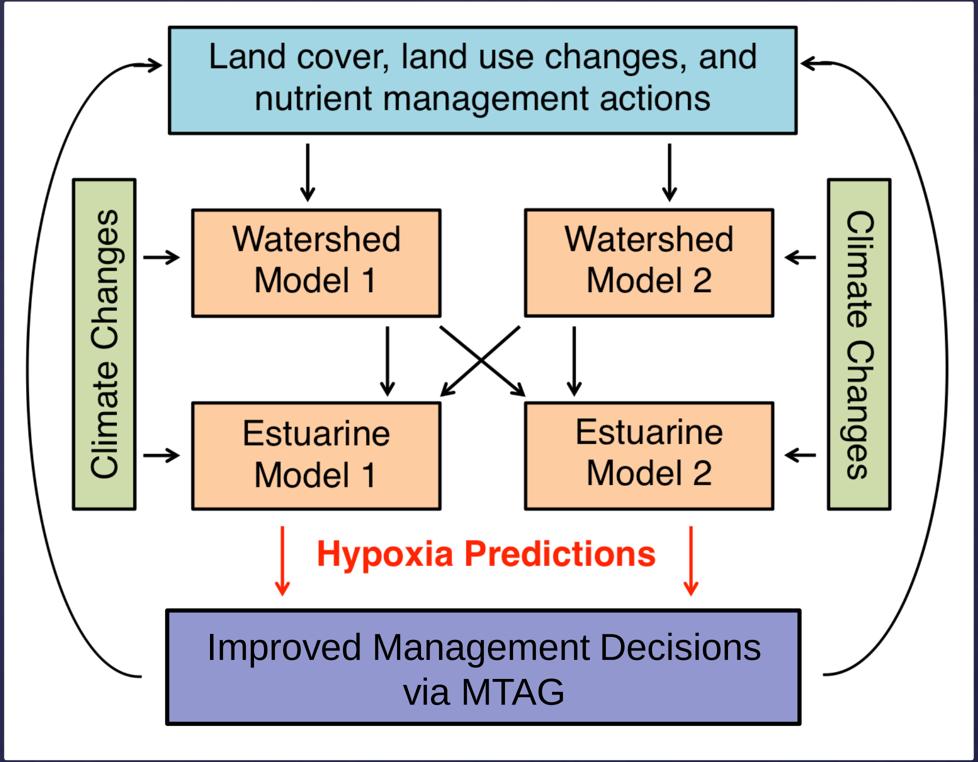

Conclusions

A Multiple Model Assessment

- Analyzing multiple models can allow us to garner more information than can be gained from any single model

Analysis of Confidence

- Generally high confidence in the eventual impact of pollution reduction on dissolved oxygen

Evaluation of Climate Change Impacts

- Impact of TMDL pollution reduction is greater than the projected impact of 2050 climate change… but that does not mean that climate change can be ignored

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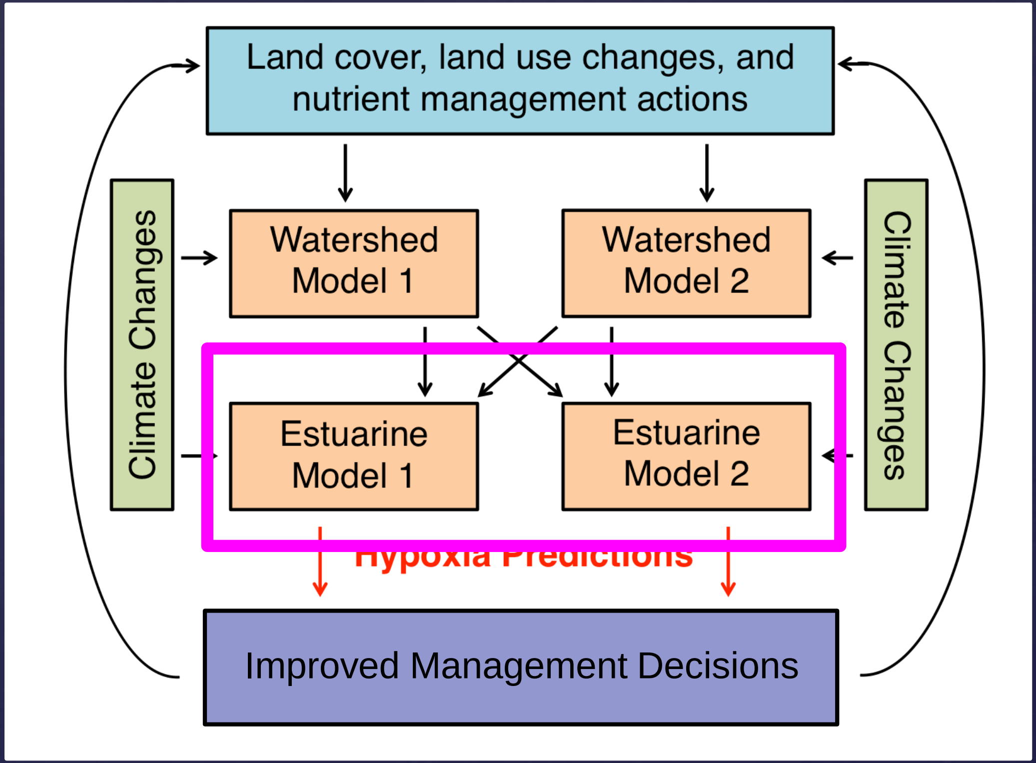
Future Research Directions

CHAMP: Chesapeake Hypoxia Analysis and Modeling Program

- Predict the impacts of future climate change and pollution on hypoxia
- Predict the future effectiveness of various pollution reduction scenarios on reducing hypoxia



