Simulating hypoxia and nutrient limitation patterns on the Texas-Louisiana shelf in the northern Gulf of Mexico

Katja Fennel *katja.fennel@dal.ca*

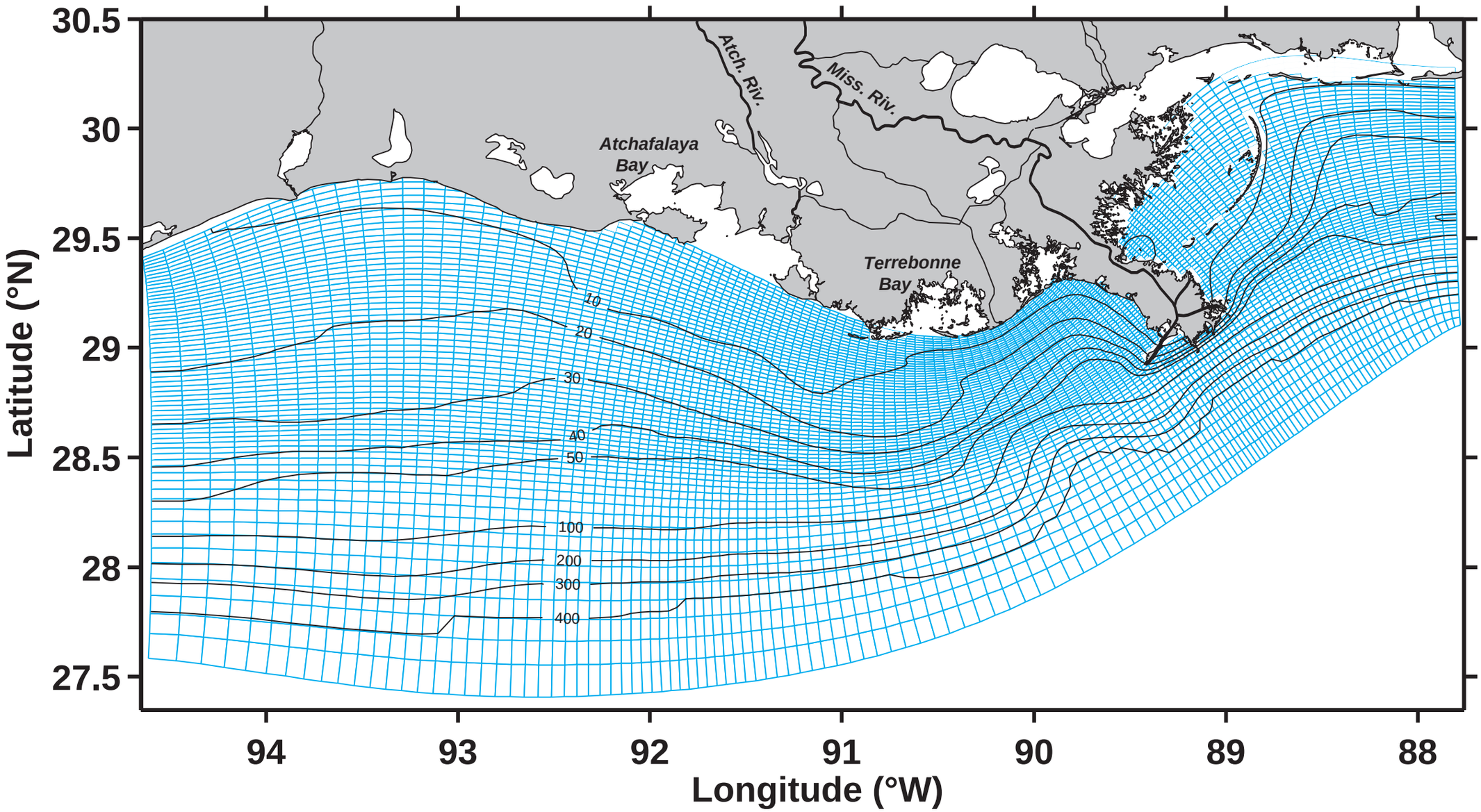
Collaborators: Arnaud Laurent, Jiatang Hu, Robert Hetland, Steven DiMarco

Sediment-water interface questions:

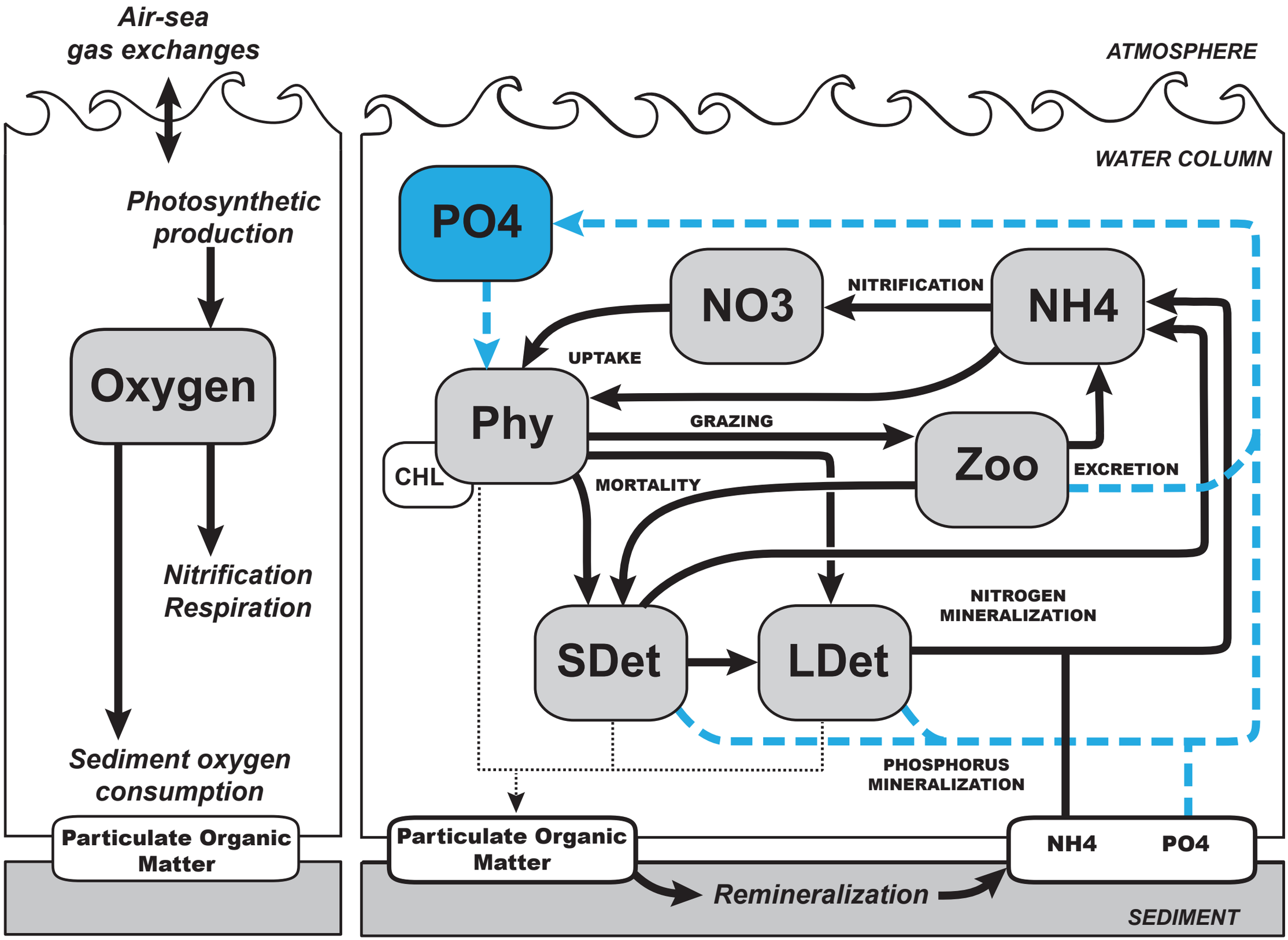
- How does the magnitude of benthic respiration vary temporally and spatially [..]? *How does it contribute to hypoxia? How can it represented in predictive models?*

