GEM3D: Model Verification and Uncertainties

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Overview

- Guidelines from the Modeling Technical Review Panel
  - Key assumptions
  - Model inputs and outputs
  - Model scalability
  - Verification
  - Model application: N and P nutrient budgets
  - Uncertainties
  - Timeline for completion

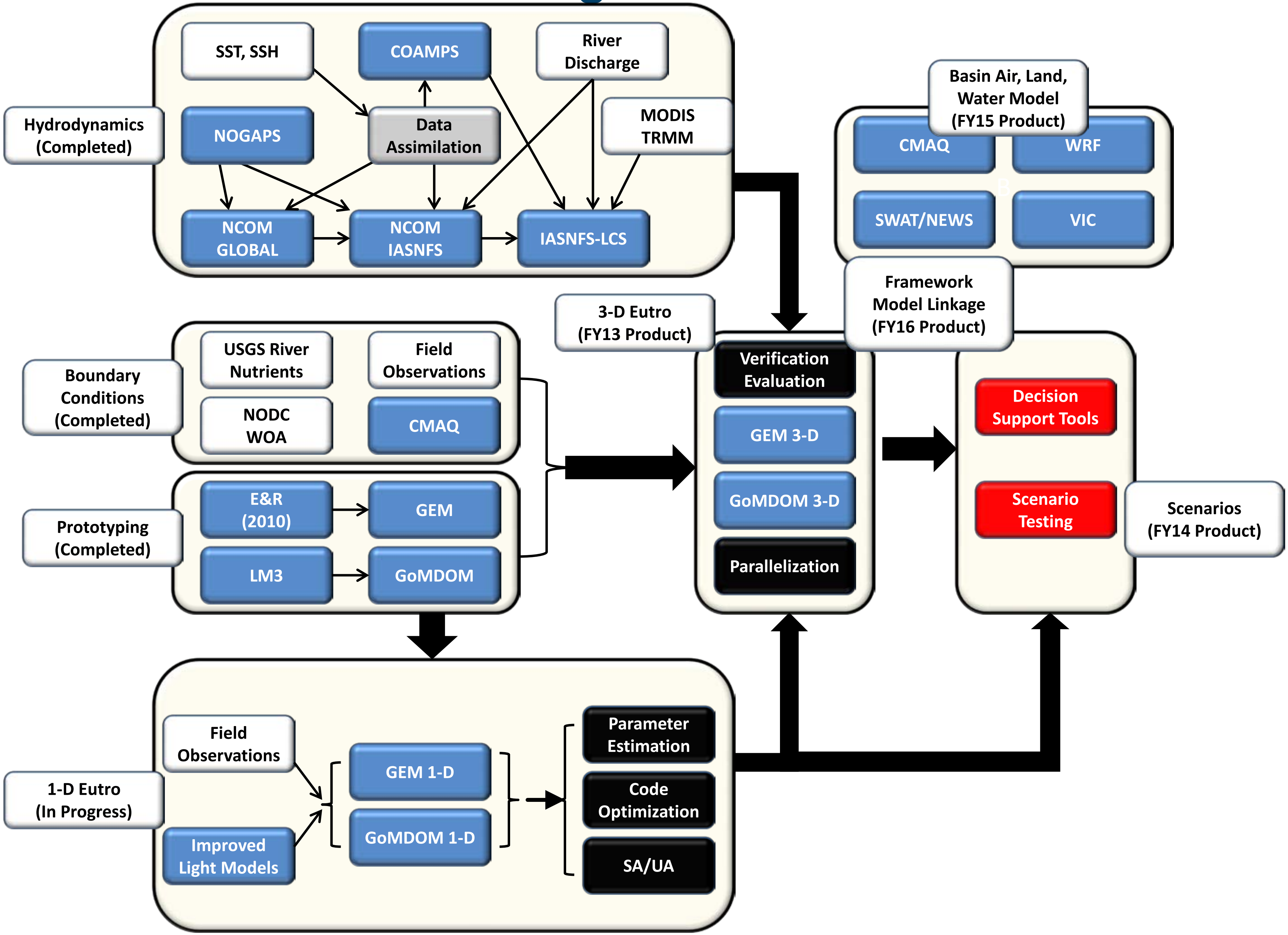
Gulf Ecosystem Model (GEM) Assumptions

- Stratification and transport are adequately represented by IASNFS-LCS
- N, P, and C loads to the model domain are accurately represented by river loads and other boundary conditions
- Organic matter oxidation and redox reactions
  - Water-column modified from Eldridge and Roelke (2010)
    - O_2, C, and nutrient kinetics from Van Cappellen and Wang (1996)
  - Sediment diagenesis (Van Cappellen and Wang 1996; Eldridge and Morse 2008; Eldridge and Roelke 2010): **not yet implemented**
    - Currently using regression equations for sediment-water exchanges
      - Exchanges as a function of overlying O2 concentration or other concentrations (Murrell and Lehrter 2011; Lehrter et al. 2012)

