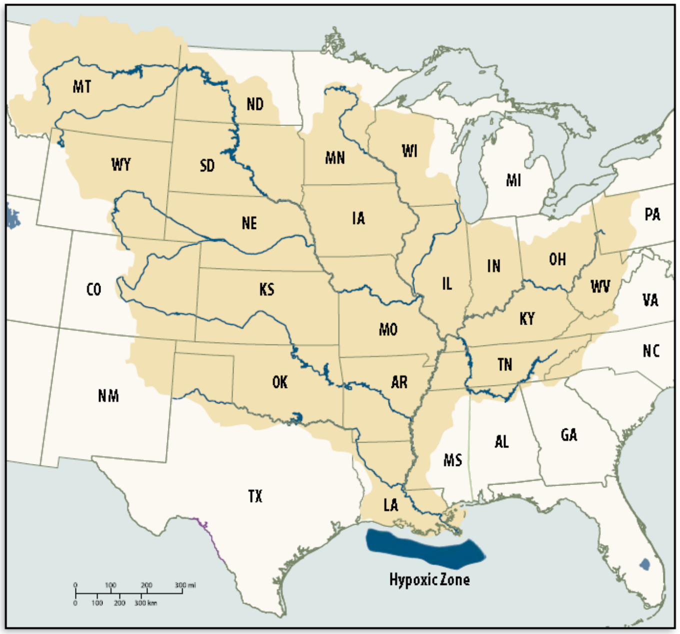
Multi-Media Nutrient and Hypoxia Modeling and Genomics

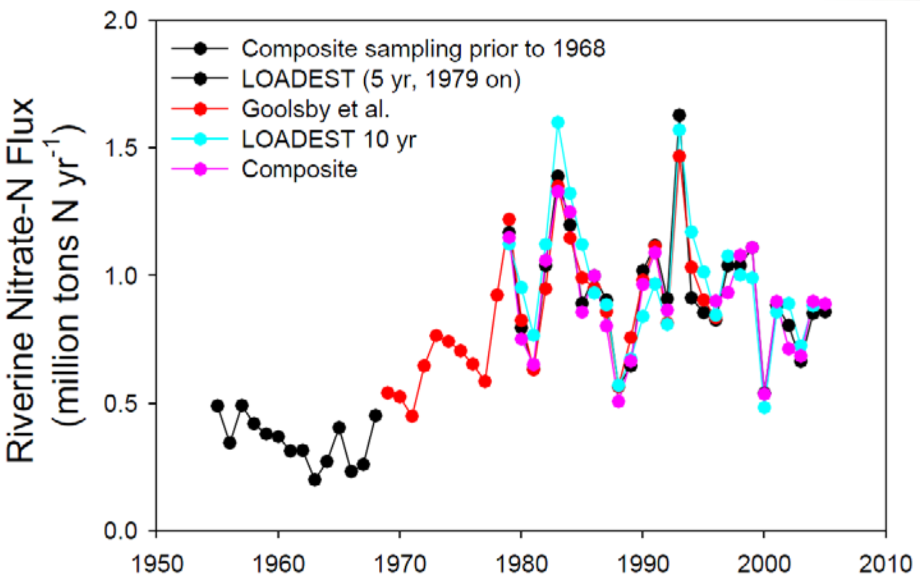
John Lehrter and Jim Hagy
U.S. EPA Gulf Ecology Division

January 21, 2015

The Mississippi River Basin and Hypoxia



http://water.epa.gov/type/watersheds/named/msbasin/upload/hypoxia_reassessment_508.pdf

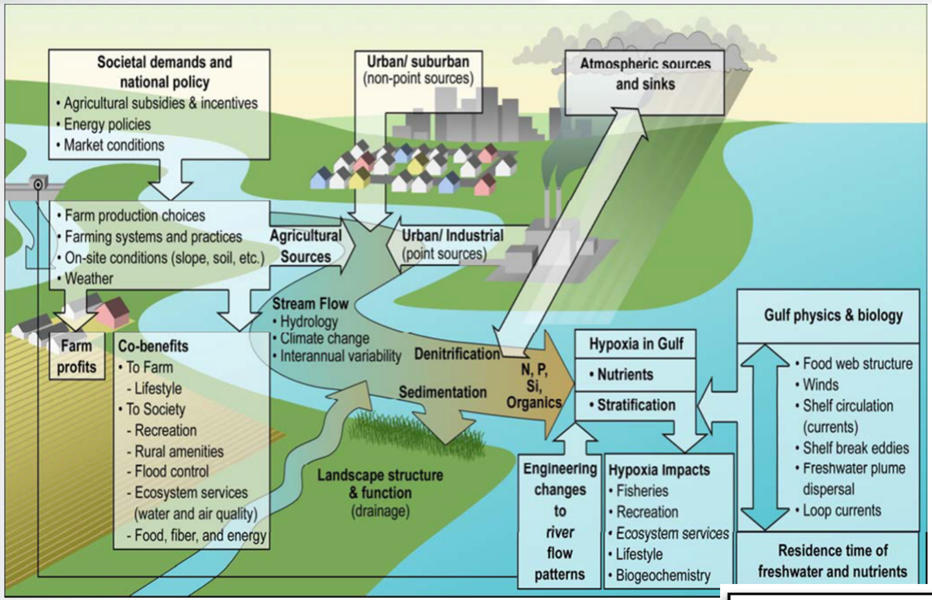


EPA SAB (2008)
http://water.epa.gov/type/watersheds/named/msbasin/upload/2008_1_31_msbasin_sab_report_2007.pdf

