The Mechanistic Model, GoMDOM: Development, Calibration and Sensitivity Analysis

Timothy J. Feist[1], James J. Pauer[2], Wilson Melendez[3], Phillip A. DePetro[4], Amy M. Anstead[4], John C. Lehrter[5], Michael C. Murrell[5], Russell G. Kreis, Jr.[2]

[1]Trinity Engineering Associates, Inc.,
[2]USEPA/ORD/NHEERL/MED, [3]Computer Sciences Corporation,
[4]ICF International, [5]USEPA/ORD/NHEERL/GED

April 18, 2013

Partners

- A joint effort between the USEPA's Mid-Continent Ecology Division (Grosse Ile, MI) and Gulf Ecology Division (Gulf Breeze, FL).
- Contract support from Trinity Engineering Associates, ICF International and CSC
- Hydrodynamics from Naval Research Lab
- Atmospheric loads from USEPA ORD, National Environmental Exposure Laboratory
- Additional computer support by USEPA Environmental Modeling and Visualization Lab

Objective

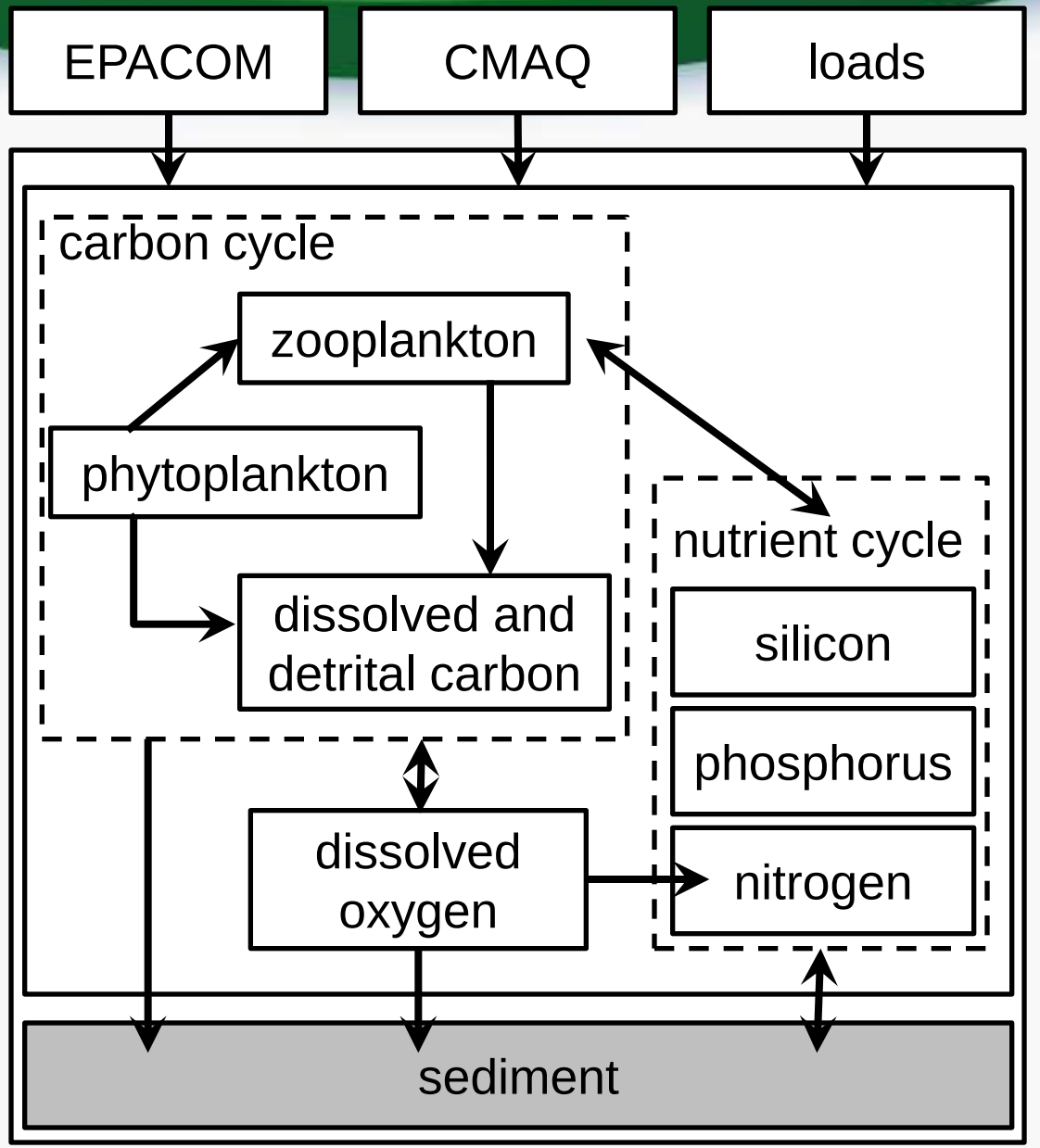
- **Goal:** Achieve a five-year running average areal extent of the Gulf of Mexico hypoxic zone of less than 5,000 km^2 (Mississippi River Gulf of Mexico Watershed Nutrient Task Force)
- **Question:** What nutrient (nitrogen and phosphorus) load reductions are necessary to achieve this goal?
- **Task at hand:** Develop a water quality model to provide a mechanistic connection between nutrient loadings and model-predicted hypoxia area, duration, and frequency.

