Developing nitrogen budgets using an Integrated Biophysical Model to investigate current and future phytoplankton dynamics in a rapidly changing subtropical estuary, Barataria Basin

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Abstract

Louisiana is undergoing rapid change from natural and anthropogenic forces, such as sea level rise, subsidence, and eutrophication. Sediment diversions on the lower Mississippi River are proposed as a large-scale restoration strategy to create new wetlands and sustain existing wetland areas in Barataria Basin, Louisiana. This will introduce a large volume of sediment and nutrient rich freshwater from the Mississippi River to the receiving basins. This will result in, at least, short term changes in light and nutrient dynamics and has potential to alter phytoplankton composition. In order to understand nitrogen dynamics in Barataria Basin due to large scale coastal restoration practices, the nitrogen budgets (including particulate and dissolved forms) were calculated from outputs of the Integrated Biophysical Model, which is based on the existing Delft3D model coupled with a water quality model (D-WAQ). Creating nitrogen budgets in estuarine systems allows for better understanding of the major sources, sinks, inputs and exports across the system, increasing understanding of the amount of nitrogen available to drive estuarine primary production. Quantification of nitrogen inputs, outputs and processes is essential because it is the limiting nutrient for most estuarine primary producers (e.g., phytoplankton and emergent macrophytes). Preliminary model results for the existing conditions suggest that the dissolved inorganic nitrogen in the estuarine waters is mainly derived from diffusional sediment fluxes and mineralization of particulate organic nitrogen. Most of the dissolved inorganic nitrogen was assimilated for phytoplankton growth. A relatively small portion of dissolved inorganic nitrogen was removed from the system through denitrification in the water column. More particulate organic nitrogen originated from emergent macrophytes than from phytoplankton primary production. These model results will help better understand how proposed sediment diversions on the lower Mississippi River may change the future ecological conditions of estuarine open water in coastal Louisiana.

DEVELOPING NITROGEN BUDGETS USING AN INTEGRATED BIOPHYSICAL MODEL TO INVESTIGATE CURRENT AND FUTURE PHYTOPLANKTON DYNAMICS IN A RAPIDLY CHANGING SUBTROPICAL ESTUARY, BARATARIA BASIN (GC23H-1305)

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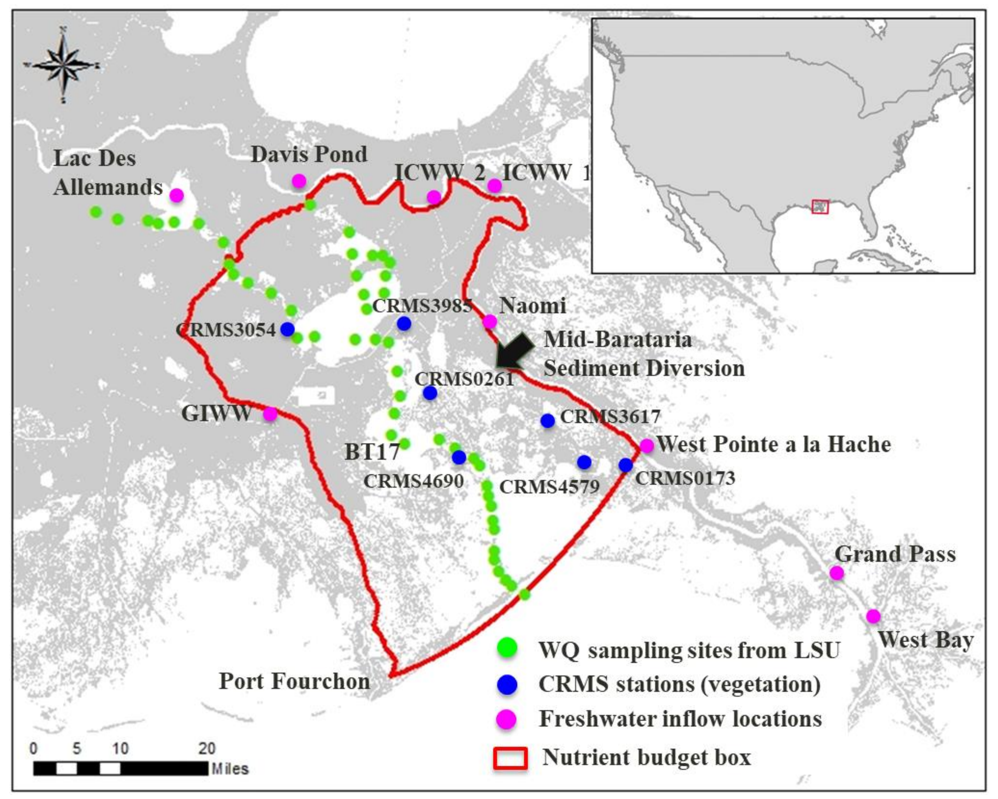
Background



Location of study area in the Barataria Basin, LA.