- 3rd largest watershed in the world
- 3rd longest river
- 5th largest discharge

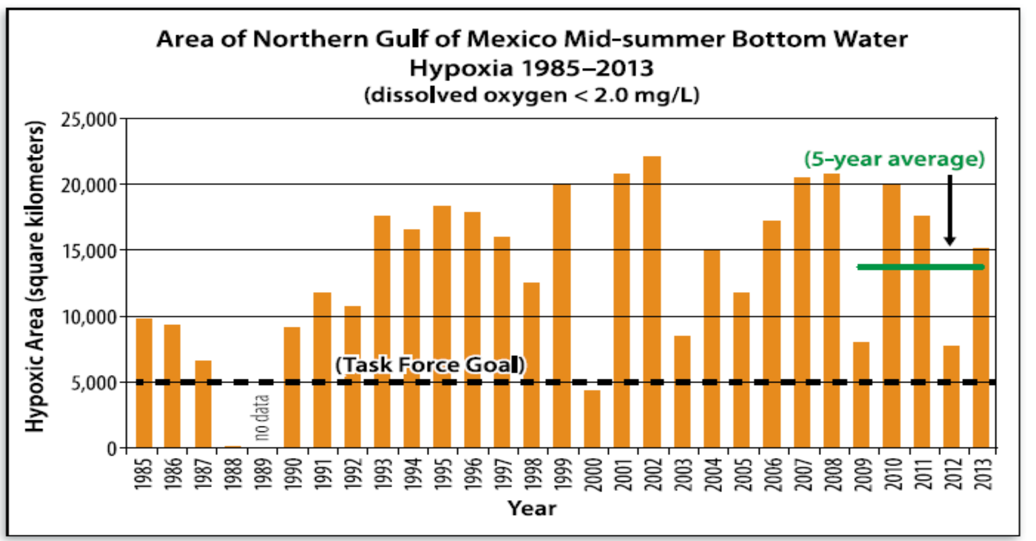
- Nitrogen loads have increased 3-fold from historical levels
- Loads increased 10% during the 2000's (USGS 2014; http://water.usgs.gov/nawqa/pubs/nitrate_trends/)

Modeling Objectives



http://water.epa.gov/type/watersheds/named/msbasin/upload/2008_1_31_msbasin_sab_report_2007.pdf

- Model nutrient sources, transport, fate, and effects
- Predict the load reductions required to achieve the hypoxia goal



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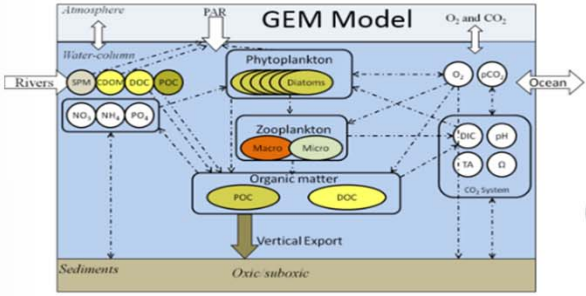
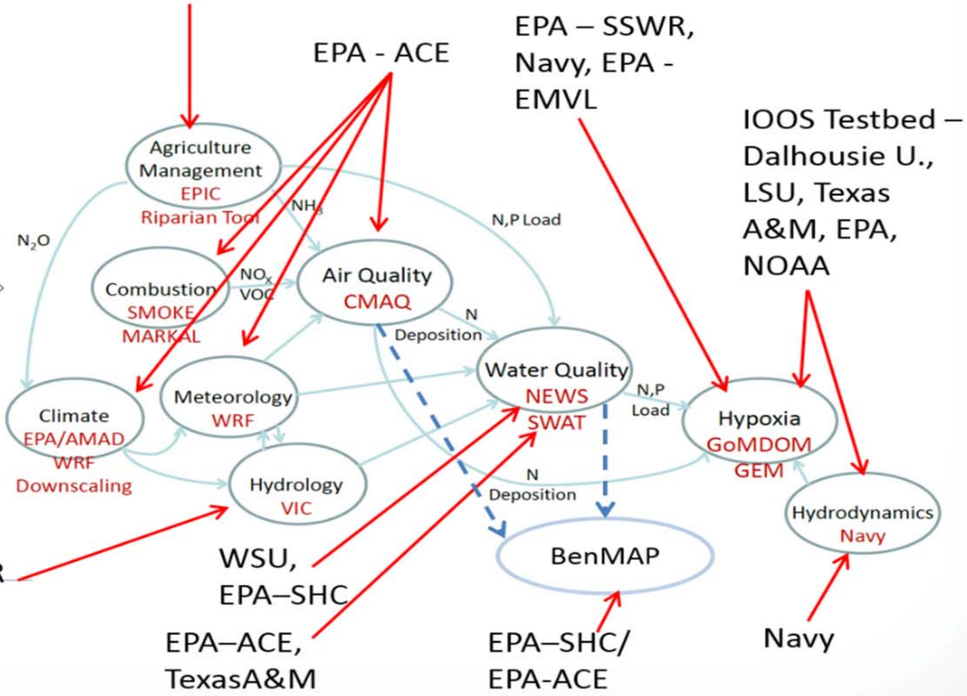
Nutrient Multi-Media Modeling

