The Abdus Salam International Centre for Theoretical Physics

2066-6

Workshop and Conference on Biogeochemical Impacts of Climate and Land-Use Changes on Marine Ecosystems

2 - 10 November 2009

Anthropogenic Effects on the Biogeochemical Dynamics of Large-River Deltaic Coastlines: The Mississippi and Yangtze Rivers

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Anthropogenic and Natural Effects on the Biogeochemistry of Organic Carbon Cycling in River-Dominated Margins: The Mississippi and Yangtze (Chanjiang) Rivers

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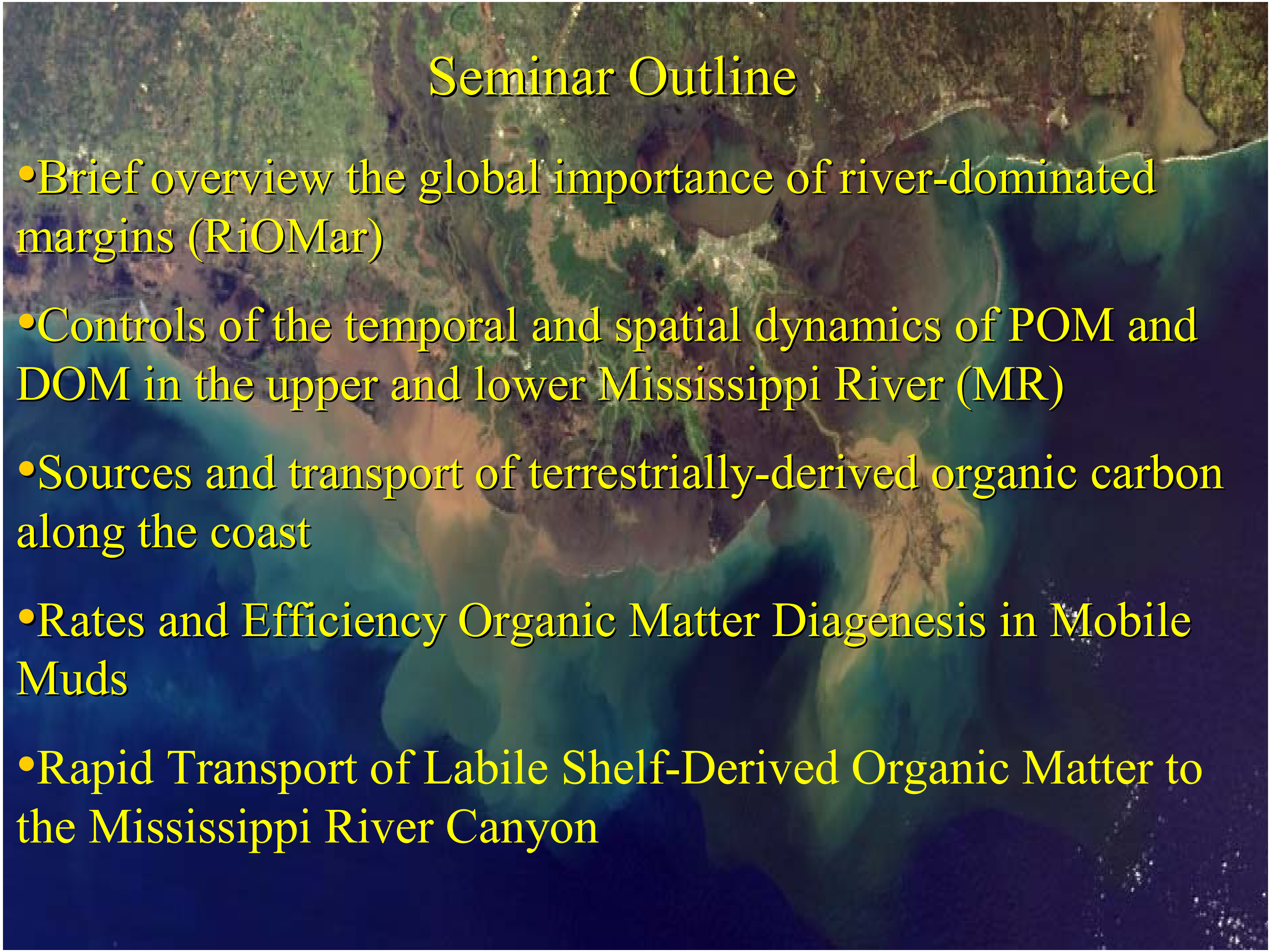
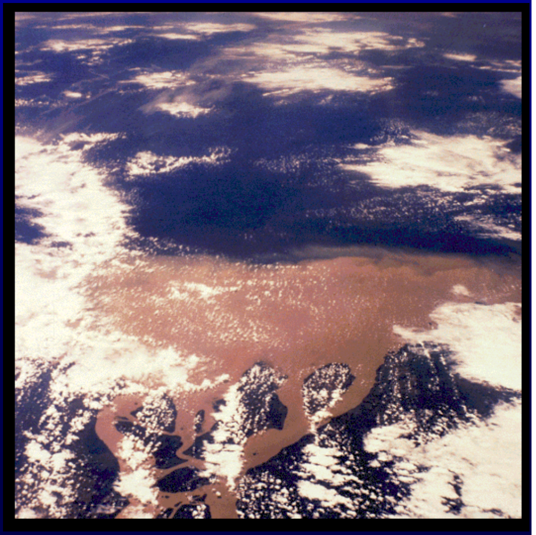

Seminar Outline
•Brief overview the global importance of river-dominated margins (RiOMar)
•Controls of the temporal and spatial dynamics of POM and DOM in the upper and lower Mississippi River (MR)
•Sources and transport of terrestrially-derived organic carbon along the coast
•Rates and Efficiency Organic Matter Diagenesis in Mobile Muds
•Rapid Transport of Labile Shelf-Derived Organic Matter to the Mississippi River Canyon

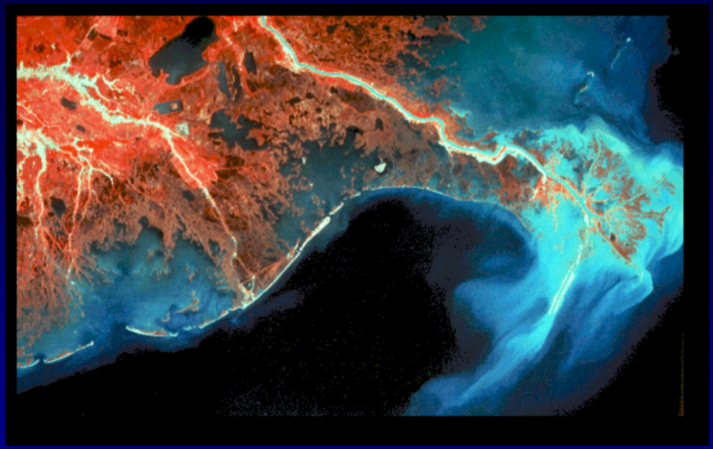
Collaborators

- Brent McKee (UNC) – radionuclides
- Mead Allison (UT) - seismic analysis and sedimentology
- Martha Sutula and Rebecca Green (ONR) – nutrients and carbon cycling
- Sid Mitra (ECU) - organics
- Nianhong Chen (postdoc at ODU), Shuiwang Duan (potsdoc at TAMUG), Bryan Grace, Troy Sampere, Laura Wysocki, - (Tulane, EES, graduate students) - chemical biomarkers (pigments, lignin), and bulk C, N, measurements

River-Dominated Ocean Margins (RiOMars)

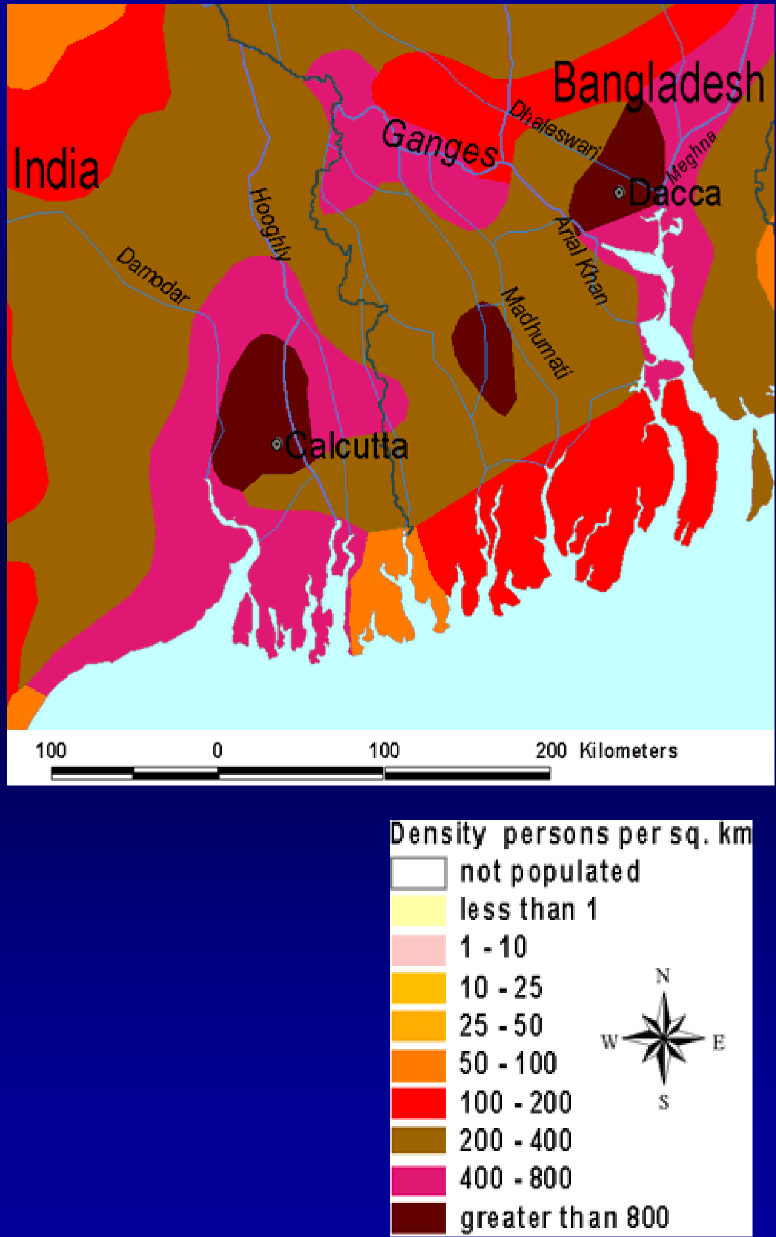
Most of the terrestrial materials (organic carbon, macronutrients, micronutrients, major/minor elements, mineral matter) transported to the oceans enter via these margin environments