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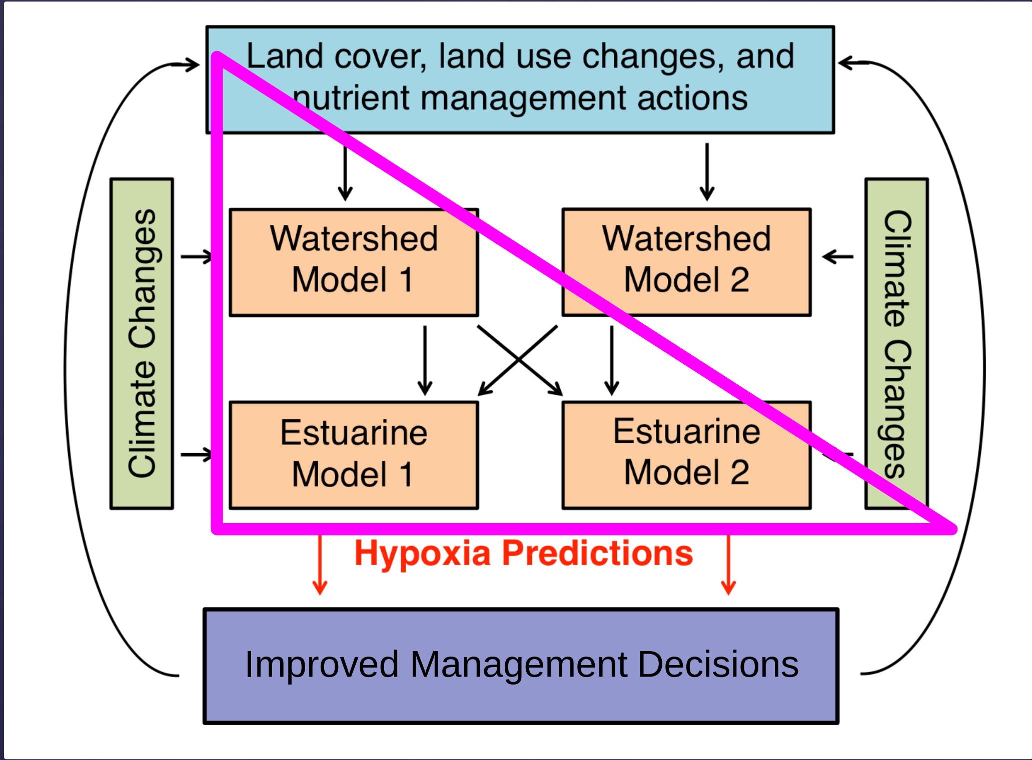

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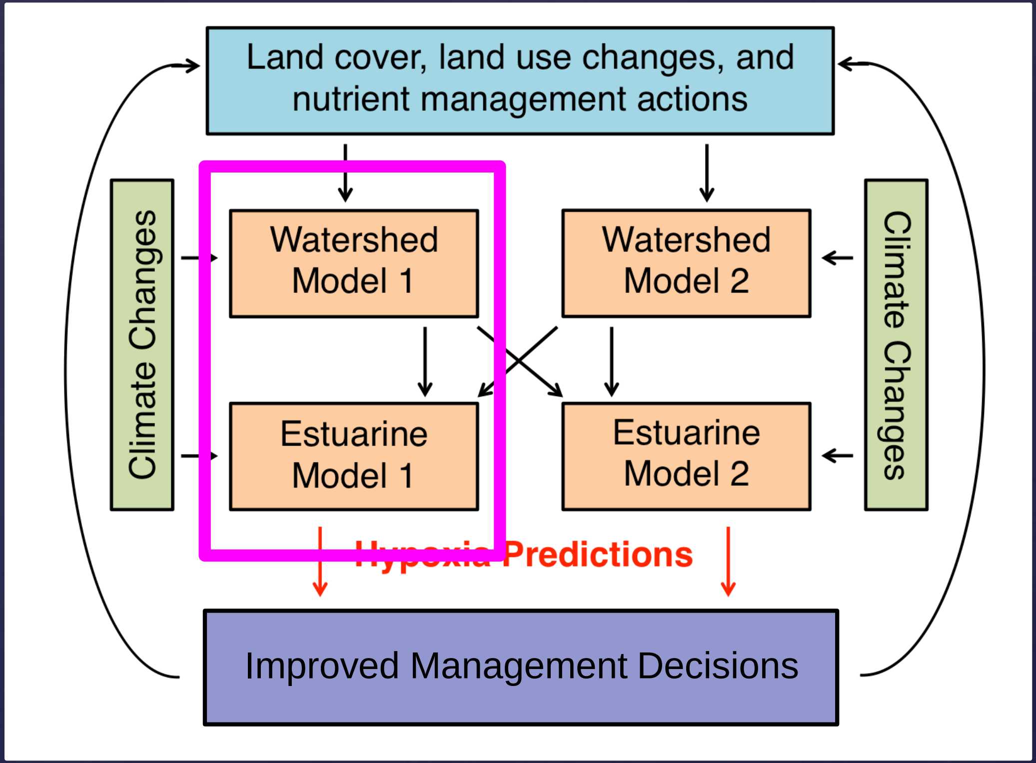

