The impact of TMDL nutrient reductions on dissolved oxygen in the Chesapeake Bay: a comparison of academic and regulatory water quality models.

-

Isaac (Ike) Irby, PhD/MPP Candidate
Advisor: Marjorie Friedrichs

Coastal Ocean Modeling Testbed: Chesapeake Bay Estuarine Hypoxia
Chesapeake Bay Program: Modeling Group

IOOS INTEGRATED OCEAN OBSERVING SYSTEM

NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION U.S. DEPARTMENT OF COMMERCE

VIMS | WILLIAM & MARY
VIRGINIA INSTITUTE OF MARINE SCIENCE

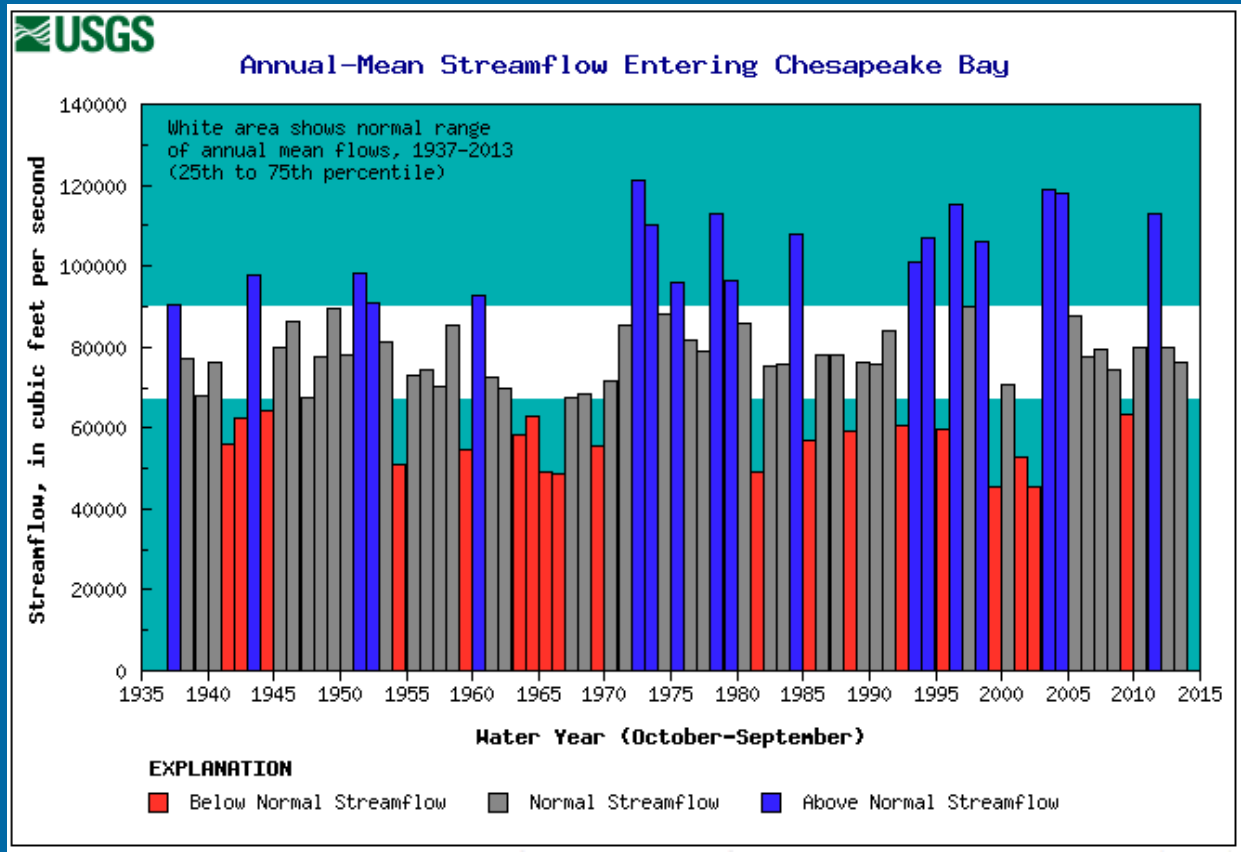
1940-2015 75 YEARS

2010 Chesapeake Bay TMDL

- **Goals for Nitrogen Reduction**
  - **Cap of 186 million lbs of nitrogen per year**
  - **25% reduction in nitrogen delivery**

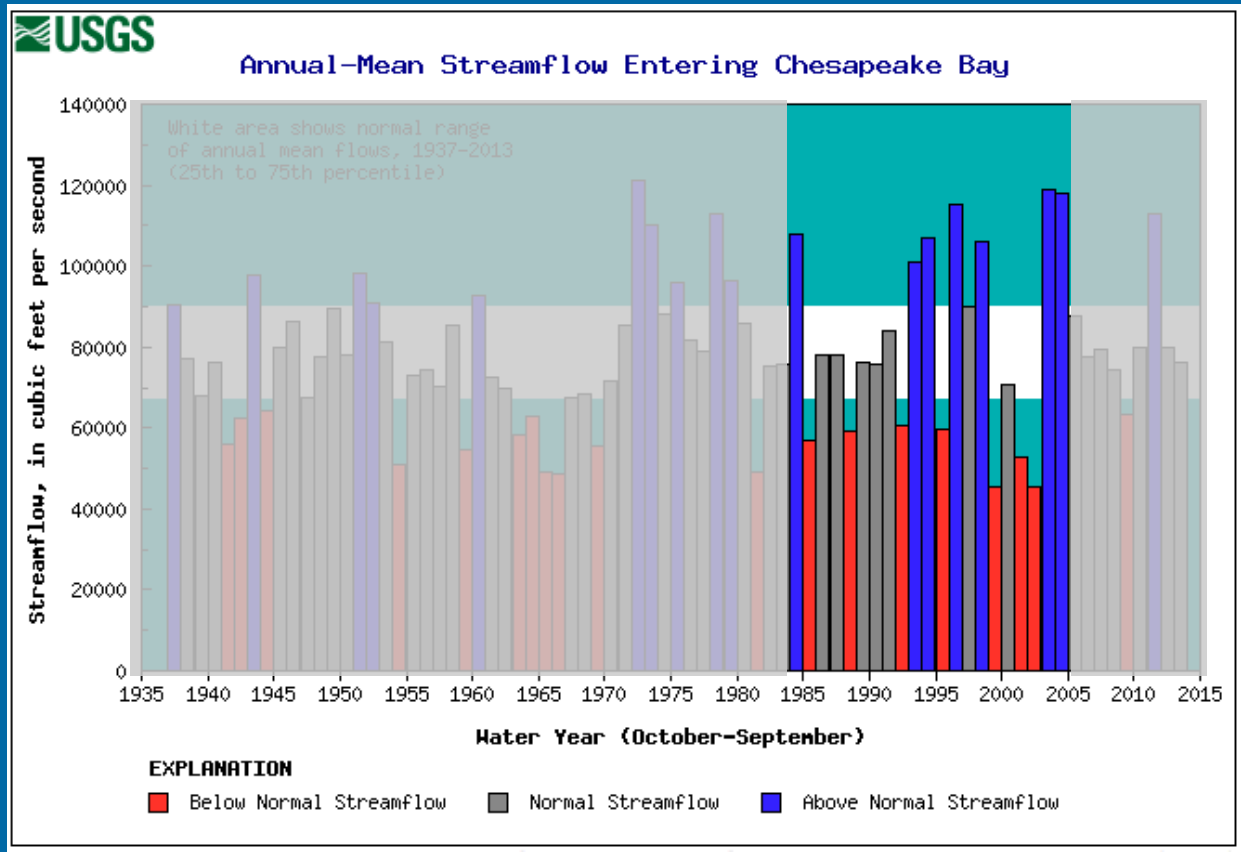
2010 Chesapeake Bay TMDL

- Goals for Nitrogen Reduction
  - Cap of 186 million lbs of nitrogen per year
  - 25% reduction in nitrogen delivery
- Hydrologic Period