Mississippi River Basin – Northern Gulf of Mexico



Cross RAP, cross EPA Lab, Multi-agency, Multi-university



EPA-ACE/
EPA –SSWR,
USDA, UofMD

EPA - ACE

EPA – SSWR,
Navy, EPA -
EMVL

IOOS Testbed –
Dalhousie U.,
LSU, Texas
A&M, EPA,
NOAA

Agriculture Management
EPIC
Riparian Tool

N_2O

NH_3

N,P Load

Combustion
SMOKE
MARKAL

NO_x
VOC

Air Quality
CMAQ

N
Deposition

Climate
EPA/AMAD
WRF
Downscaling

Meteorology
WRF

Water Quality
NEWS
SWAT

N,P
Load

Hypoxia
GoMDOM
GEM

Hydrology
VIC

N
Deposition

Hydrodynamics
Navy

BenMAP

EPA – ACE/EPA - SSWR
UW, PNNL

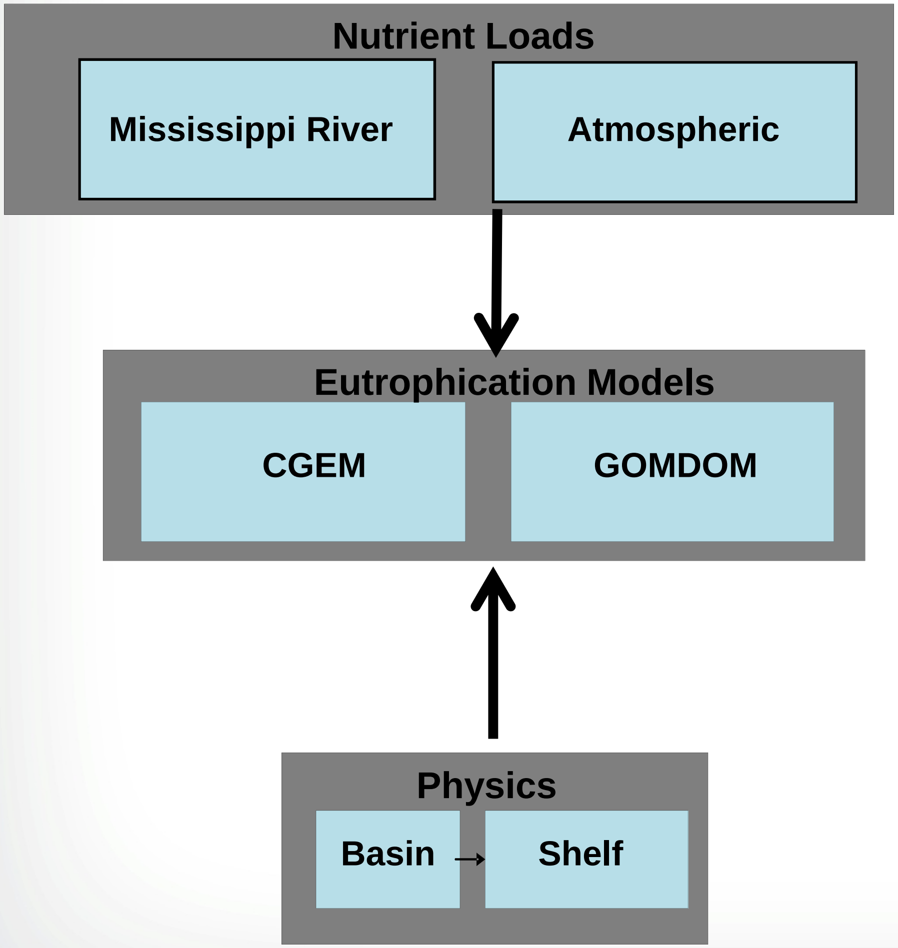
WSU,
EPA–SHC

EPA–ACE,
TexasA&M

EPA–SHC/
EPA-ACE

Navy

Gulf Modeling Scheme



Nutrient Loads

Mississippi River

Atmospheric

Eutrophication Models

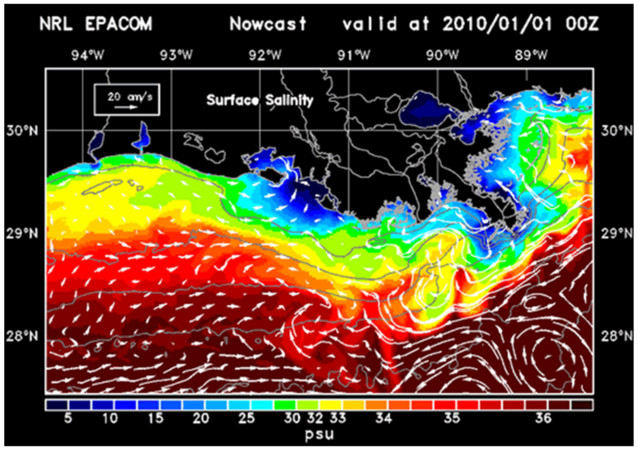
CGEM

GOMDOM

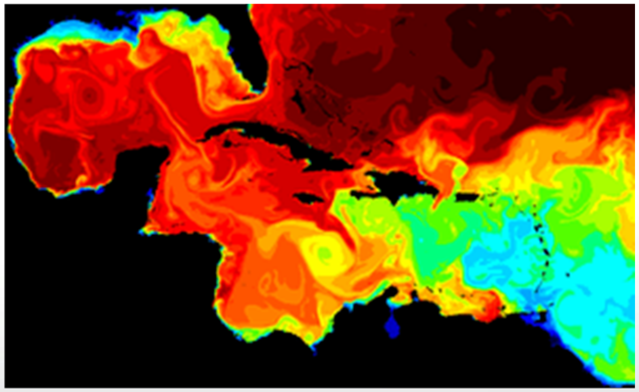
Physics

Basin → **Shelf**

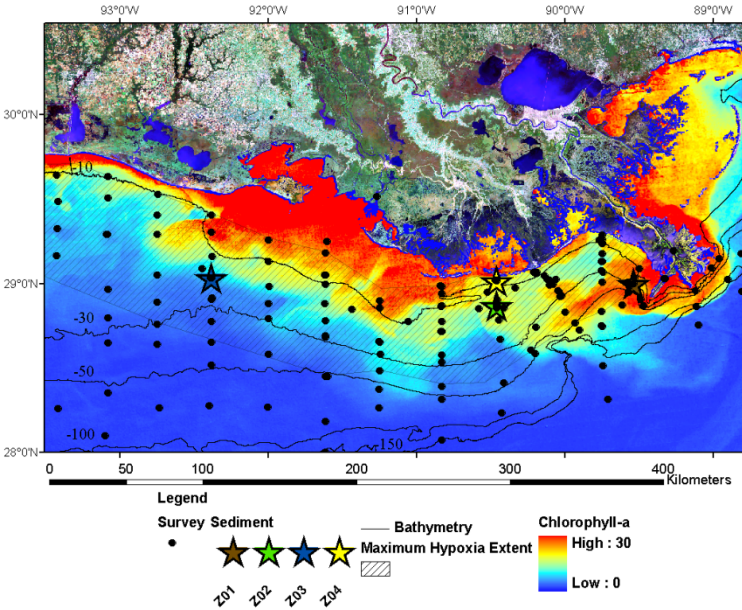