Model Background

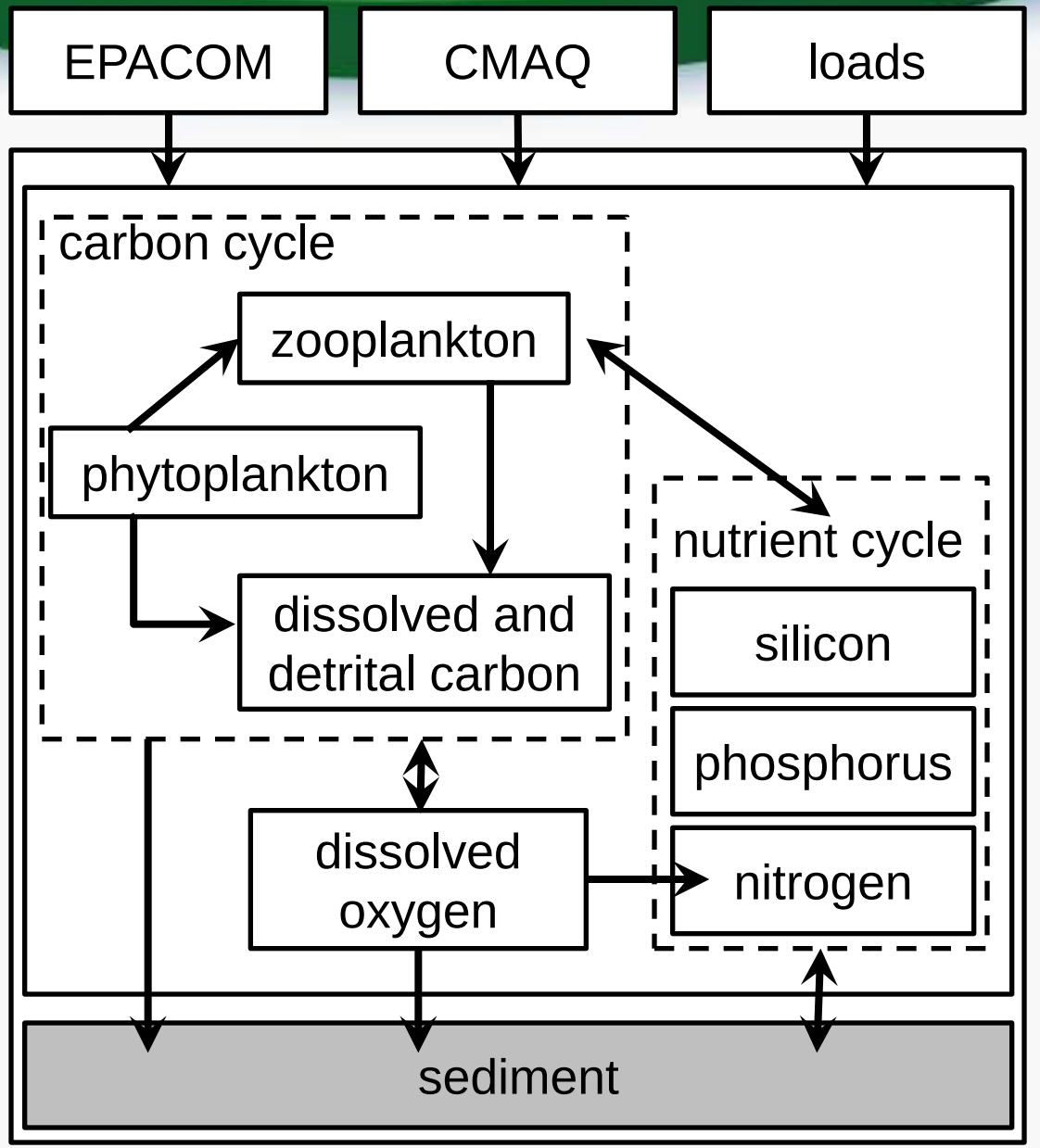
- Gulf of Mexico Dissolved Oxygen Model – GoMDOM
- Similar kinetics to CE-QUAL-ICM (Cerco and Cole 1993, 1995)
- Code from LM3-Eutro (Melendez et al, 2009, Pauer et al, 2006, 2008)
- Added dissolved oxygen kinetics
- Use “relatively simple” kinetics to start, add complexity as needed

Model Assumptions – Supporting Models

- EPACOM version 5 – NRL hydrodynamics model
  - aggregated ~ 2 km cells to ~6 km for GoMDOM
  - advective and dispersive flows, temperature, solar radiation, wind
- CMAQ – EPA atmospheric model
  - atmospheric nitrogen loads
- GoMDOM-1D – served as kinetics test platform and for preliminary parameterization



- 20 state variables
- nitrogen
  - NO_3, NH_4
  - DON, LON, RON
- phosphorus
  - SRP, DOP, LOP, ROP
- carbon
  - DOC, LOC, ROC
- silicon – SA, SU
- 2 phytoplankton
- 1 zooplankton



- dissolved oxygen
  - primary production
  - reaeration
  - respiration and metabolism
  - DOC mineralization
  - nitrification
  - sediment oxygen demand
    - (Lehrter et al. 2012, Murrell and Lehrter 2010)