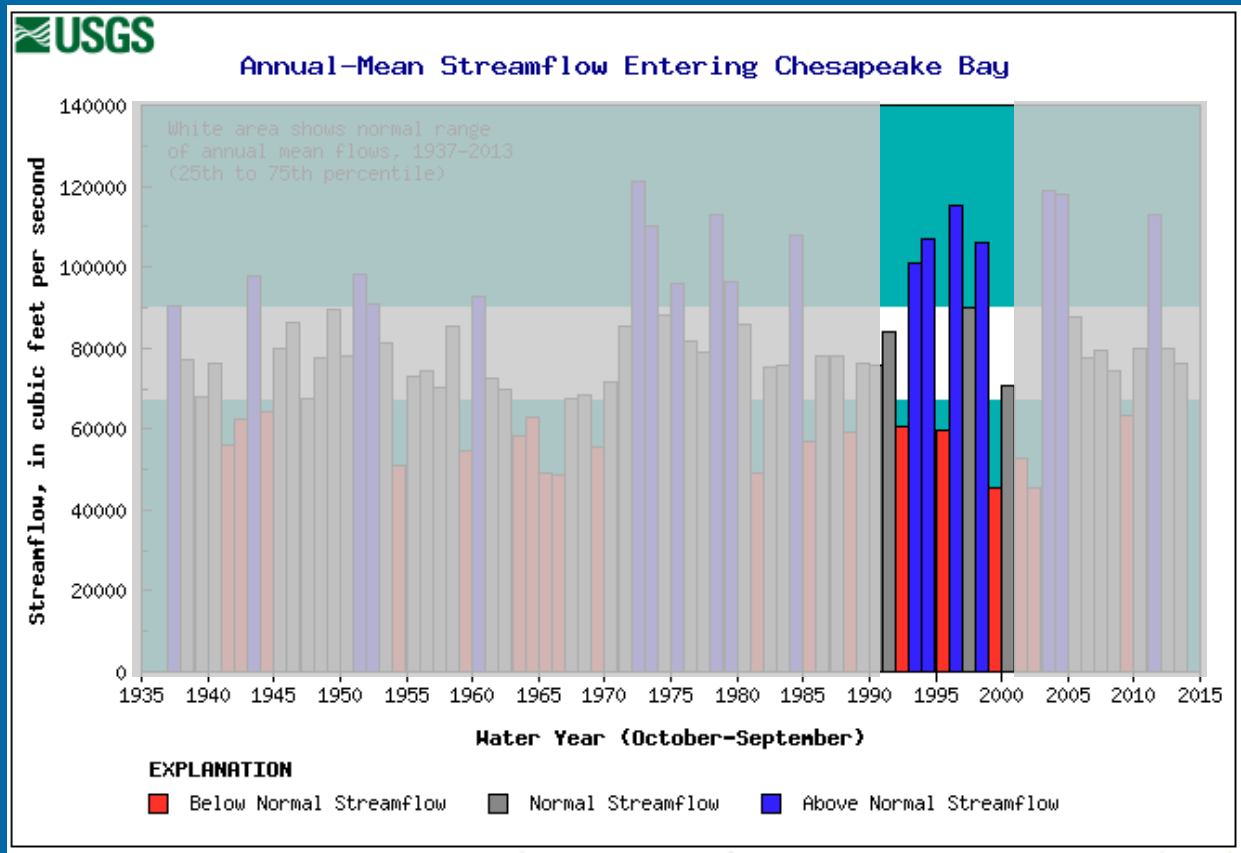
2010 Chesapeake Bay TMDL

- Goals for Nitrogen Reduction
  - Cap of 186 million lbs of nitrogen per year
  - 25% reduction in nitrogen delivery
- Hydrologic Period



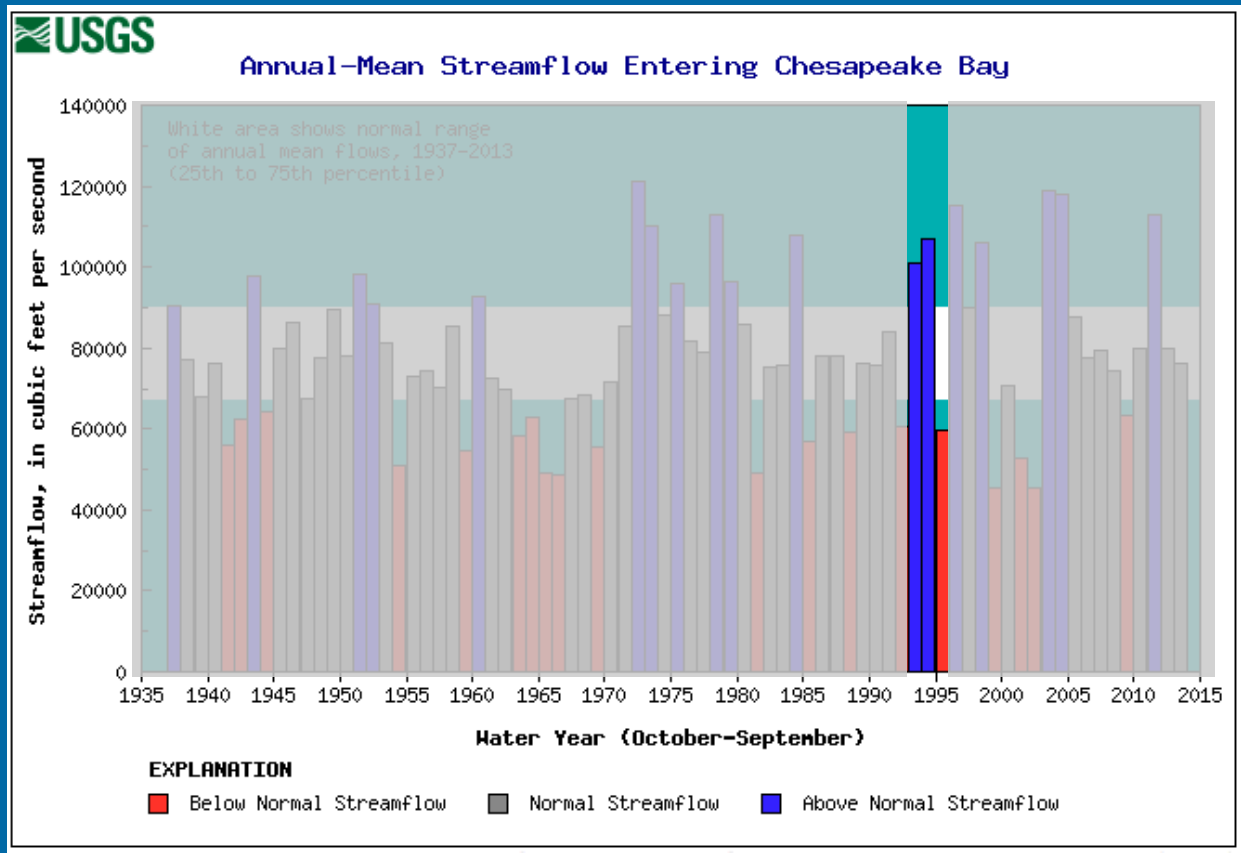
2010 Chesapeake Bay TMDL

- Goals for Nitrogen Reduction
  - Cap of 186 million lbs of nitrogen per year
  - 25% reduction in nitrogen delivery
- Hydrologic Period
  - 1991 – 2000

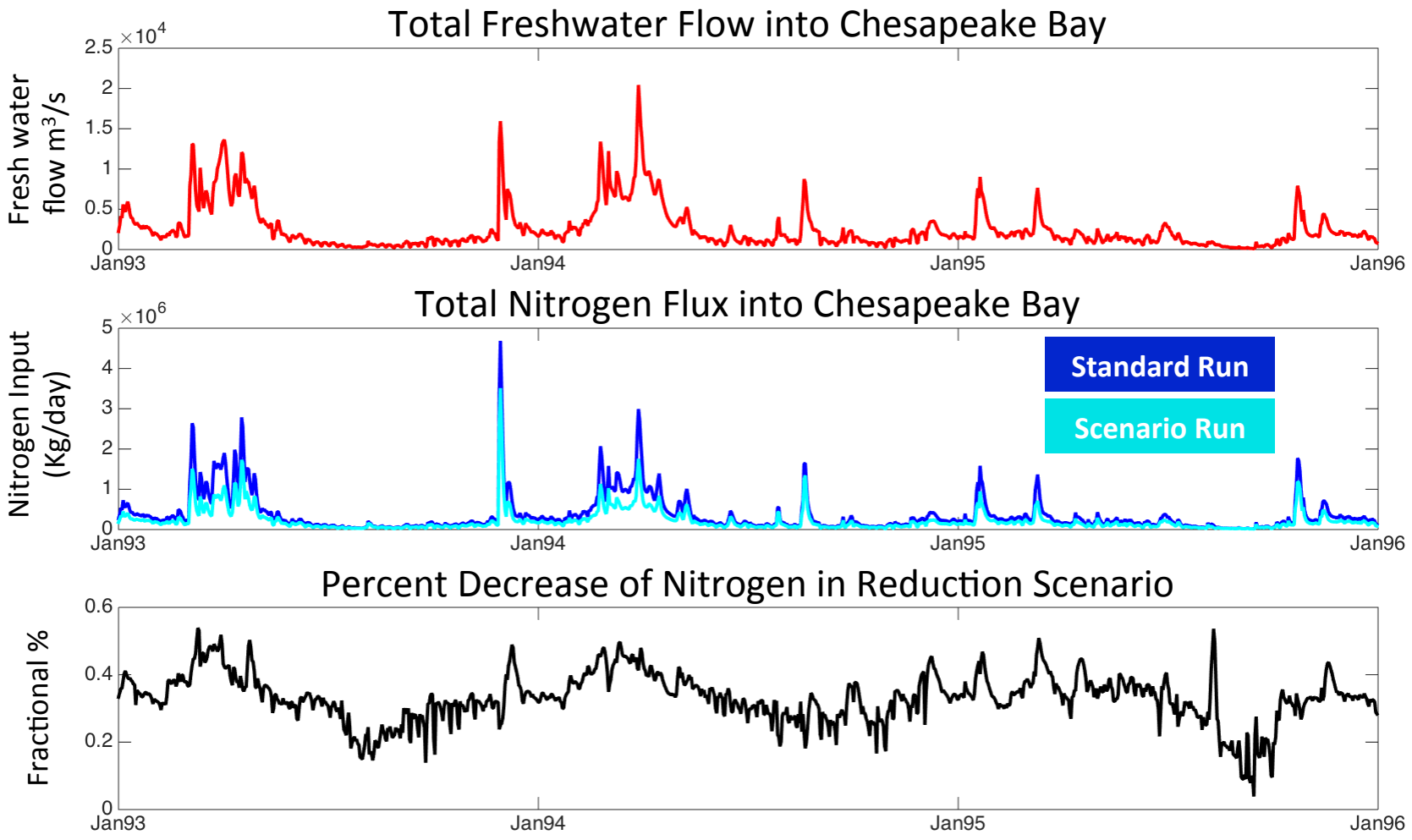


2010 Chesapeake Bay TMDL

- Goals for Nitrogen Reduction
  - Cap of 186 million lbs of nitrogen per year
  - 25% reduction in nitrogen delivery
- Hydrologic Period
  - 1991 – 2000
- Critical Period
  - 1993 – 1995