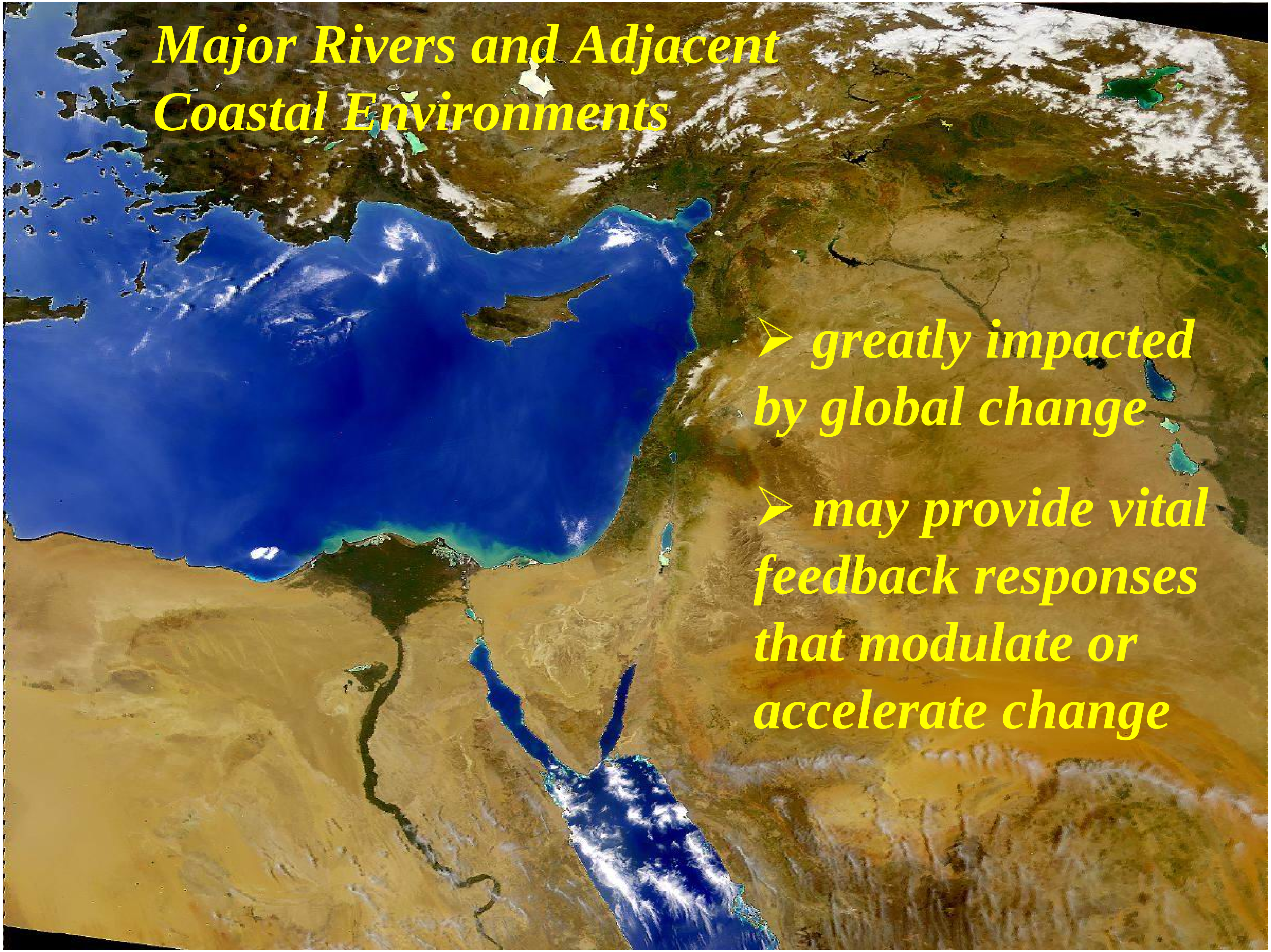




Rivers and Coasts are regions of high population density

- By 2025, ~ 75% of world's population will live in the coastal zone
- Most of the remaining 25% will live near a major river




Major Rivers and Adjacent Coastal Environments
➢ greatly impacted by global change
➢ may provide vital feedback responses that modulate or accelerate change

Large River Delta-Front Estuary (LDE)

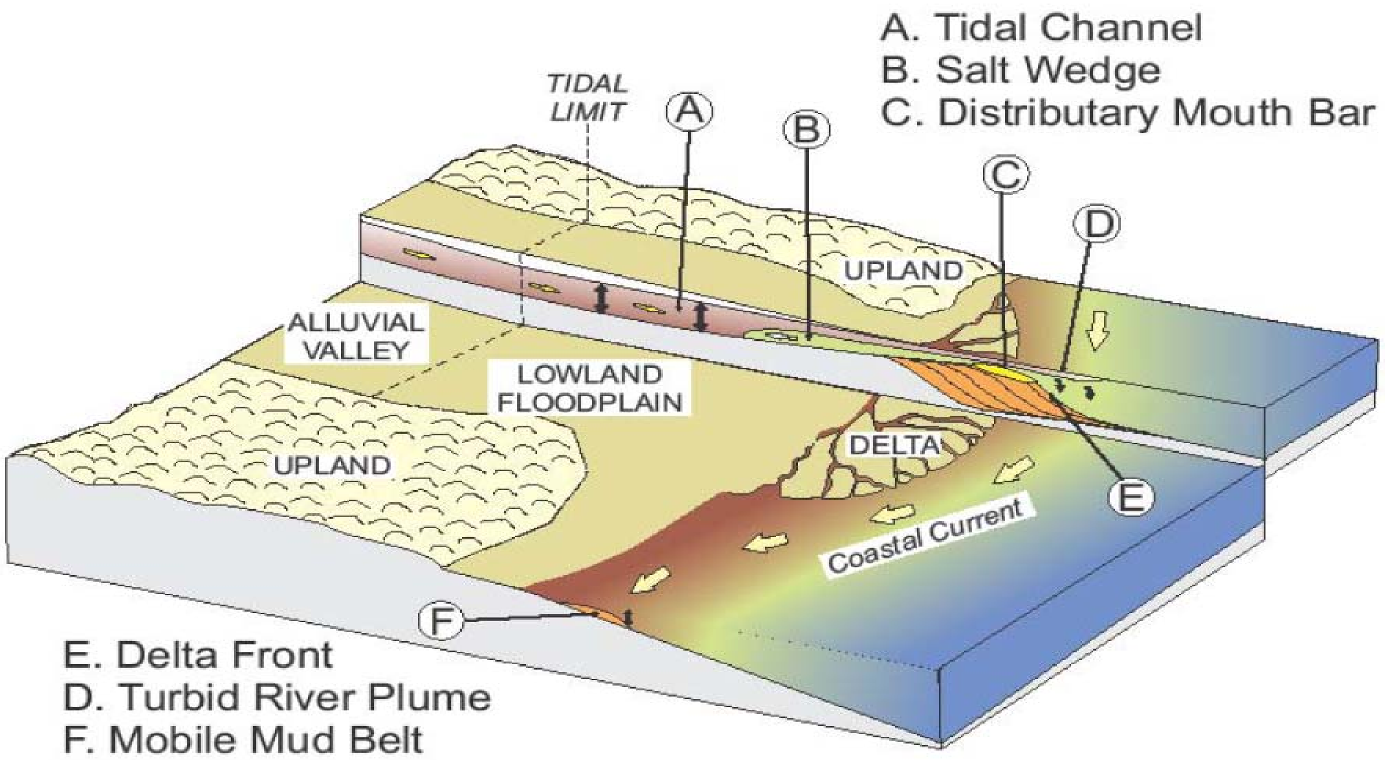
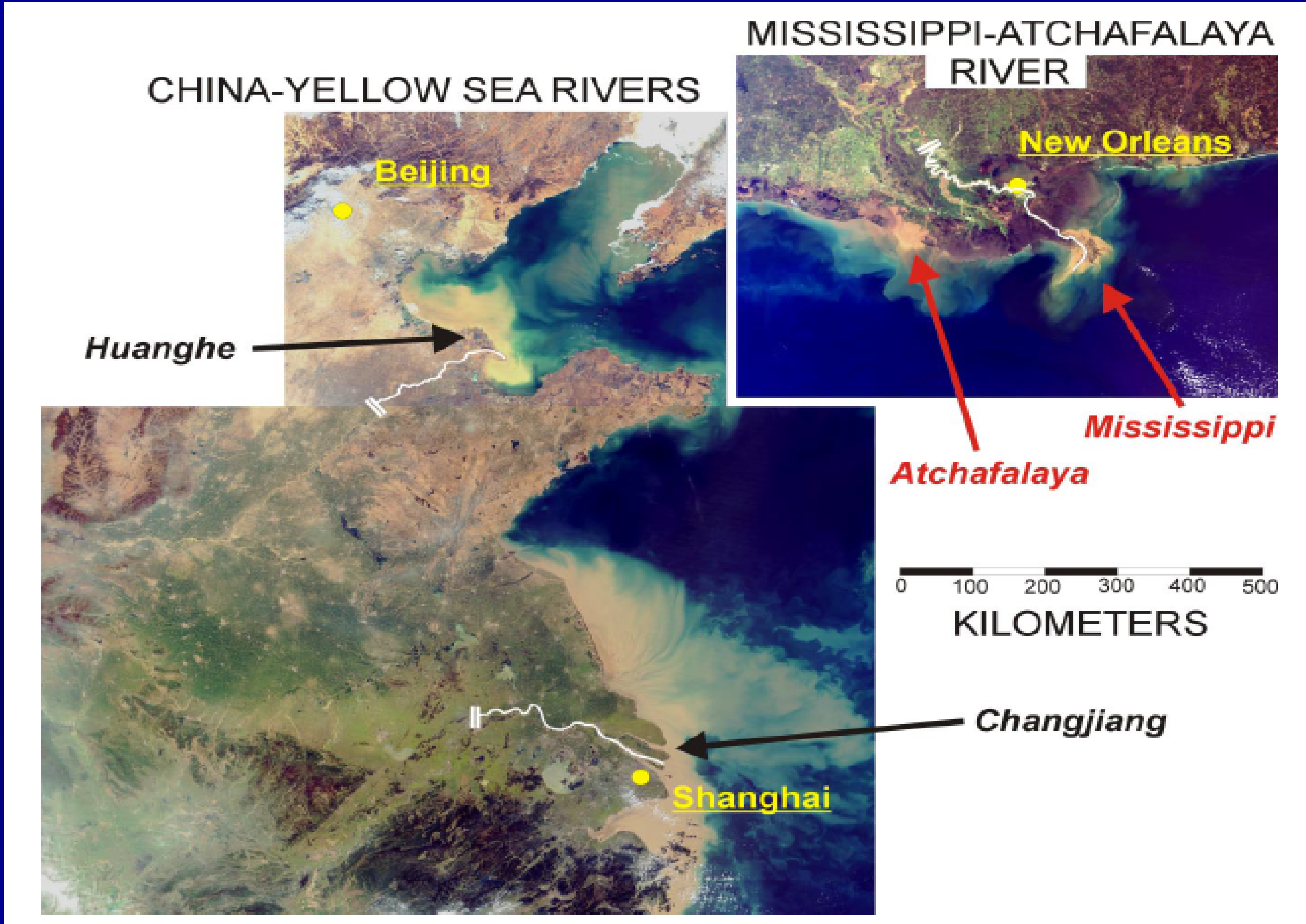


Figure 2. Regional geomorphogical boundaries and associated sedimentary deposits within an LDE.