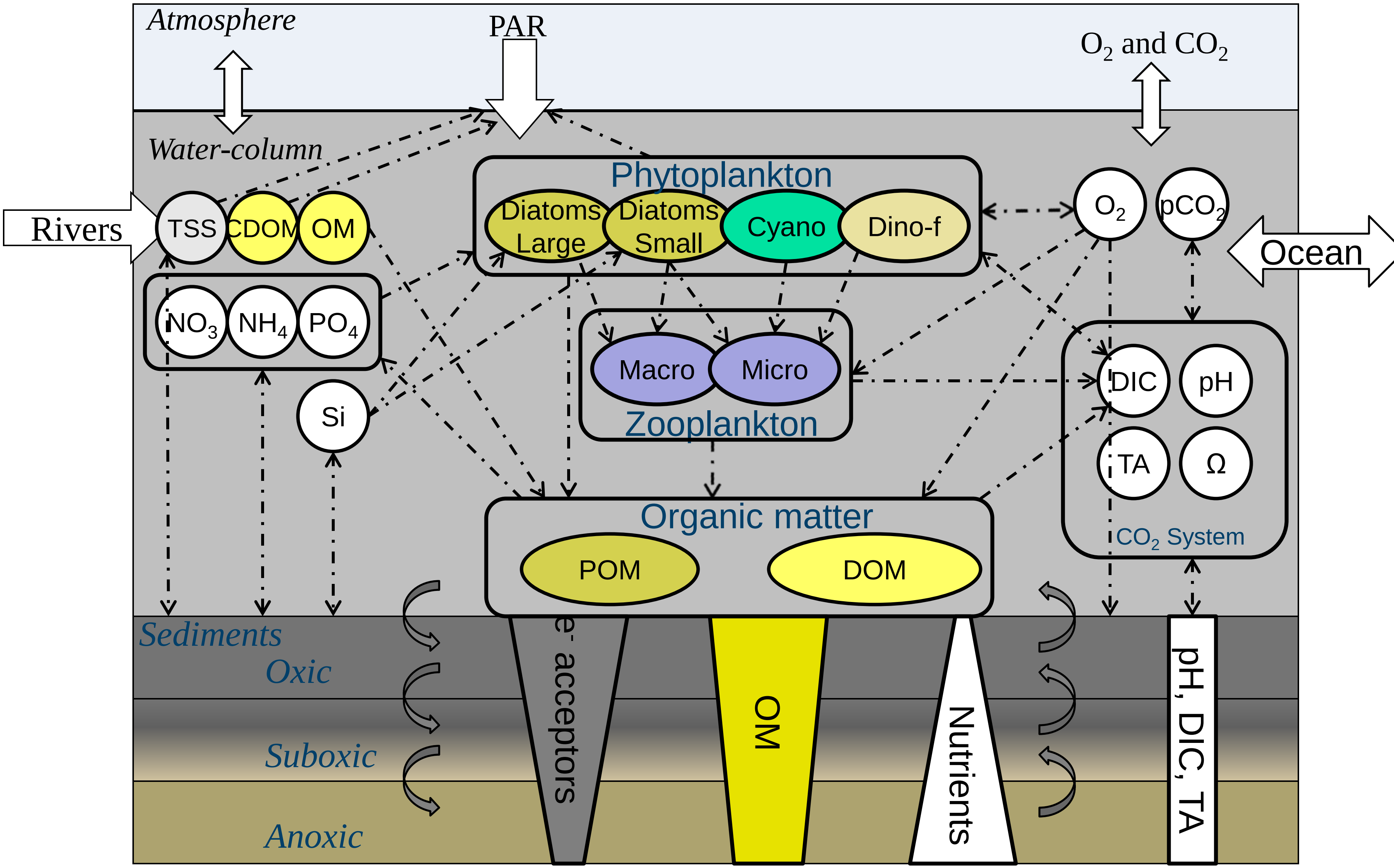
GEM Assumptions (cont'd)

- Phytoplankton light, nutrient, and mortality kinetics
  - Photosynthesis-irradiance (Jassby and Platt 1976)
    - Light attenuation (Kd_{PAR}) represented by absorption due to CDOM and chlorophyll*a* (Penta et al. 2008)
  - Droop kinetics for phytoplankton nutrient uptake and limitation with flexible C:N:P stoichiometry (Eldridge and Roelke 2010)
  - Zooplankton grazing and other phytoplankton mortality (Eldridge and Roelke 2010)
- Phytoplankton community represented by up to 6 groups
- Zooplankton community represented by up to 2 groups