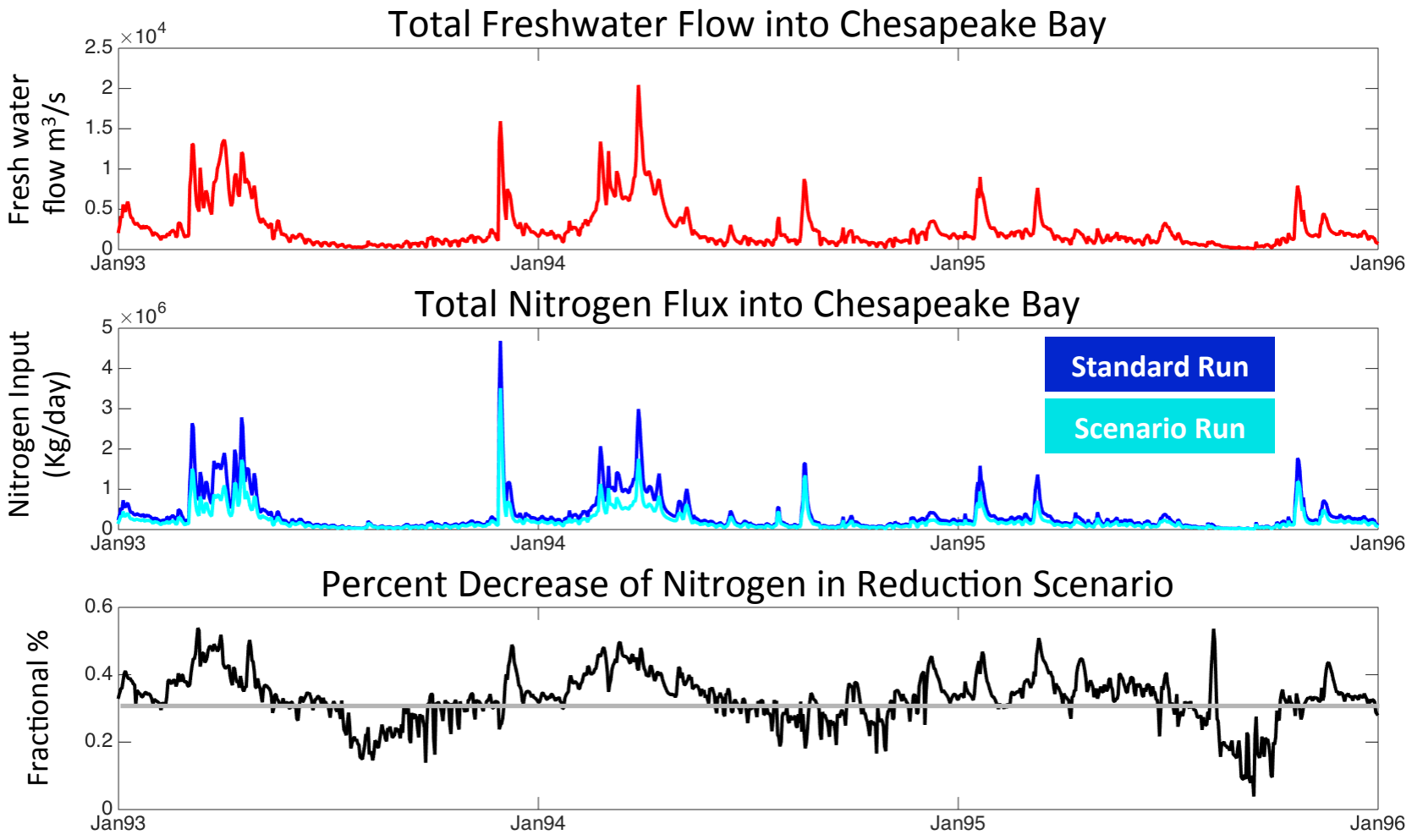


Nutrient Reduction Scenario



VIMS | William & Mary
Virginia Institute of Marine Science
1940-2015 75 Years

Nutrient Reduction Scenario



Mean decrease in nitrogen: ~30%

VIMS | William & Mary
Virginia Institute of Marine Science
1940-2015 75 Years

Model Comparison

Previous Work

Challenges associated with modeling low-oxygen waters in Chesapeake Bay: a multiple model comparison

Isaac D. Irby[1], Marjorie A. M. Friedrichs[1], Carl T. Friedrichs[1], Aaron J. Bever[2], Raleigh R. Hood[3], Lyon W. J. Lanerolle[4,5], Ming Li[6], Lewis Linker[7], Malcolm E. Scully[8], Kevin Sellner[9], Jian Shen[1], Jeremy Testa[6], Hao Wang[3], Ping Wang[10], and Meng Xia[11]

8 models
2004-2005
13 main stem stations

Biogeosciences
doi: 10.5194/bg-13-2011-2016

VIMS | William & Mary
Virginia Institute of Marine Science
1940-2015 75 Years

Model Comparison

Regulatory: CH3D-ICM
Academic: ChesROMS-ECB

Regulatory	Academic
--	--
1km xy-resolution	1.8km xy-resolution
z-grid	sigma-grid
Extensive Calibration	Community Model
High Complexity BGC	Intermediate Complexity BGC