Louisiana Shelf

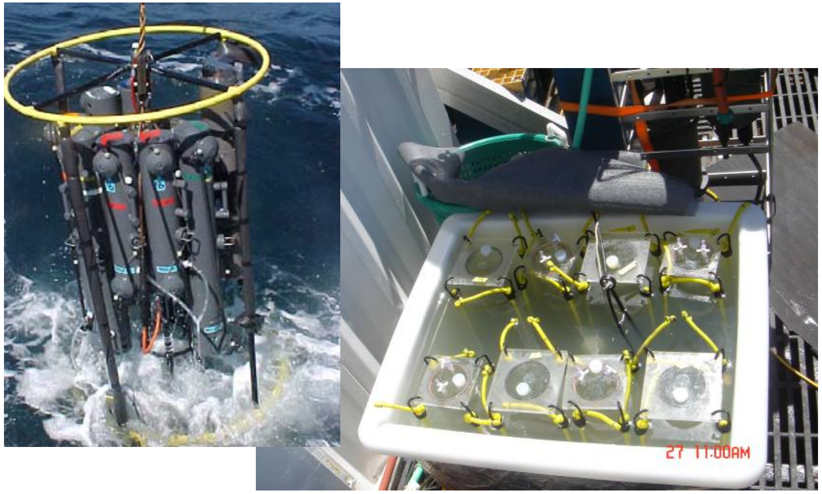


Basin-scale for Boundary Conditions



State Variables and Processes Measured

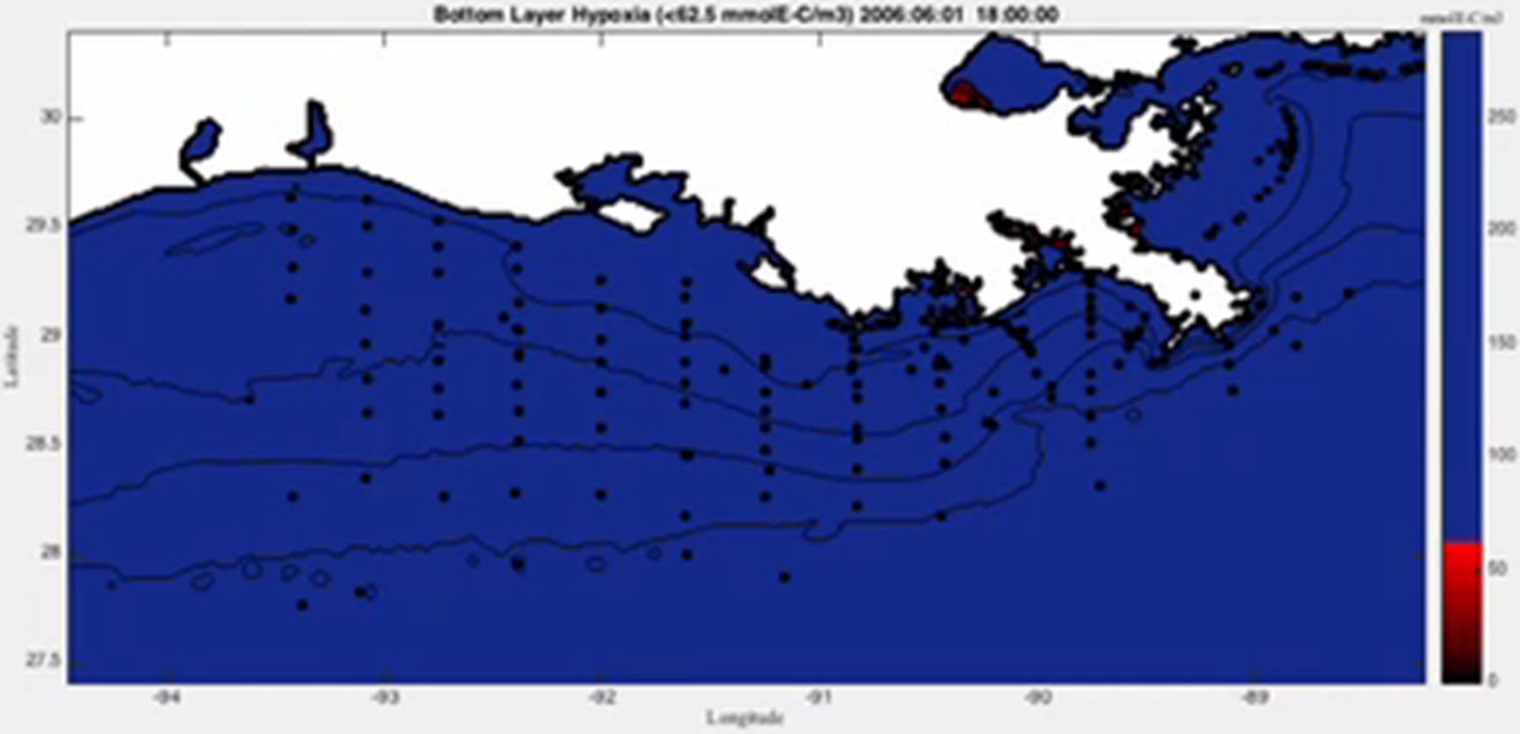




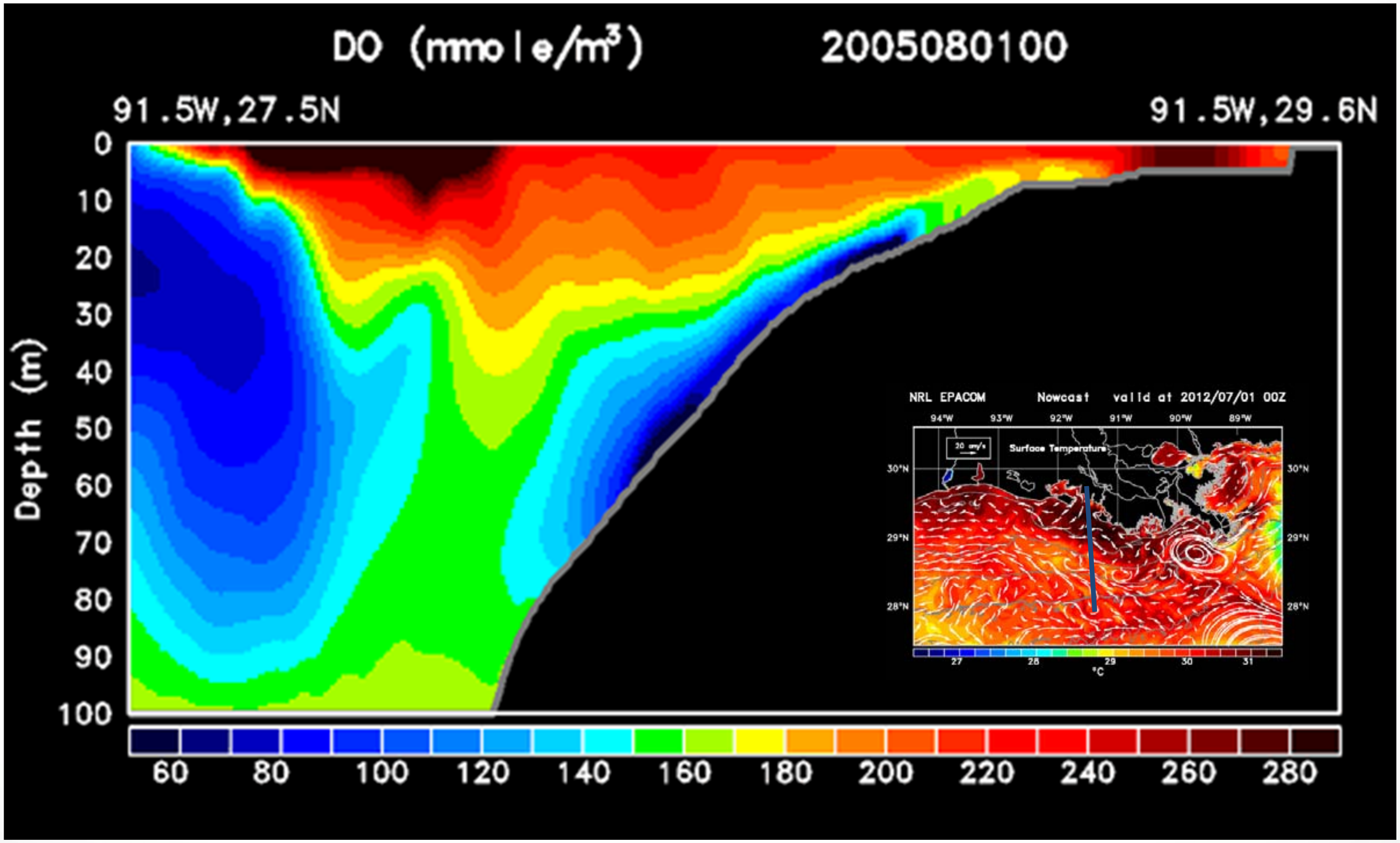
State and Process	Water	Sediment
Dissolved Inorganic – NO_x, PO_4, NH_4, Si	X	
Particulate C, N, P	X	X
Total Dissolved N, P, Total N, P	X	
Dissolved organic carbon	X	
Total Suspended solids	X	
Chlorophyll a	X	X
PAR, Secchi depth, attenuation	X	
Dissolved oxygen	X	
T, S, turbidity, in vivo fluorescence	X	
Phytoplankton species composition	X	
Primary productivity rates	X	
Plankton Respiration rates	X	
Bacterioplankton production rates	X	
O_2, DIC, and nutrient flux rates		X
Denitrification rates		X
Sulfate, Fe, Mn reduction rates		X
Grain size, Bulk density, porosity, % water		X
Pore water Fe, Mn, SO_4, NH_4, DIC, TN, TP		X
Solid phase Fe, C, N, P		X
Stable Isotope $\delta^{13}C$, $\delta^{15}N$		X