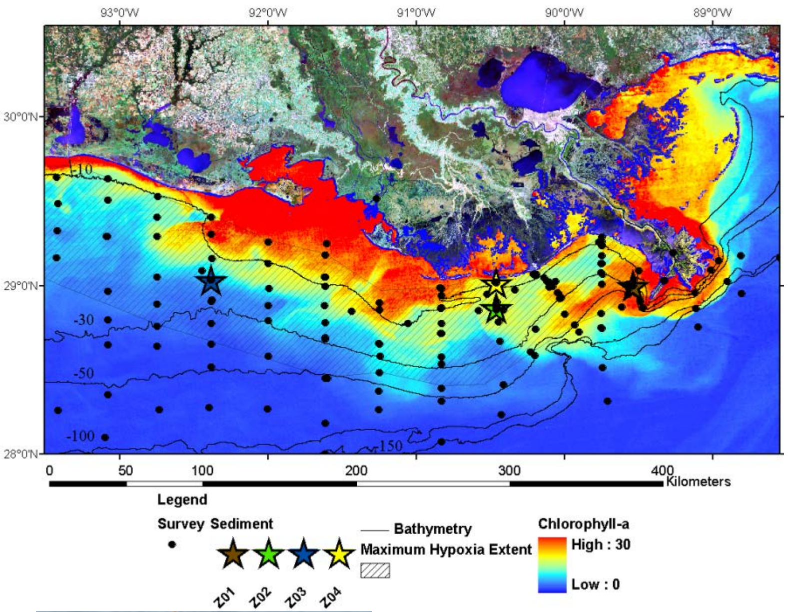
Modeling Framework

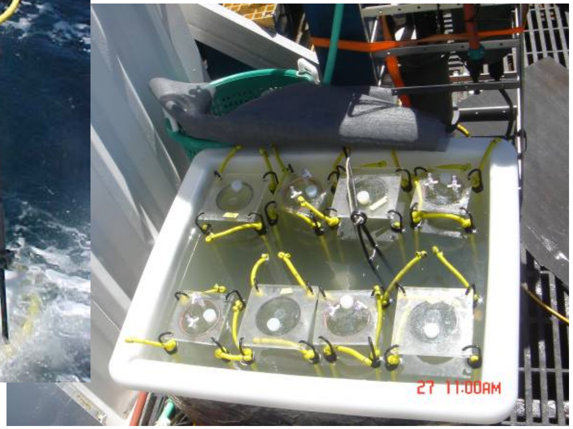


GEM State Variables



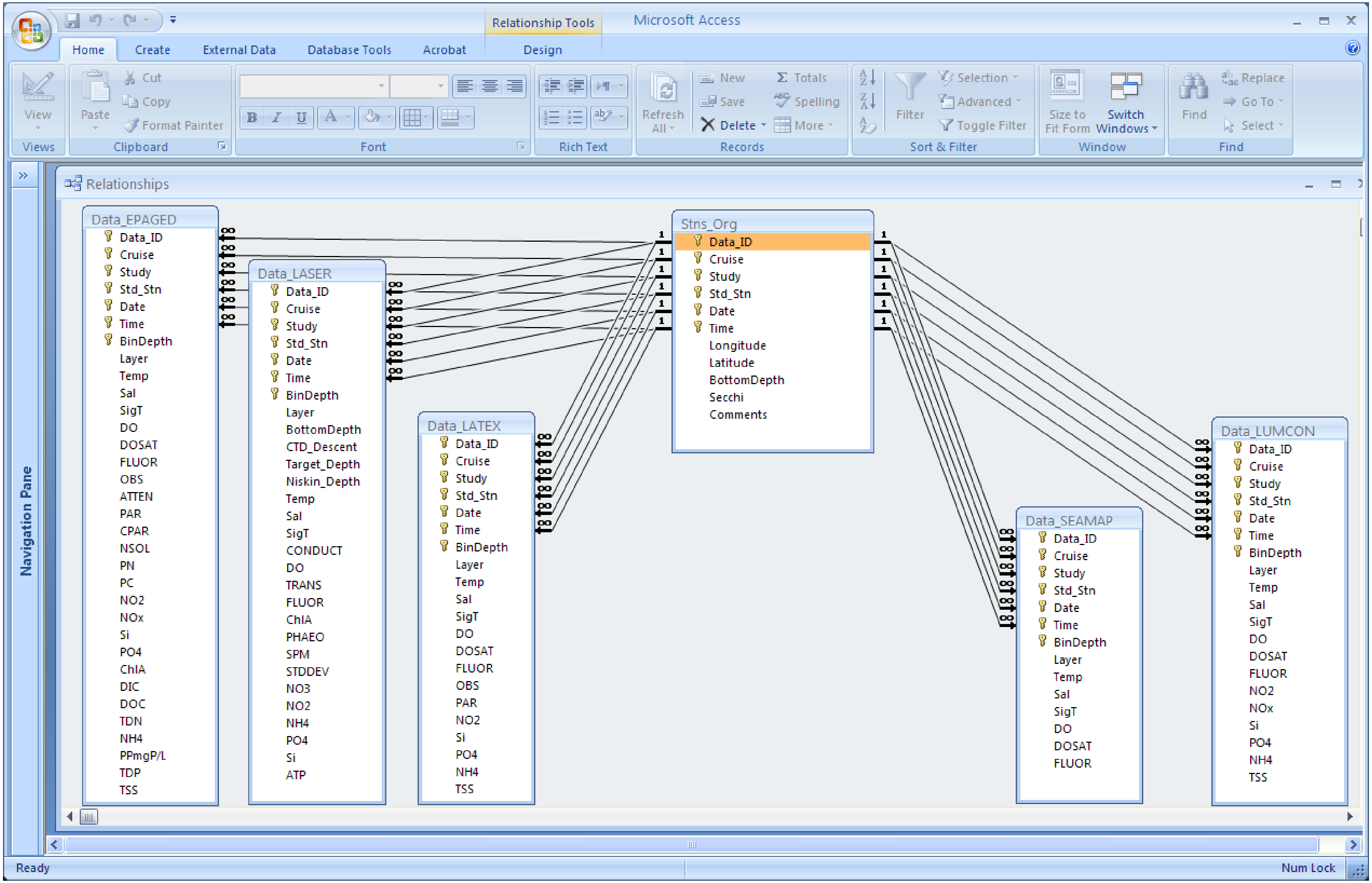
Field Program Consisted of 13 Cruises (2002-2010)