Regulatory Watershed Model Forcing

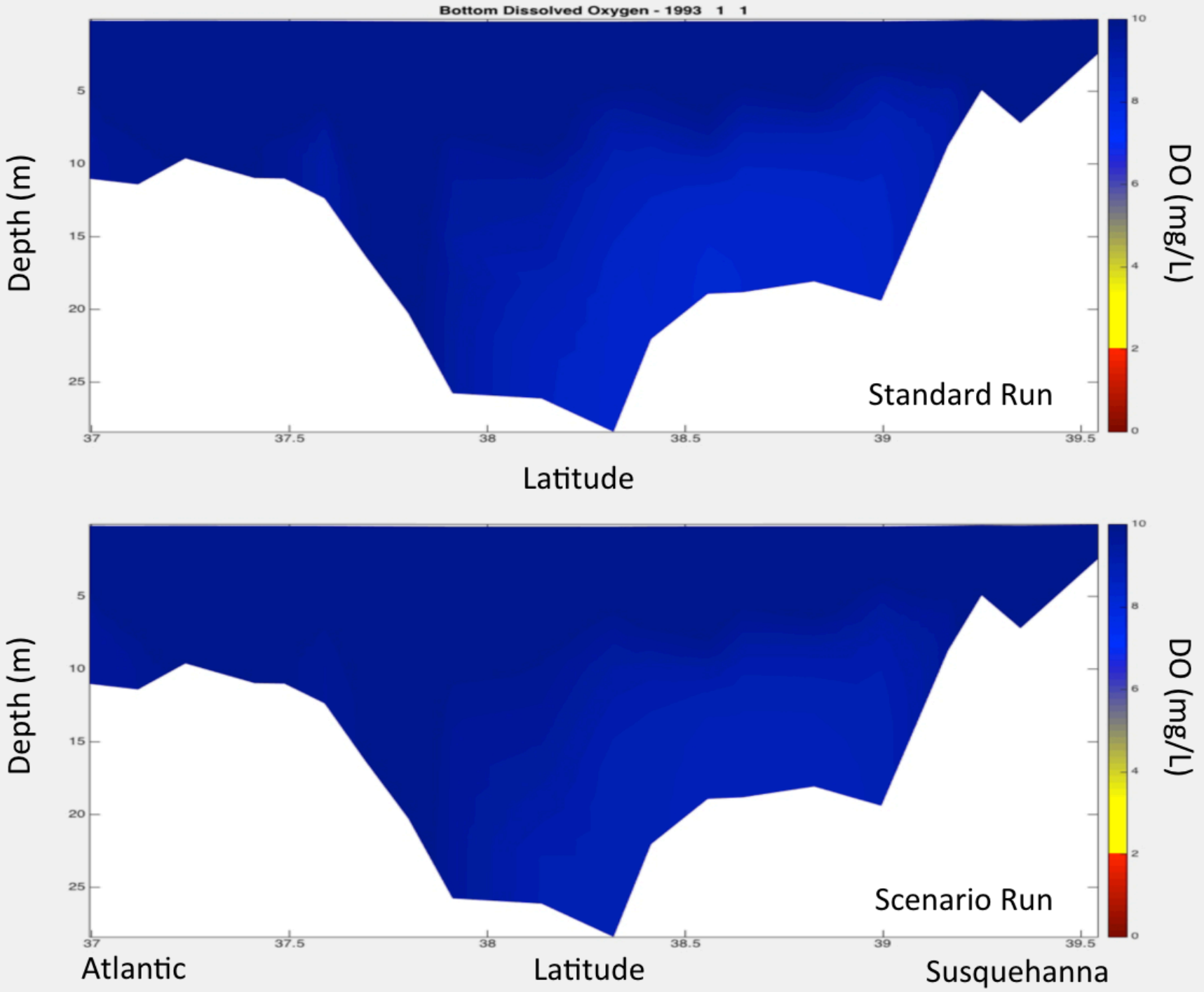
Model Comparison

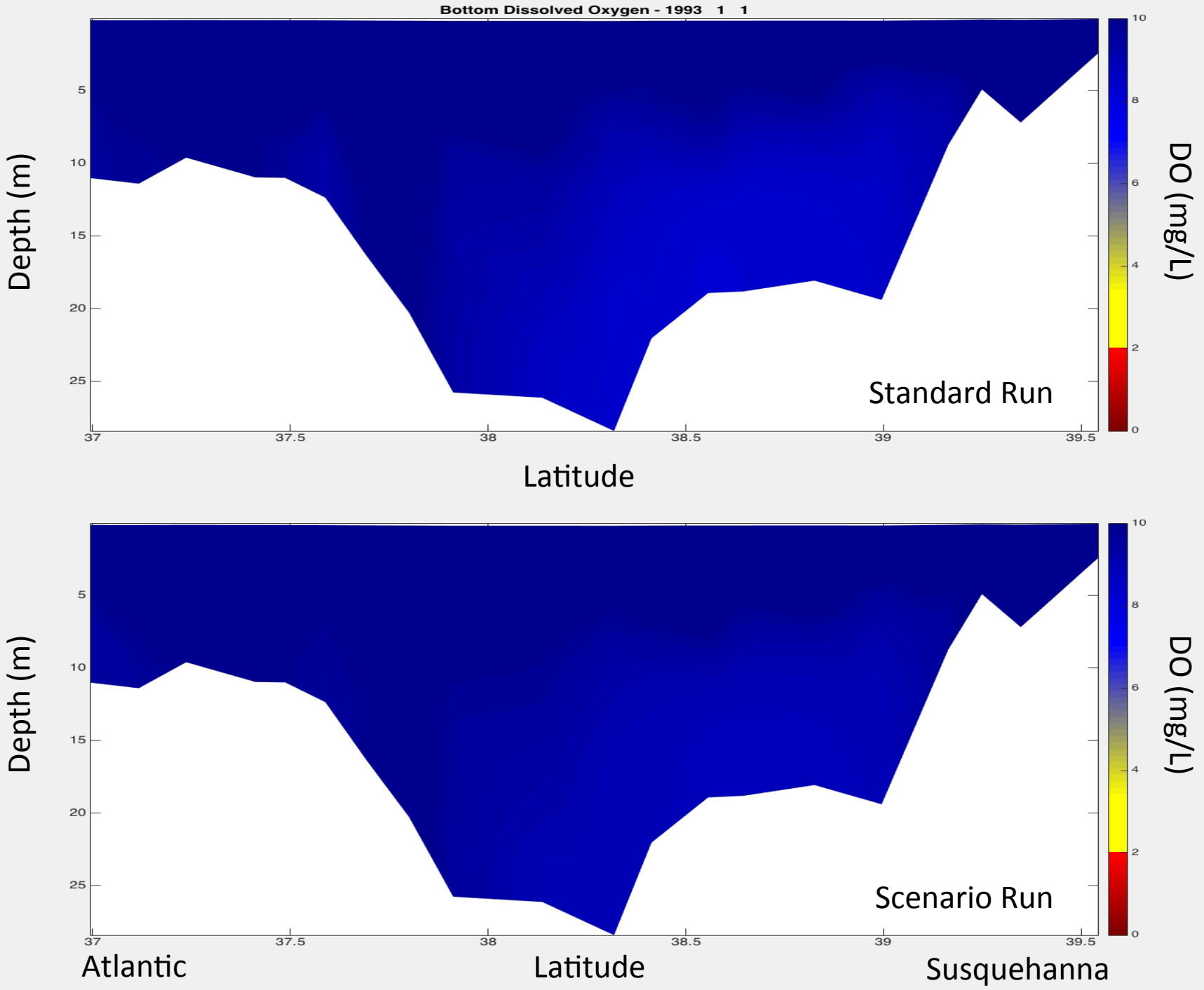
Regulatory: CH3D-ICM
Academic: ChesROMS-ECB

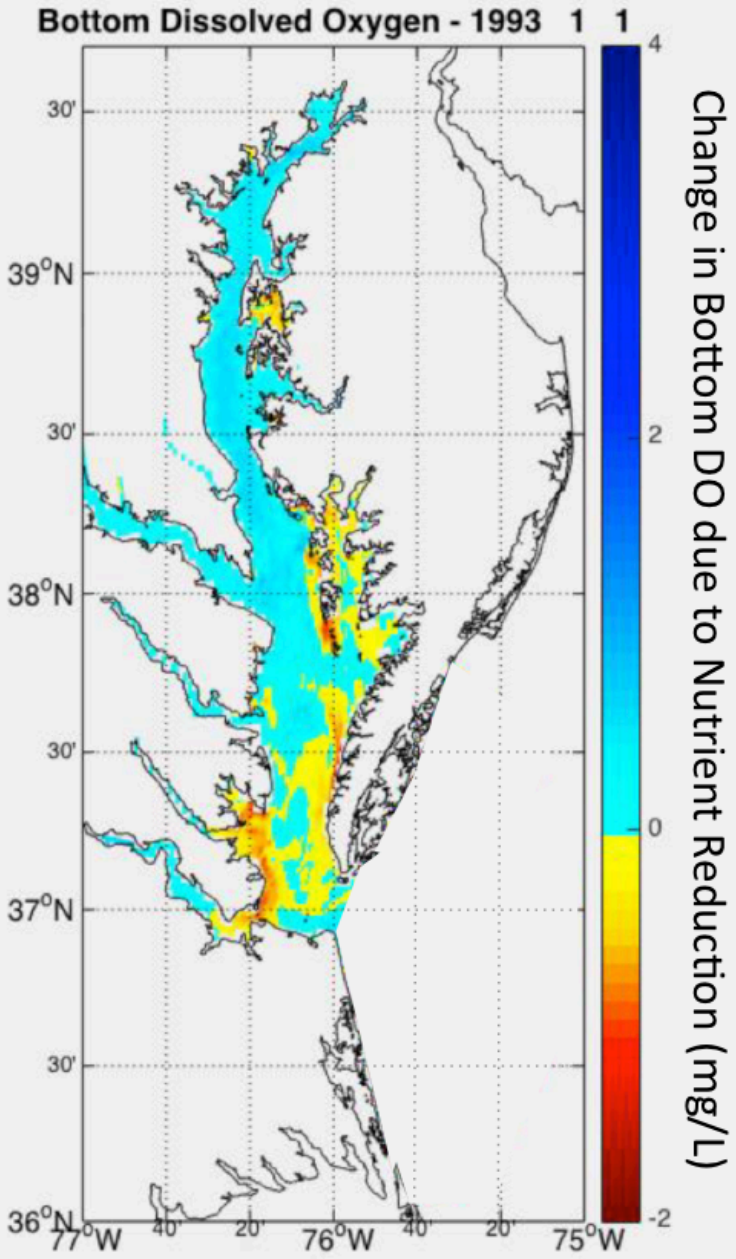
1985 - 2005
Main stem & Tributary Stations

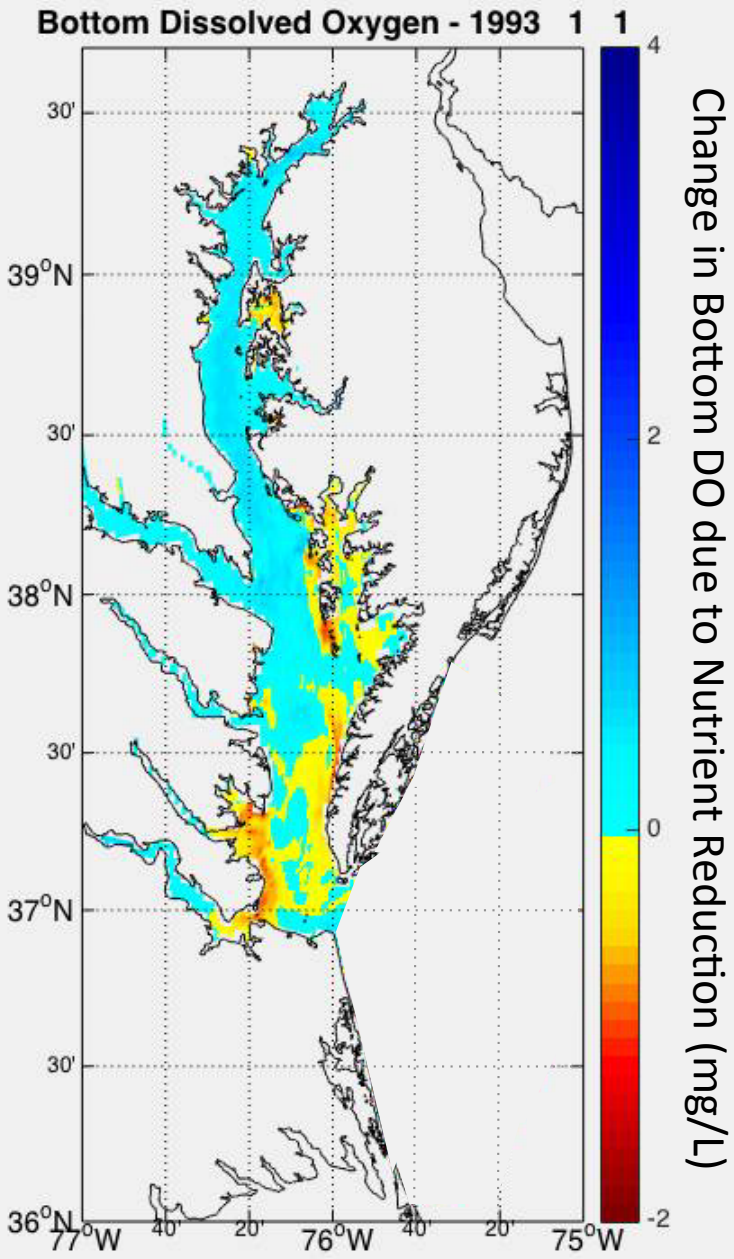
VIMS | William & Mary
Virginia Institute of Marine Science
1940-2015 75 Years

How do nutrient reductions impact dissolved oxygen concentrations?