Murrell et al. (2014)

CGEM Hypoxia Animation



CGEM Hypoxia Animation

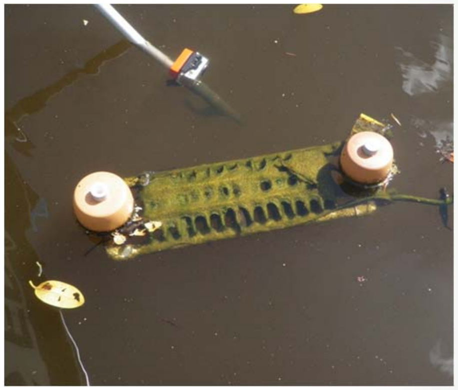


Indicators of Stream Condition Response to Nutrients

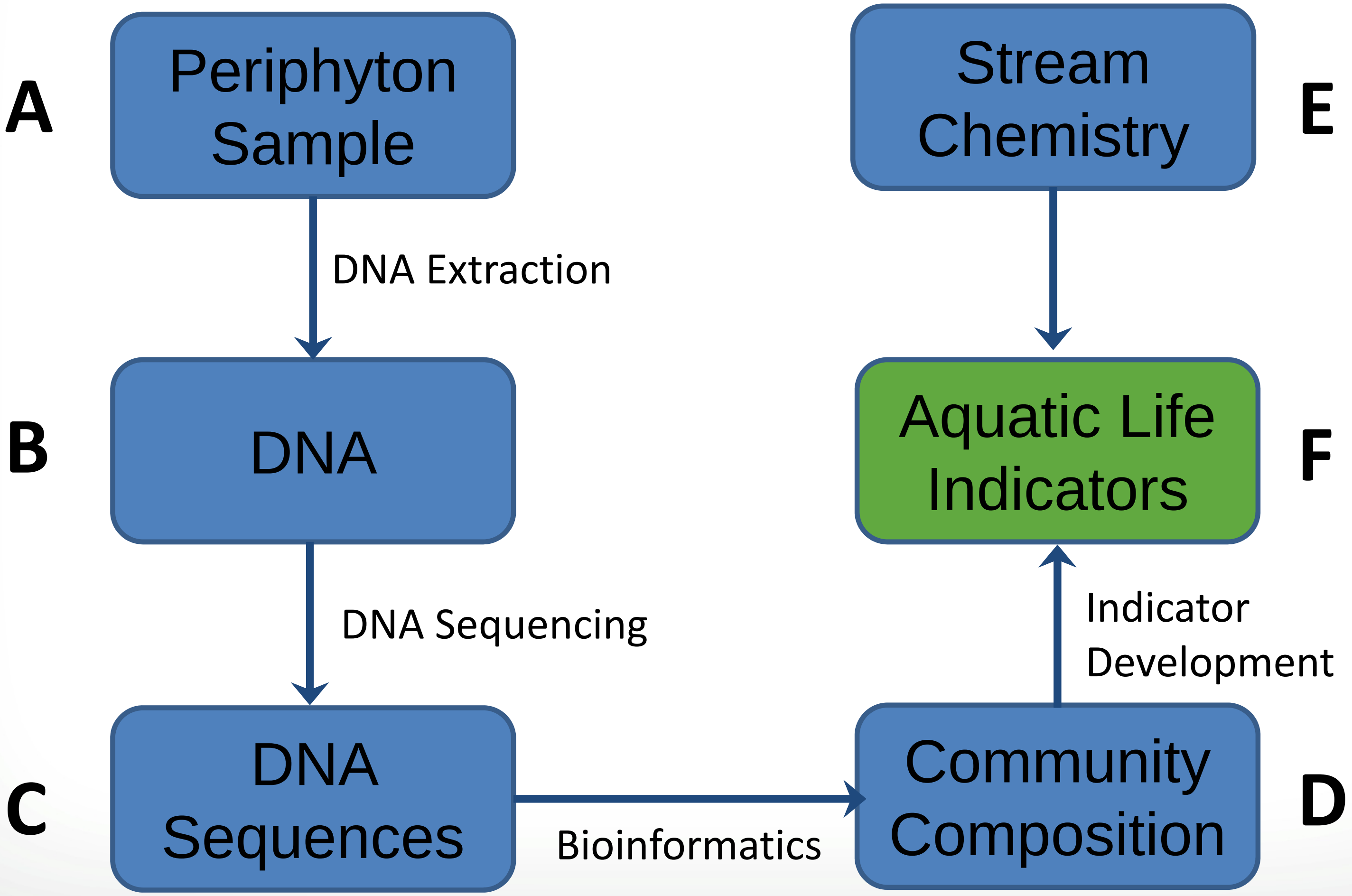
Problem: Quantifying the benefits of stream restoration to reduce nutrients and pathogens is limited by availability of sensitive and stressor-specific indicators of biotic condition.