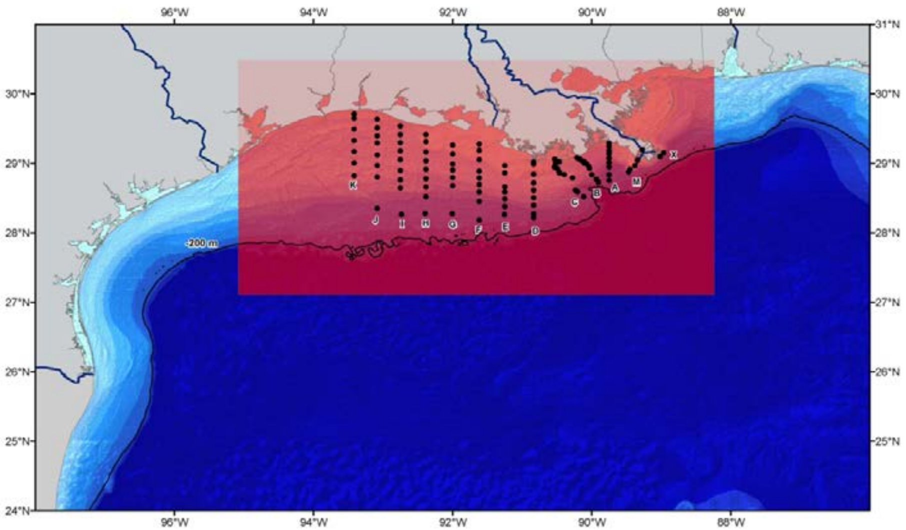
State and Process	Water	Sediment
Dissolved Inorganic – NO_x, PO_4, NH_4, Si	X	X
Particulate C, N, P	X	X
Total Dissolved N, P, Total N, P	X	
Dissolved organic carbon	X	
Total Suspended solids	X	
Chlorophyll a	X	X
PAR, Secchi depth, attenuation	X	
Dissolved oxygen	X	
T, S, turbidity, in vivo fluorescence	X	
Phytoplankton species composition	X	
pH, DIC, alkalinity	X	X
Primary productivity rates	X	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		X
Solid phase Fe, C, N, P		X
Stable Isotope $\delta^{13}C$, $\delta^{15}N$		X
Radioisotopes Pb-210, Cs-137, Be-7		X