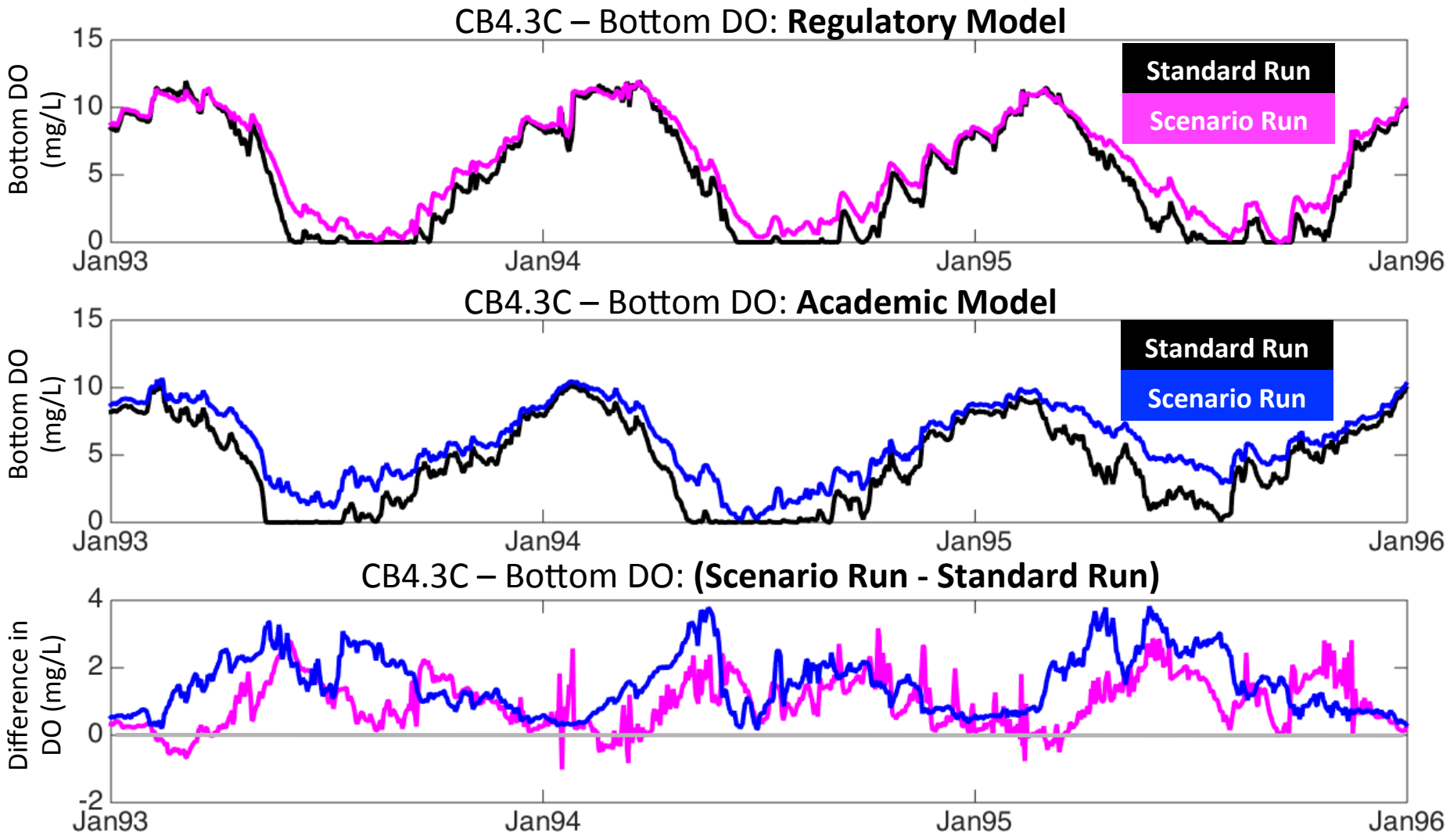

Bottom Dissolved Oxygen - 1993 1 1
Depth (m)
5
10
15
20
25
37
37.5
38
38.5
39
39.5
Latitude
DO (mg/L)
10
8
6
4
2
0
Standard Run
Depth (m)
Scenario Run
Atlantic
Latitude
Susquehanna
DO (mg/L)


Bottom Dissolved Oxygen - 1993 1 1
Depth (m)
5
10
15
20
25
37
37.5
38
38.5
39
39.5
Latitude
DO (mg/L)
10
8
6
4
2
0
Standard Run
Depth (m)
Scenario Run
Atlantic
Latitude
Susquehanna
DO (mg/L)

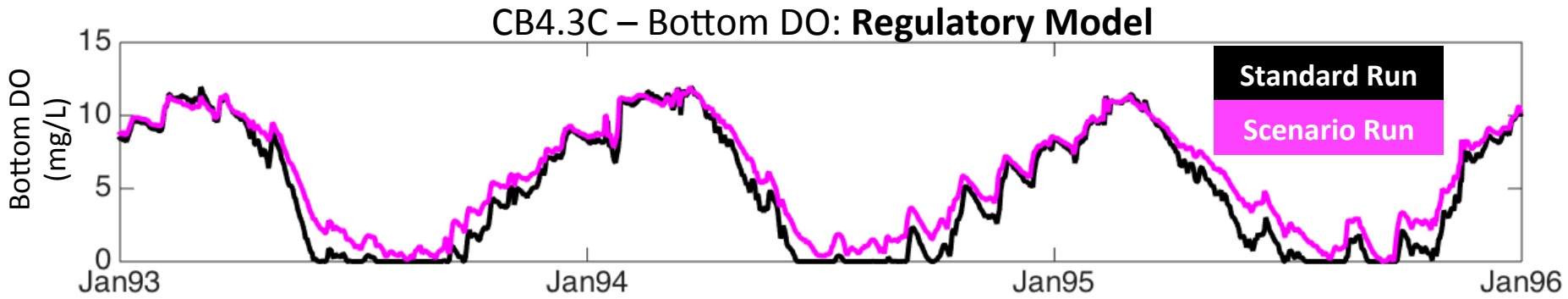

Bottom Dissolved Oxygen - 1993 1 1
30'
39°N
30'
38°N
30'
37°N
30'
36°N
77°W
40'
20'
76°W
40'
20'
75°W
4
2
0
-2
Change in Bottom DO due to Nutrient Reduction (mg/L)

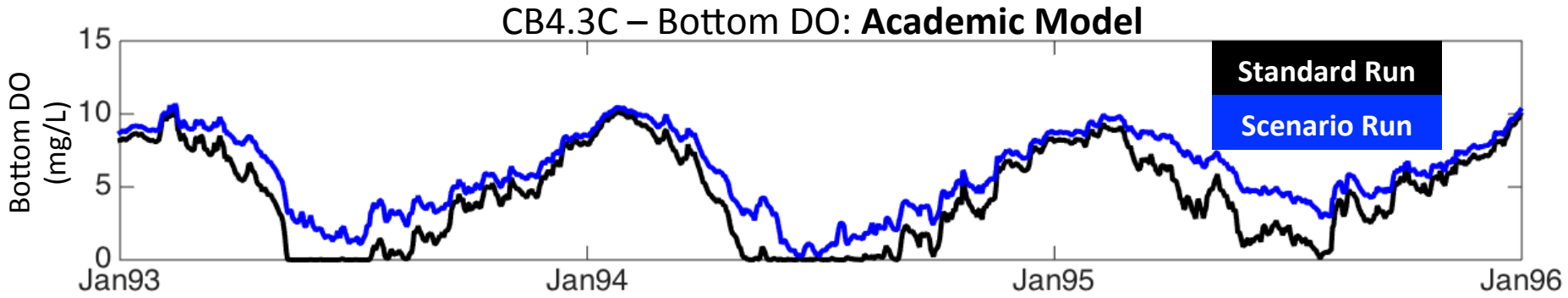

Bottom Dissolved Oxygen - 1993 1 1
30'
39°N
30'
38°N
30'
37°N
30'
36°N
77°W
40'
20'
76°W
40'
20'
75°W
4
2
0
-2
Change in Bottom DO due to Nutrient Reduction (mg/L)