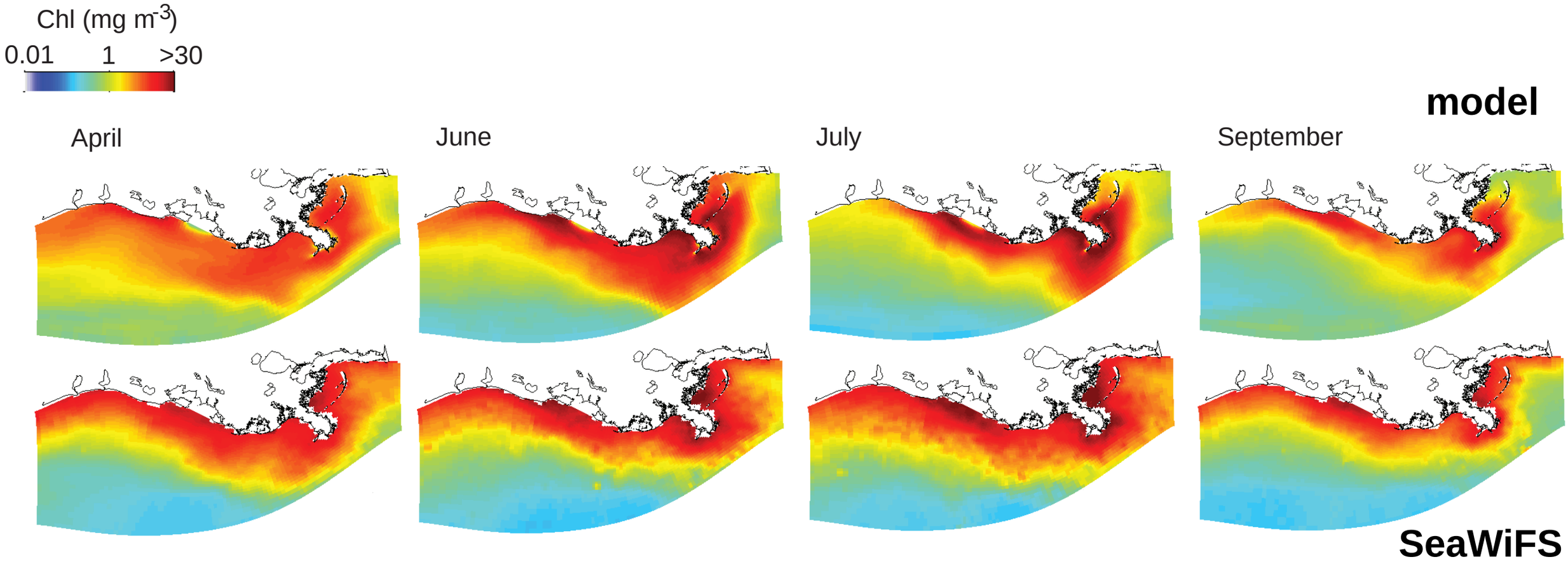
Water column questions:

- What are the temporal and spatial patterns of nutrient co-limitation (N vs. P)?
- How do these patterns affect PP and hypoxia development?



Physical model: ROMS v3.0
Biological model: BIO_FENNEL with OXYGEN
Resolution: 3-5 km in horizontal, 20 or 30 vertical layers
Forcing: 3-hourly NCEP NARR winds; climatological surface heat and freshwater fluxes
River inputs: daily measurements of FW input by U.S. Army Corps of Engineers;
monthly estimates of nutrient and particulate matter loads from USGS
Horizontal b.c.s: climatology, HYCOM or IASNFS NCOM for physics; climatology for biology


Air-sea
gas exchanges
ATMOSPHERE
WATER COLUMN
Photosynthetic
production
Oxygen
PO4
NO3
NITRIFICATION
NH4
UPTAKE
Phy
GRAZING
Zoo
CHL
MORTALITY
EXCRETION
Nitrification
Respiration
NITROGEN
MINERALIZATION
SDet
LDet
PHOSPHORUS
MINERALIZATION
Sediment oxygen
consumption
Particulate Organic
Matter
Particulate Organic
Matter
NH4
PO4
Remineralization
SEDIMENT