Approach:

- Monitor nutrients and pathogens in stressed watersheds and in similar restored watersheds
- Deploy periphytometers and evaluate periphyton community using conventional measures combined with a genomics (DNA sequencing) approach.

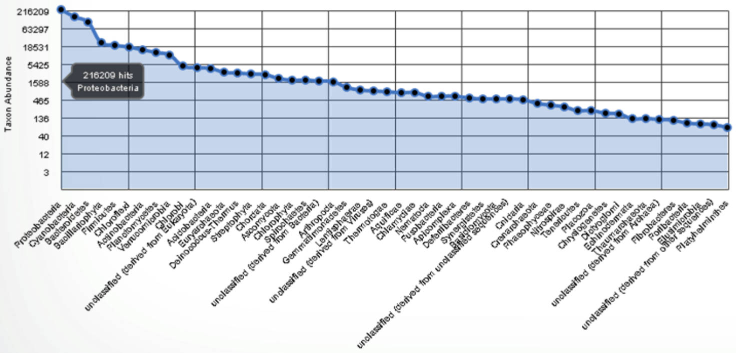


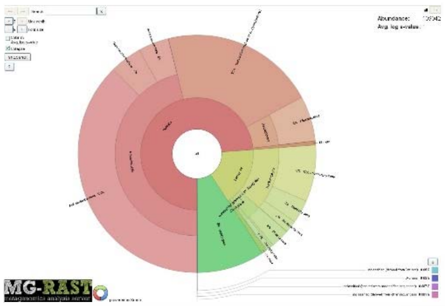
Genomics Approach

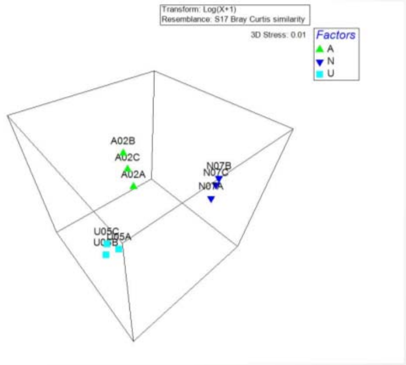


Bioinformatics

- Widespread application of high-throughput gene sequencing creates large and growing scientific resource.
- Online data access and high-performance desktop and/or cloud-based computing enables sophisticated analysis of DNA sequences.
- Result analysis includes high-dimension datasets quantifying algal and microbial community.
- Multivariate analysis of results from pilot study in Tampa Bay shows that differences are highly replicated.