Relational Database for Model Calibration

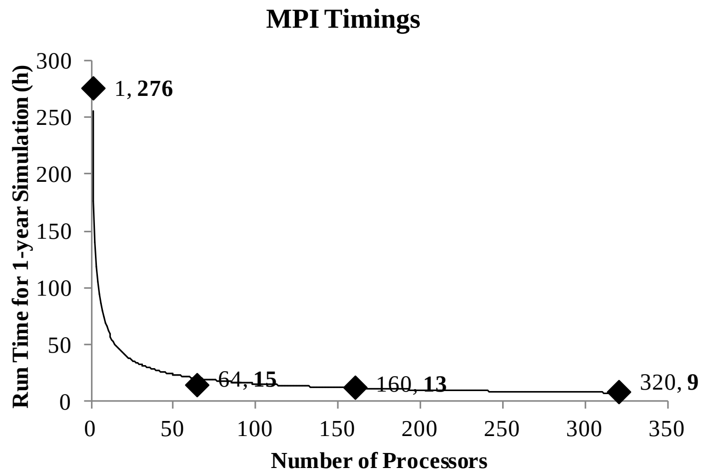


GEM Scalability

- Code is scalable; dependent on scale of hydrodynamic and other inputs

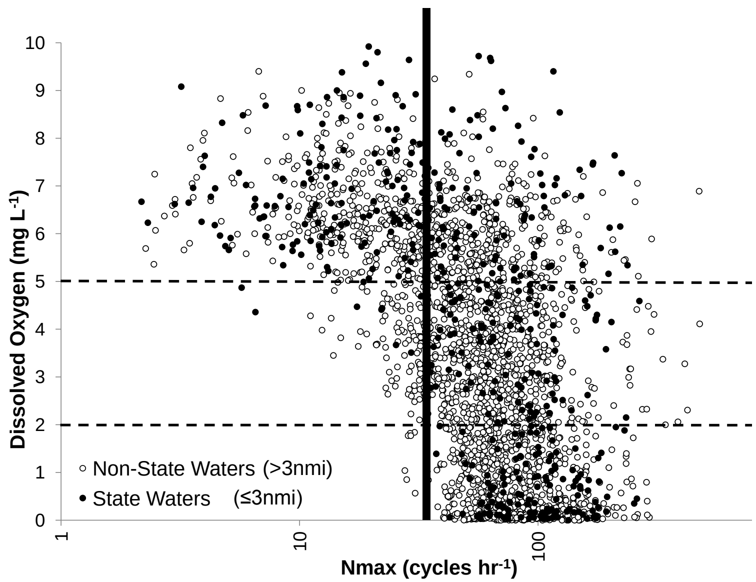


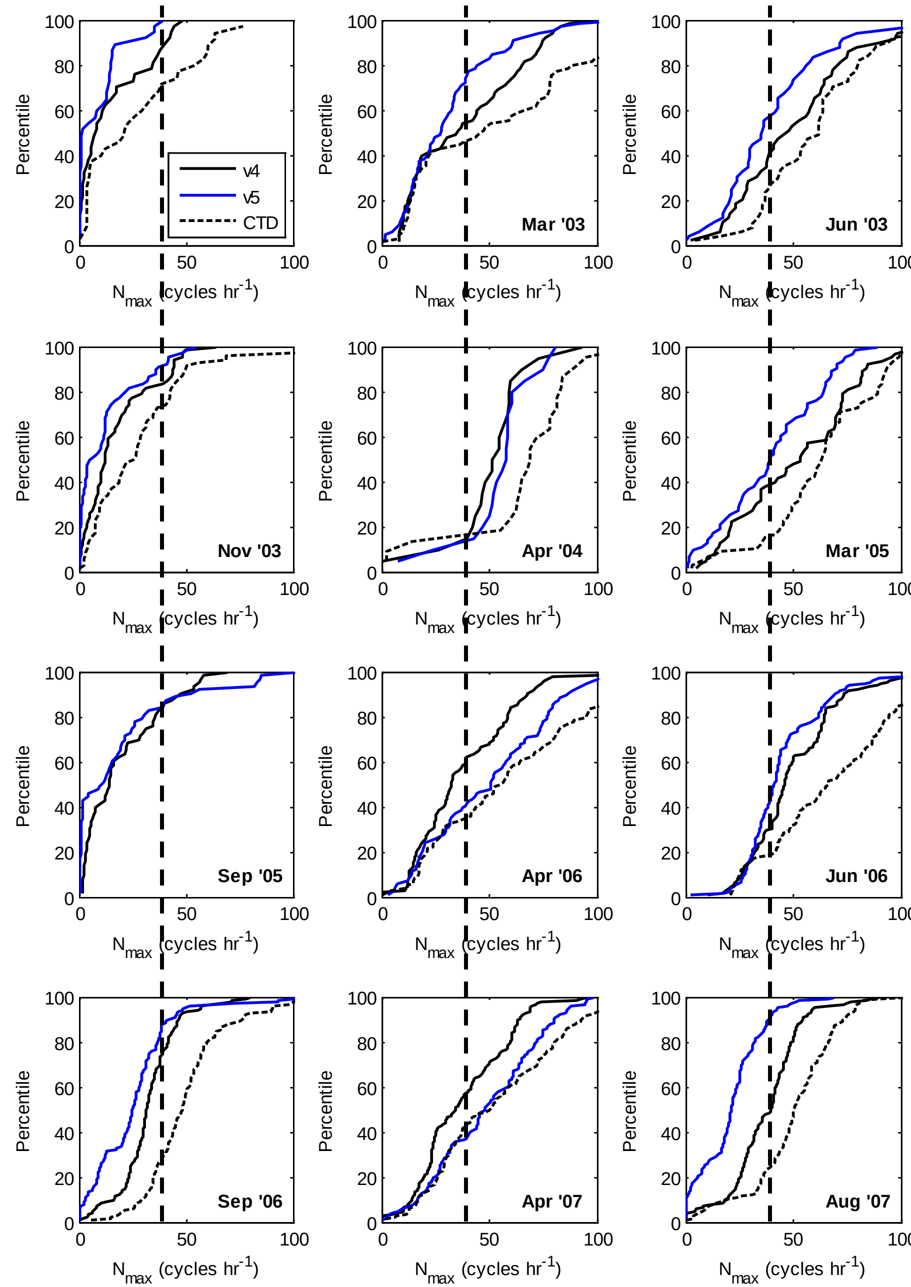
- Parallelized code running on 64 processors requires 15 hours to simulate 1 year
  - Scalable to any number of processors evenly divisible into 320
  - 64 processors optimal due to tradeoff between run time and queue time