Bianchi and Allison (2009) PNAS



Bianchi and Allison (2009) PNAS

The World's Twelve Largest Rivers

Sediment Discharge

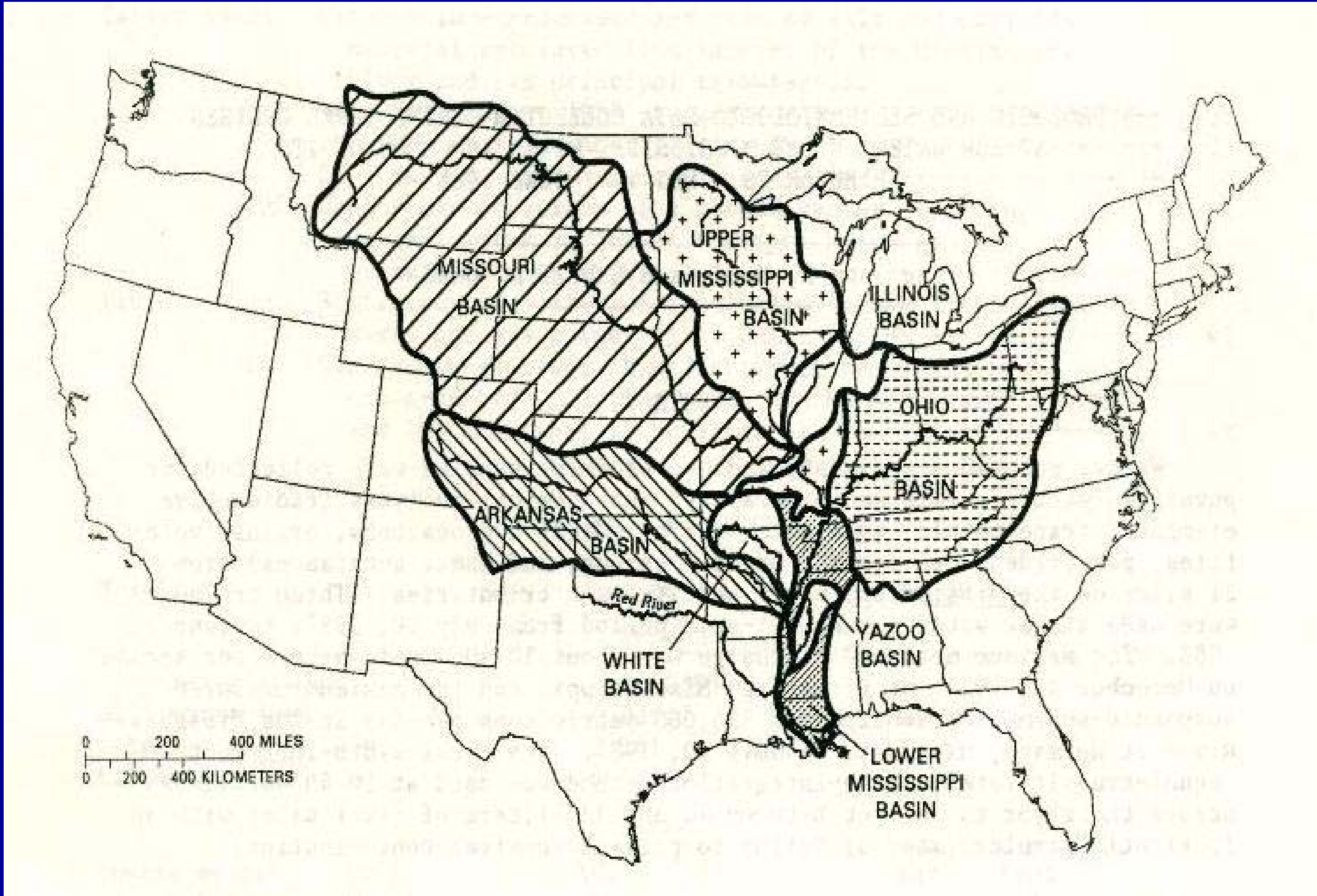
River	Discharge (10^6 t y^{-1})
1. Amazon	1000-1300
2. Yellow (Huanghe)	1100
3. Ganges/Brahmaputra	900-1200
4. Yangtze (Changjiang)	480
5. Irrawaddy	260
6. Magdalena	220
7. Mississippi	**210**
8. Godavari	170
9. Red (Hunghe)	160
9. Mekong	160
10. Orinoco	150
11. Purari/Fly	110
12. MacKenzie	100

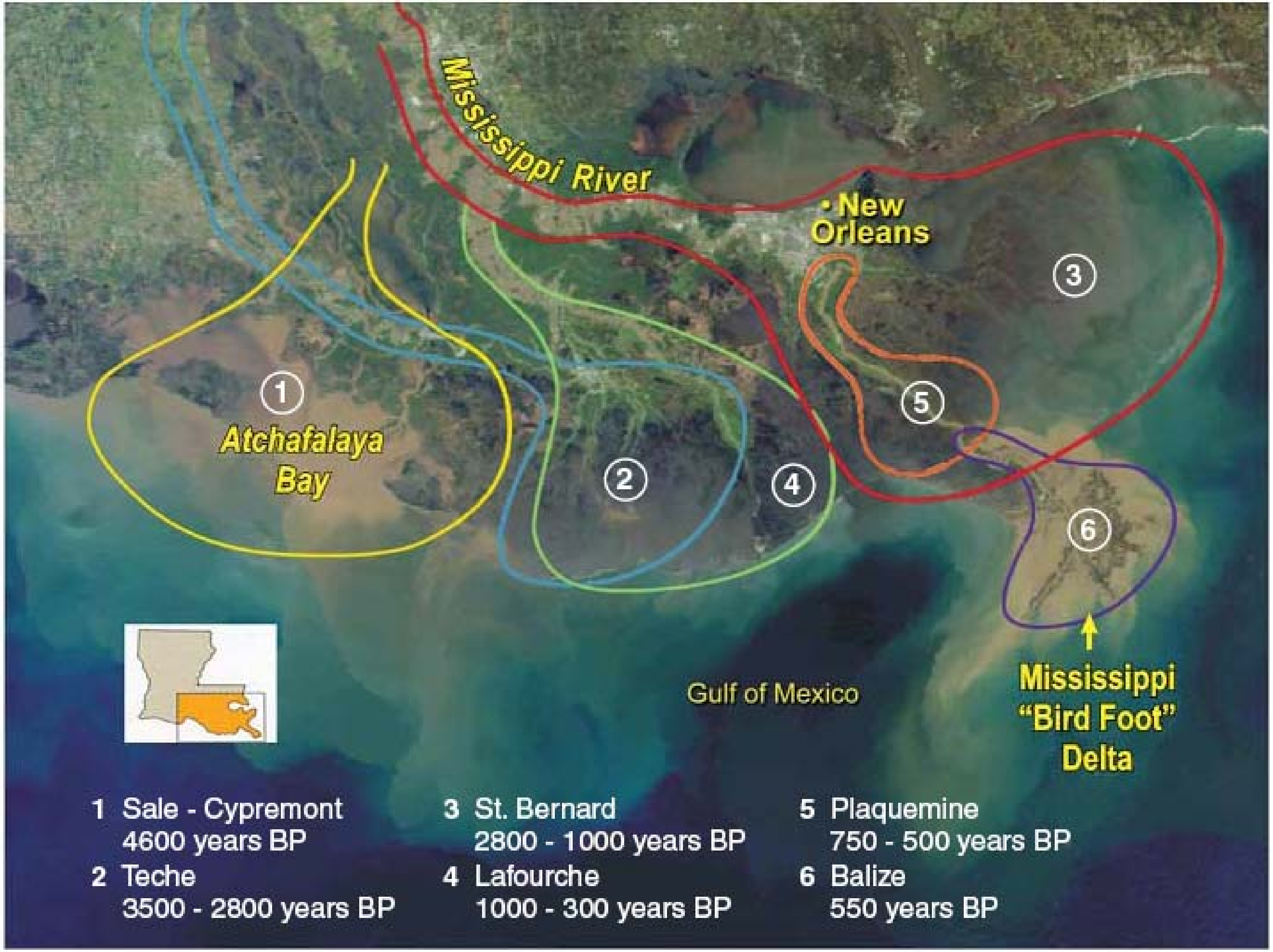
Water Discharge

River	Discharge (10^9 m^3 y^{-1})
1. Amazon	6300
2. Zaire	1250
3. Orinoco	1200
4. Ganges/Brahmaputra	970
5. Yangtze (Changjiang)	900
6. Yenisey	630
7. Mississippi	**530**
8. Lena	510
9. Mekong	470
9. Parana/Uruguay	470
10. St. Lawrence	450
11. Irrawaddy	430
12. Ob	400