Scalability - Model Requirements

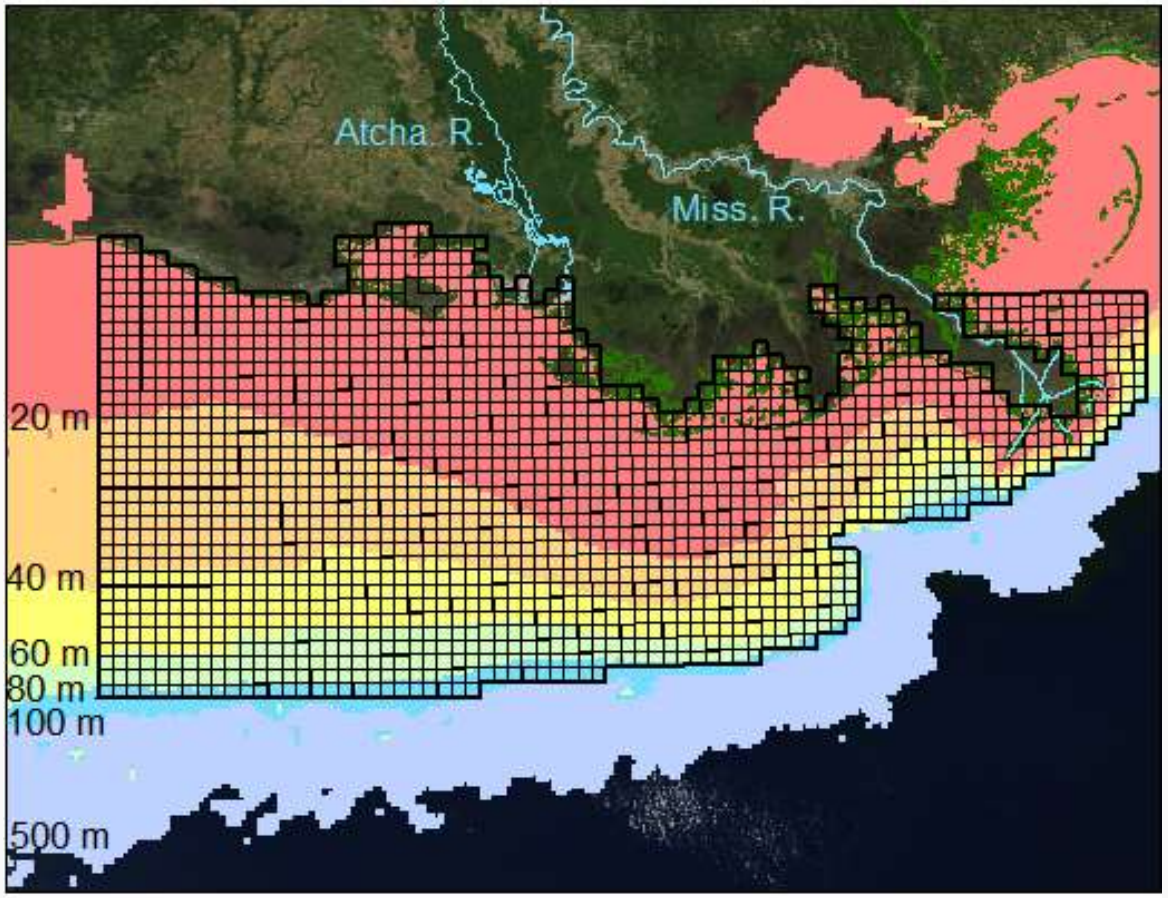
- Written in Fortran, runs on LINUX server, single CPU
- 365-day model runs
- Uses 5-minute time step

Scalability – Model Grid

- Grid from shore to 100 m contour
- ~6 km x ~6 km cells
- 26 sigma layers

- 1695 cells/layer
- 44,070 total cells

- 56 tributaries



Model Inputs

- Tributary loading sources
  - N, P, and Si loads from major tributaries from USGS estimates (Aulenbach et al. 2010)
  - C and D.O. loads and minor tributaries from STORET concentration data and USGS flows
- Initial and boundary concentrations based upon GED cruises 2003-2007
- Is being calibrated to 2006 GED cruise data, corroborated to 2003

Model Status

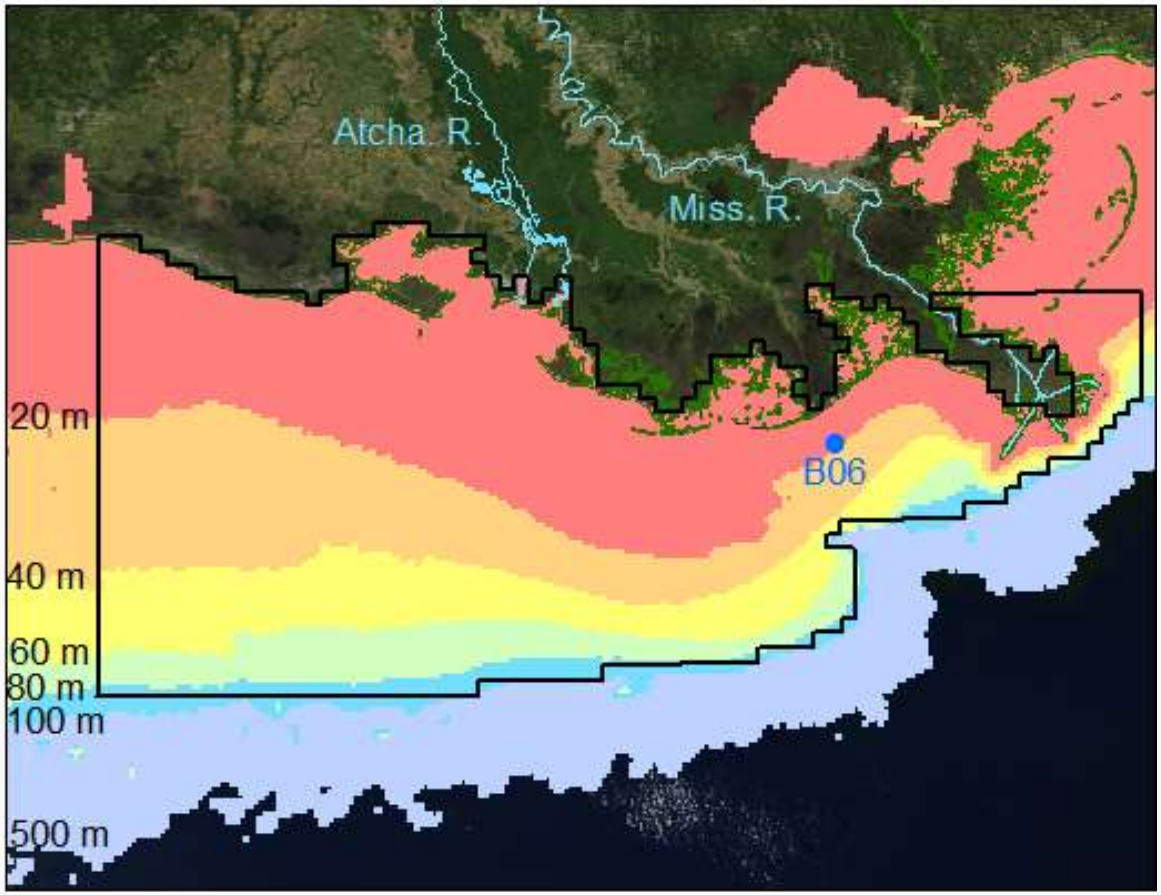
- Calibration (2006 data) nearing completion
- Model represents processes well
- Needs additional refinement