Verification: Stratification strength required for hypoxia

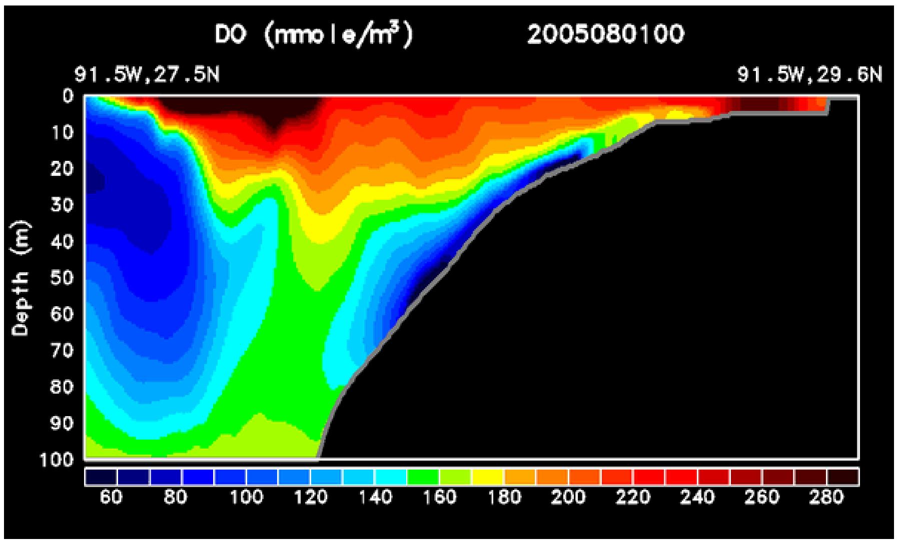
Observed relationship between hypoxia and stratification strength



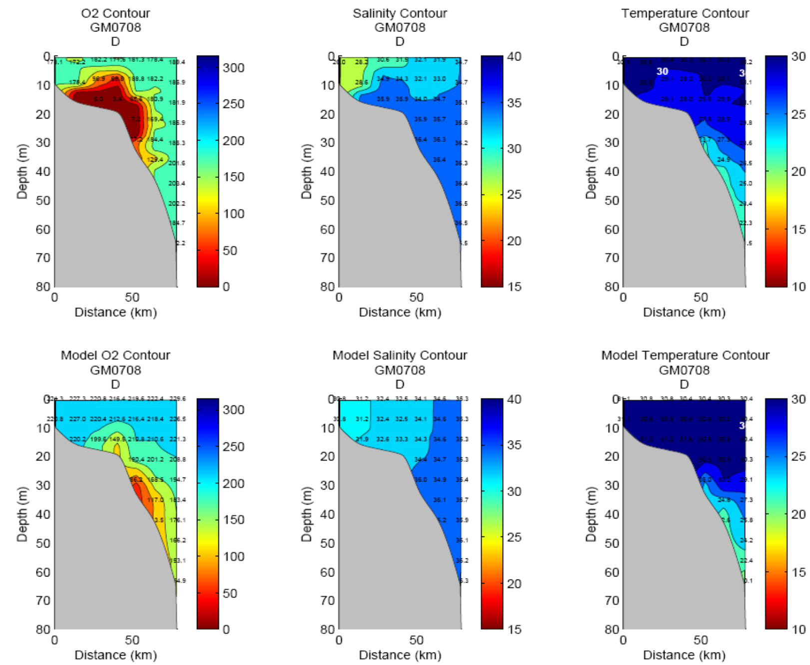


Verification: Model-Data Comparisons

- Calibration is ongoing
- Modeled hypoxic area is similar to observed mid-summer, but is geographically displaced offshore of the observed hypoxic area