Meade, 1996

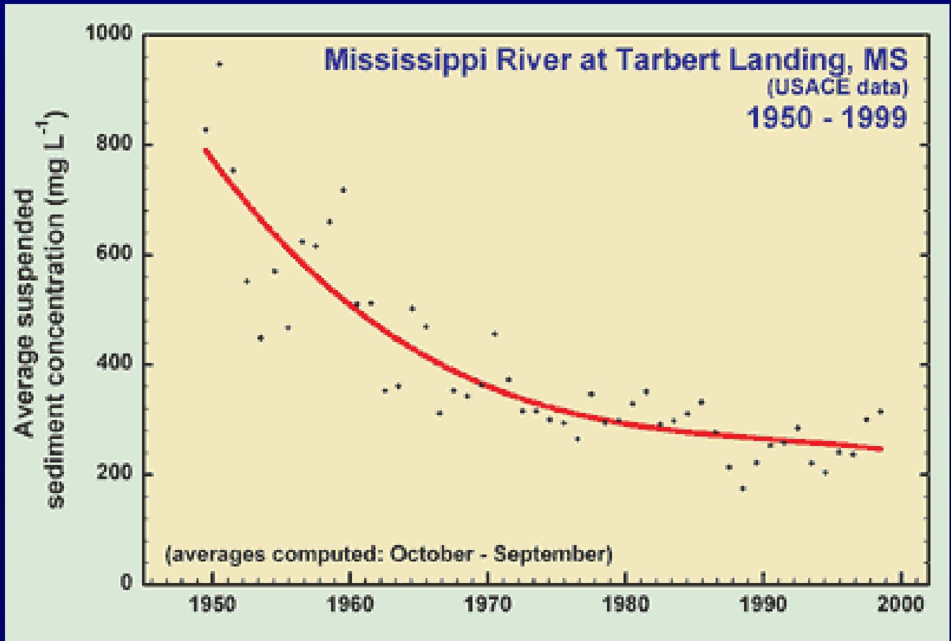
The Mississippi River and its Tributary Drainage Basins

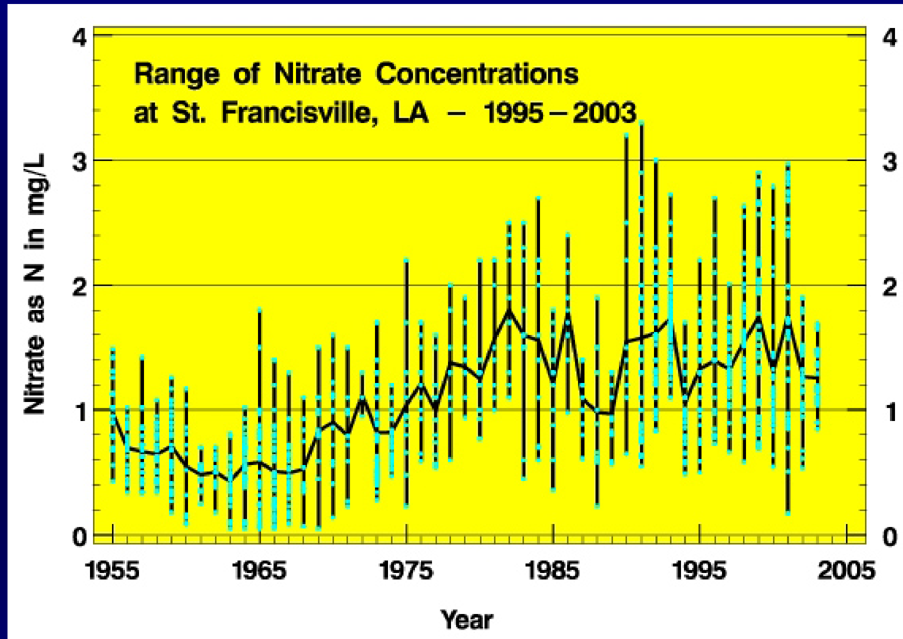




Day et al. (2007), as modified from Boyd and Penland (1988)

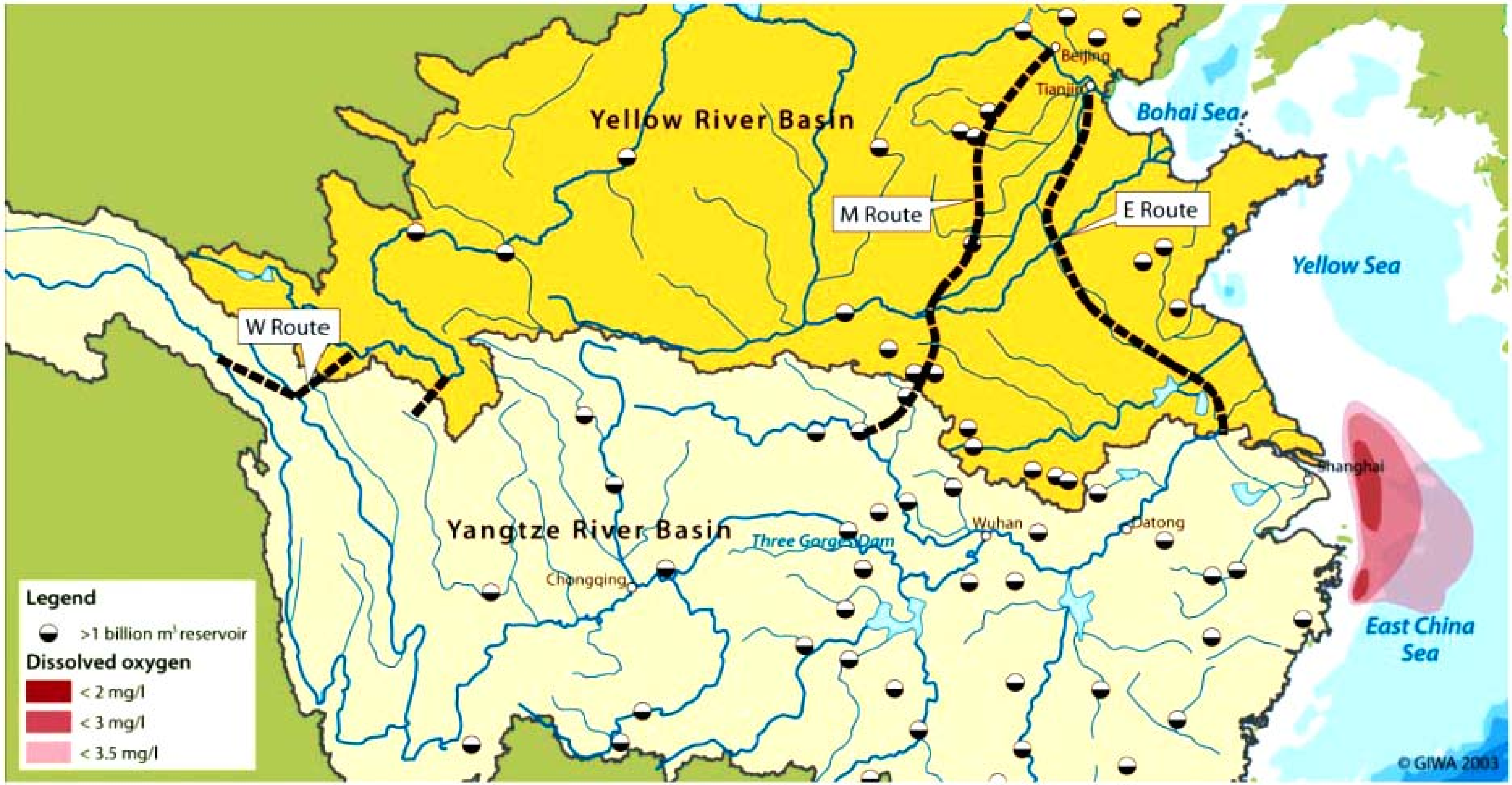
Historical Changes in the Suspended Particulate Matter and Nitrate Concentration in the Lower MR



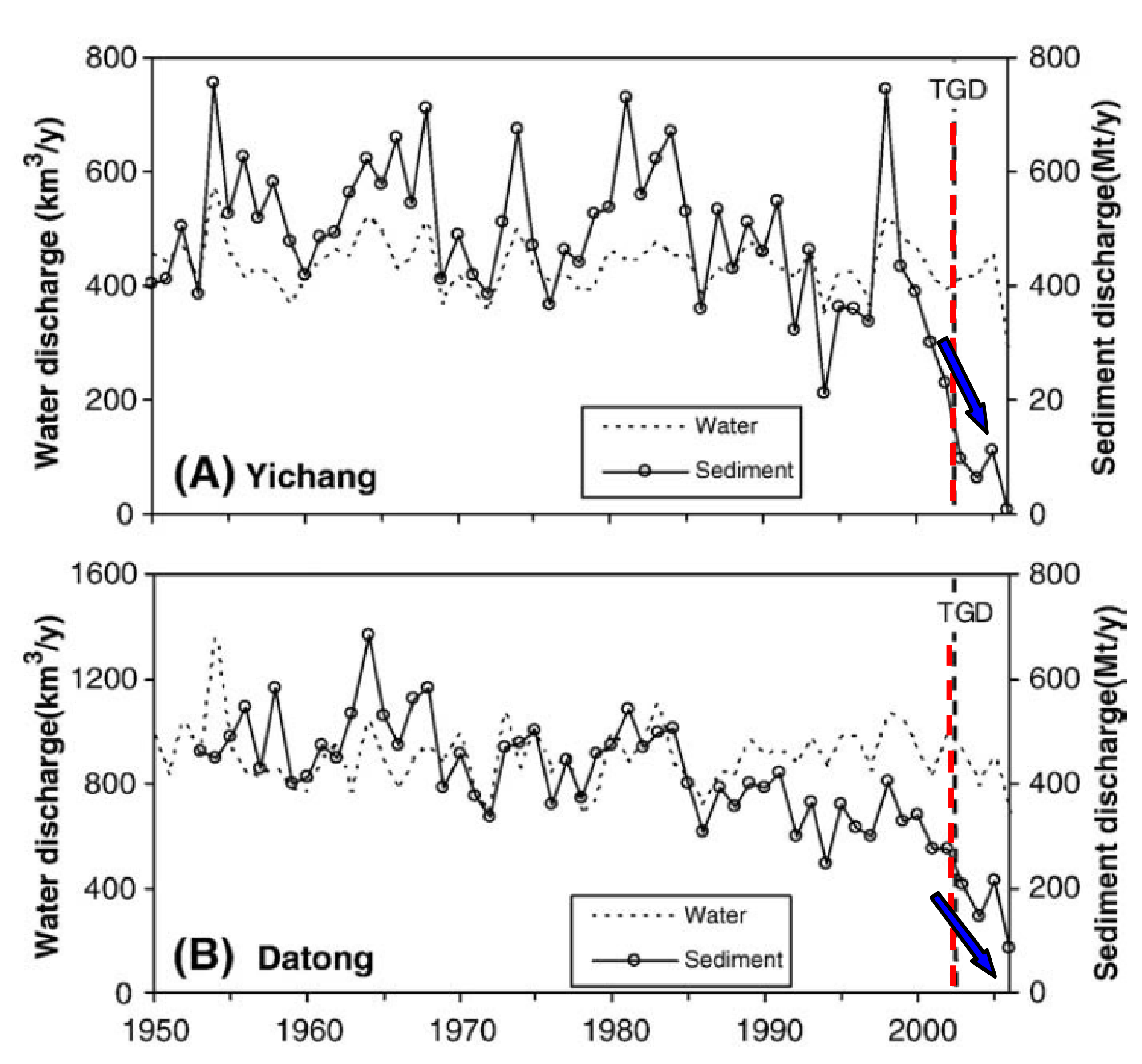


SPM concentrations decreased from 800 mg L^{-1} in 1950s to 250 mg L^{-1} in 1990s due to dam construction in the upper river.