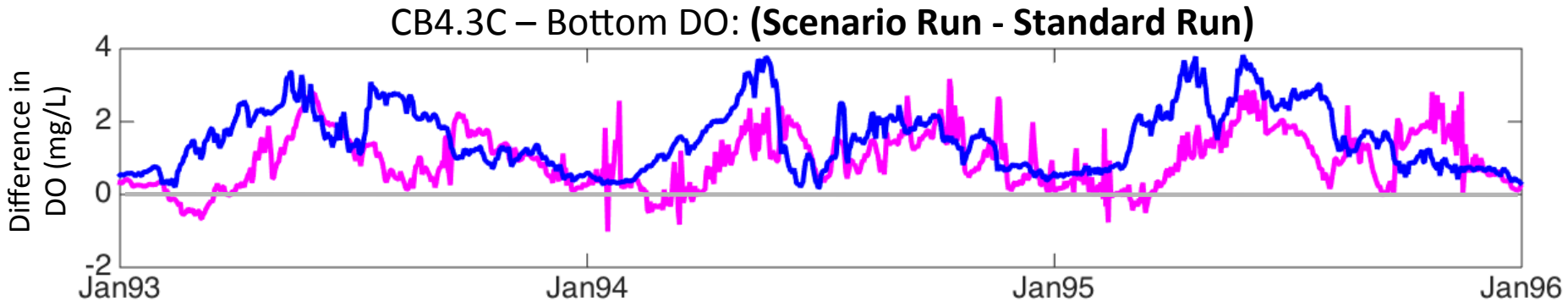
Nutrient Reduction Scenario



Nutrient Reduction Scenario

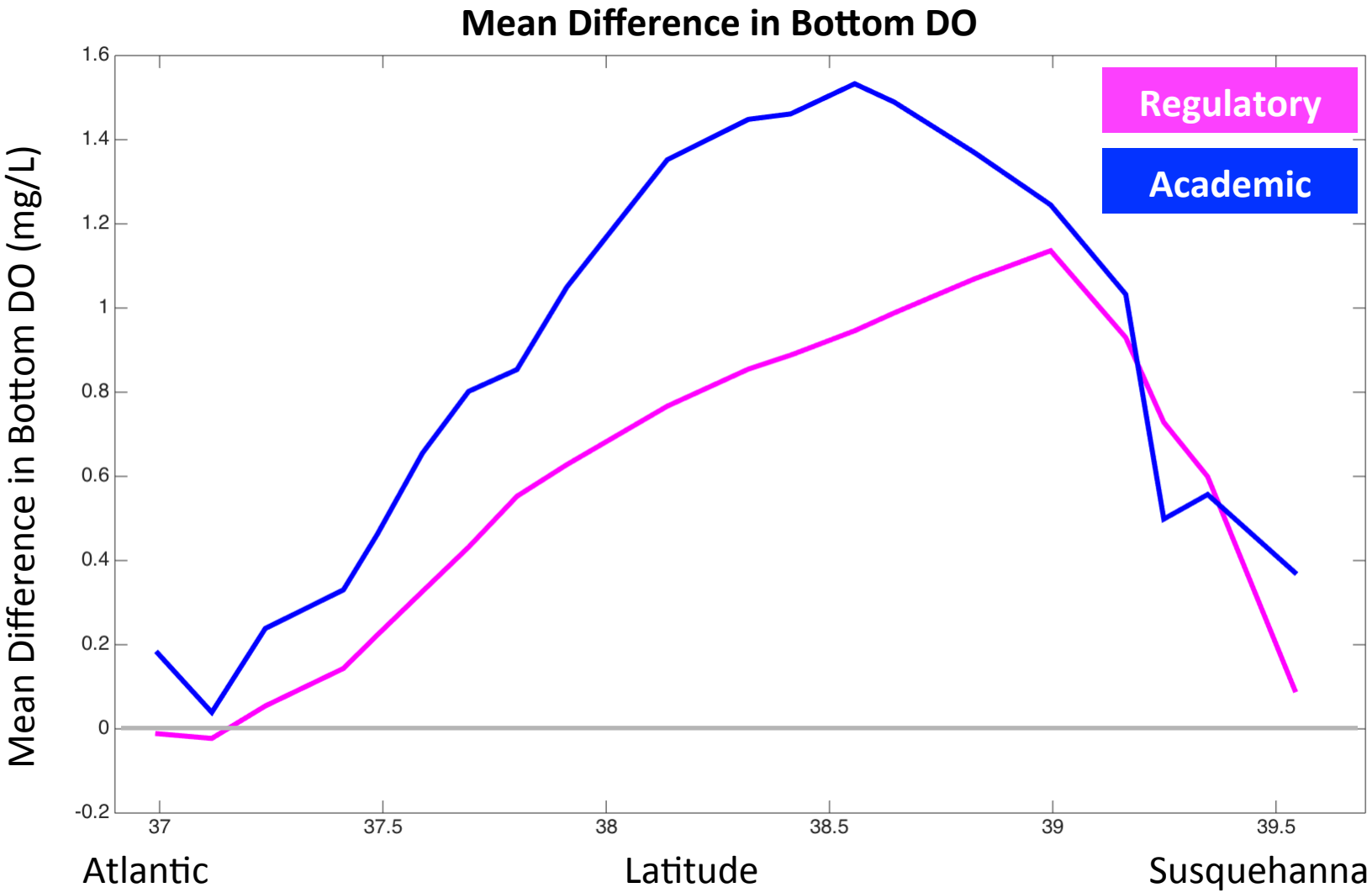




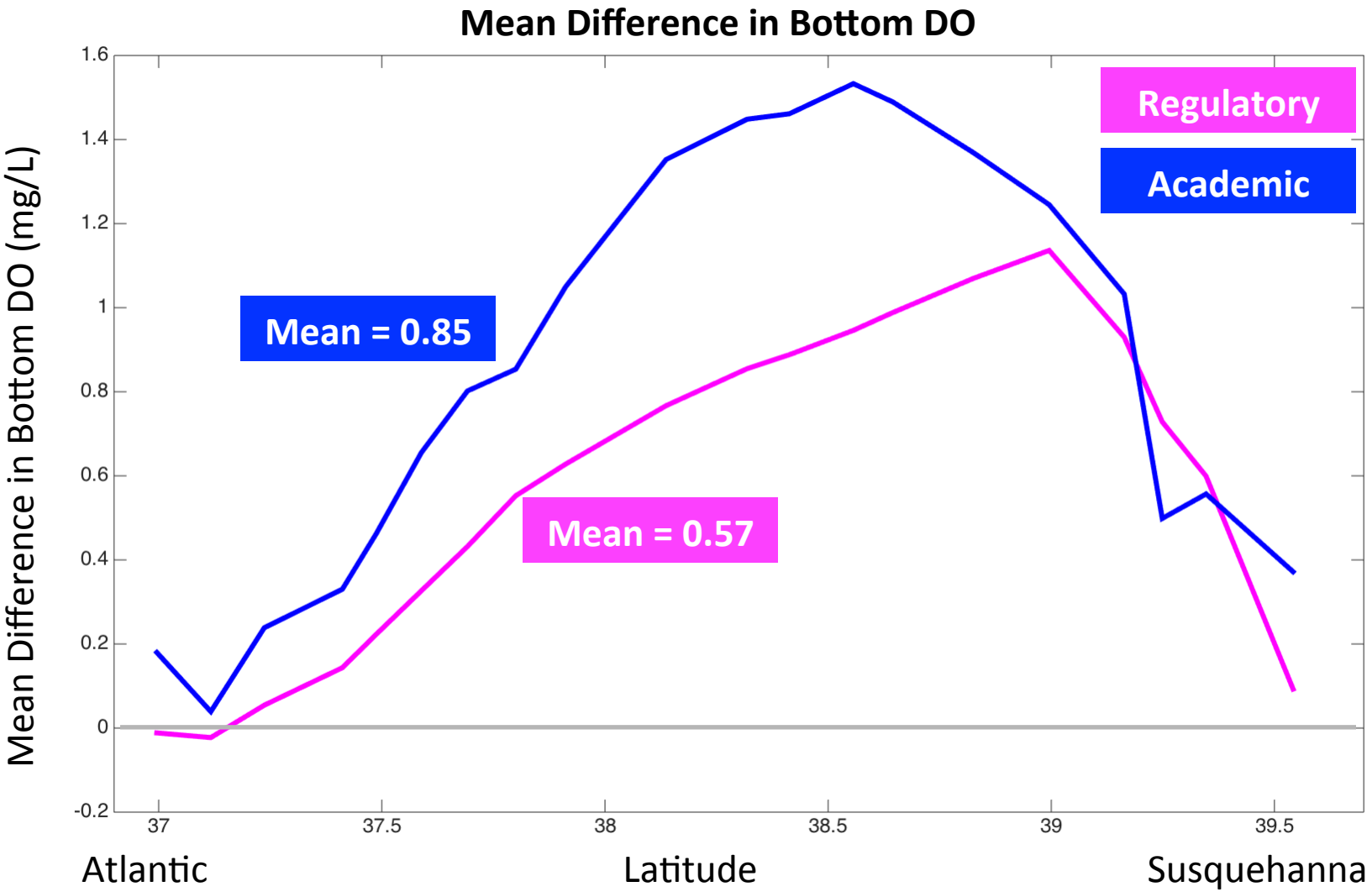


Average DO increase: **0.95 mg/L** **1.53 mg/L**

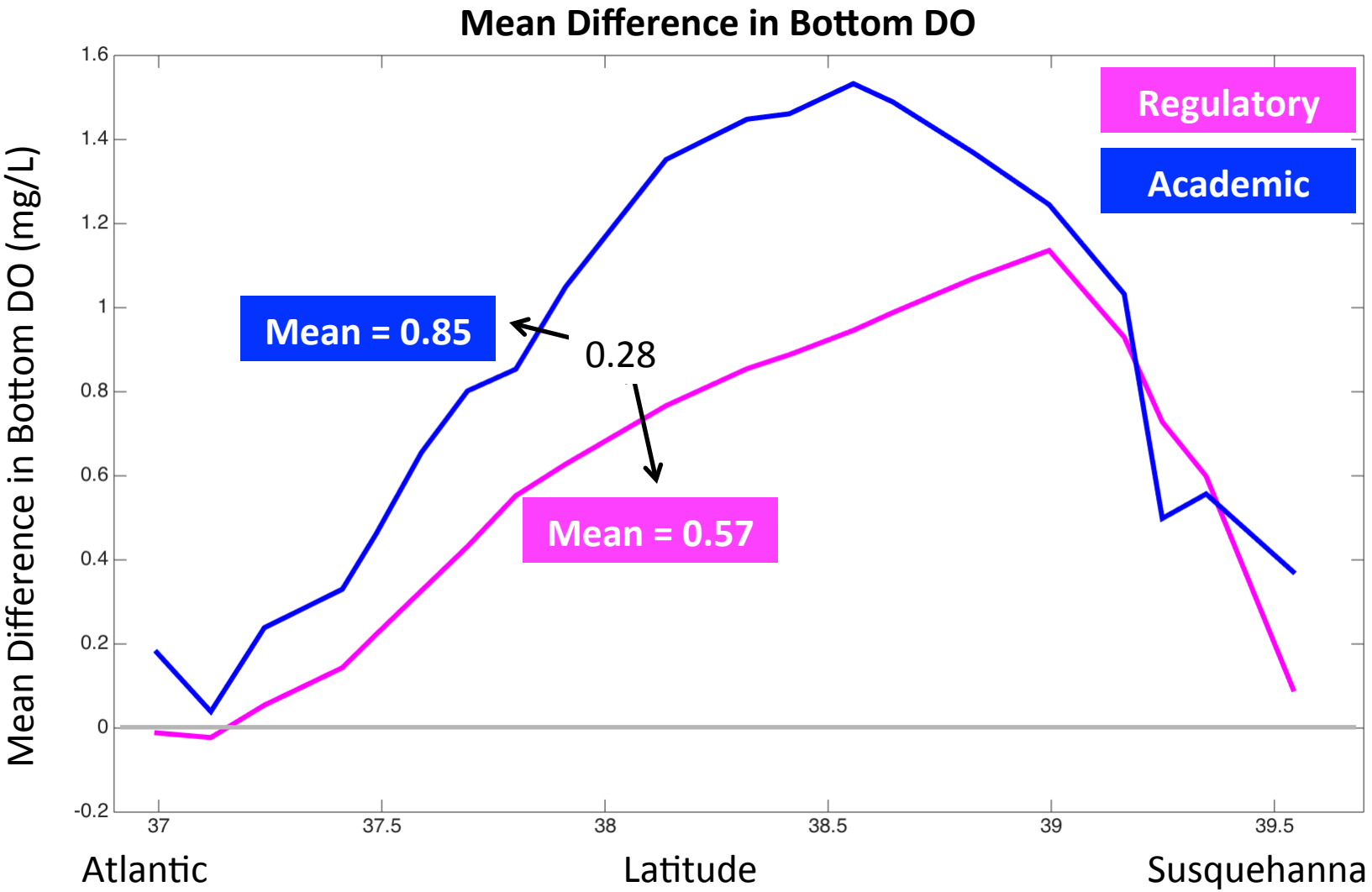
Nutrient Reduction Scenario



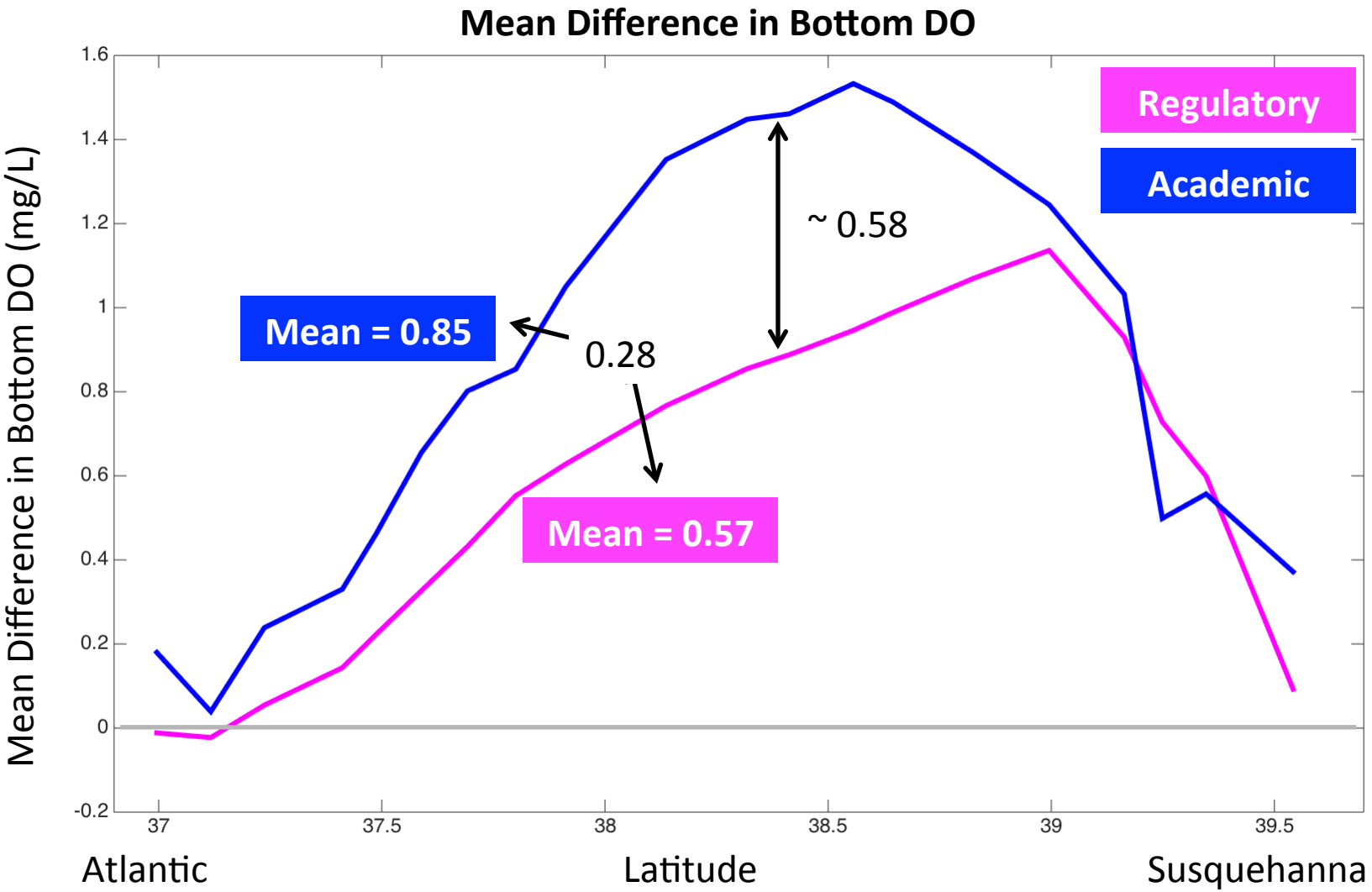
Nutrient Reduction Scenario



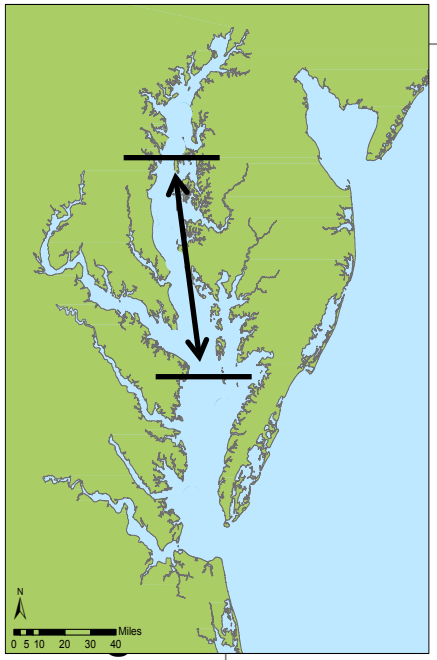
Nutrient Reduction Scenario

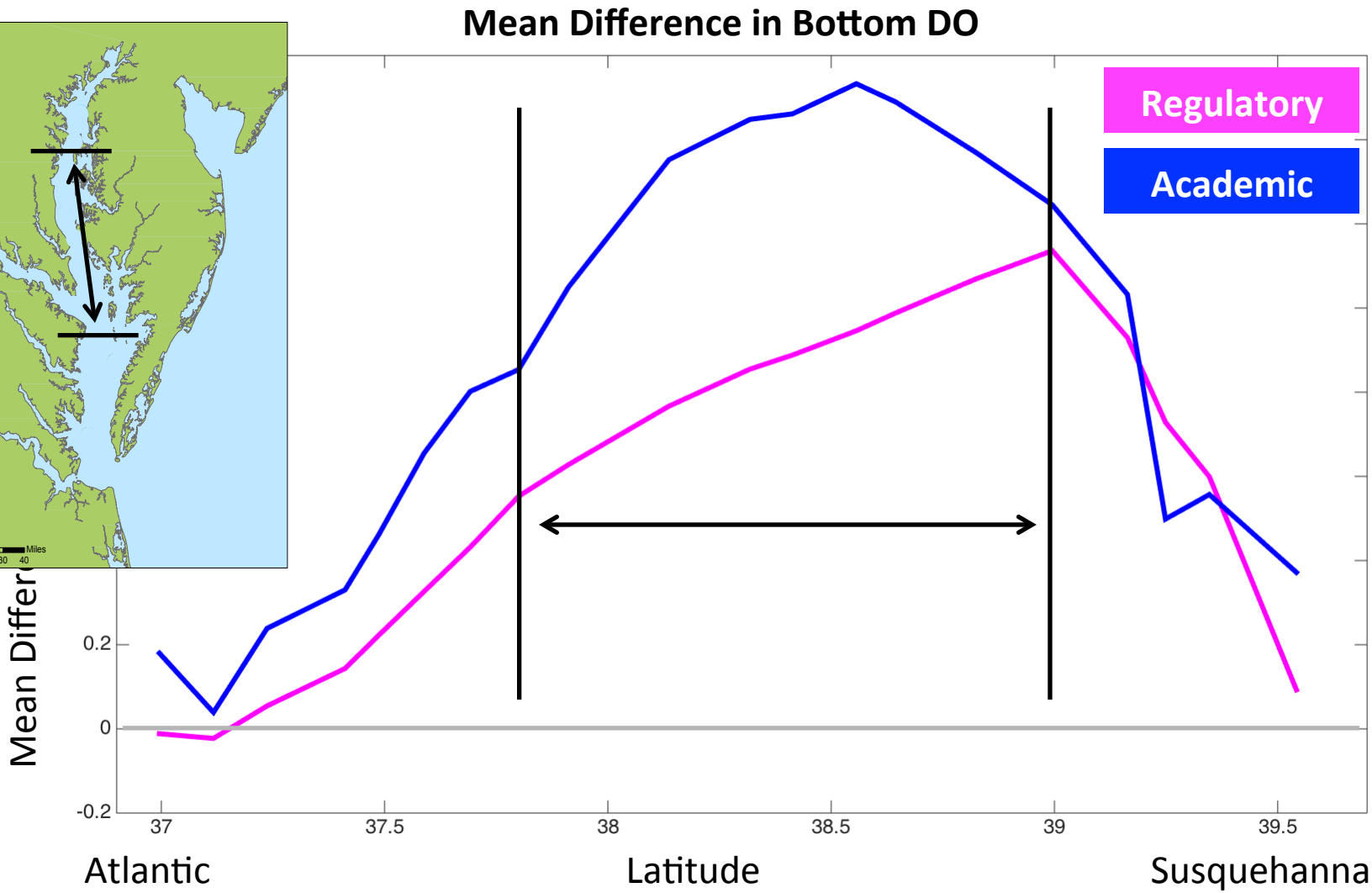


Nutrient Reduction Scenario

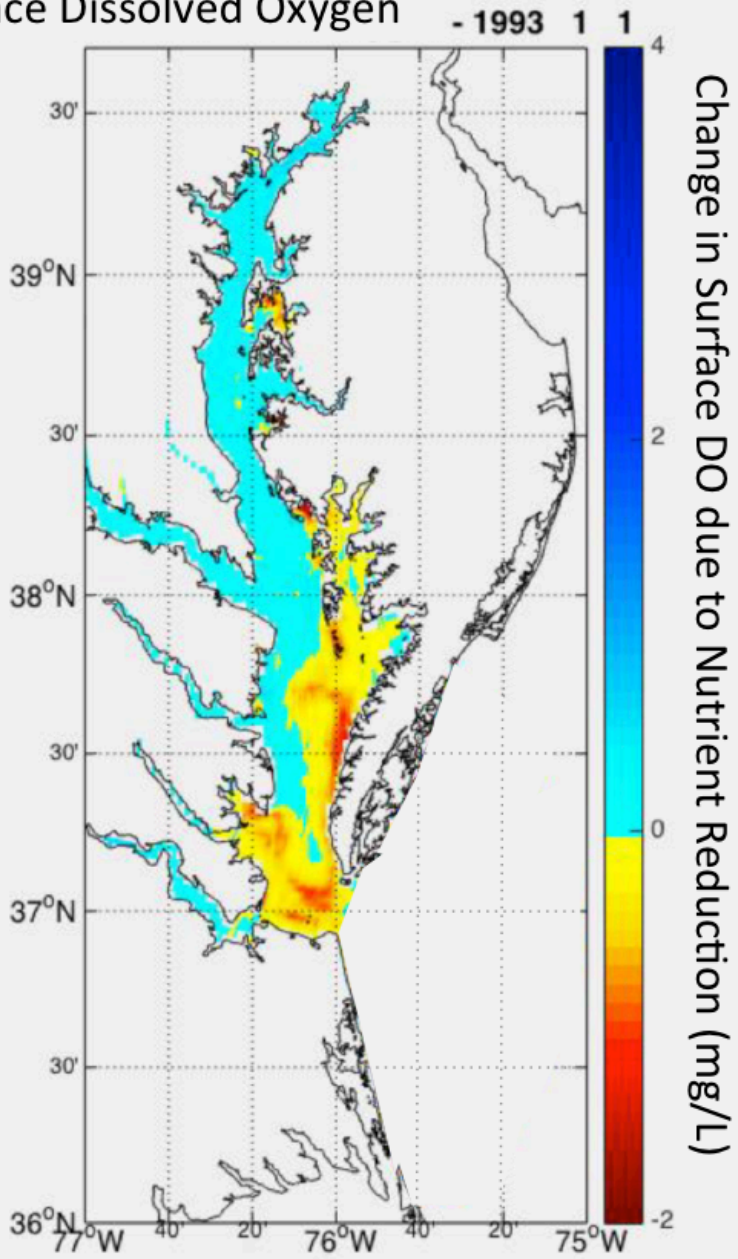