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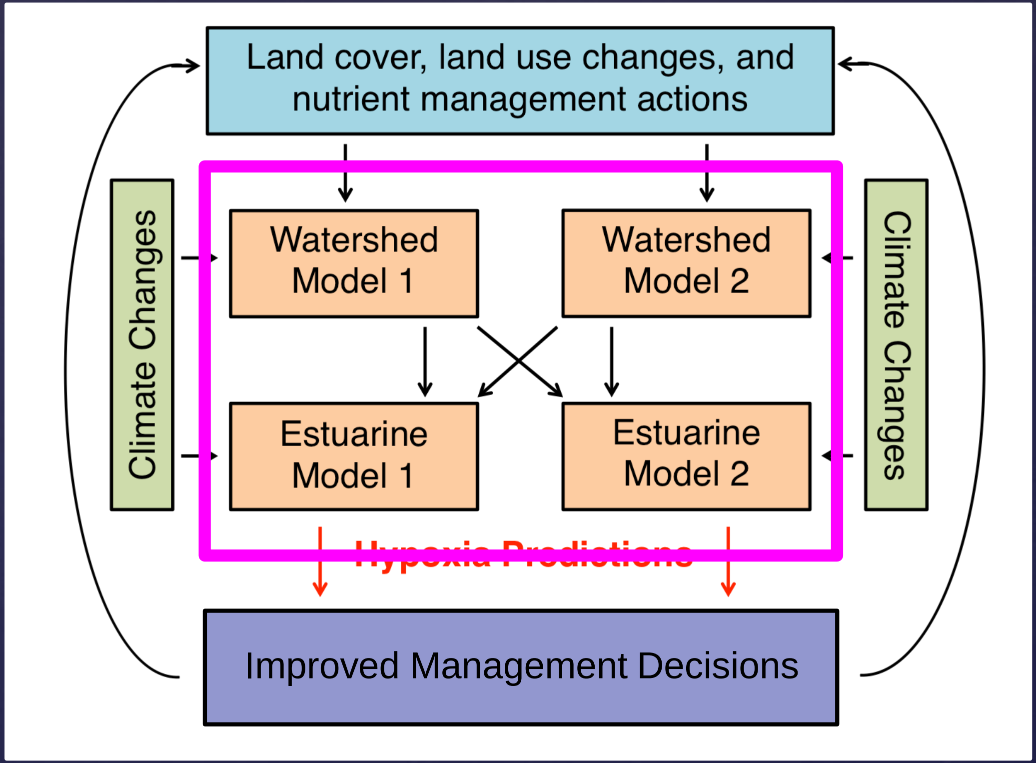

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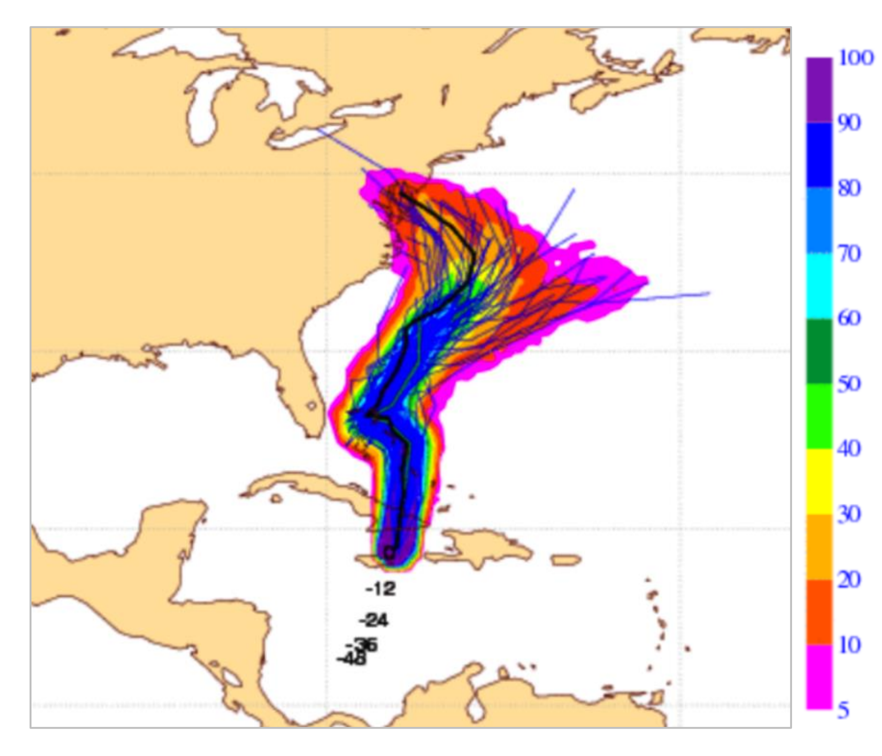
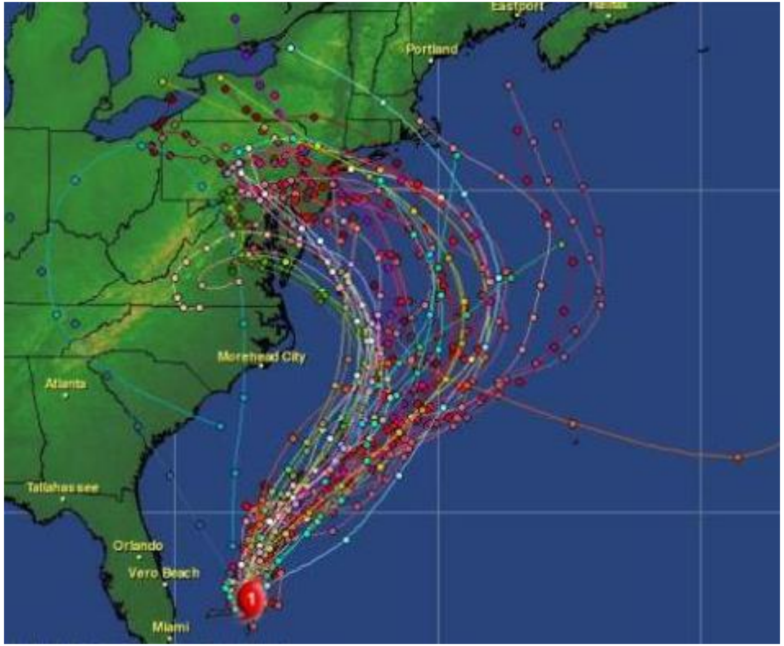