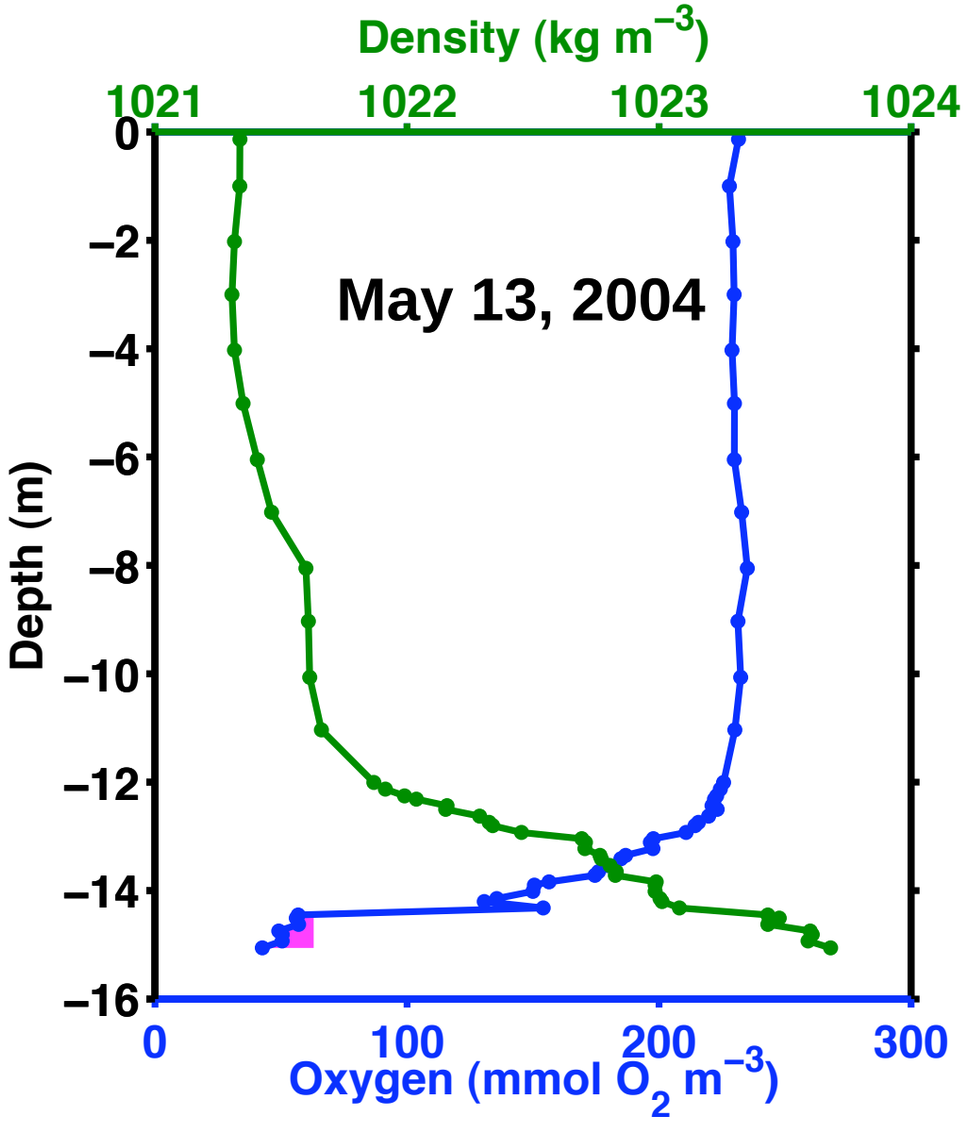


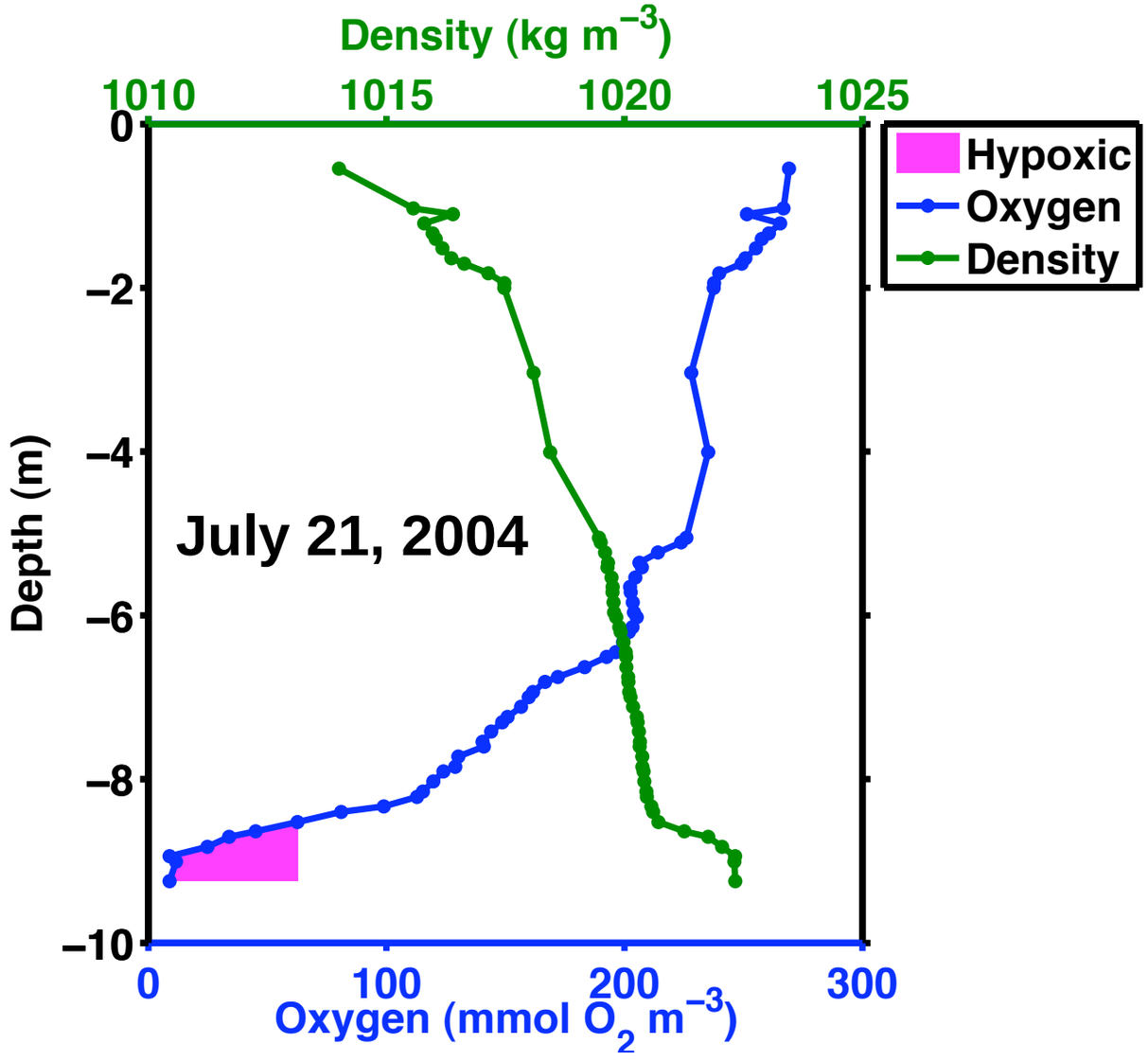
Fennel et al. *Biogeosciences* 2011 (open access journal)

http://www.biogeosciences.net/8/1881/2011/bg-8-1881-2011.pdf

SeaWiFS
ROMS
Mississippi delta
Mississippi intermediate
Far–field
Chlorophyll biomass (mg m^{-3})
30
20
10
0
15
10
5
0
5
2.5
0
01/98
07/98
01/99
07/99
01/00
07/00
01/01
07/01
01/02
07/02
01/03
07/03
01/04
Texas
Louisiana
Sabine R.
Atchafalaya Bay
Atch. R.
Miss. R.
30°N
29°N
28°N
10 m
20 m
30 m
40 m
50 m
100 m
200 m
300 m
far-field
intermediate
delta
Mississippi River Delta
95°W
94°W
93°W
92°W
91°W
90°W
89°W
88°W

Fennel et al. *Biogeosciences* 2011





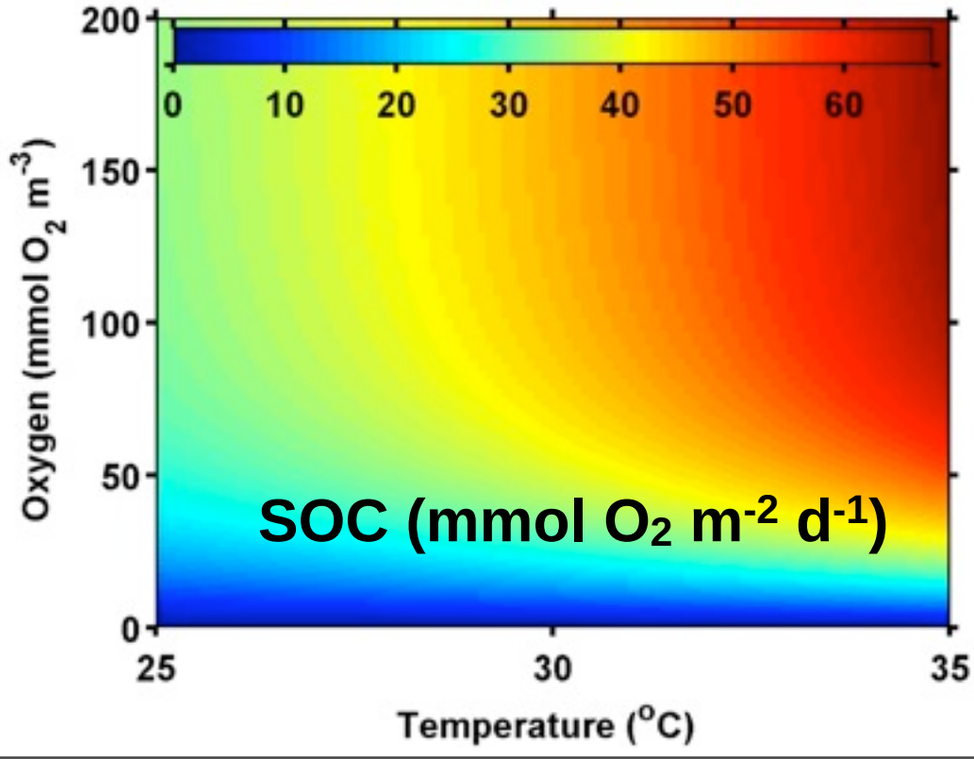
Three treatments of Sediment Oxygen Consumption (SOC):

1) instantaneous remineralization (depends only on organic matter flux)

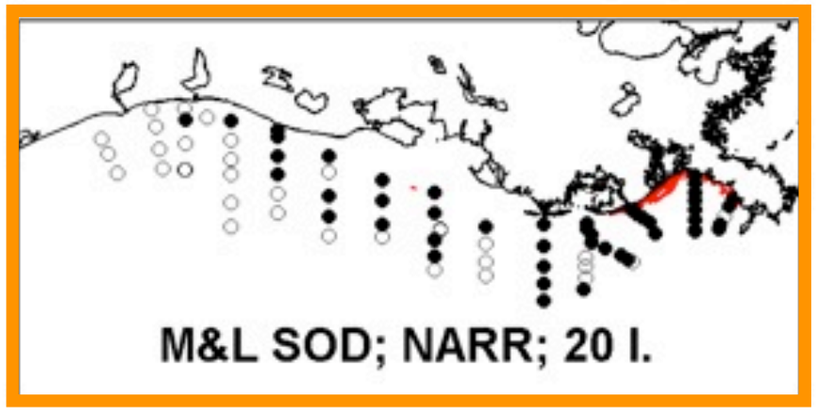
2) SOC parameterization (depends on bottom water T and DO)