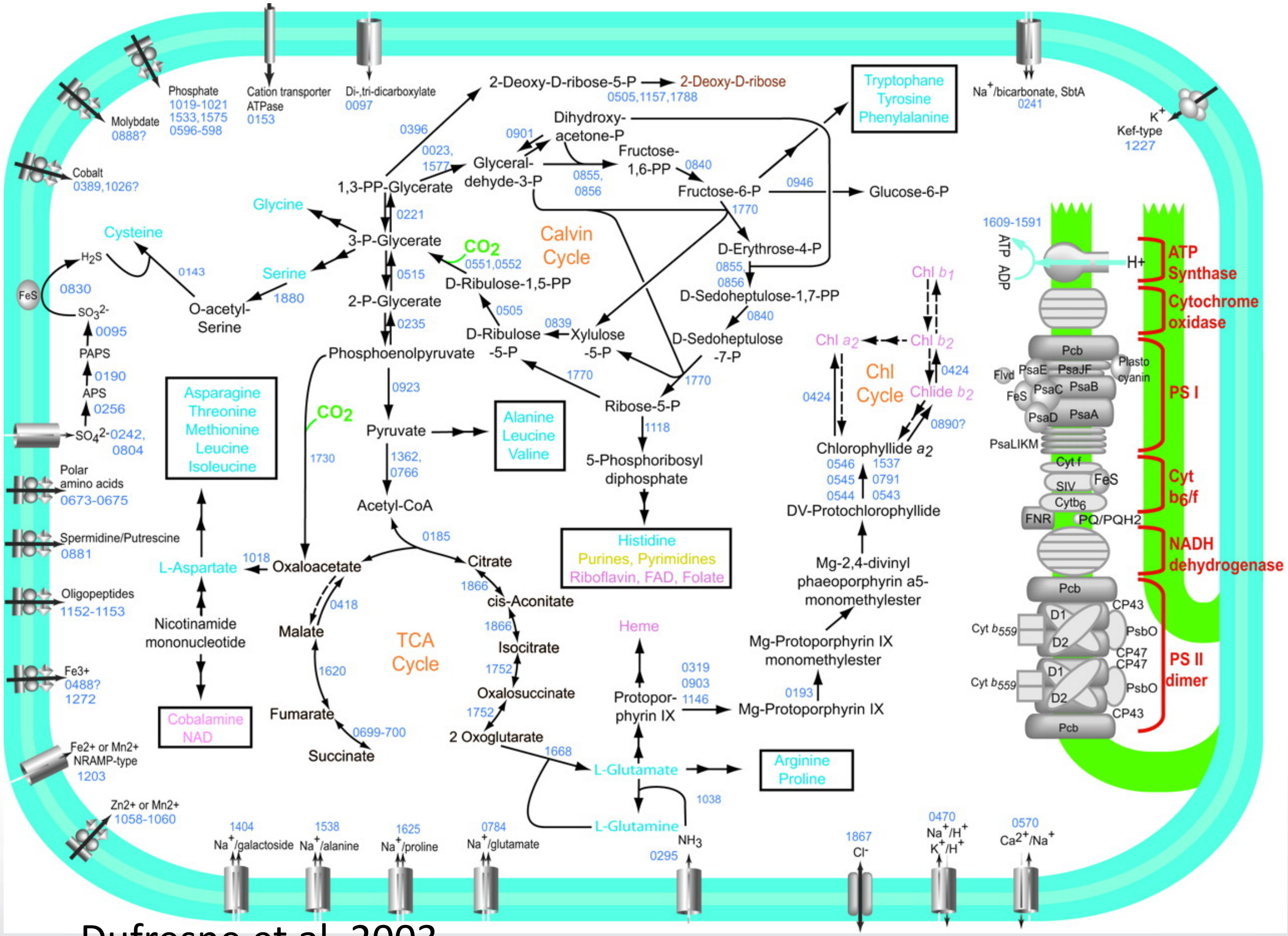






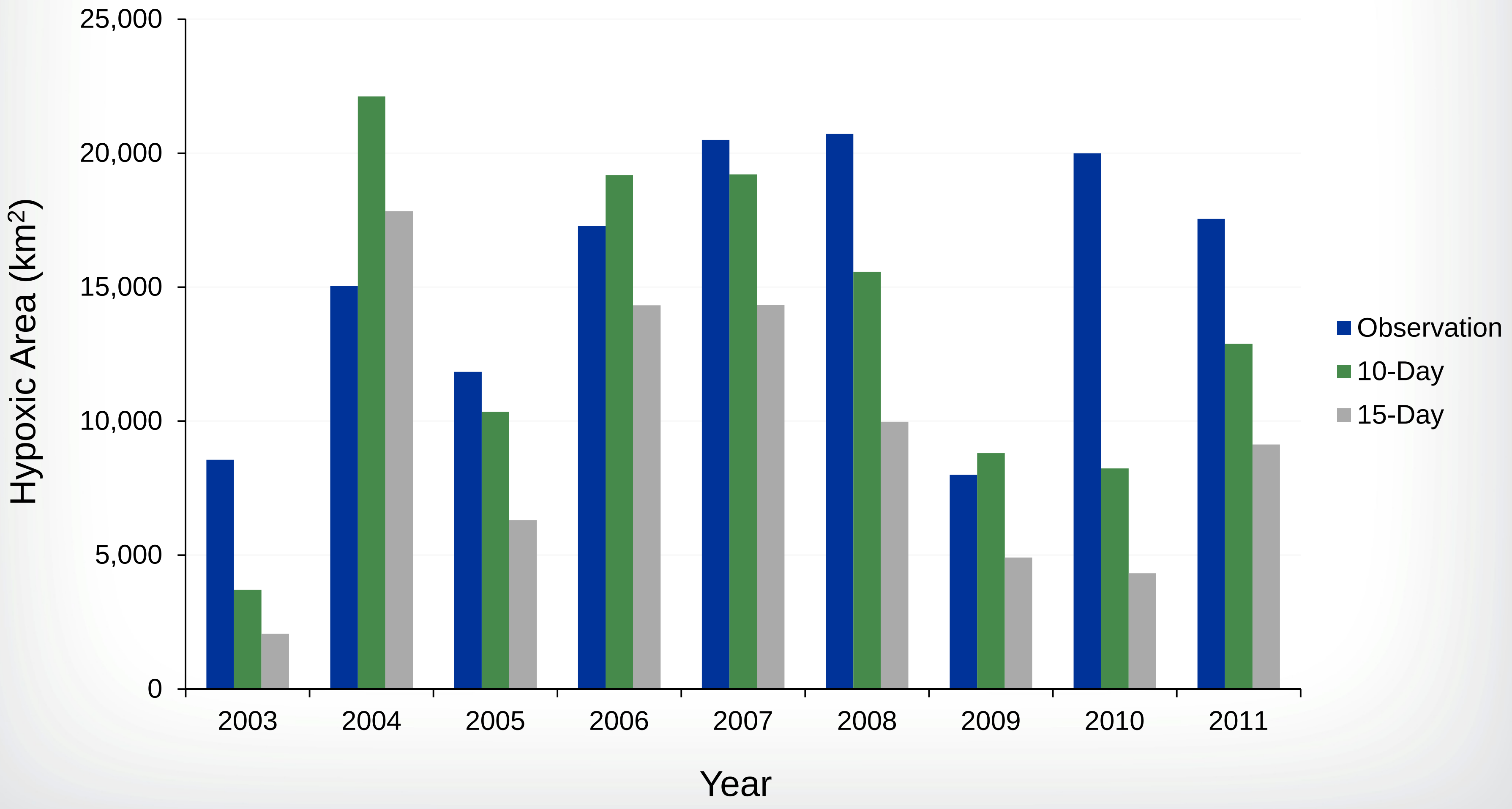
Can we use this information to improve our models?