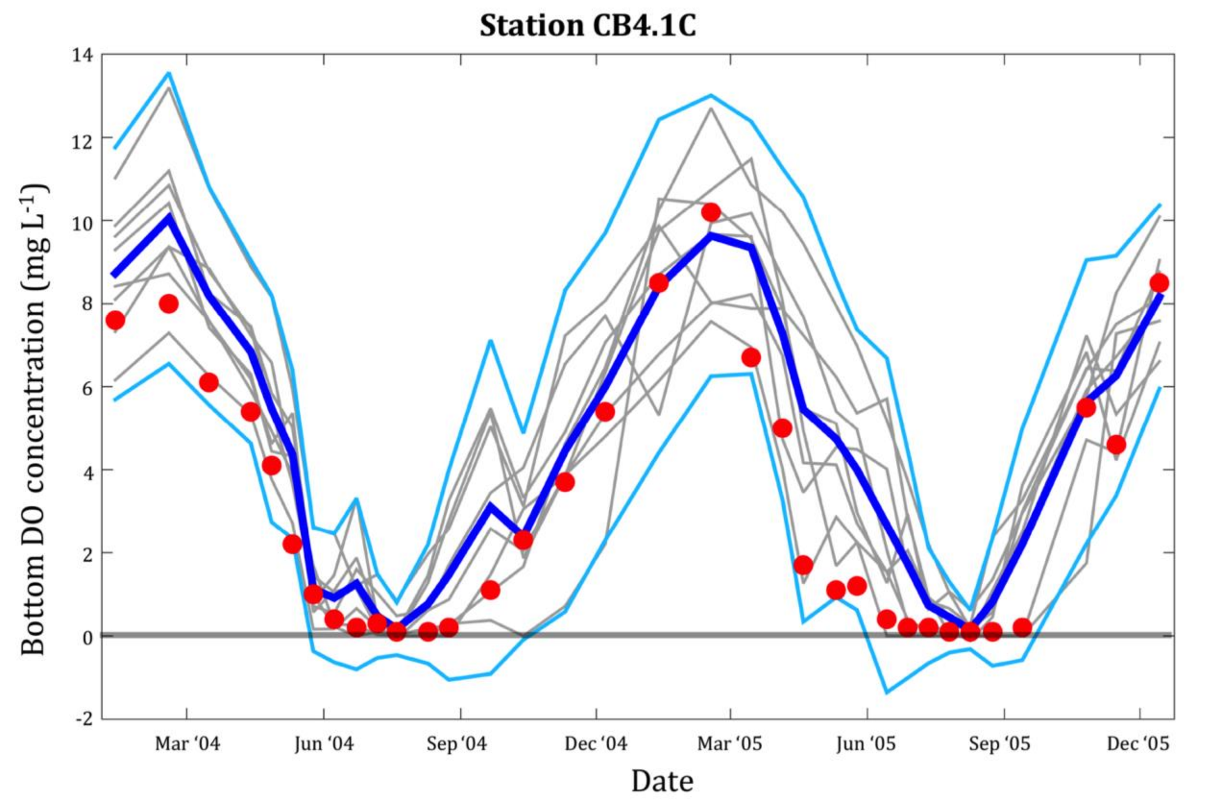
5 days out



3 days out

http://www.nhc.noaa.gov/data/tcr/AL182012_Sandy.pdf; http://www.weathernationtv.com/news/risk-to-new-york-city-increases-from-hurricane-sandy/

A Multiple Model Assessment



- Model mean is better than any individual model across a suite of variables
- In terms of DO, the simple biology models are just as good as the complex models

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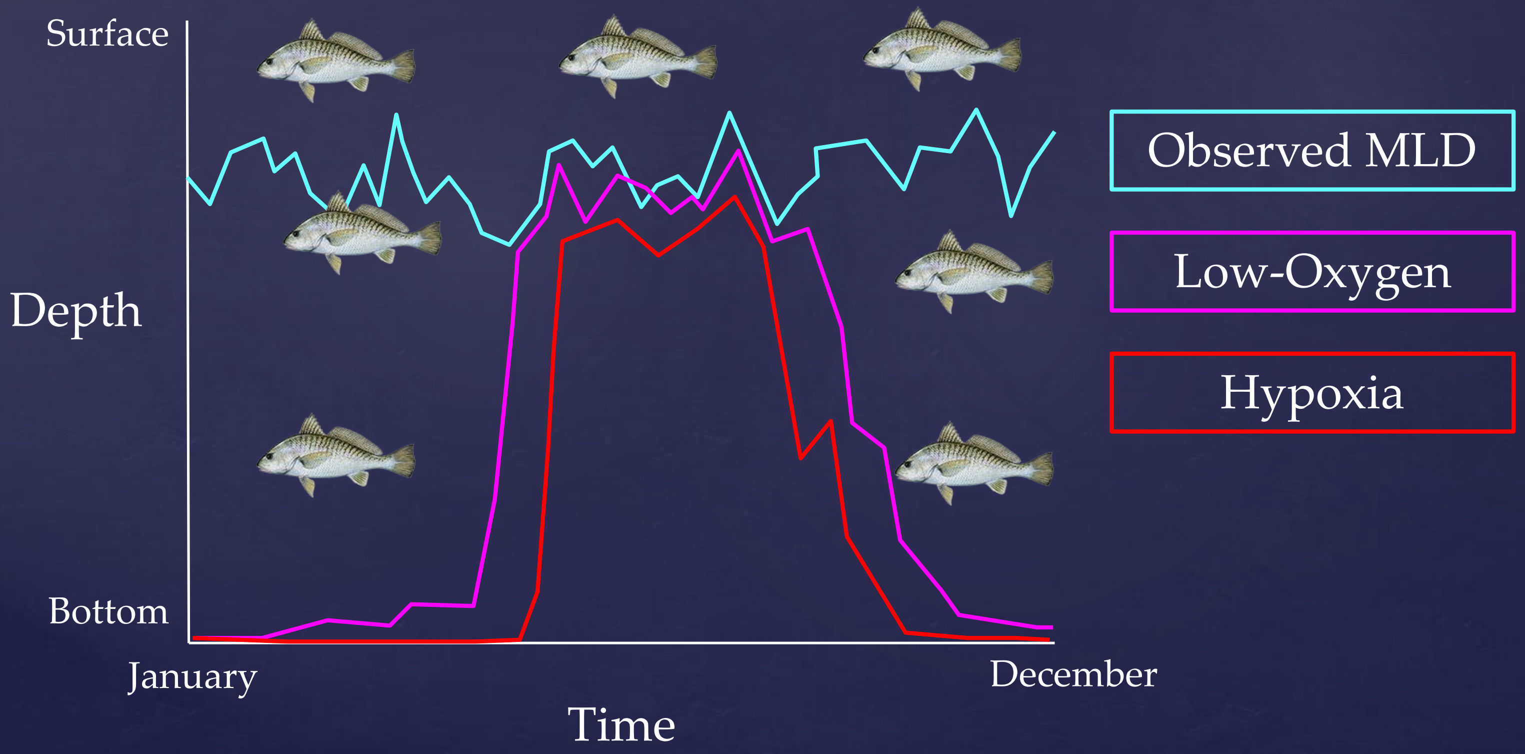