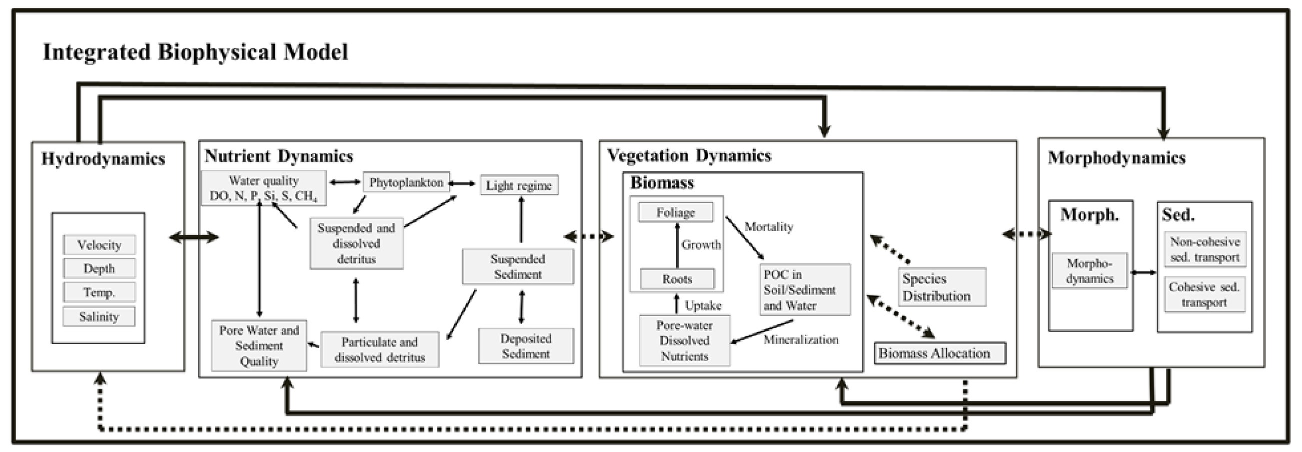
- Sediment diversions on the lower Mississippi River are proposed as a large-scale restoration strategy to create new wetlands and sustain existing wetland areas in Barataria and Breton Sound basins, Louisiana.
- Introduction of significant amount of nutrient-rich freshwater along with sediment to the receiving basins will likely drive changes in light and nutrient dynamics as well as phytoplankton composition, resulting in ecosystem-level changes.
- In order to understand nitrogen dynamics in the Barataria Basin due to large scale coastal restoration practices, quantification of nitrogen inputs, outputs and processes is essential because it is the limiting nutrient for most estuarine primary producers (e.g., phytoplankton and emergent macrophytes).
- Creating nitrogen budgets in the system will allow for better understanding of the major sources, sinks, inputs and exports across the system, increasing understanding of the amount of nitrogen available to drive estuarine primary production.

Objectives

- Develop a water quality model using an Integrated Biophysical Model
- Develop a nitrogen budget for Barataria Basin and quantify nitrogen inputs, outputs and processes
- Investigate potential impacts on nitrogen and phytoplankton dynamics due to the large-scale restoration project (proposed sediment diversion)