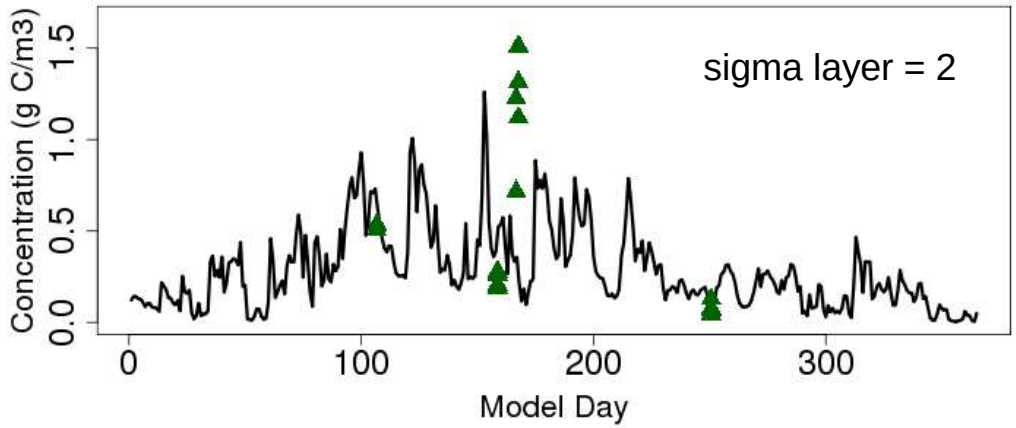
Model Status - Future Work

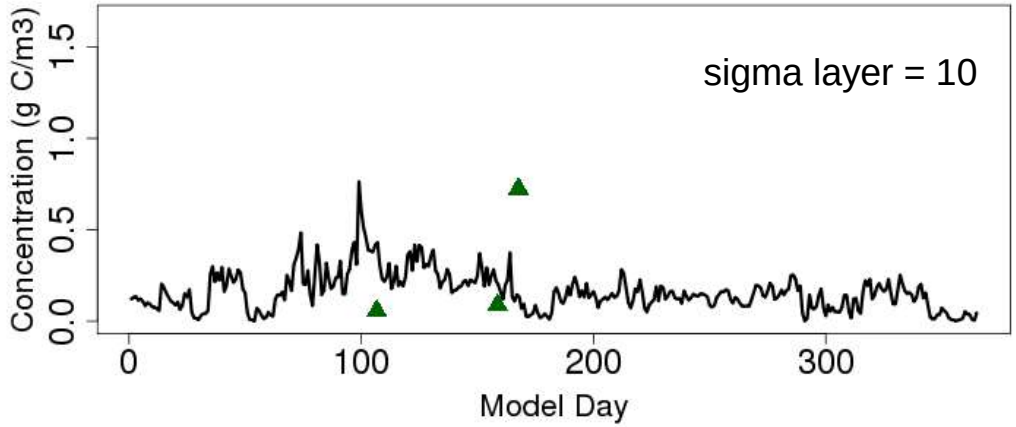
- Complete final calibration, corroboration (2003 data), and sensitivity analyses
- Run model for years 2003-2007 to assist in evaluating relationships between nutrient loads and hypoxic area
- Include updated NRL hydrodynamics
- Model code is being parallelized
  - 2 km x 2 km grid version
  - Extend boundary farther offshore