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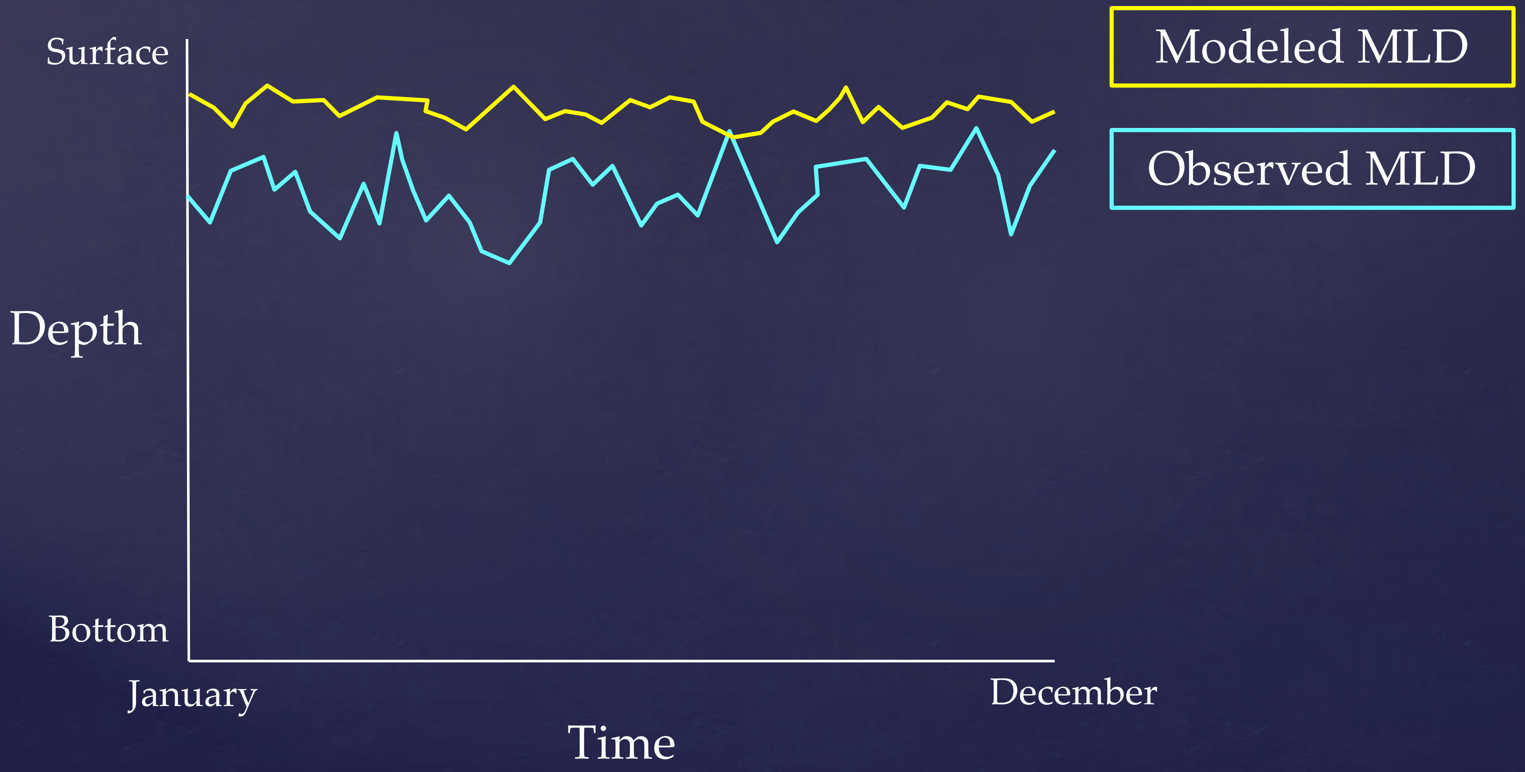