Average nitrate concentrations increased from 0.6 to 0.7 mg L^{-1} in 1950s to the present level of about 1.5 mg L^{-1} because of utilization of chemical fertilizers.



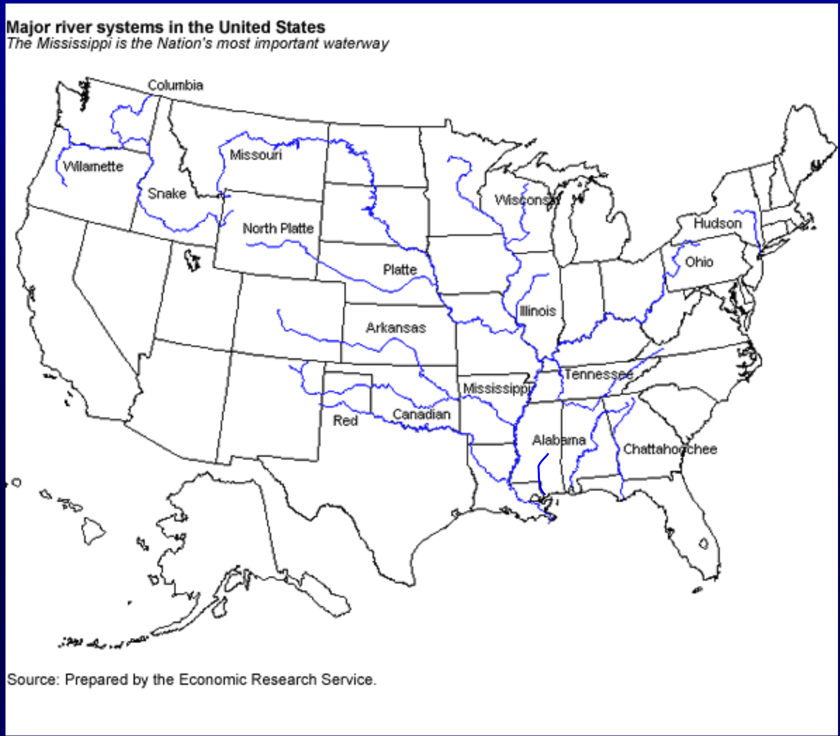
(Chai et al., 2006; Chen et al., 2007; Li et al., 2002)



Temporal variations of annual water and sediment discharge in upper (Yichang station) and lower (Datong station) reaches of the Yangte River in 1950–2006. Red vertical dashed lines TGD June 2003.The dramatic decrease after 2003 was mainly caused by the TGD (Xu and Milliman, 2009)

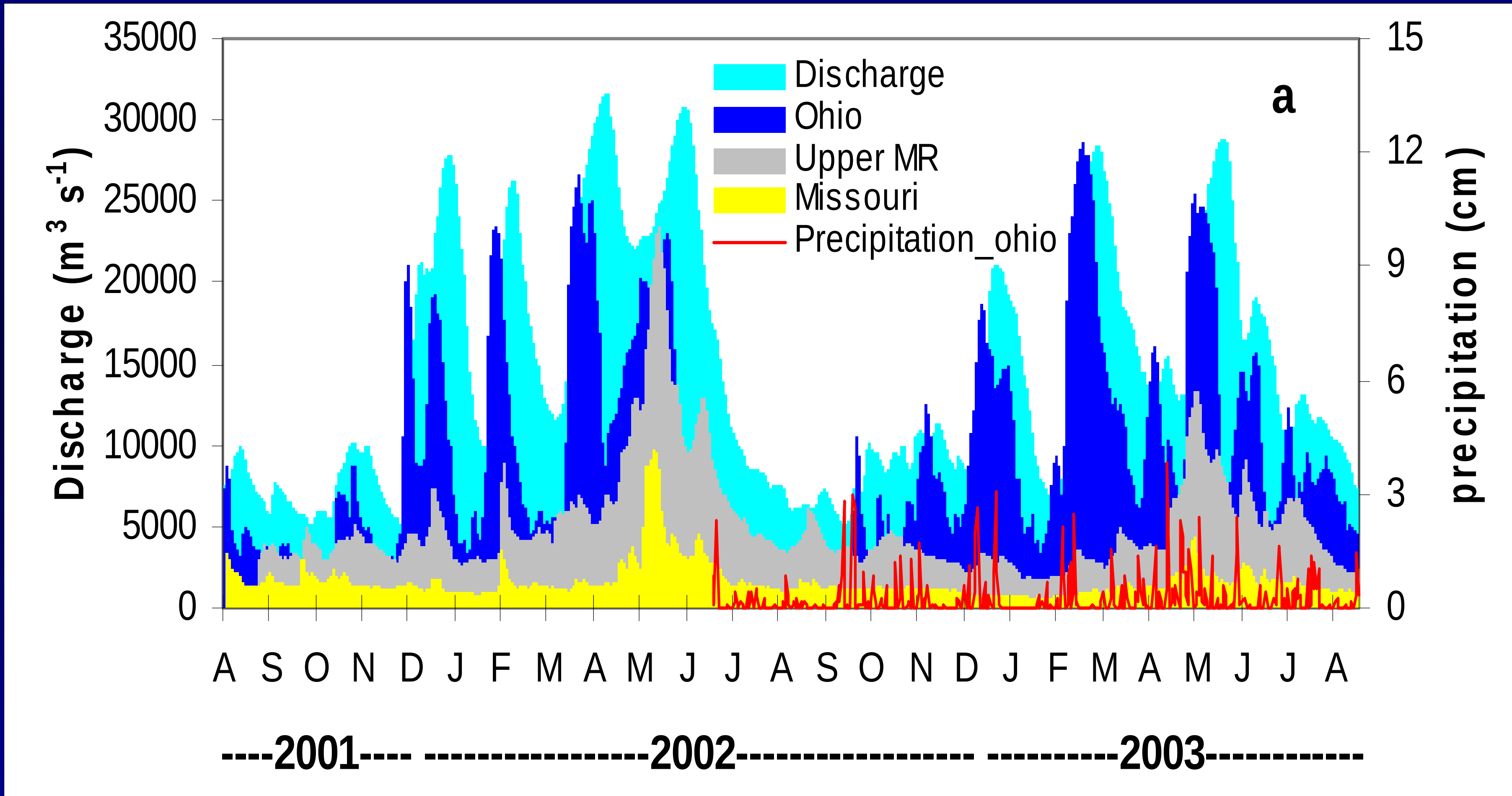
Controls on Temporal and Spatial Dynamics of POM and DOM in the Upper and Lower Mississippi River (MR)

Temporal Sampling



Mississippi River Sampling : Sept.2001-August 2003
Duan and Bianchi (2006)

Discharge Patterns of Mississippi, Ohio, and Missouri Rivers

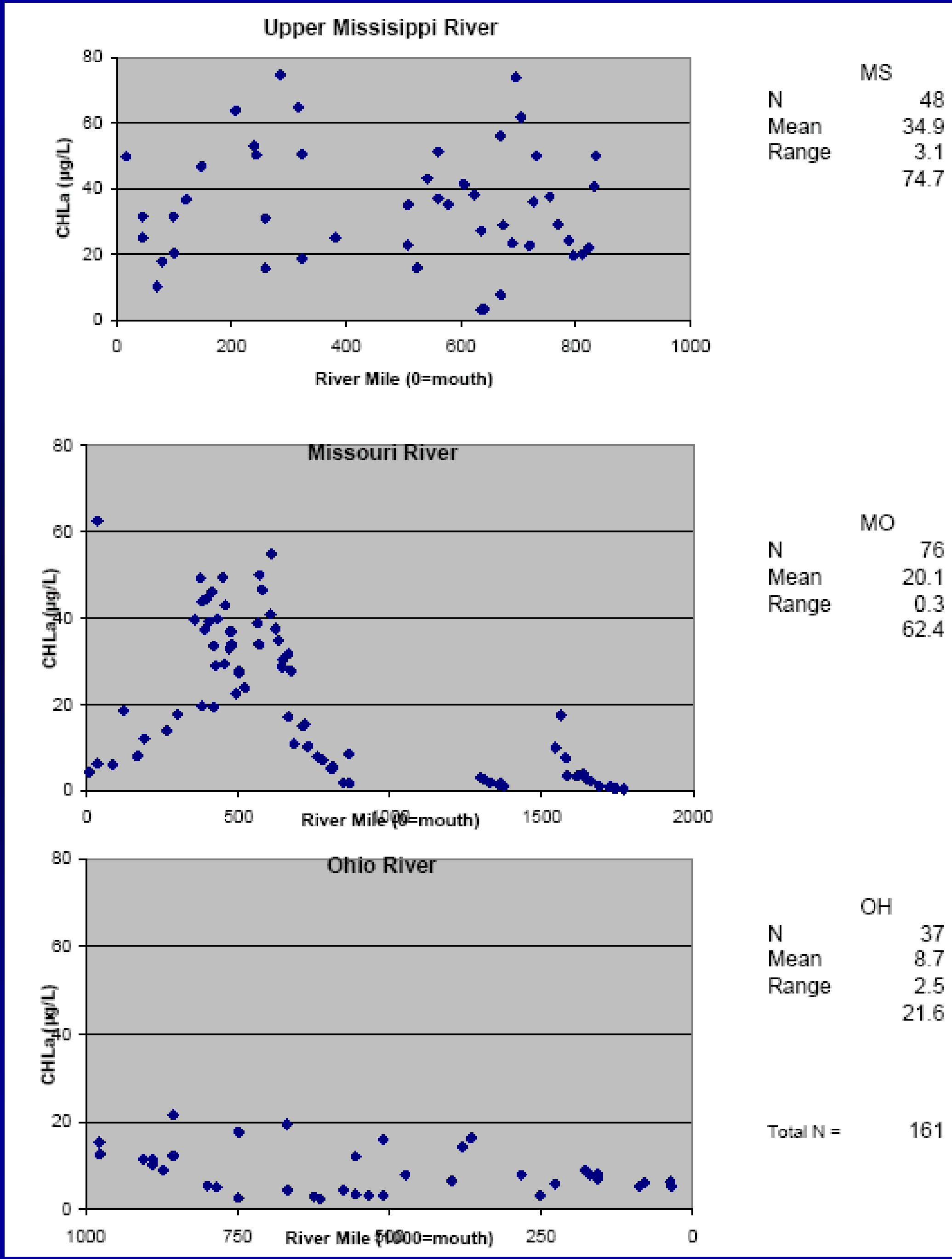


Duan and Bianchi (2006)