The results are preliminary, please do not cite

- Station B06 will be shown as an example







Preliminary Results

Phytoplankton Biomass

Station B06

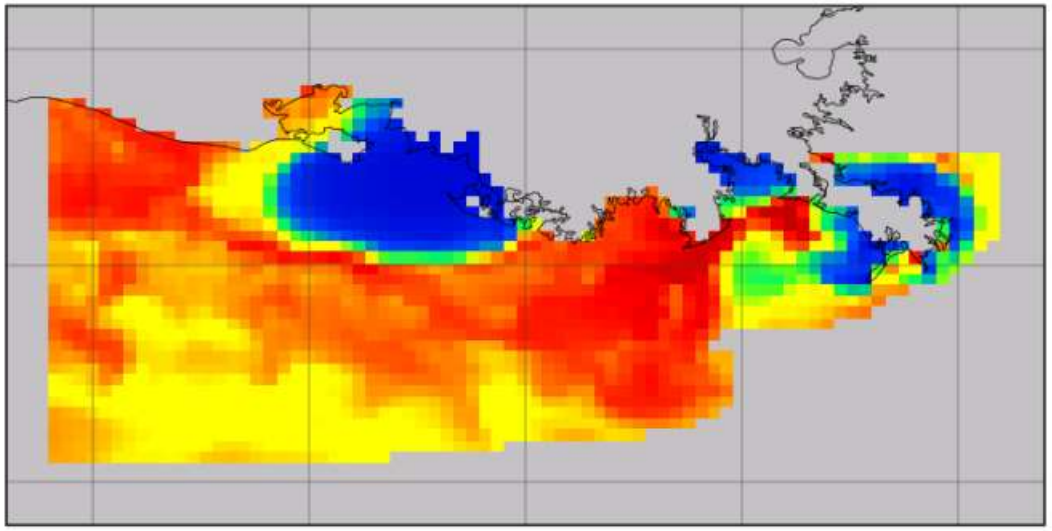
Model run for year 2006

Lines = model output

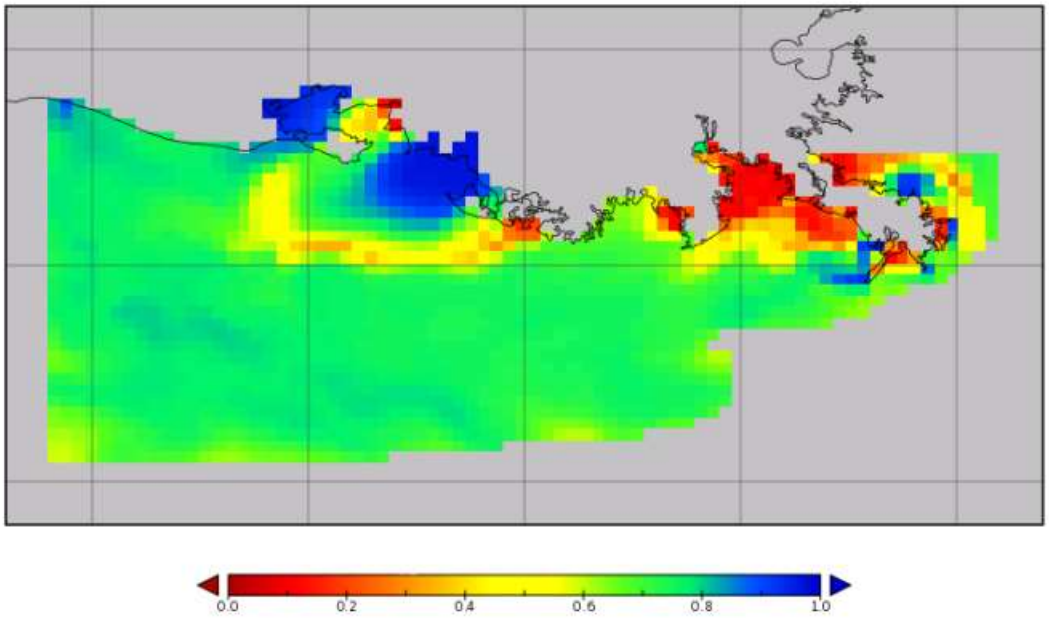
Triangles = GED data

(includes data from one sigma layer above and below model)