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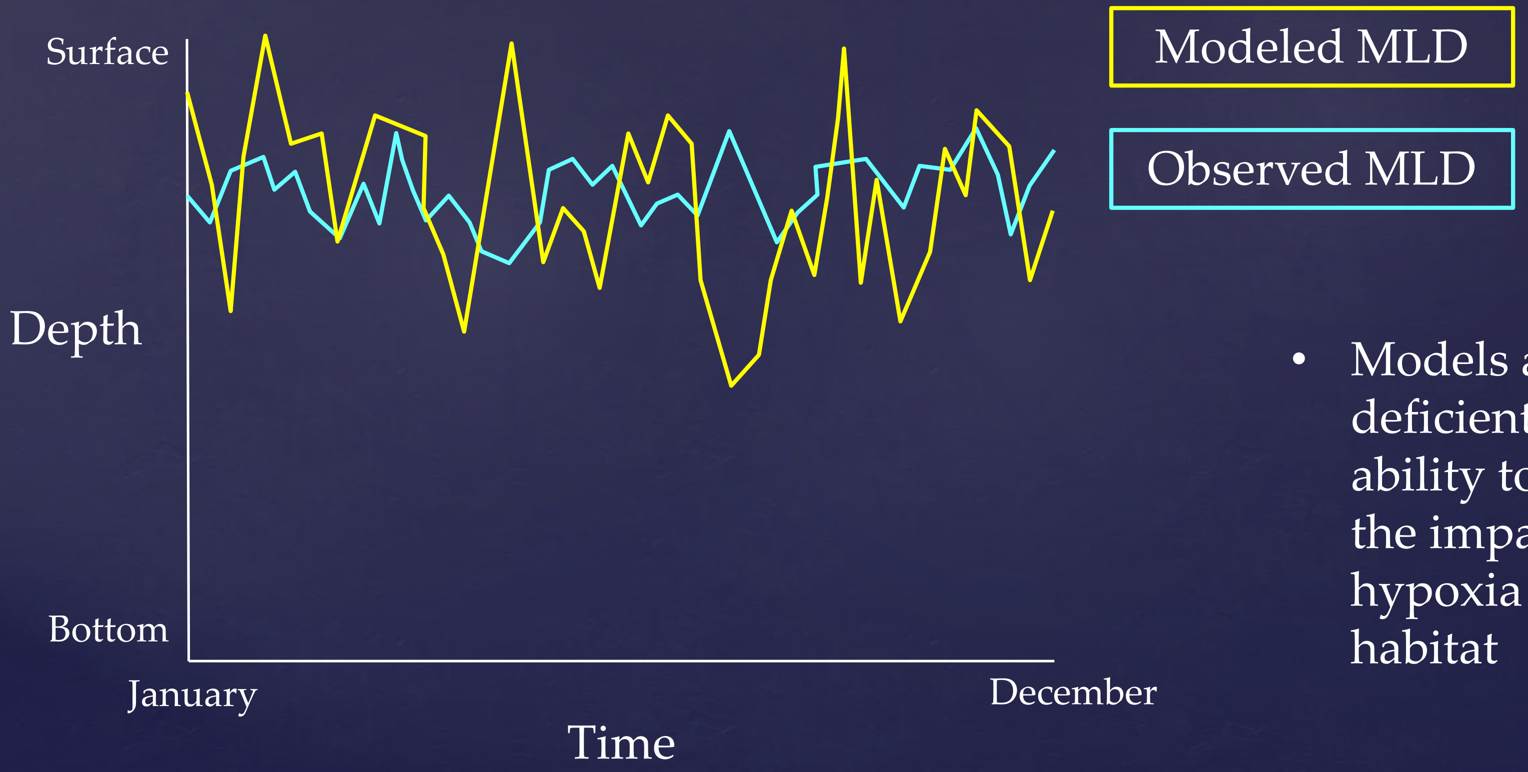


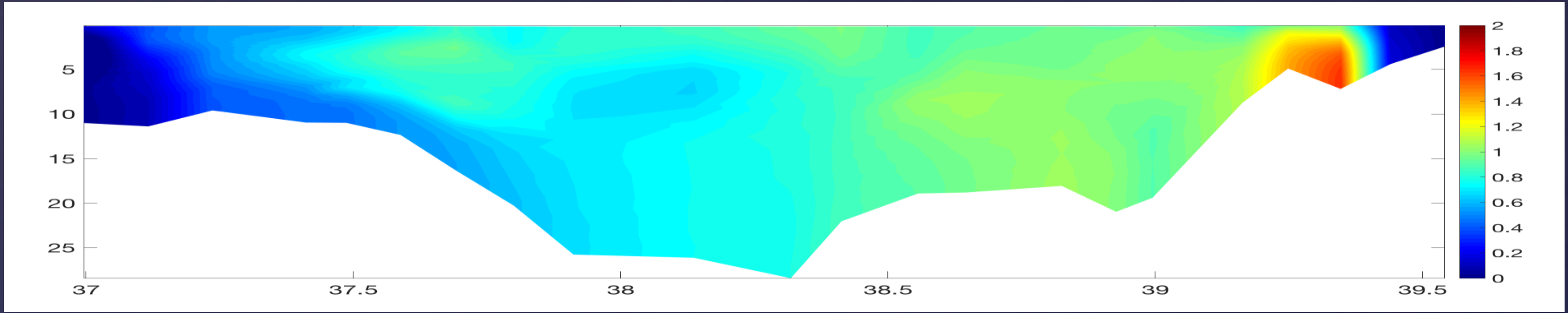
- Models are deficient in their ability to simulate the impact of hypoxia on spatial habitat

SLR Comparison
ChesROMS-ECB vs Hong & Shen, 2012

Difference in average June salinity after 0.5m SLR

Wet Year

ChesROMS-ECB



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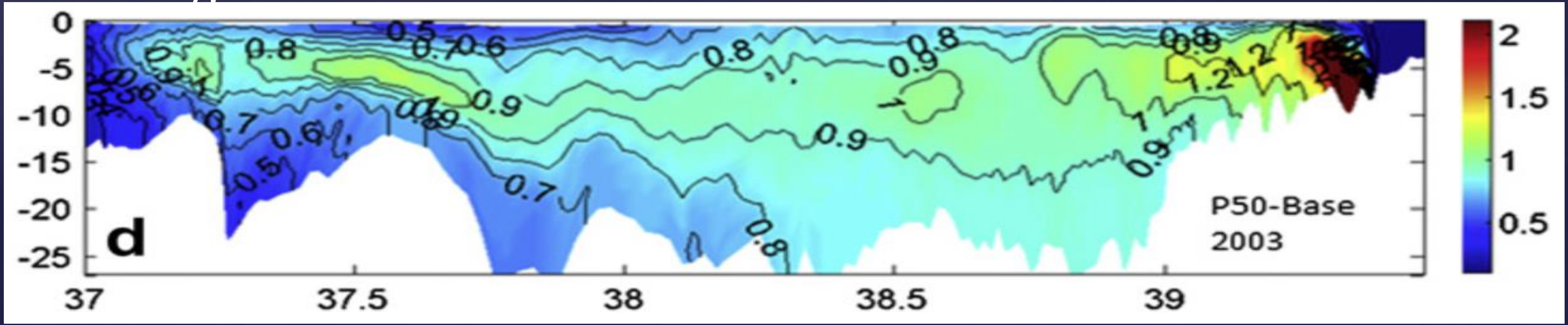