Phytoplankton Abundance in Primary Tributaries of the MR

(EPA-EMAP, 2004)

Likely due to export of phytoplankton biomass from backwater reservoirs, navigation locks, and wetlands of tributaries during high-flow periods. Duan and Bianchi (2006)



Particulate Organic Carbon and Chlorophyll-a

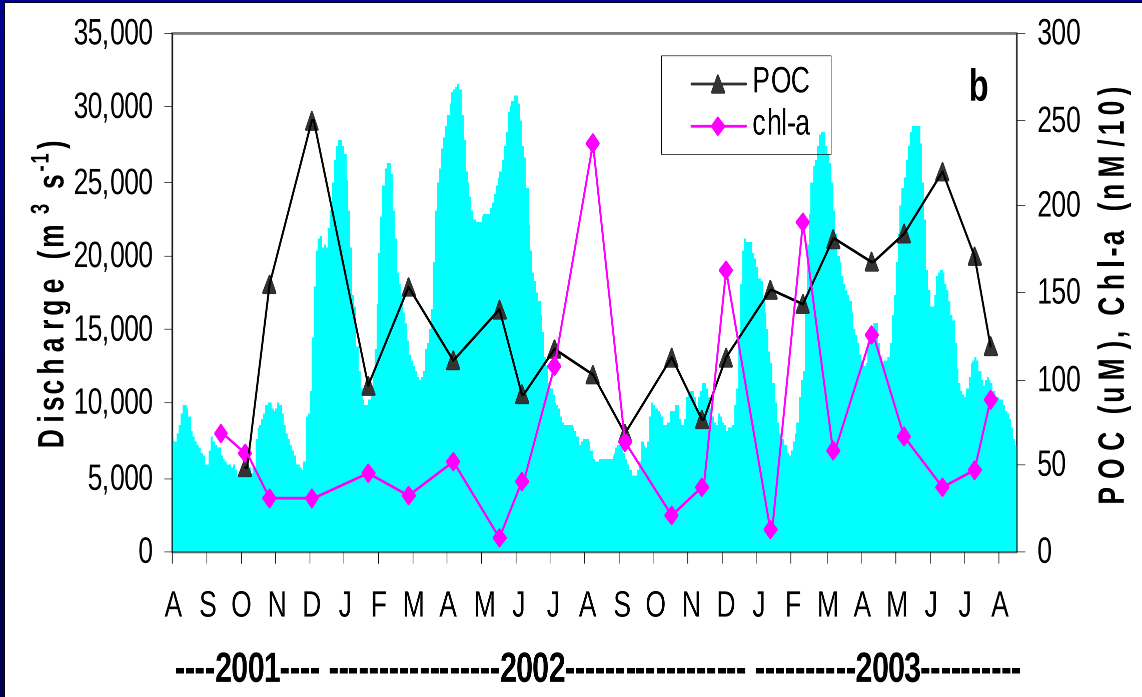
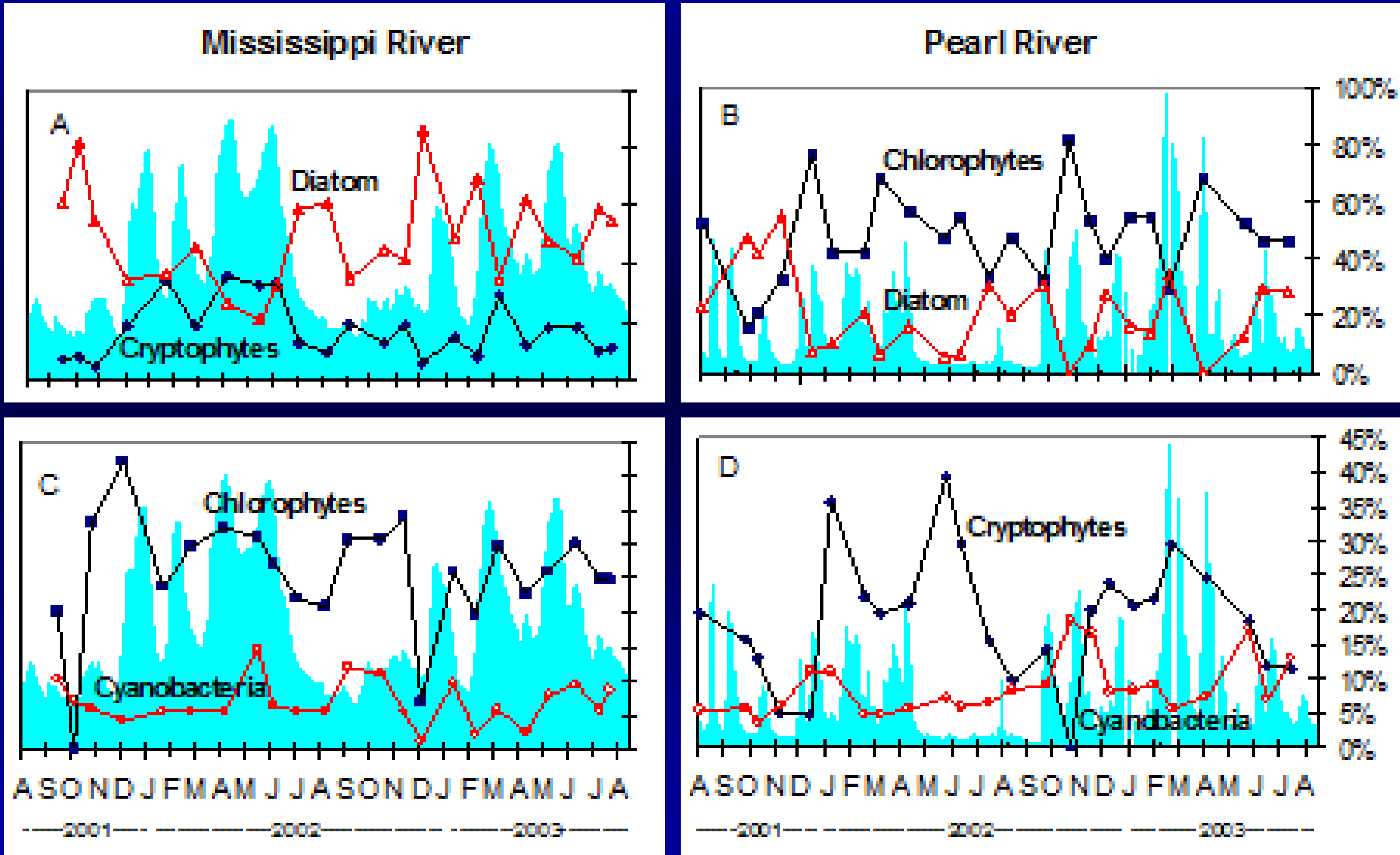


Table 1 Comparation of Chl-a concentration in MR, PR with other aquatic systems			
	Range (uM)	Average(uM)	Source
Lower Mississippi	0.8 - 23.6	7.1	This study
Pearl	0.8 - 10.7	3.4	This study
Columbia (USA)	1.1 - 22.2		Sullivan et al. 2001
Ohio (USA)	1.1 - 17.7		Sellers and Bukaveckas, 2003
MR Plume	0.44 - 31.1	3.2/6.9	Wysocki, et al., 2005
Lake Pontchartrain (U	0.3 - 7.7	2.6	Bianchi and Argyrou, 1997
Plumes in Baltic Sea		6.5-13.1	Wasmund et al., 1999
Suwannee (USA)	< 0.1		
Amazon	0.17-2.38		Saliot et al., 2001

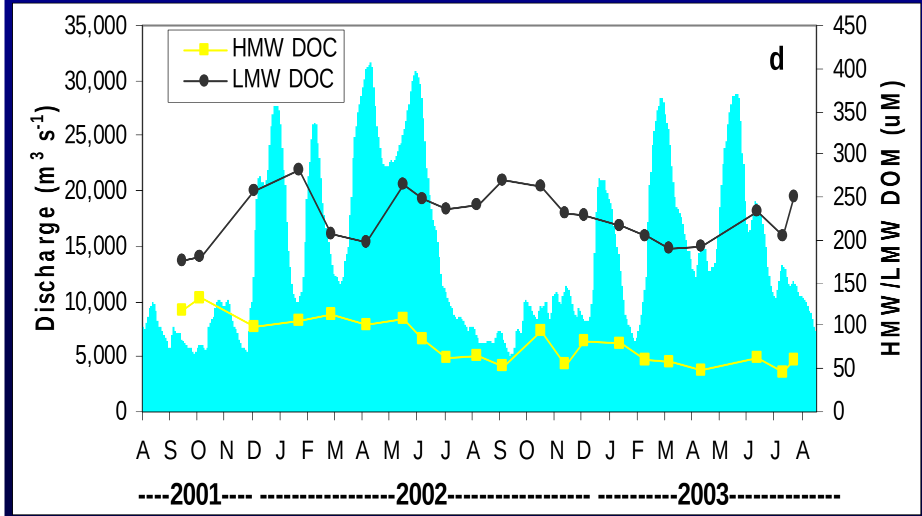
Duan and Bianchi (2006)