Nitrogen limitation



Phosphorus limitation

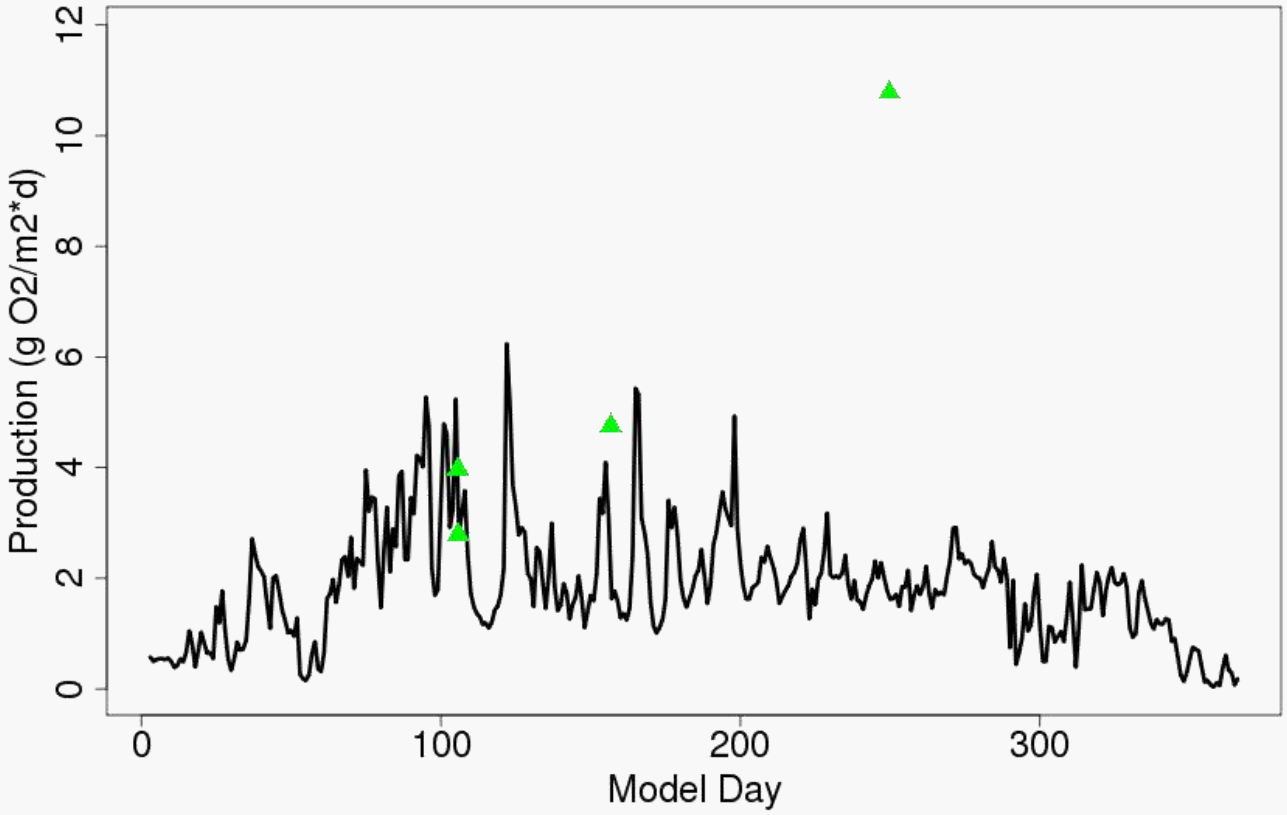


Preliminary Results

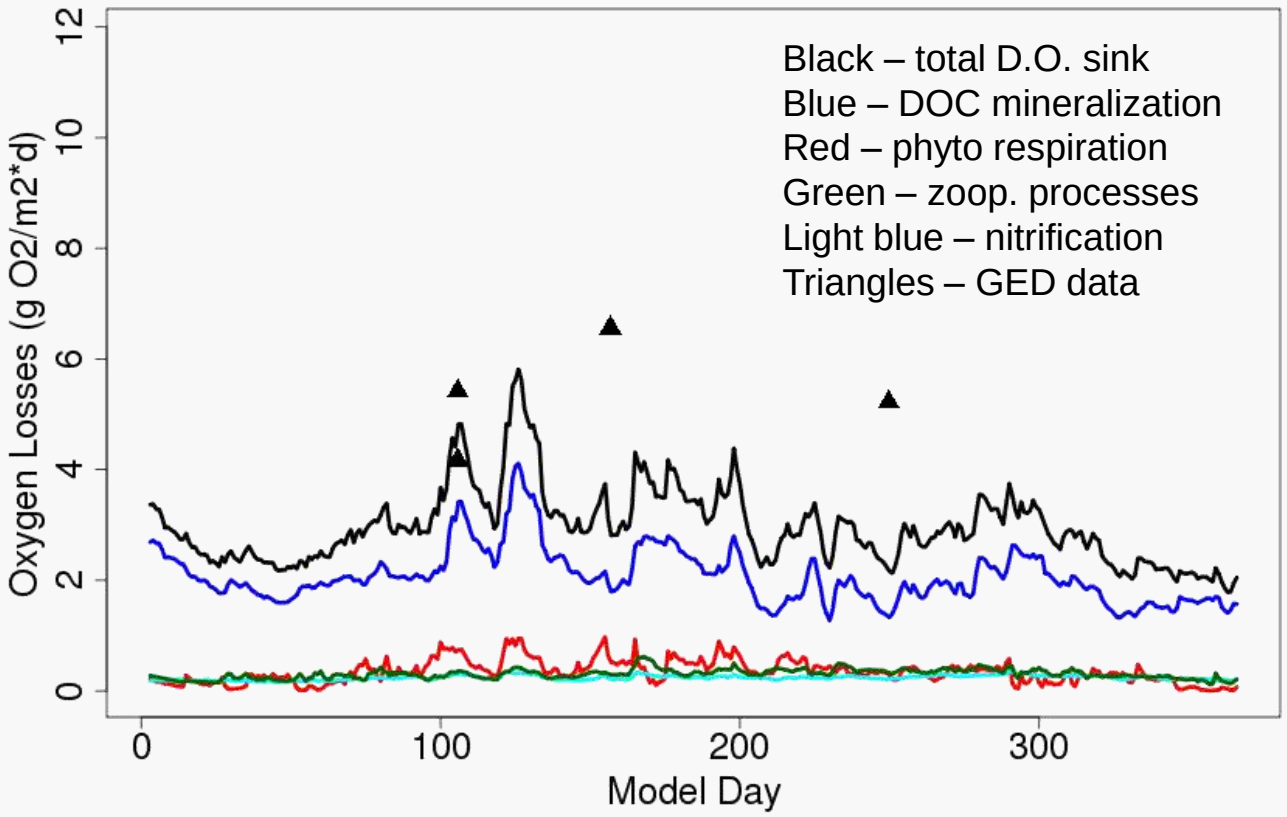
N/P limitations

Results for date July 1, 2006