Hypoxia disappears due to strong mixing caused by Hurricane Katrina

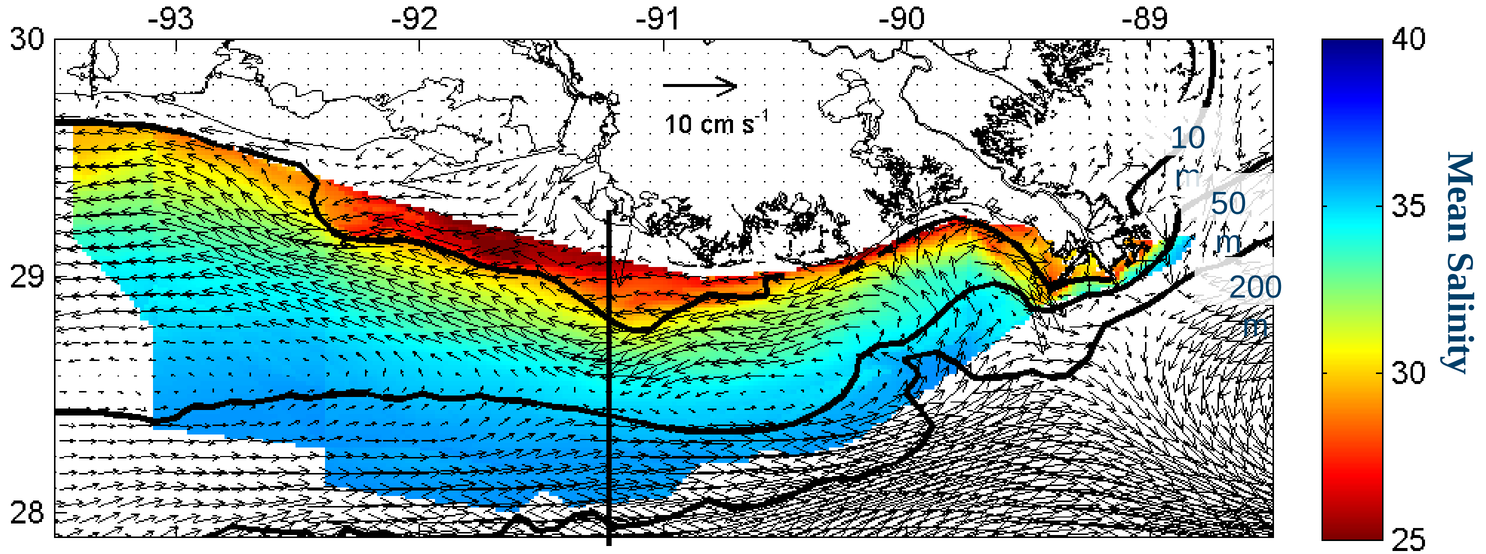


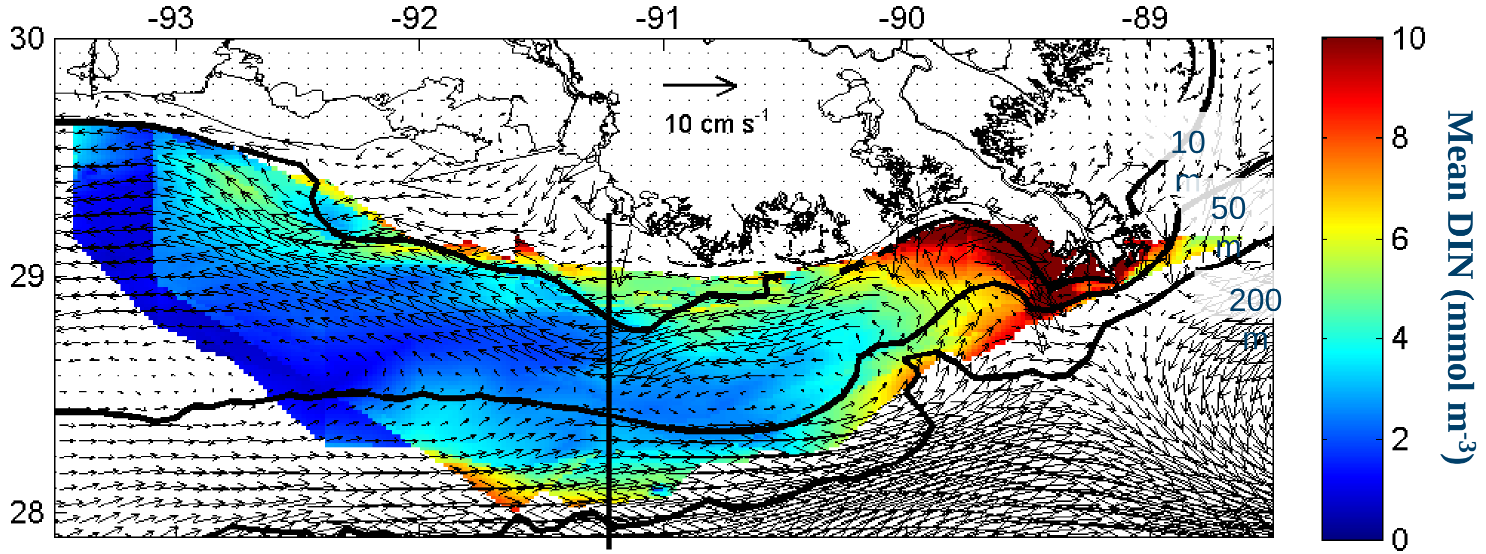
Comparisons of cross-shelf measured (upper) and modeled (lower) O2, salinity, and temperature.