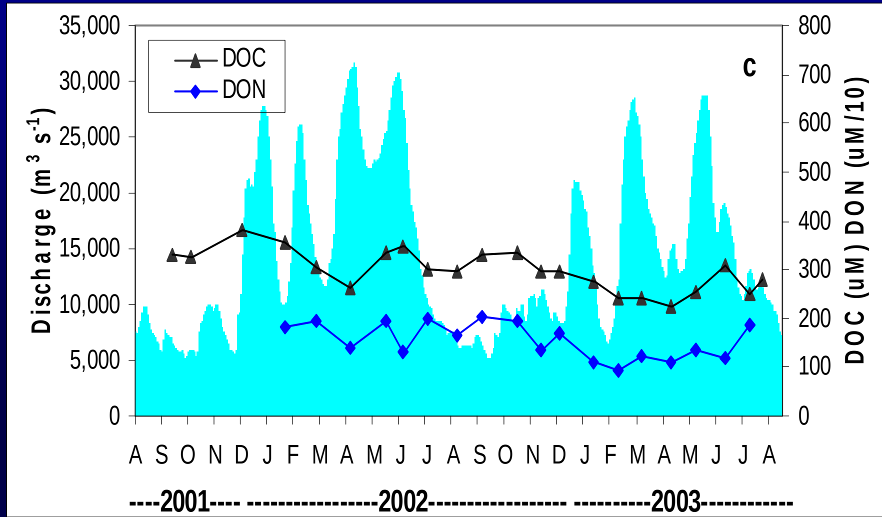
Phytoplankton Composition



Duan and Bianchi (2006)

High-Molecular Weight (> 1 kDa) (colloidal) and Low Molecular (< 1 kDa) Organic Carbon



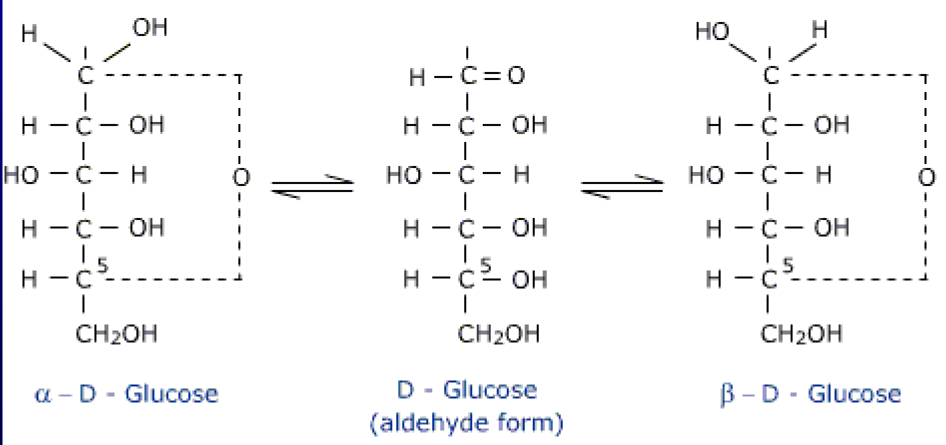


HMW DOC: 82 ± 26 μM; 25 ± 6%; LMW DOC: 236 ± 45 μM; 75 ± 7 %

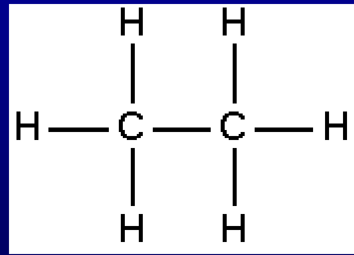
Duan et al. (2007)

Mean molecular weight in the MR was lower than expected based on other studies. However, this is consistent with size continuum concept (Amon and Benner, 1996) whereby *in-situ* processing decreases OM size. Tilling activity in agricultural watershed blocks formation of large molecules (e.g. humic substances) producing more LMW DOM in runoff (Dalzell et al., 2005).