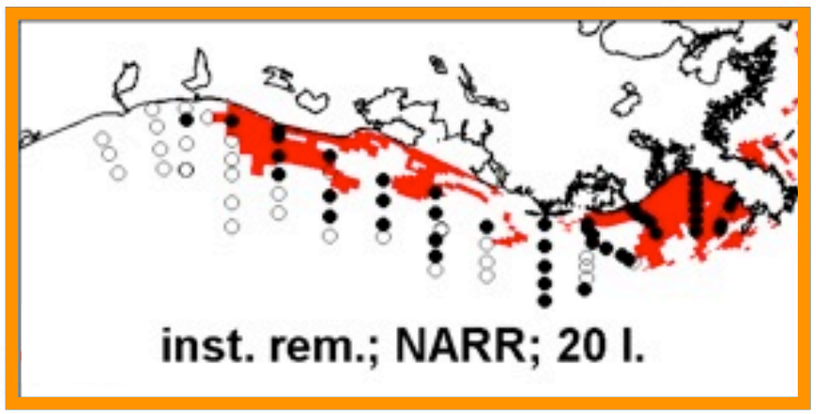
2.a) Murrell and Lehrter (2011)

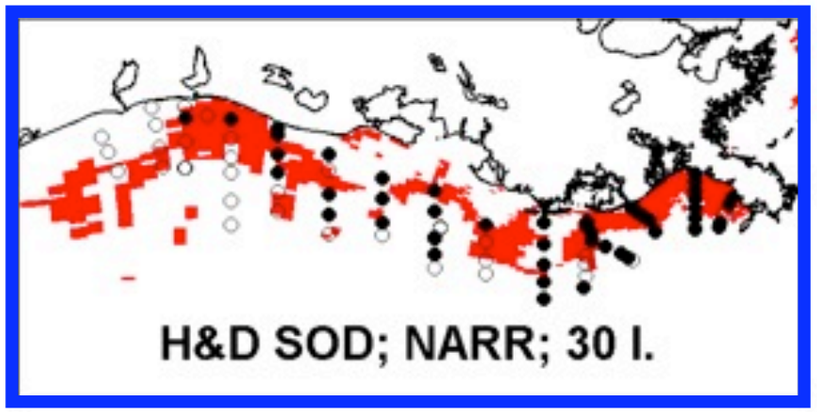
2.b) Hetland and DiMarco (2008)

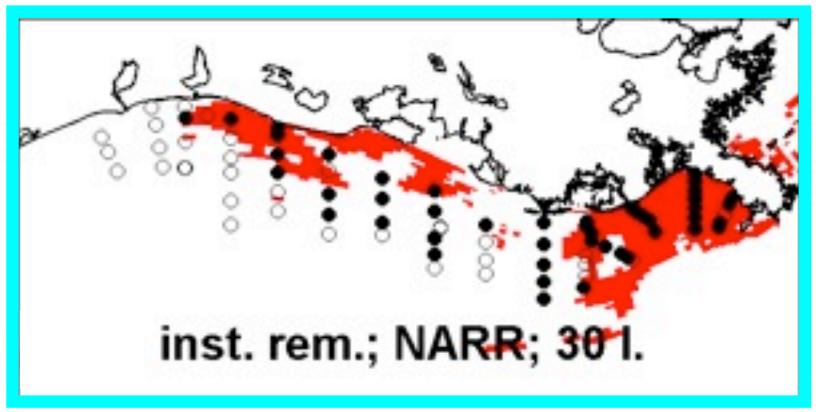


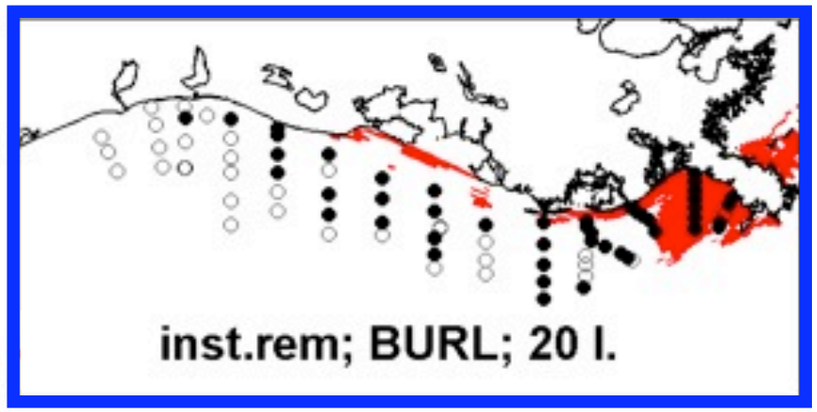
Hypoxic area (O_2 < 62.5 mmol m^{-3}) in July 2004: ROMS (red) and observed (circles)





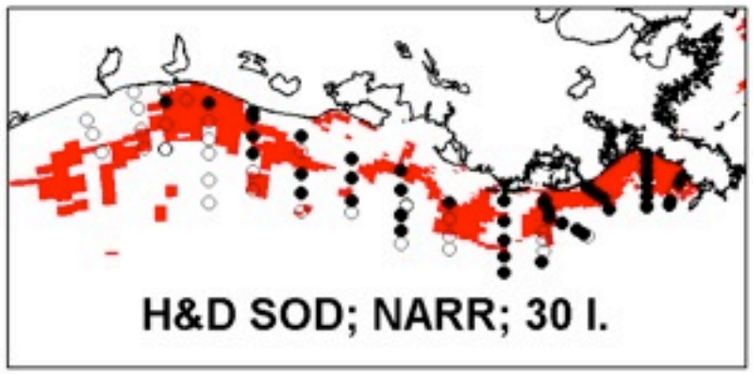


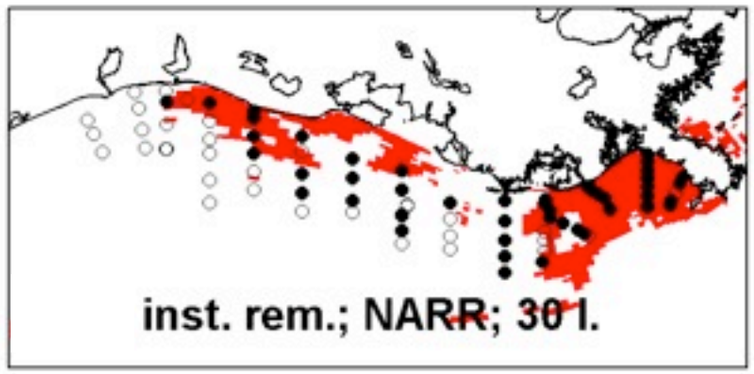




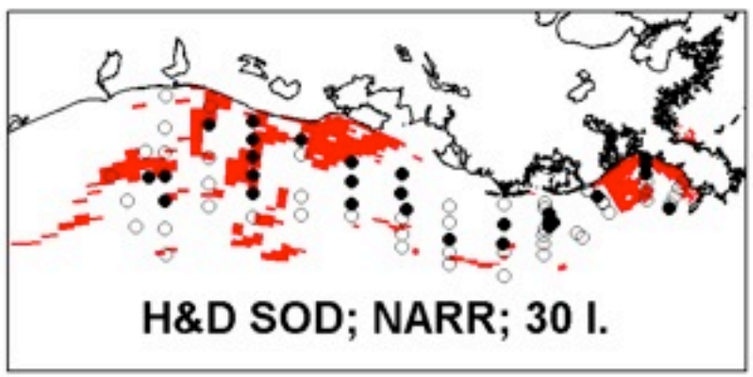
- changes in model physics (vertical resolution, wind forcing, boundary conditions) matter little
- choice of SOC parameterization has largest effect
- in 2004 (here) both, H&D and instantaneous remineralization, look reasonable