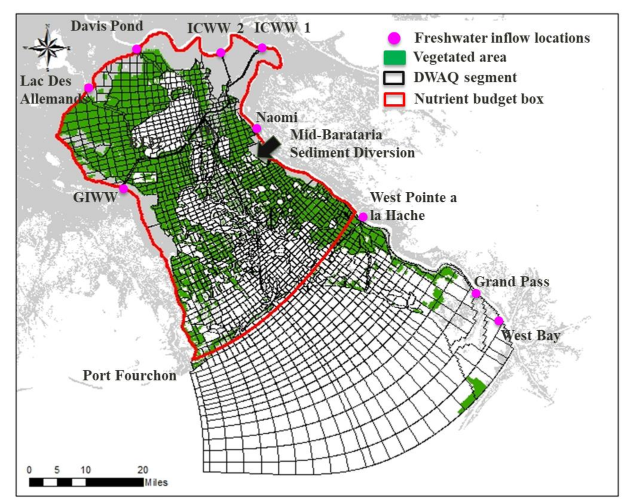
Methods

Integrated Biophysical Model



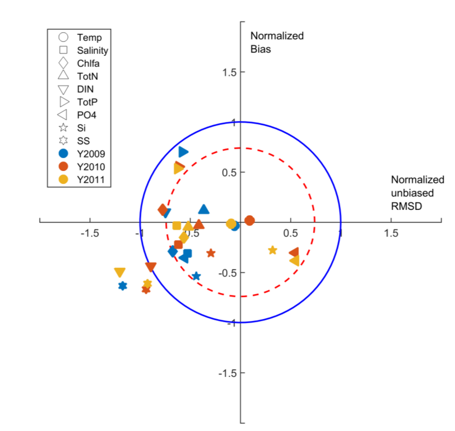
Conceptual overview of the Integrated Biophysical Model that includes the feedbacks between components (Baustian et al., 2018)

- Water quality variables
  - TOC, POC, DOC, PON, DON, NH4, NO3, POP, DOP, PO4, Si, Silt, Clay, Sand, DO
- Seven sediment/soil layers
- 8 Phytoplankton groups
  - Freshwater Diatoms, Freshwater Flagellates, Green Algae, *Microcystis*, *Anabaena*
  - Marine Diatoms, Marine Flagellates, Dinoflagellates
- Seven vegetation taxa
  - **Saline:** *Spartina alterniflora*
  - **Brackish:** *Spartina patens*
  - **Intermediate:** *Sagittaria lancifolia*, *Phragmites* spp., *Typha* spp.
  - **Fresh:** *Sagittaria latifolia*, *Zizaniopsis miliacea*

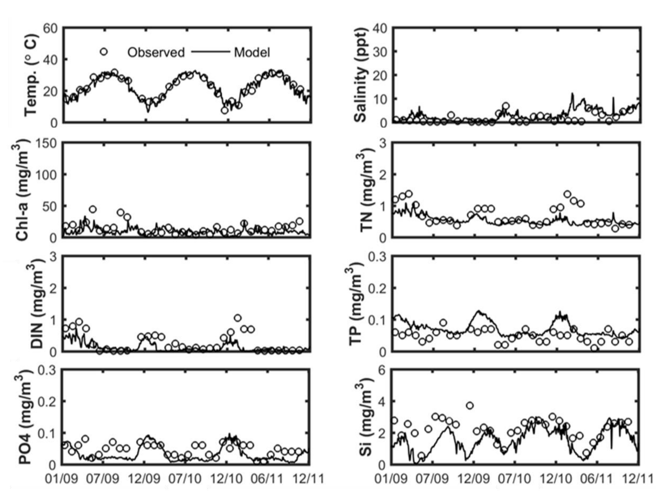


D-WAQ model segments and vegetated area

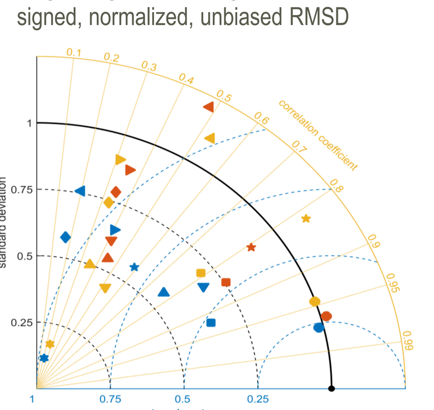
Model Calibration and Validation



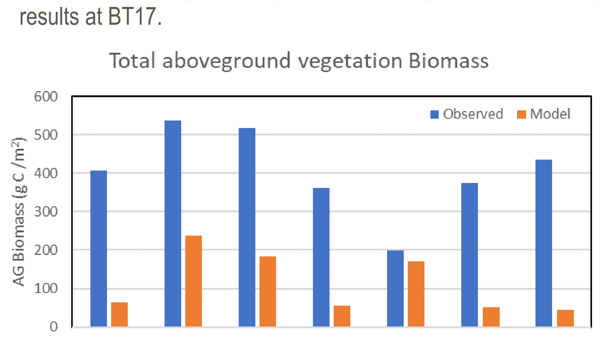
Target diagram, showing normalized bias and signed, normalized, unbiased RMSD



Model calibration (year 2009) and validation (year 2010 to 2011) results at BT17.