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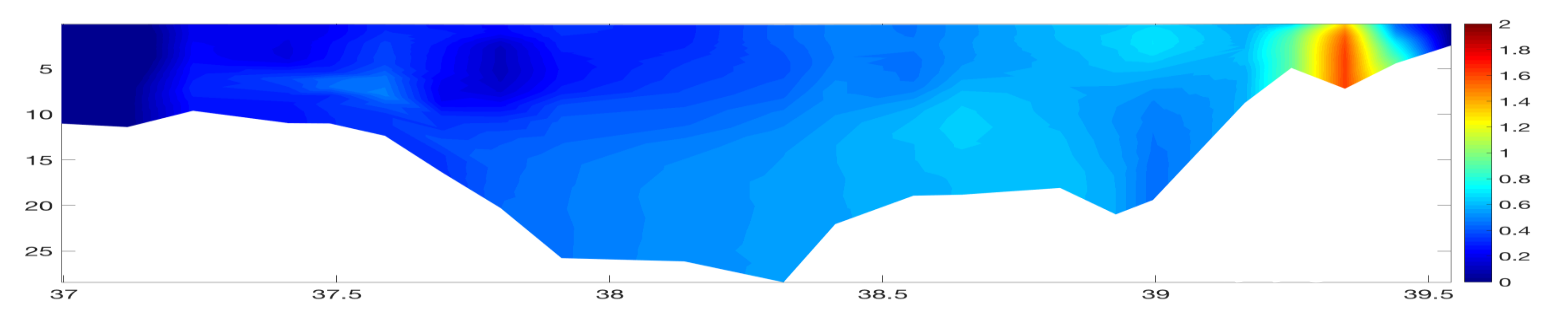

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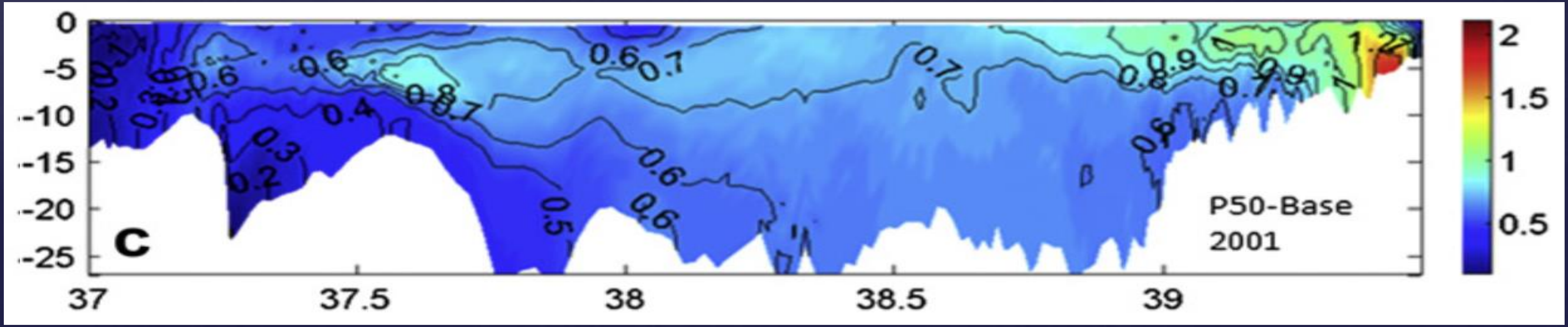

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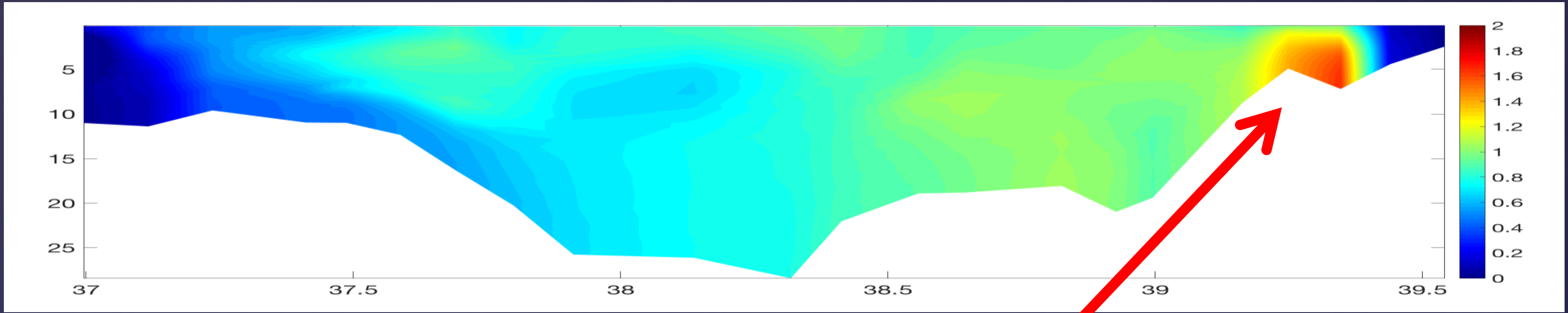
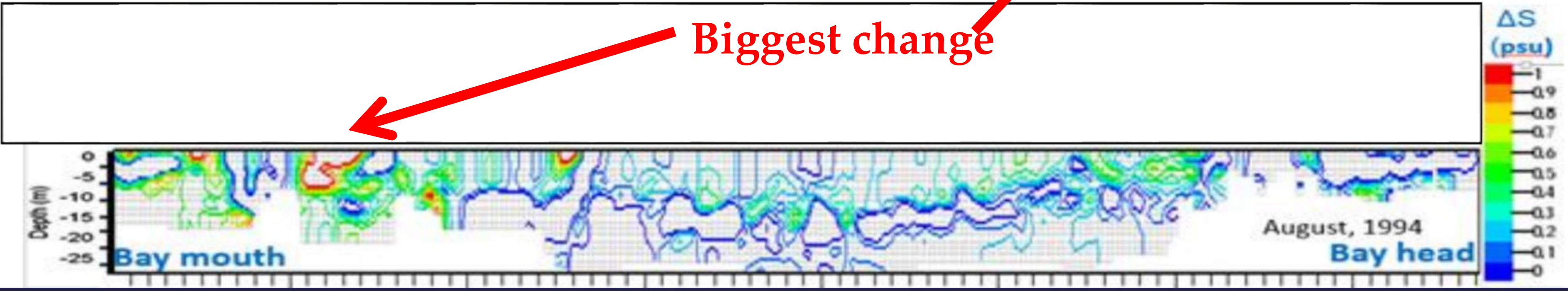
ChesROMS-ECB: June