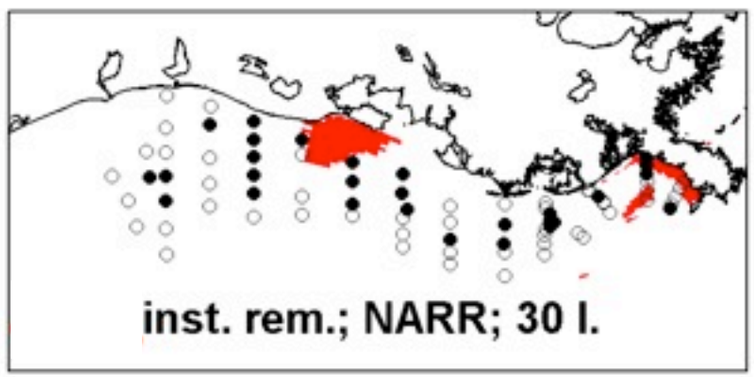
2004



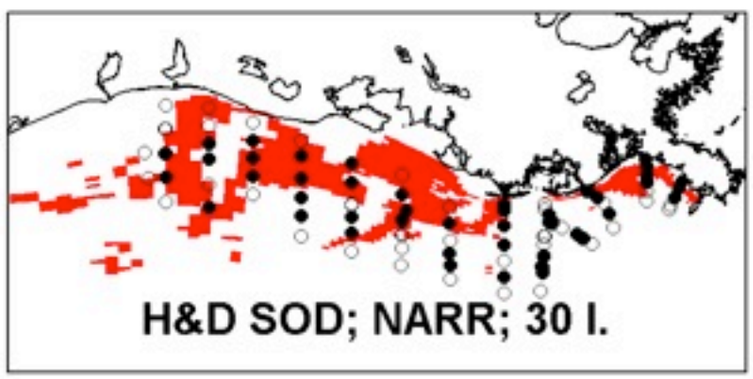


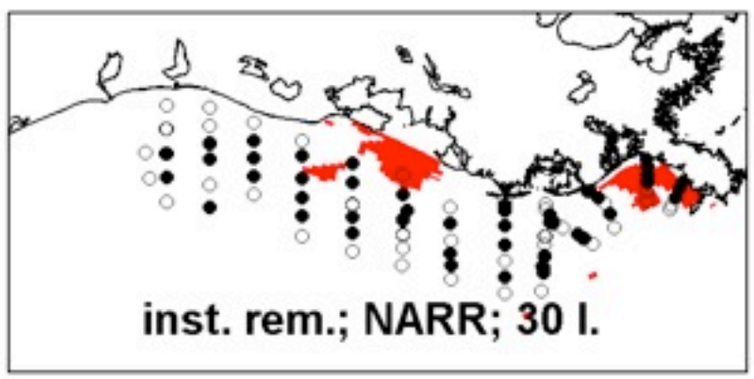
2005





2006

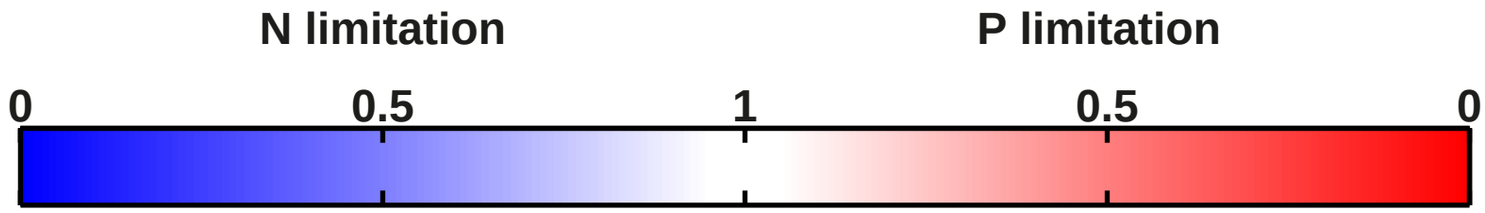


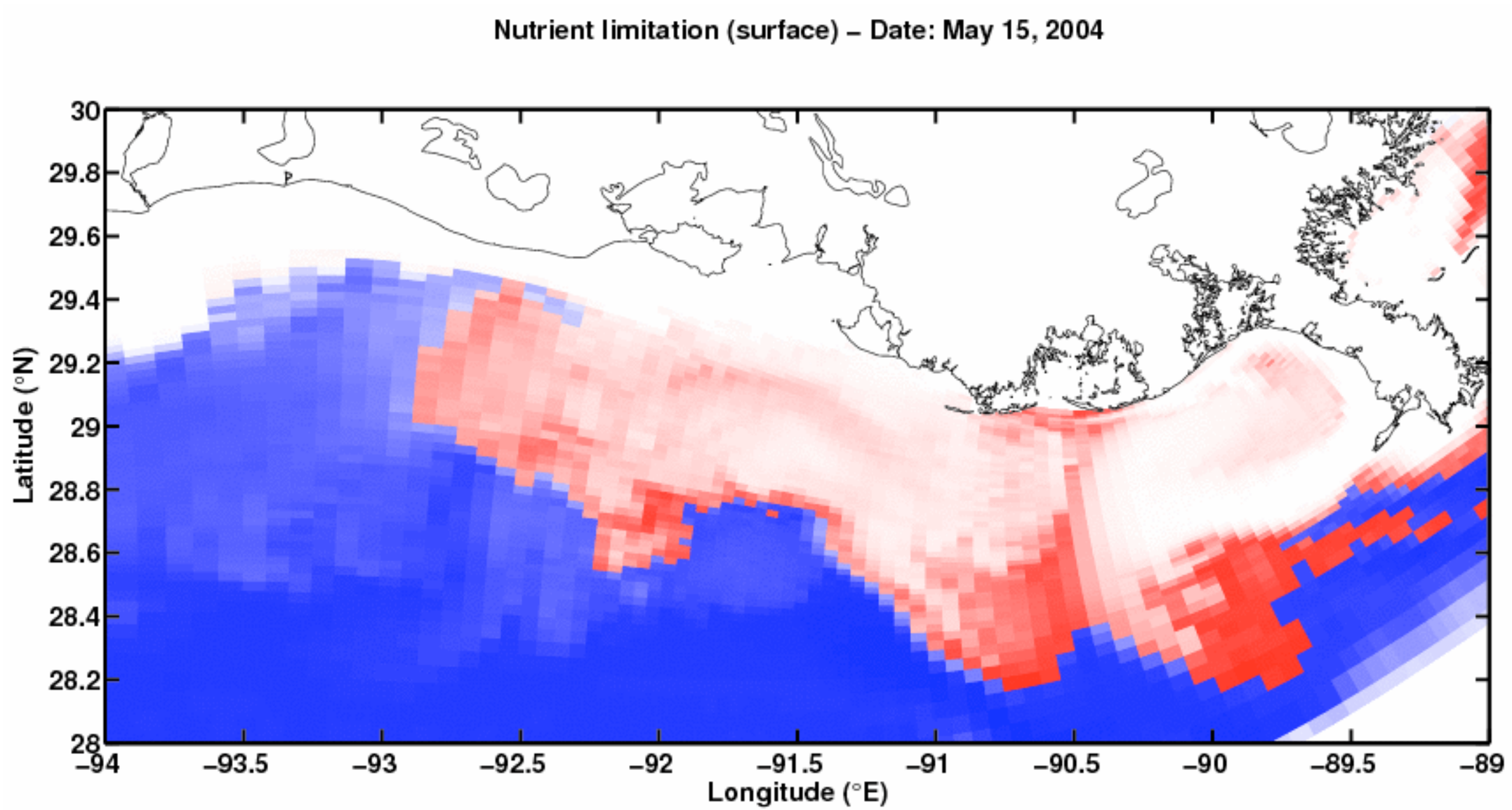


- H&D parameterization appears better able to capture hypoxic conditions on the shelf
- delays in organic matter processing that are not captured with inst. rem. but implicitly in H&D are important