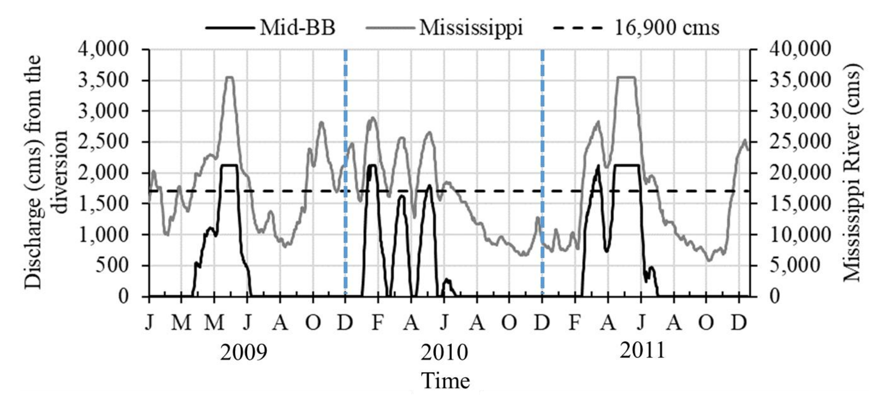
Taylor diagrams, showing standard deviation, correlation coefficient, and centered RMSD



Aboveground vegetation biomass comparison at CRMS stations

Results

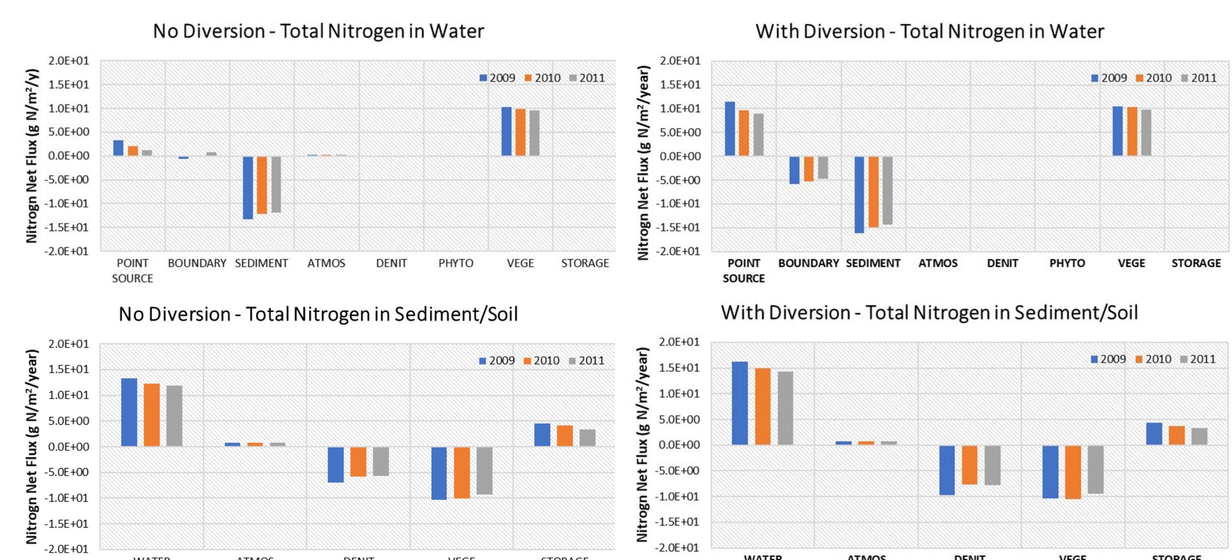
Operation Plan of Mid-Barataria Sediment Diversion