Nutrient Reduction Scenario

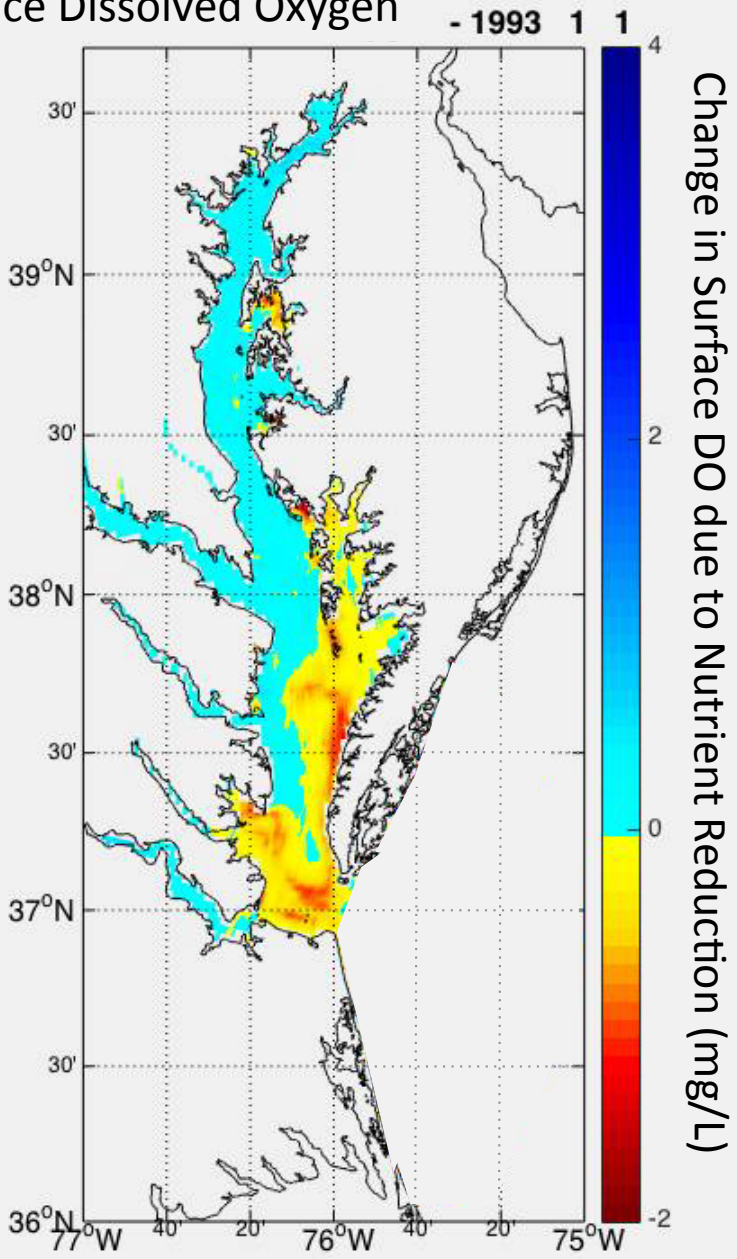




Surface Dissolved Oxygen



Surface Dissolved Oxygen



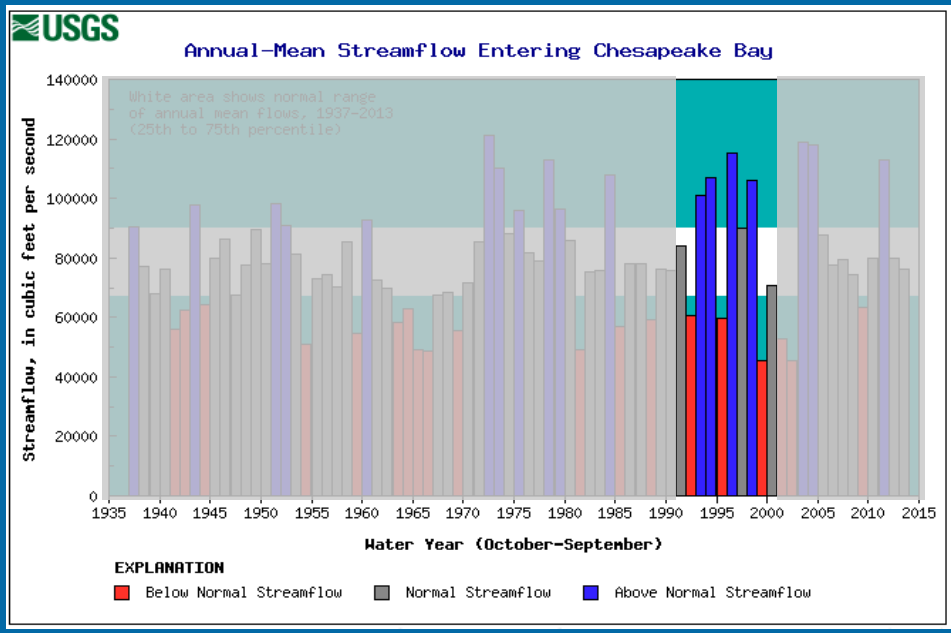
Conclusions

- Both models generally react to nutrient reductions similarly
  - Bottom DO is elevated and low-oxygen conditions are greatly reduced
  - Surface DO is generally decreased

- Academic model tends to be slightly more sensitive to nutrient reductions
  - Particularly in mid-Bay

Future Work

- Apply regulatory water quality standard assessment
  - Compare levels of attainment as a result of nutrient reductions for both models