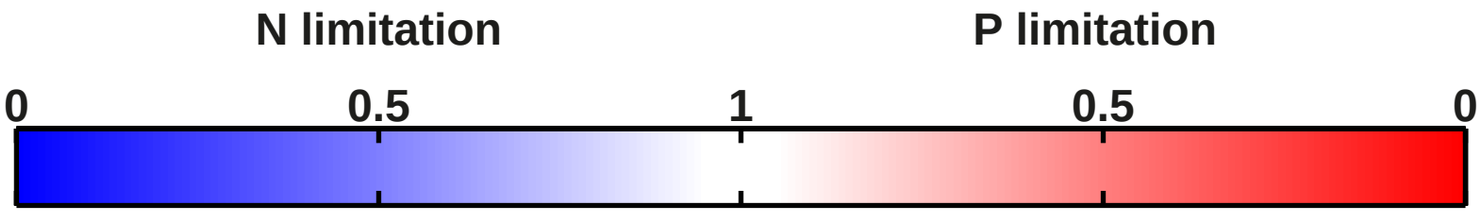
Surface phosphorus and nitrogen limitation

Jan – Dec 2004

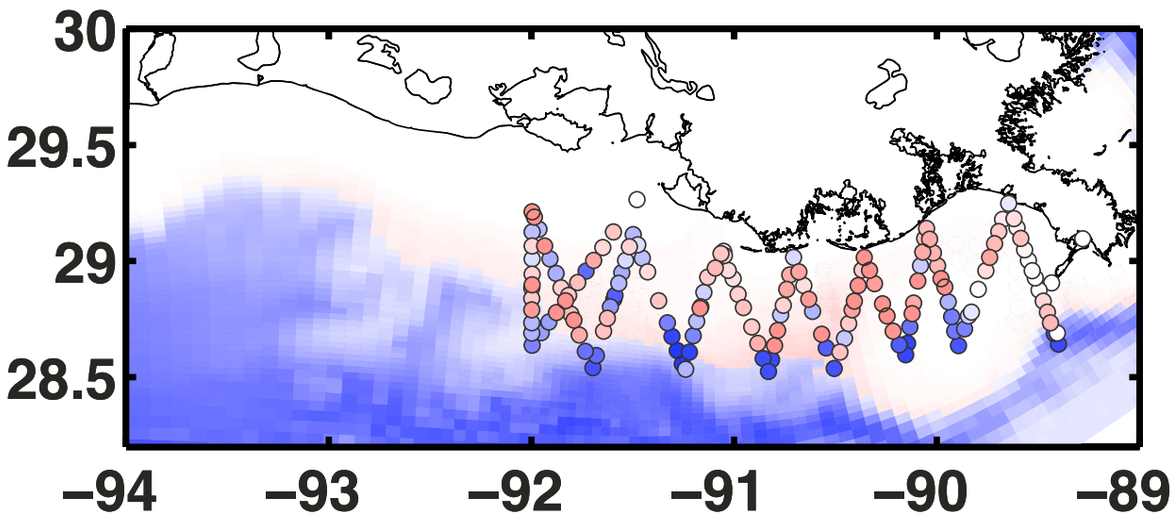




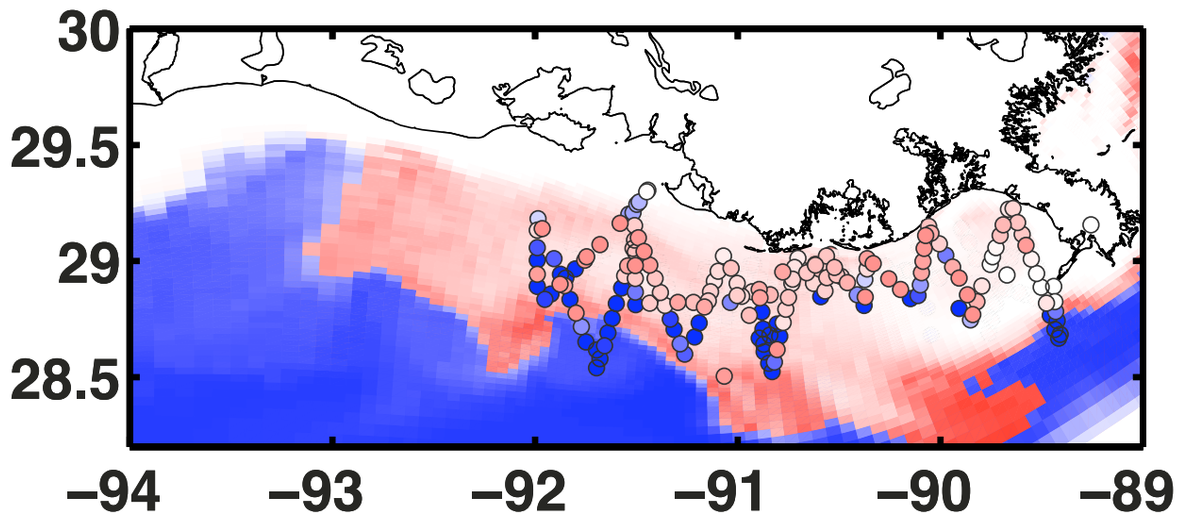
Nutrient limitation: model vs observations