Genome sequence of the cyanobacterium *Prochlorococcus marinus*



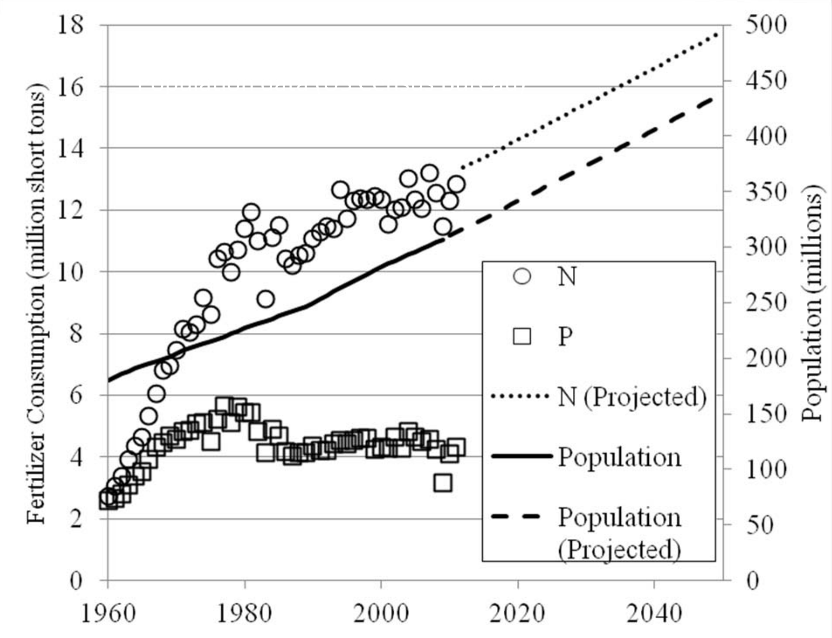
Dufresne et al. 2003

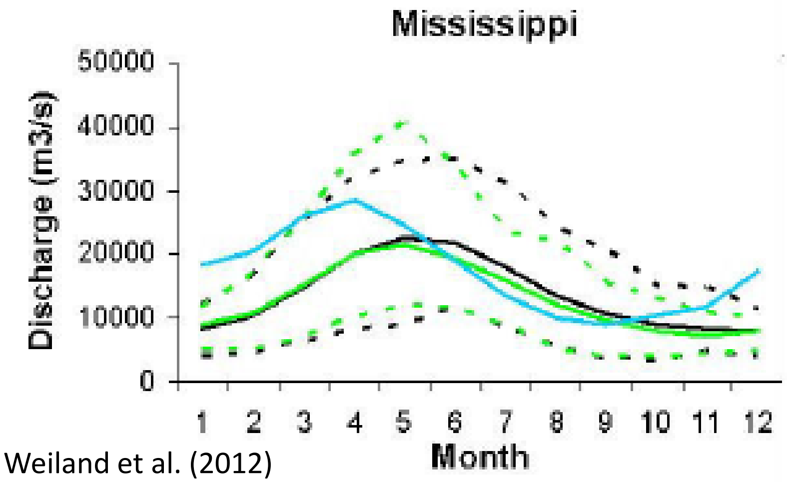
Modeled Versus Observed Hypoxic Area



Modeling Future Scenarios

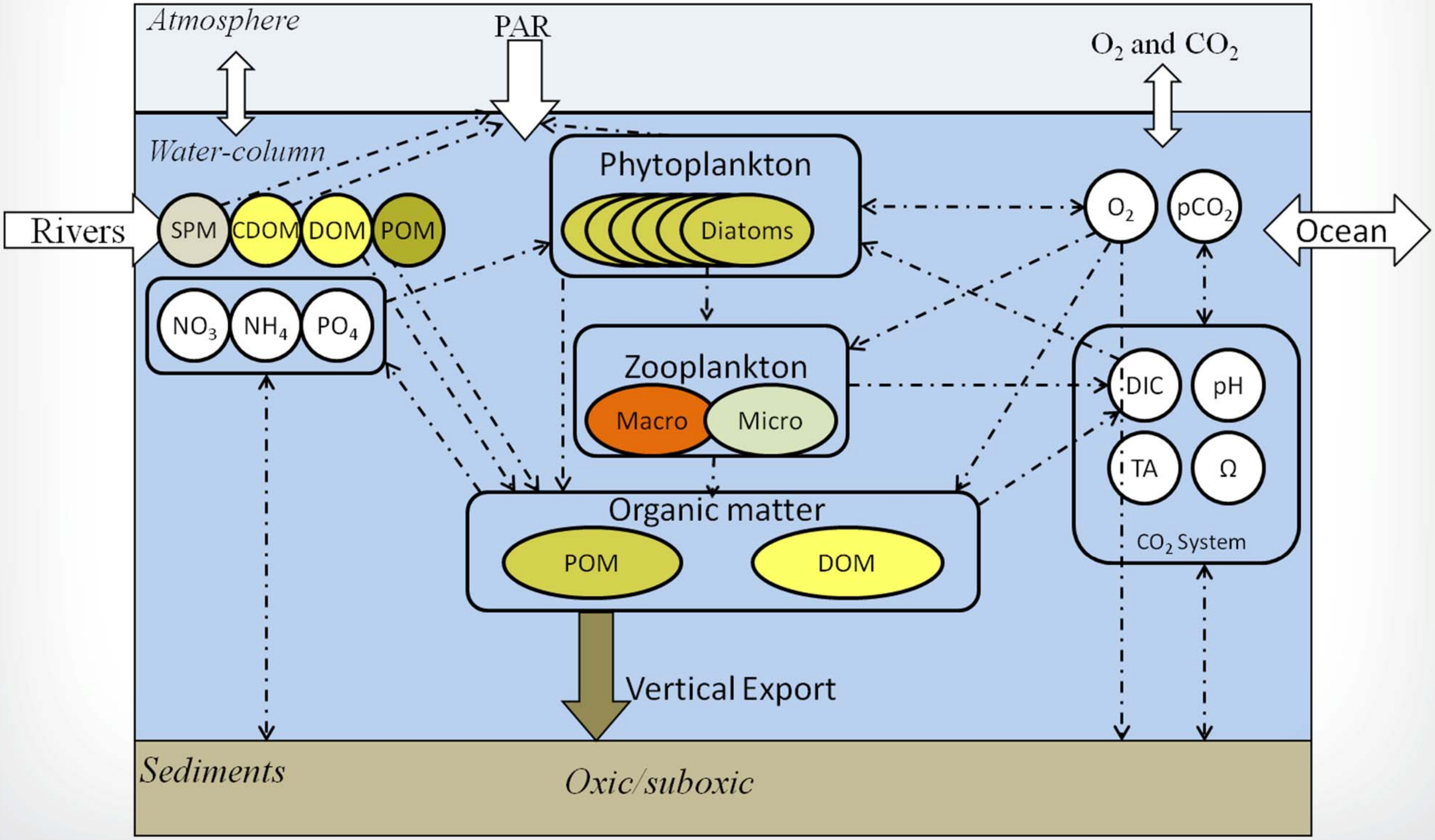
- Nutrient Scenarios
  - Business as usual
  - Nutrient loads to achieve Task Force goal
- Climate Scenarios
  - Increased Air Temp
  - Increased River Discharge
  - Ocean Acidification





Weiland et al. (2012)

Coastal General Ecosystem Model (CGEM)

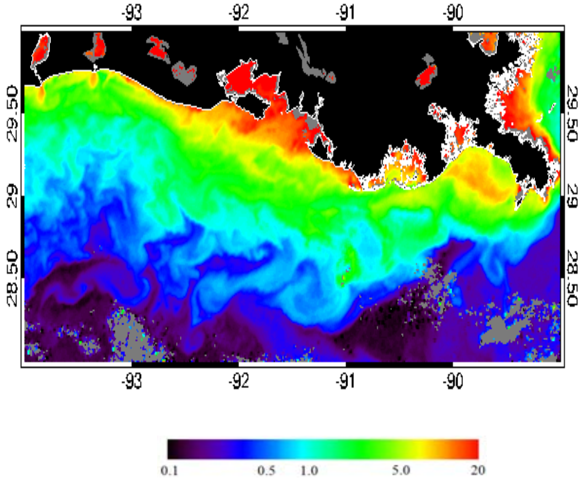


Water Quality Analysis Tool (WQAT)

Problem: Water quality decision-making could be improved with ready access to the 30-year satellite data time-series for lakes, reservoirs, and coastal systems

Approach:

- Developed WQAT for <u>simplified</u> access to remote sensing imagery of indicators of nutrient pollution
    - For example, EPA's satellite remote sensing methodology for the Florida nutrient criteria rulemaking could be reproduced with WQAT
- Targeted as a niche tool for water quality management of nutrient pollution, water clarity, and suspended sediments



Chlorophyll-a (μg/l)

Satellite retrieved phytoplankton biomass (chlorophyll-a) for the Louisiana shelf in the area affected by the Mississippi River

***Impact**:* WQAT is being evaluated as a nutrient management tool by our partners in the Office of Water, Office of Science and Technology. Pilot efforts are underway to demonstrate the tool at the state level (SC and OR) and nationally using NARS data.