- To date, model performance has also been evaluated for state variables (e.g. PAR, nutrients, chlorophyll) and rate variables (primary production and respiration

Application: N and P Budgets for the Louisiana Shelf

The model reproduced mean circulation patterns (Cochrane and Kelly 1986; Nowlin et al. 1995; Wiseman et al. 1997) and freshwater transport rates (Dinnel et al. 1986; Etter et al. 2005; Zhang et al. 2013)

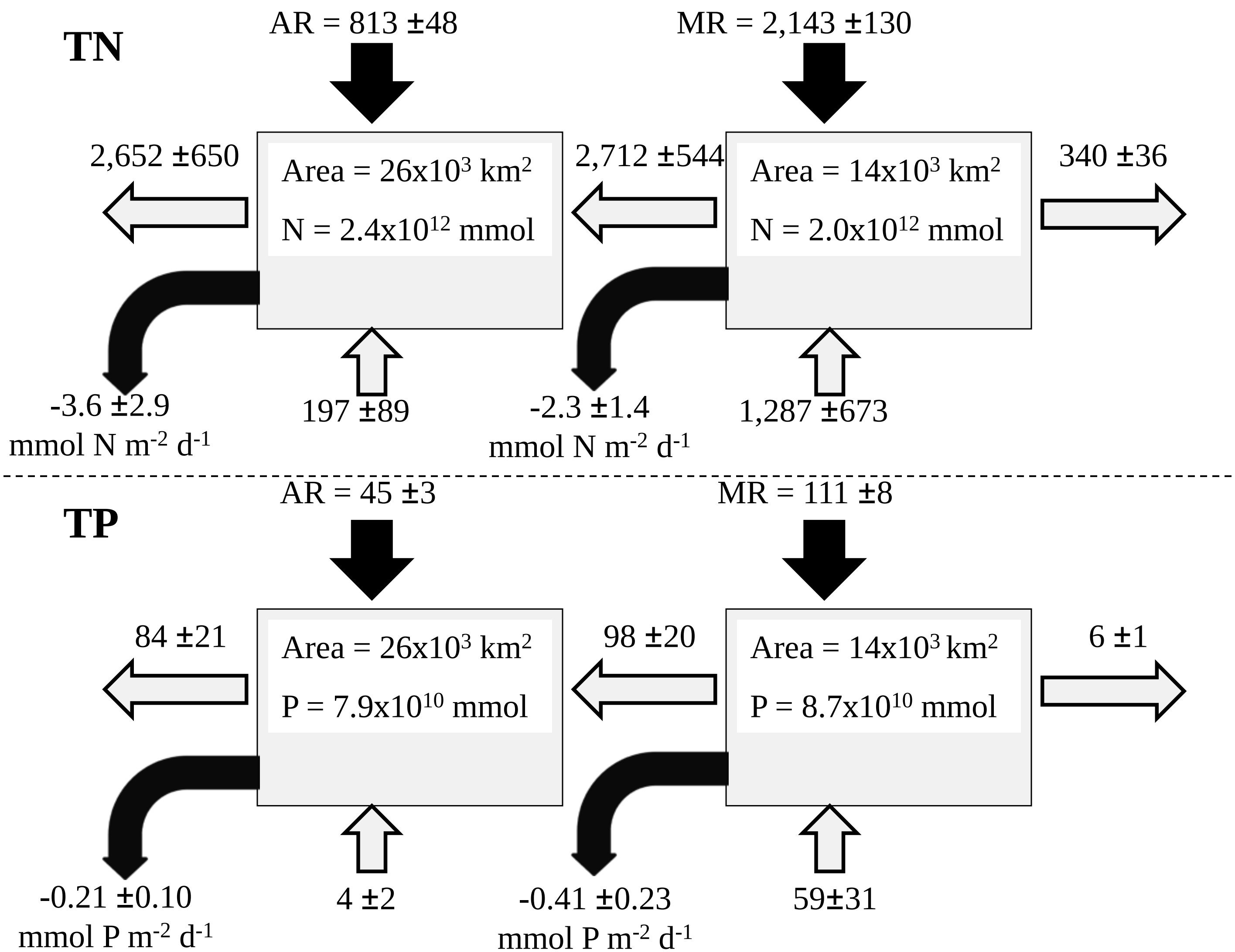




Lehrter et al. submitted.

Mean N and P Budgets for the Eastern and Western shelf, depth < 50 m (2002-2007)

Flux rates = 10^3 mmol s^{-1}



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Key Points

- MR and AR were the dominant sources of N and P
- Offshore sources represented approximately 50% and 41% of River N and P loads, respectively
- Sinks accounted for 33% of the N and 59% of the P inputs to the inner shelf

Hierarchical Uncertainties

- Model uncertainty
  - Do the models contain the “right” processes?
    - N-fixation
    - Sediment resuspension and transport
    - Benthic primary production
  - Model inter-comparison
- Parameter uncertainty
  - Grazing coefficients
  - Light and nutrient kinetics
  - Redox kinetics
- Data uncertainty

Timeline for Completion

- FY13-14
  - Development and application of hypoxia modeling tools for improved understanding and reduced uncertainty about the linkages of Mississippi River nutrients with coastal hypoxia (FY13)
  - Application of modeling tools for scenario simulations (FY14)
    - Nutrient reduction scenarios
    - Climate change scenarios


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