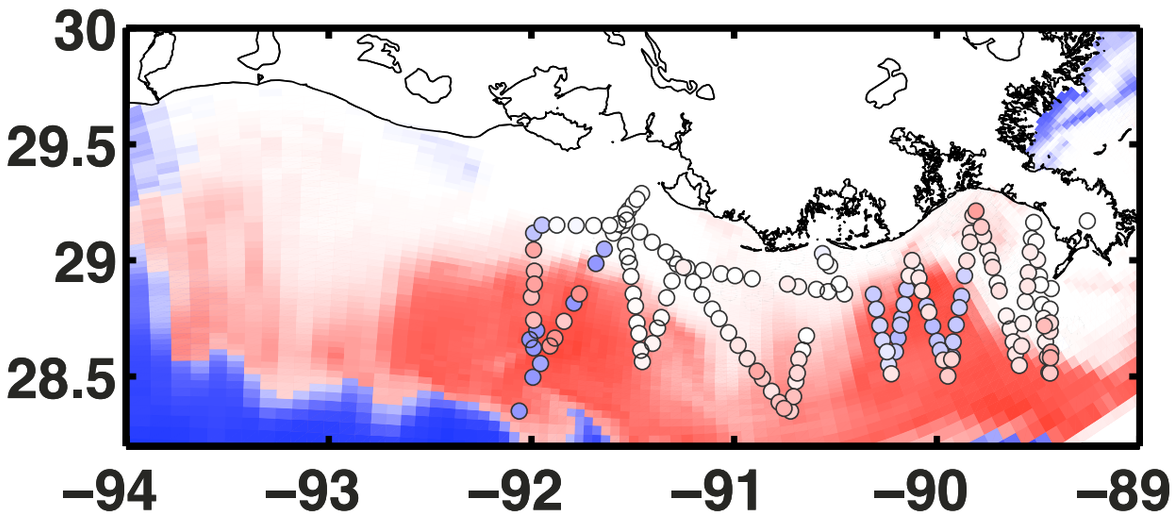
March 20–24, 2004



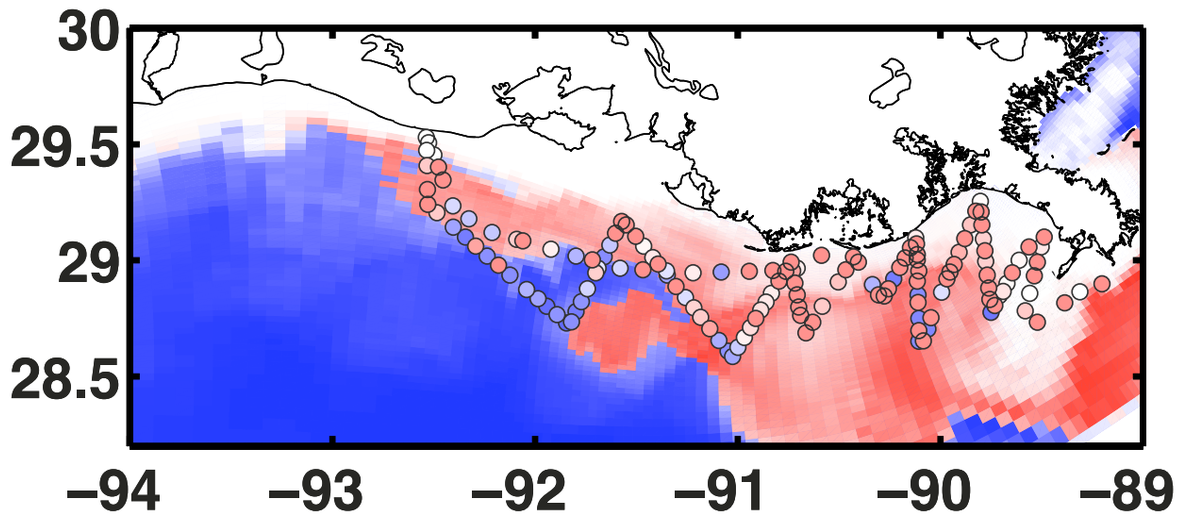
May 16–19, 2004



July 06–10, 2004



September 29–October 03, 2004

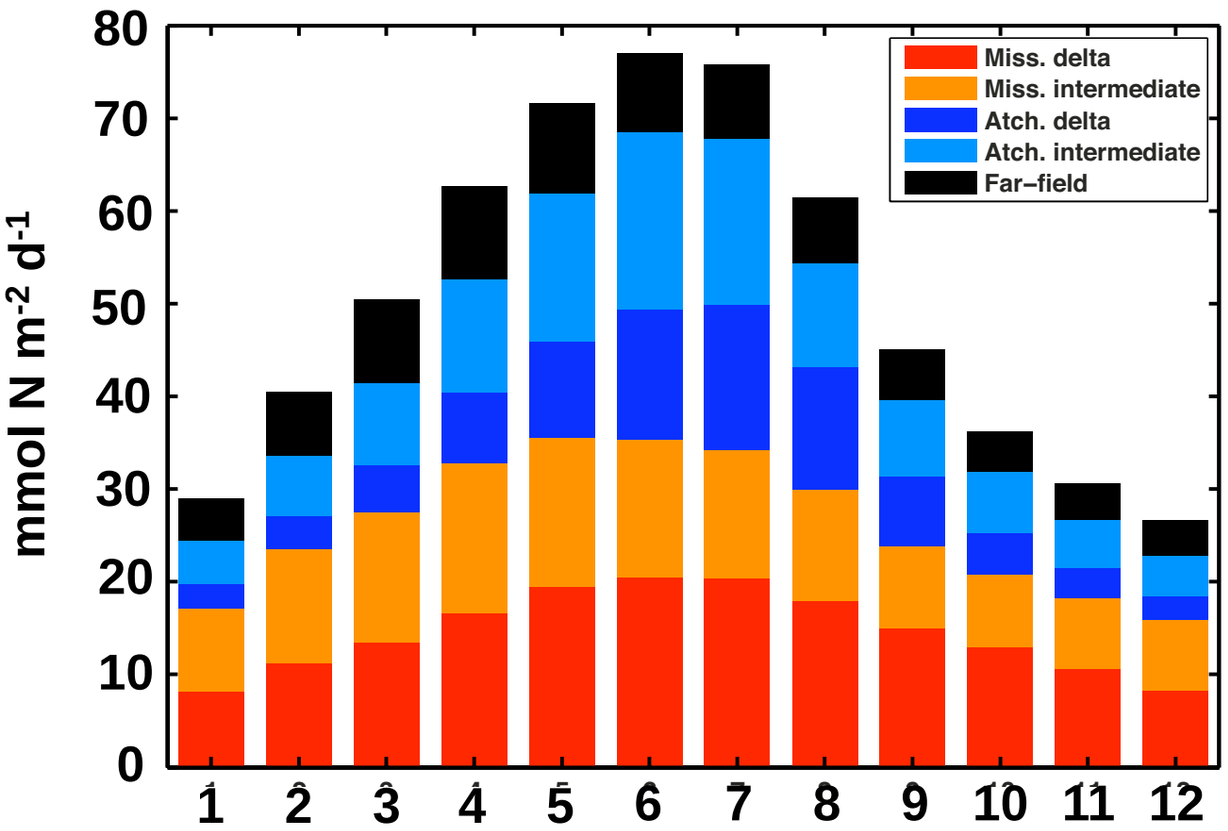


Laurent et al. *Biogeosciences* (to be submitted)