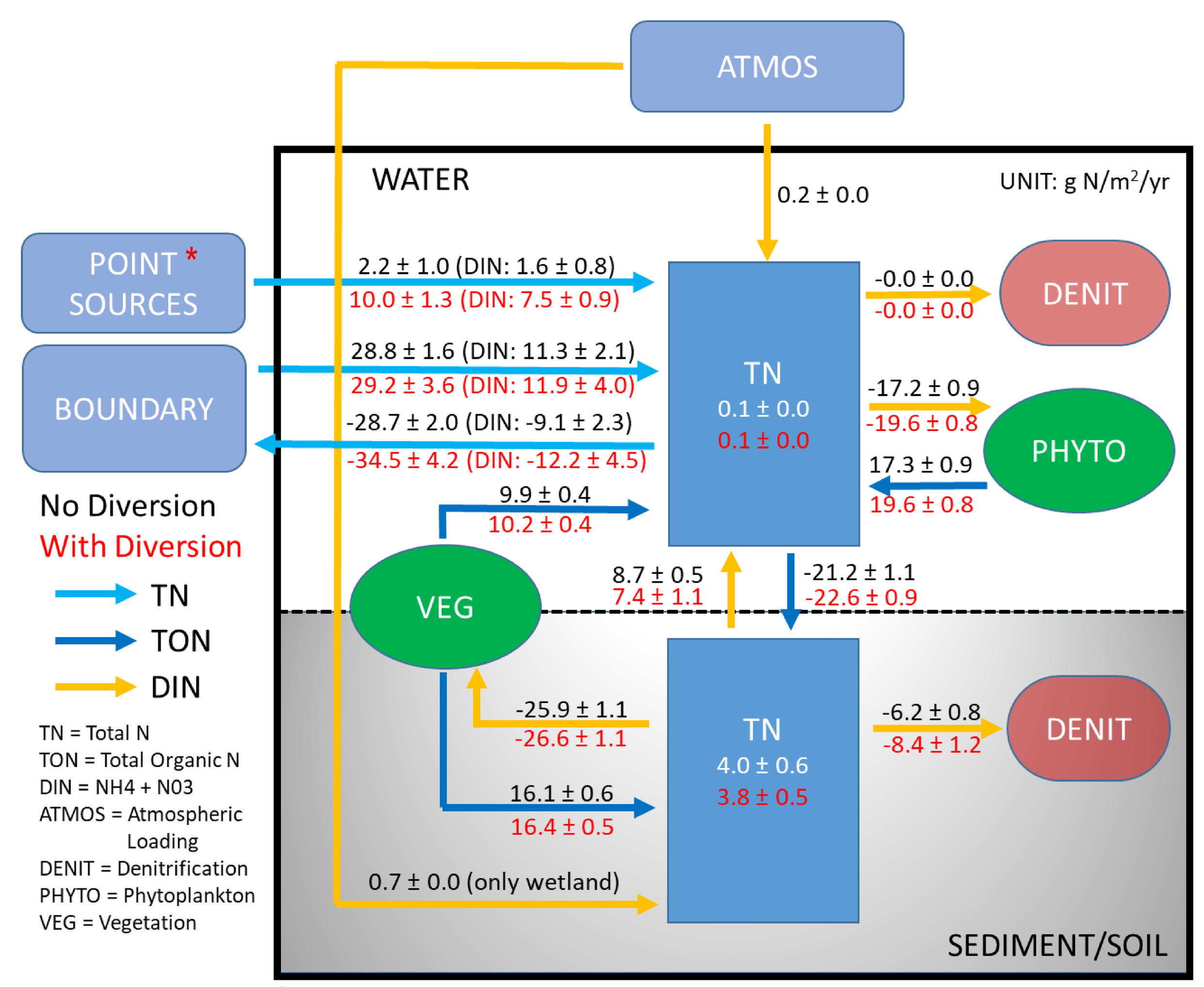


Flow conditions of the Mississippi River and proposed Mid-Barataria Sediment Diversion

The diversion diverts freshwater to a maximum capacity 2,123 cms (= 75,000 cfs) when the Mississippi River discharge is more than 16,900 cms (= 600,000 cfs) between February and August 2009, 2010, 2011 related to nitrogen budget figures below.