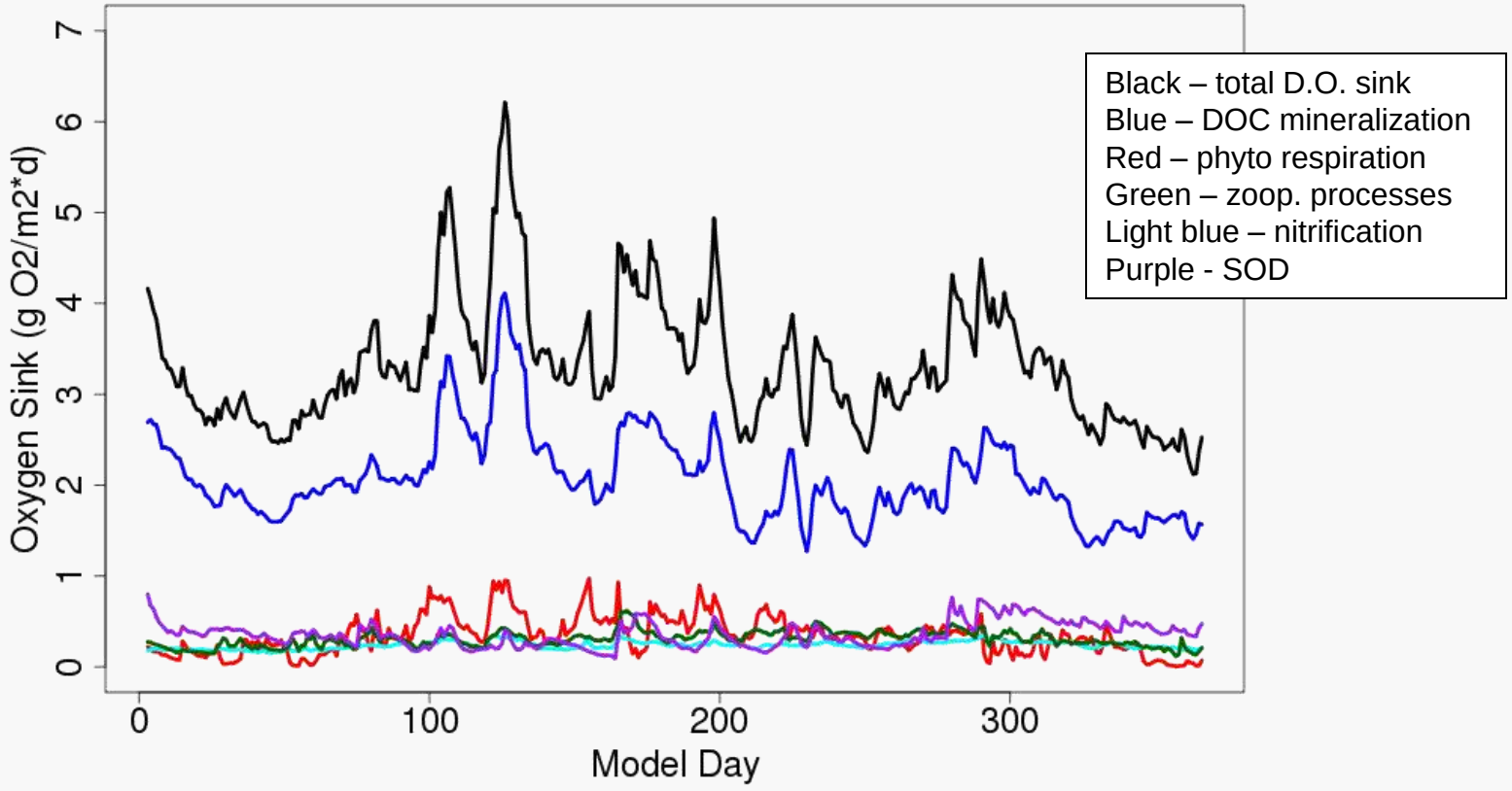
Preliminary Results: Primary Production

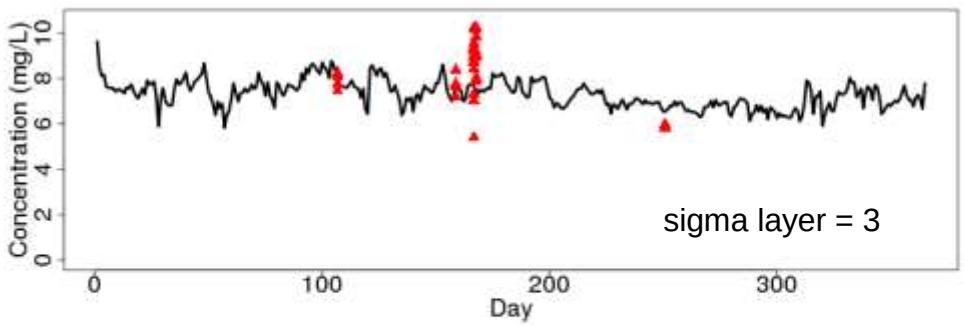


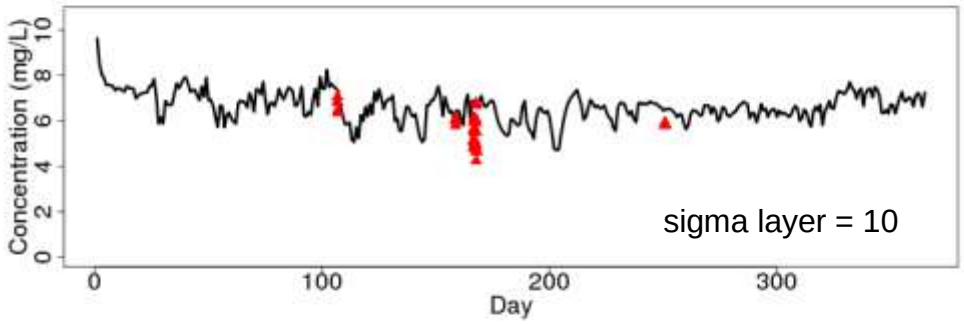
Preliminary Results: Water Column Respiration