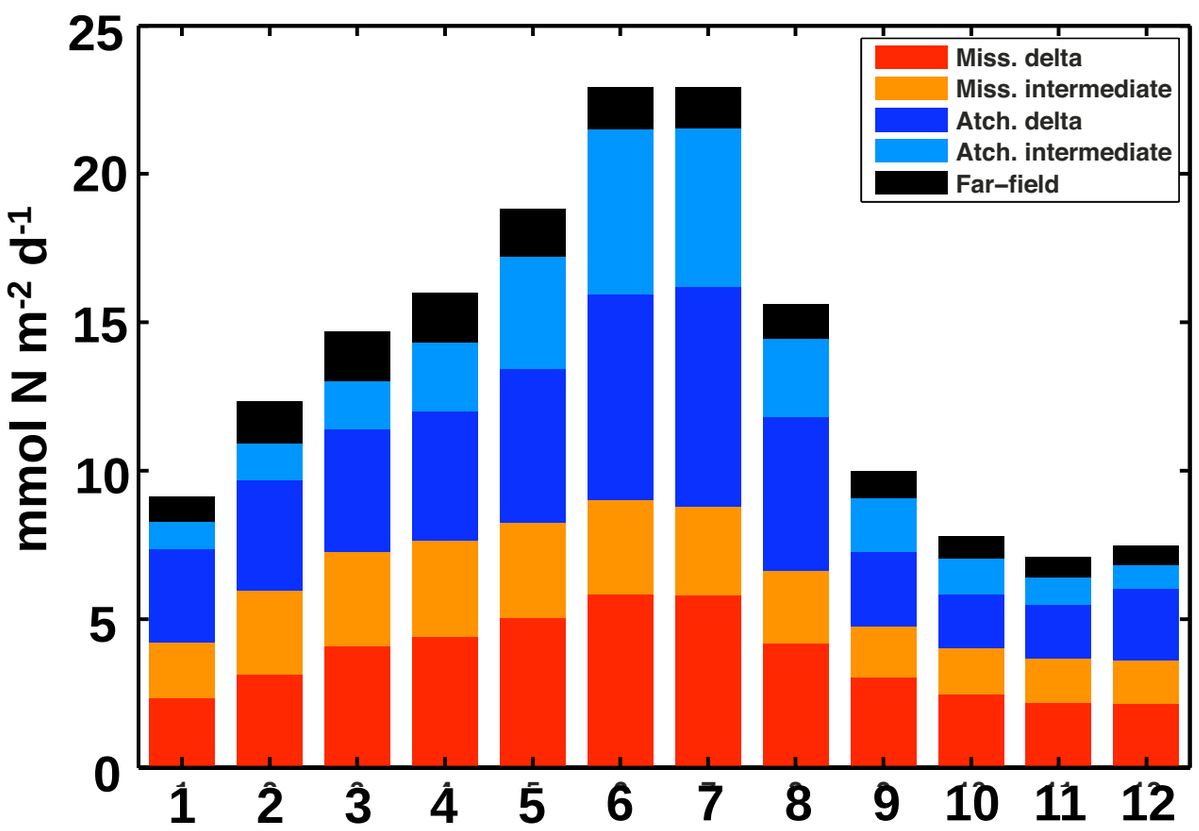
Effect of phosphorus limitation

Miss. delta
Miss. intermediate
Atch. delta
Atch. intermediate
Far–field

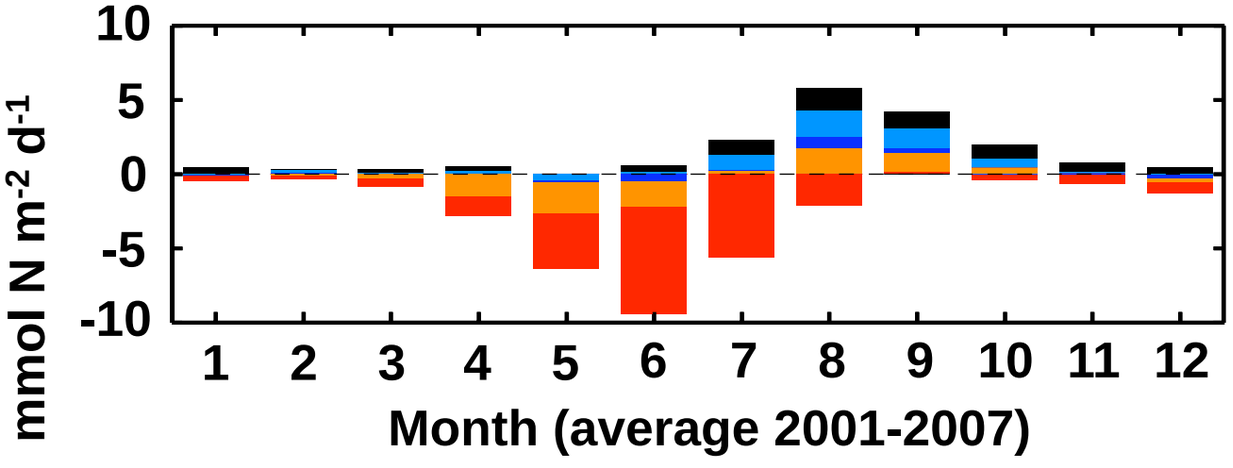
Primary production

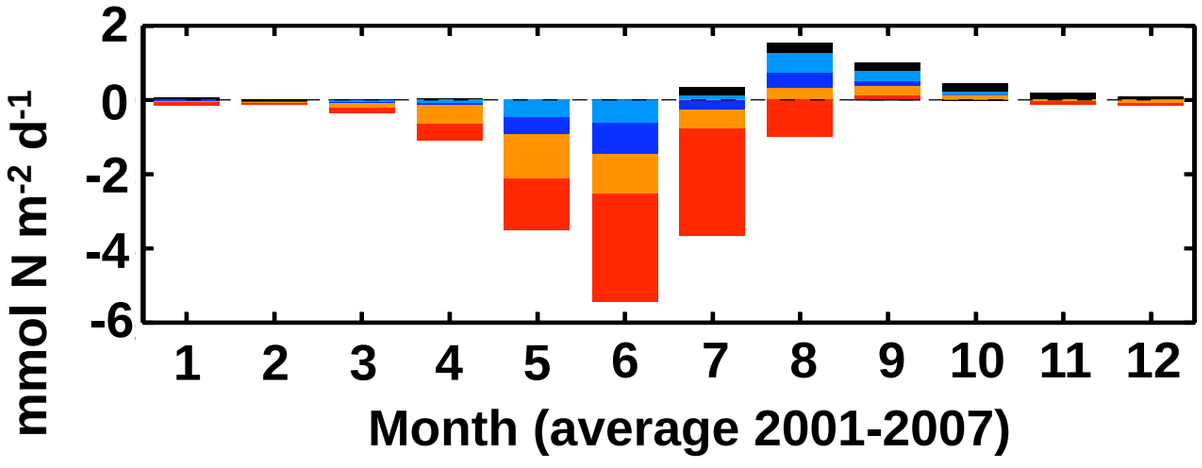


Particulate fluxes



Anomalies





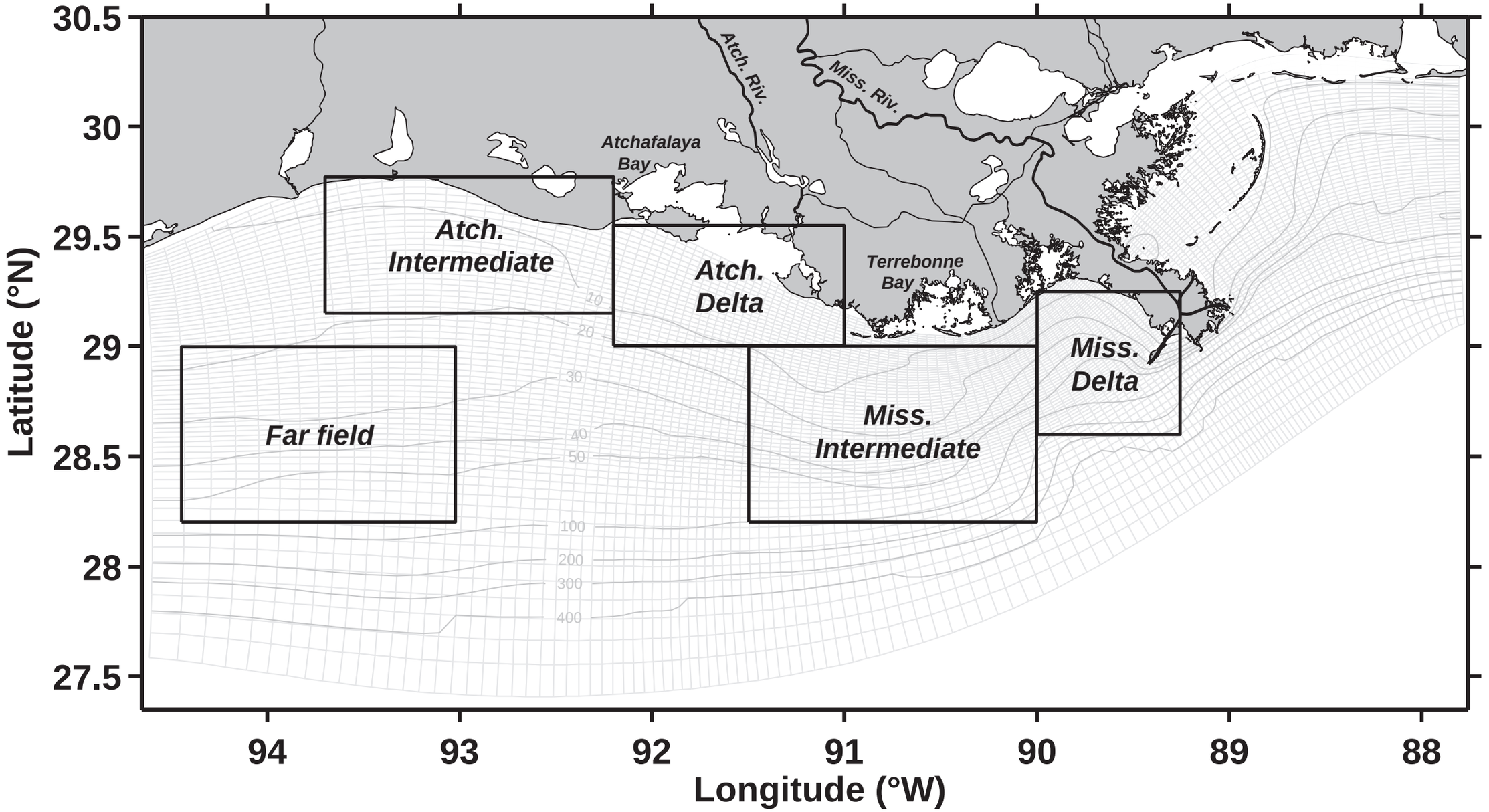
Laurent et al. *Biogeosciences* (to be submitted)

Summary

Greatest uncertainty in model predictions of hypoxia is in specification of Sediment Oxygen Consumption (SOC).

Model simulations suggest that primary production is limited by P during spring and early summer.

P-limitation effectively extends the area influenced by allochthonous nutrients.


30.5
30
29.5
29
28.5
28
27.5
Latitude (°N)
94
93
92
91
90
89
88
Longitude (°W)
Atch. Riv.
Miss. Riv.
Atchafalaya Bay
Terrebonne Bay
Atch. Intermediate
Atch. Delta
Miss. Delta
Miss. Intermediate
Far field
10
20
30
40
50
100
200
300
400