  - Examine impact of critical period



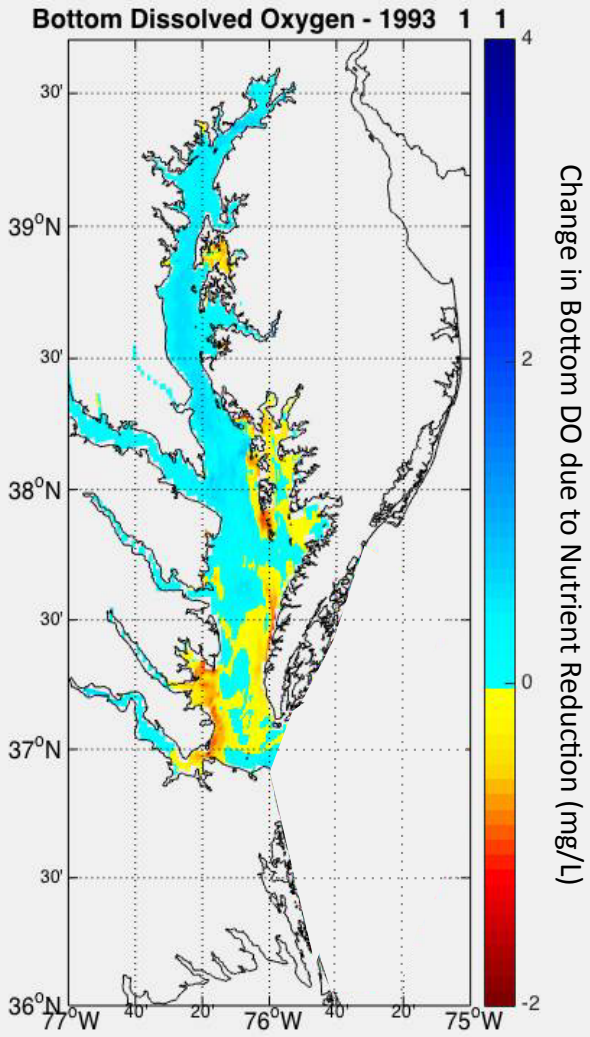
VIMS | William & Mary
Virginia Institute of Marine Science
1940-2015 75 Years

Future Work

- Apply regulatory water quality standard assessment
  - Compare levels of attainment as a result of nutrient reductions for both models
  - Examine impact of critical period

- Assess impact of climate change on efforts to increase water quality via nutrient reductions

Questions?



VIMS | William & Mary
Virginia Institute of Marine Science
1940-2015 75 Years