Nitrogen Budget



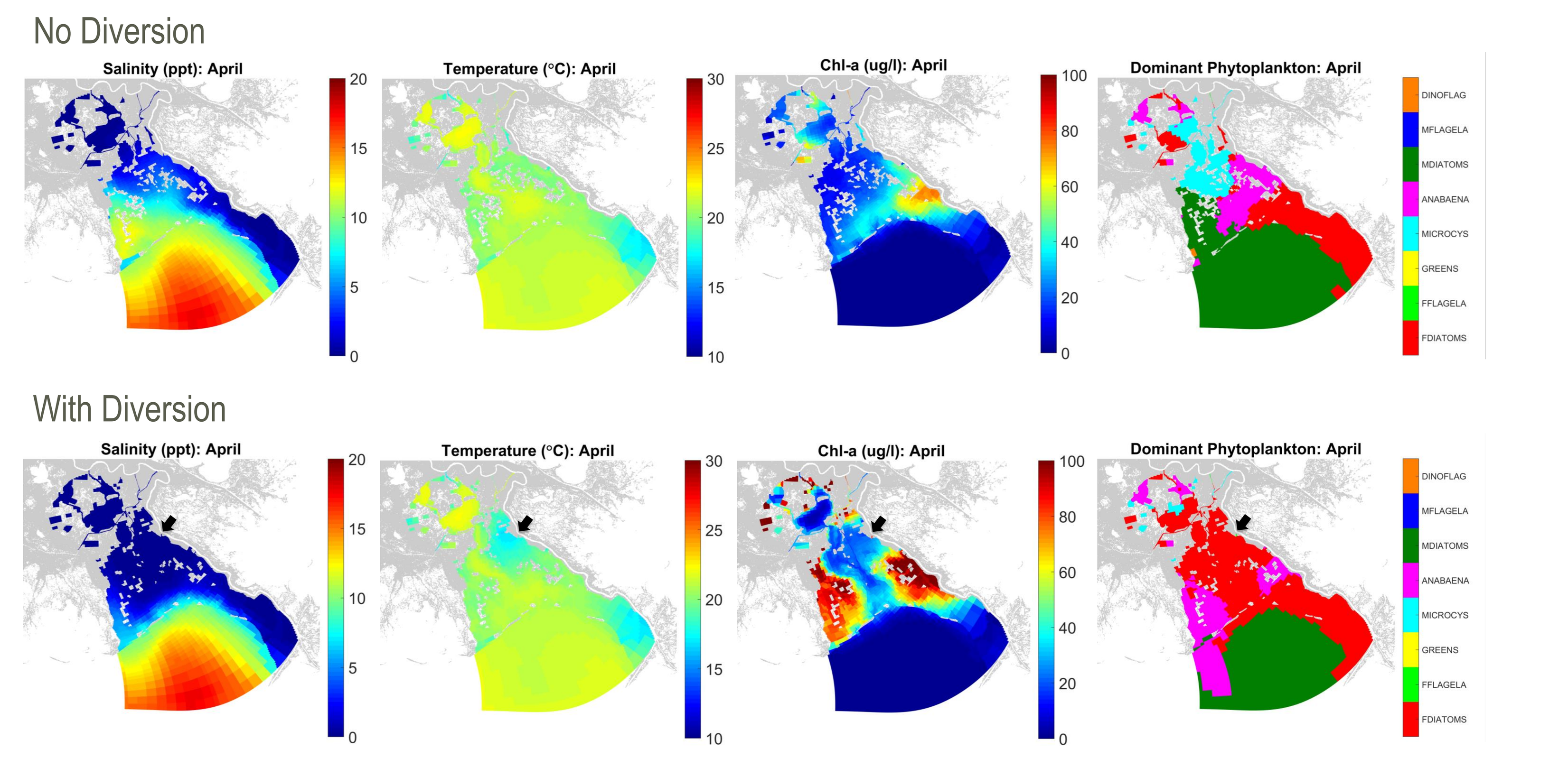


* Point sources including the proposed diversion

Coastal Changes and Phytoplankton Response

No Diversion

With Diversion



Conclusions

Introduction of freshwater into the Barataria Basin

- In case of "No Diversion"
  - Major source of DIN was the bottom sediment flux
  - Phytoplankton and wetland vegetation is a major consumer of DIN in water column and sediment/soil, respectively
  - In sediment/soil, settling of TON was major source of nitrogen
- In case of "With Diversion"
  - The operation of the diversion was one of major sources of DIN.
  - Increase in TON supply from vegetation might be related to increase in inundation mortality
  - Diversion operation increased the flushing rate of the system and thus increased TN export rate through the boundary
- Changes in Phytoplankton Dynamics
  - Dominant phytoplankton taxa in April changed from cyanobacteria of Anabaena and Microcystis to more freshwater diatoms in the mid and upper basin due to input of cold freshwater and silicate from the Mississippi River when proposed sediment diversion is operating.

Acknowledgements

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