Note: scale difference

Wang et al., 2017: Aug

Biggest change



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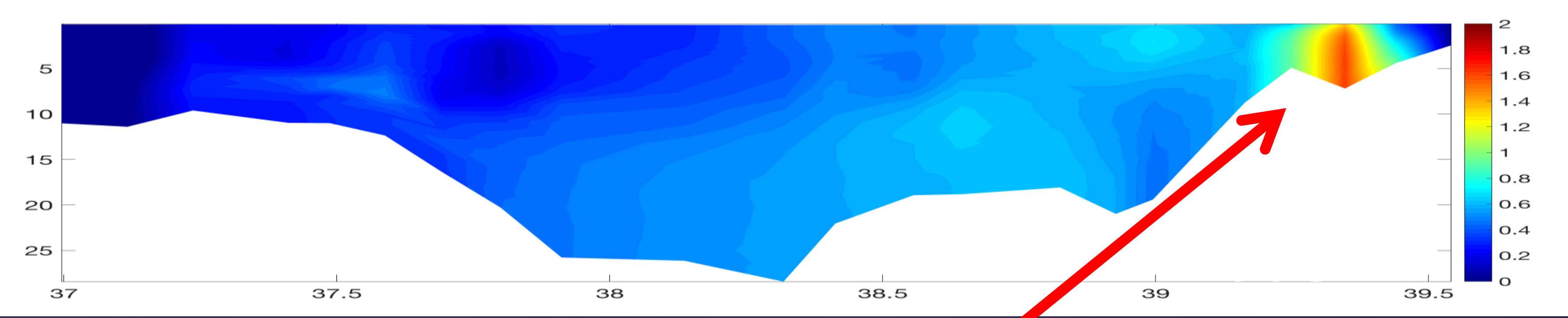

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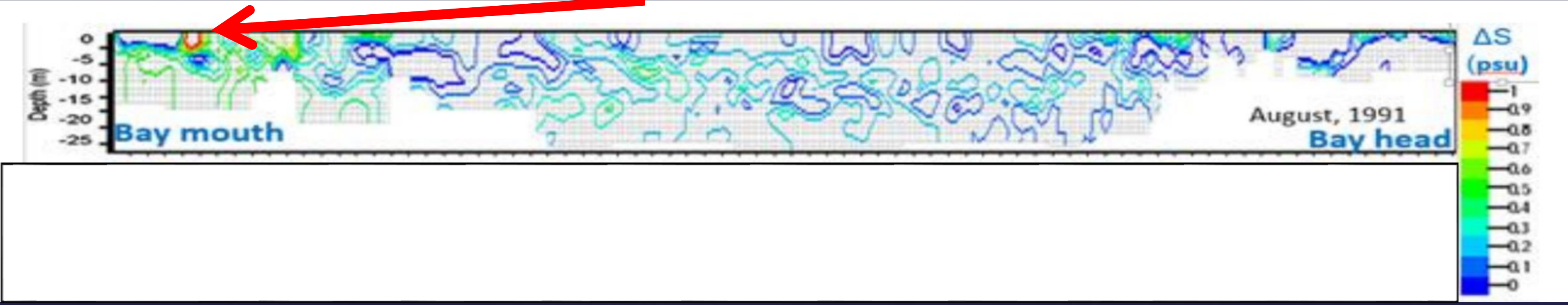

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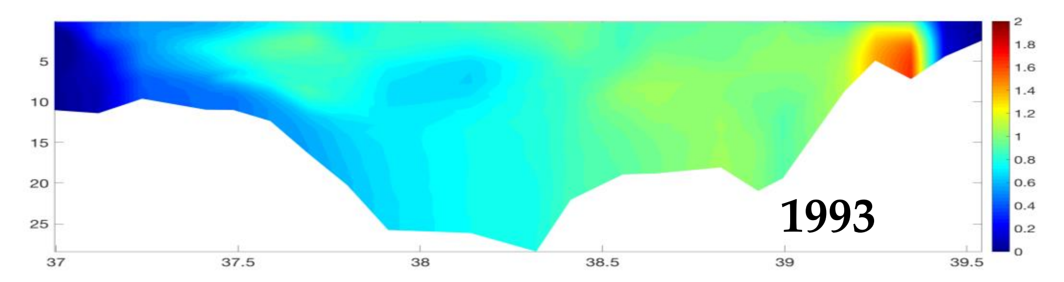

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