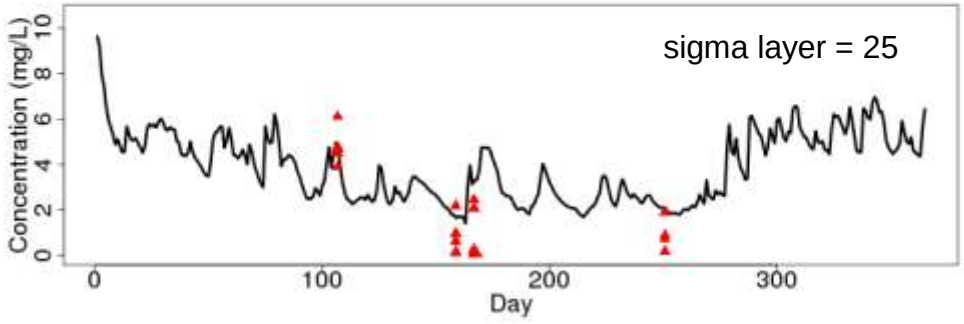


Preliminary Results: Total Oxygen Demand









Preliminary Results

Dissolved Oxygen

Station B06

Model run for year 2006

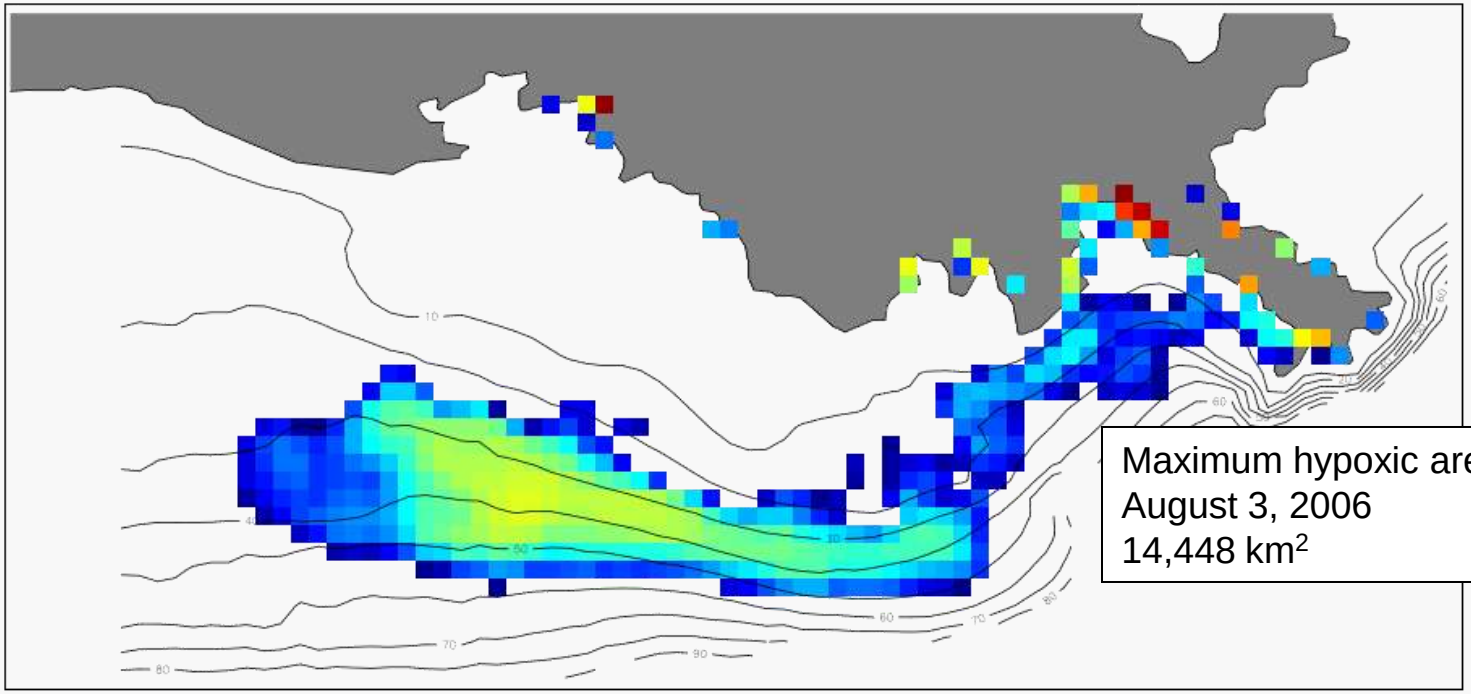
Lines = model output

Triangles = GED data

(includes data from one sigma layer above and below model)

Preliminary Results

Model Simulation Hypoxic Area



Preliminary Results

Mass Balance and Sensitivity

Nitrogen Mass Balance	(kg/yr)
Sources:	
Tributary, sediment, atmospheric loads	1.1e+09
Cross-boundary flow in	1.1e+10
Sinks:	
Cross-boundary flow out	1.2e+10
Settling	2.4e+08

Preliminary Results

Mass Balance and Sensitivity

Carbon Mass Balance	(kg/yr)
Sources:	
Tributary loads	2.9e+09
Cross-boundary flow in	1.1e+11
Primary Production	1.5e+10
Sinks:	
Cross-boundary flow out	1.1e+11
DOC mineralization	1.3e+10
Biological processes	5.8e+09
Settling	1.2e+09

Preliminary Results

Mass Balance and Sensitivity

Oxygen Mass Balance	(kg/yr)
Sources:	
Tributary loads	3.9e+09
Cross-boundary flow in	3.3e+11
Photosynthesis	3.9e+10
Reaeration	1.8e+10
Sinks:	
Cross-boundary flow out	3.3e+11
DOC mineralization	3.6e+10
Biological processes	1.5e+10
Nitrification	5.1e+09
Sediment oxygen demand	8.3e+09

Summary

- Important processes in modeling Gulf hypoxia:
  - Hydrodynamics, including vertical movement and cross-boundary flows
  - DOC mineralization
  - Organic carbon and nitrogen:
    - sources (tributary, boundary concentration, autochthonous)
    - lability and availability
    - mineralization rates
  - Sediment oxygen demand

Concerns and Remaining Needs

- Additional process studies and biological data
  - Algal bioassays and cell counts
  - Zooplankton data
- Increased spatial and temporal coverage for sediment studies
  - Settling
  - Sediment oxygen demand
- High frequency monitoring data

Thank You

Tim Feist feist.timothy@epa.gov
James Pauer pauer.james@epa.gov
Russ Kreis kreis.russell@epa.gov