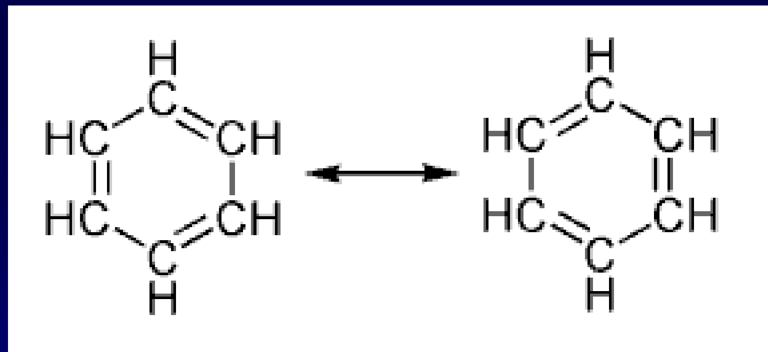
Carbon Functional Groups



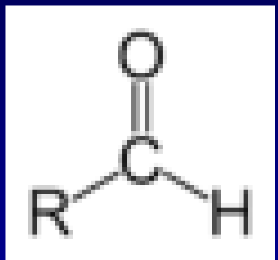
anomeric



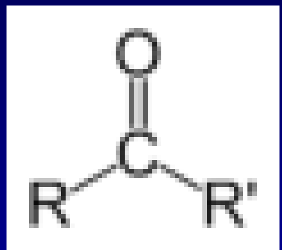
aliphatic



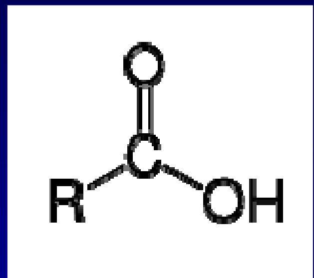
aromatic



aldehyde

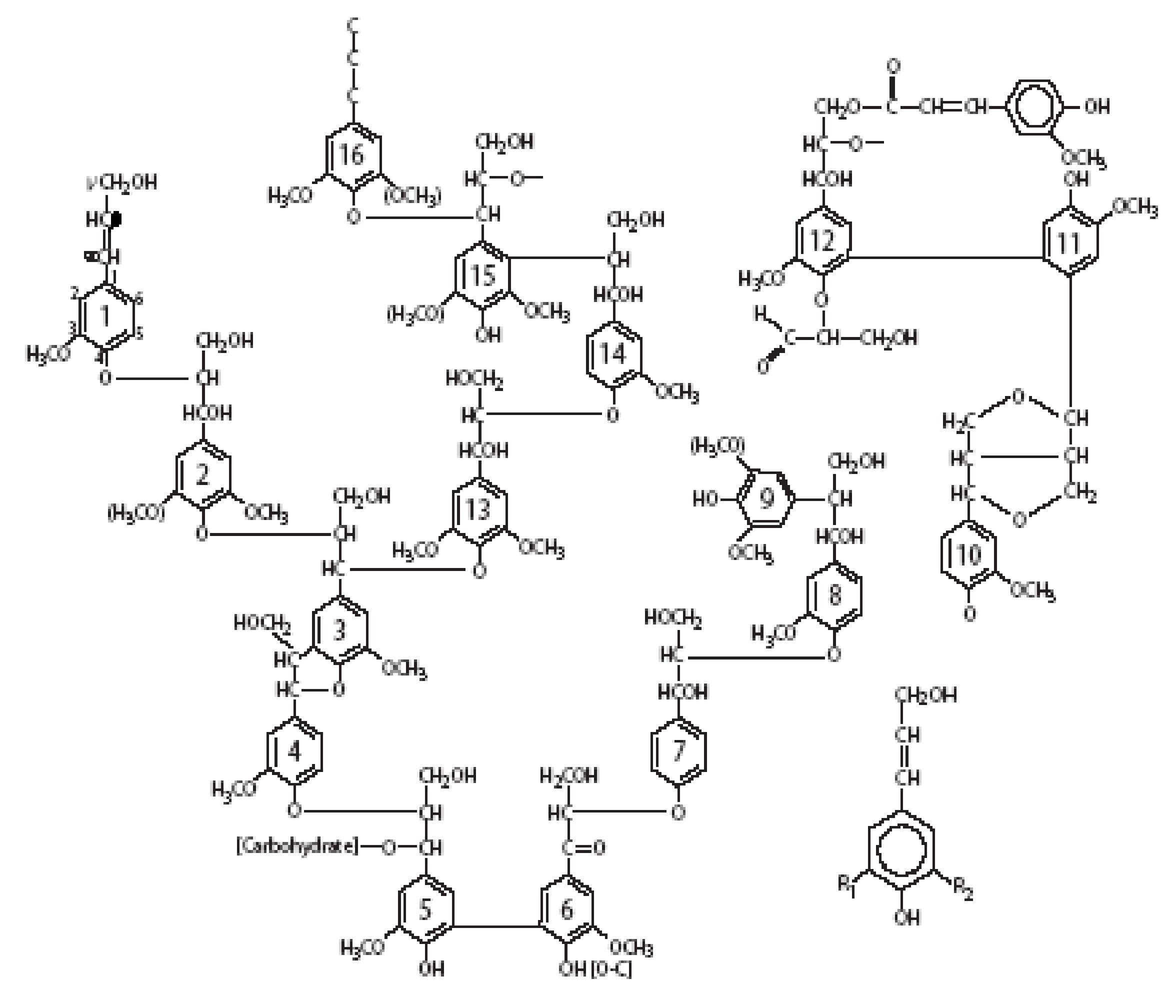


ketone

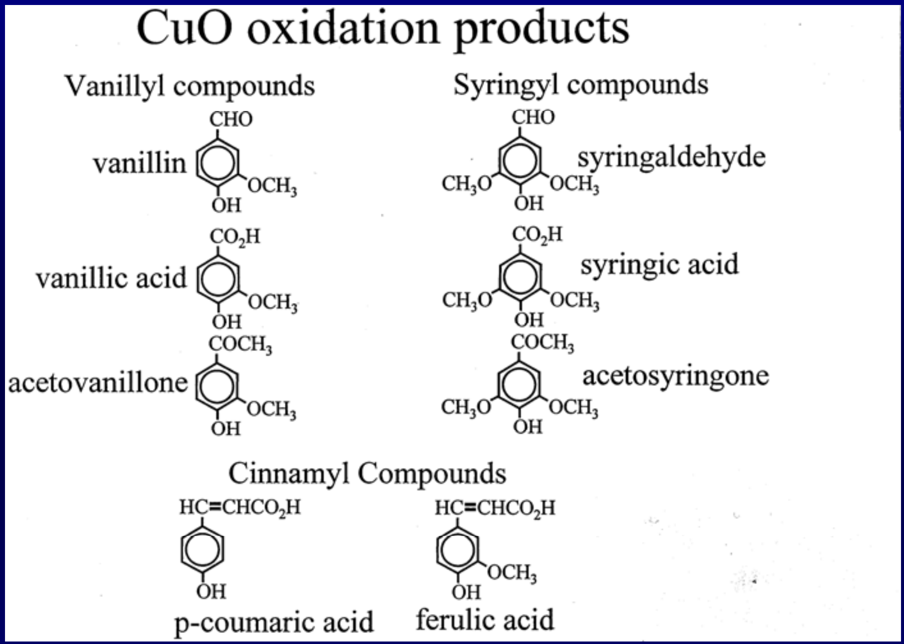


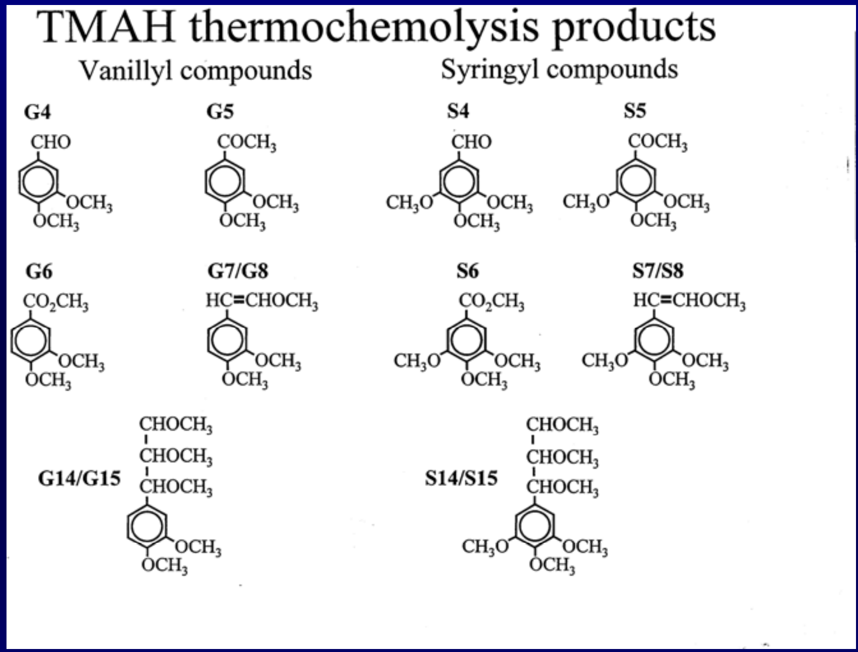
carboxyl

Lignin

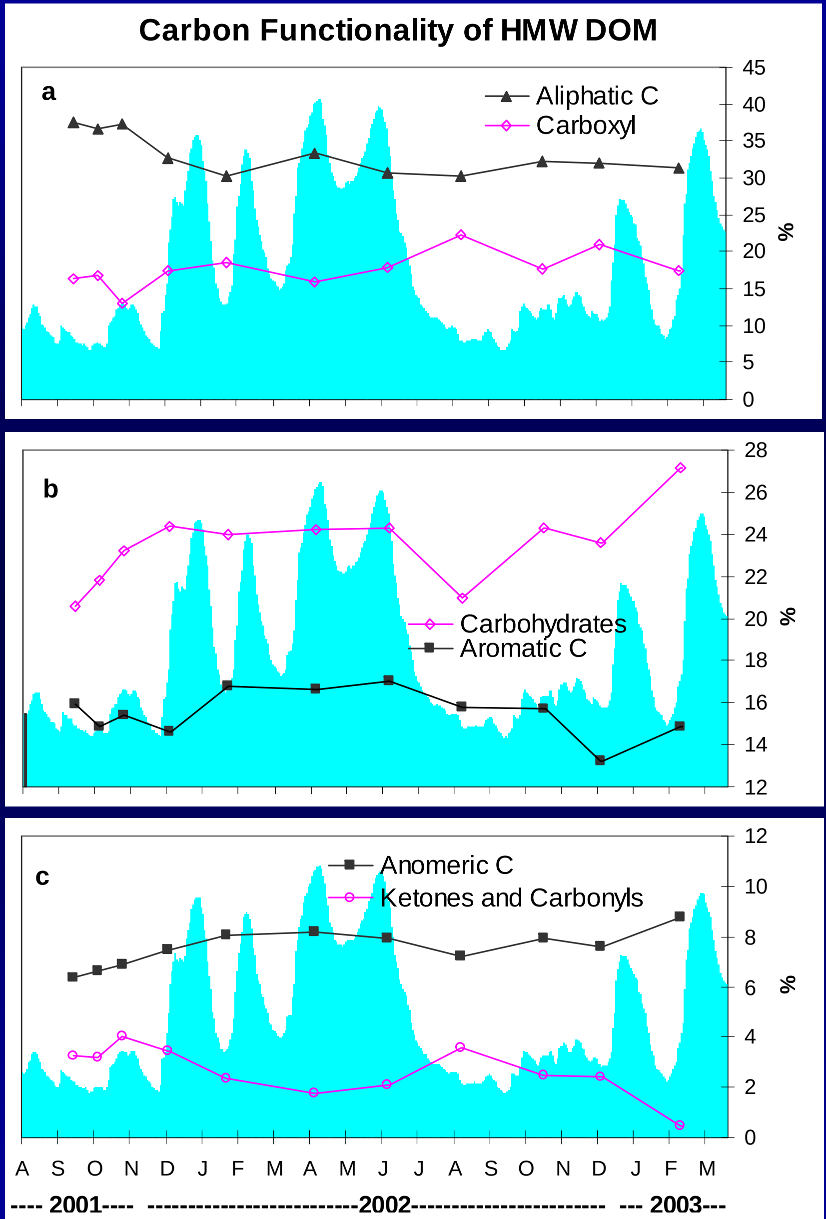


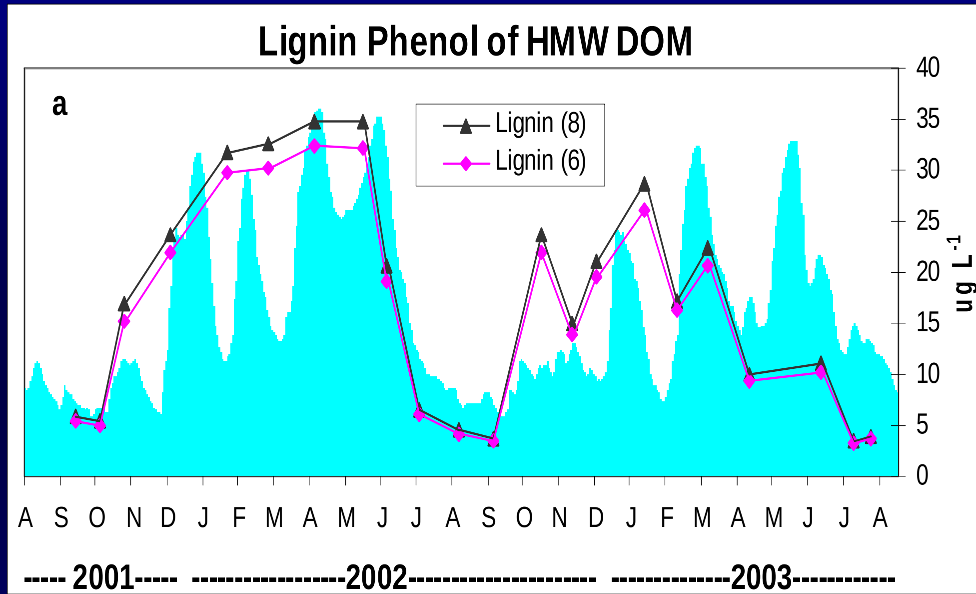
Lignin Biomarkers





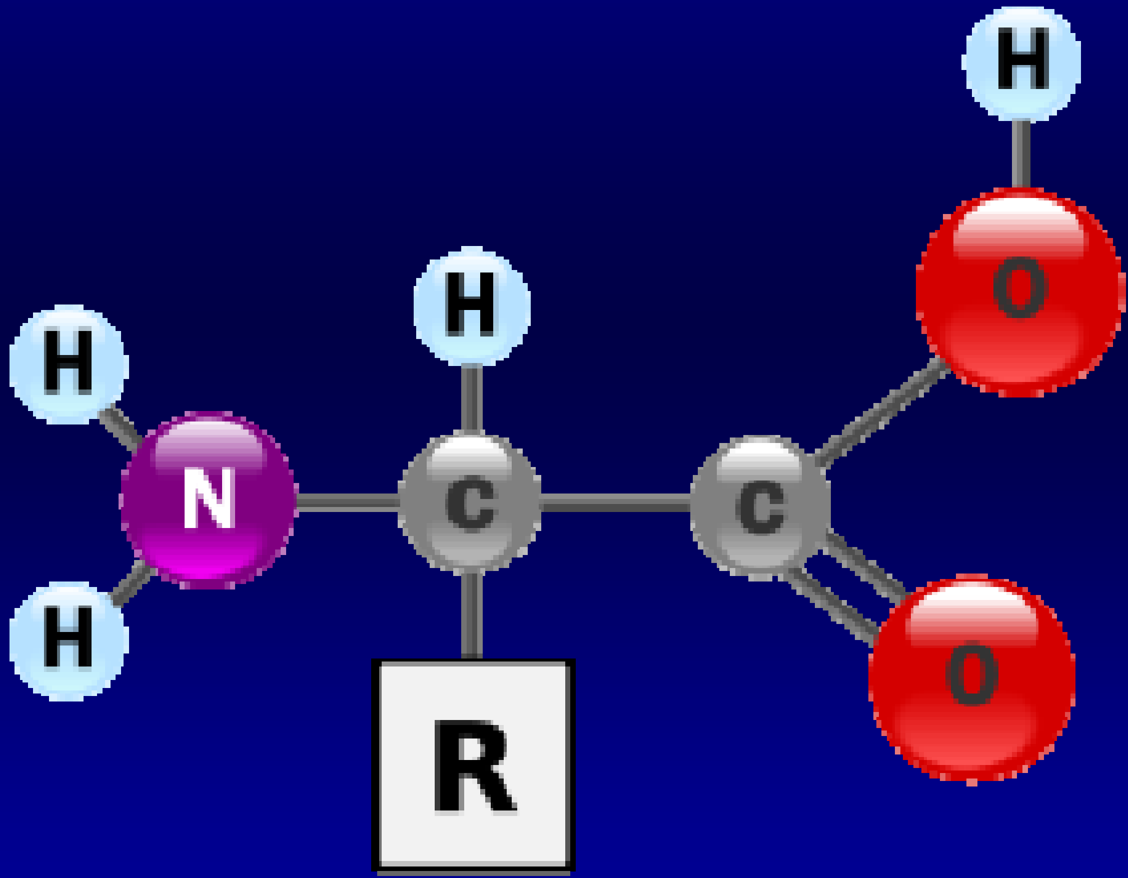
^{13}C-NMR and Lignin Analysis of HMW DOM



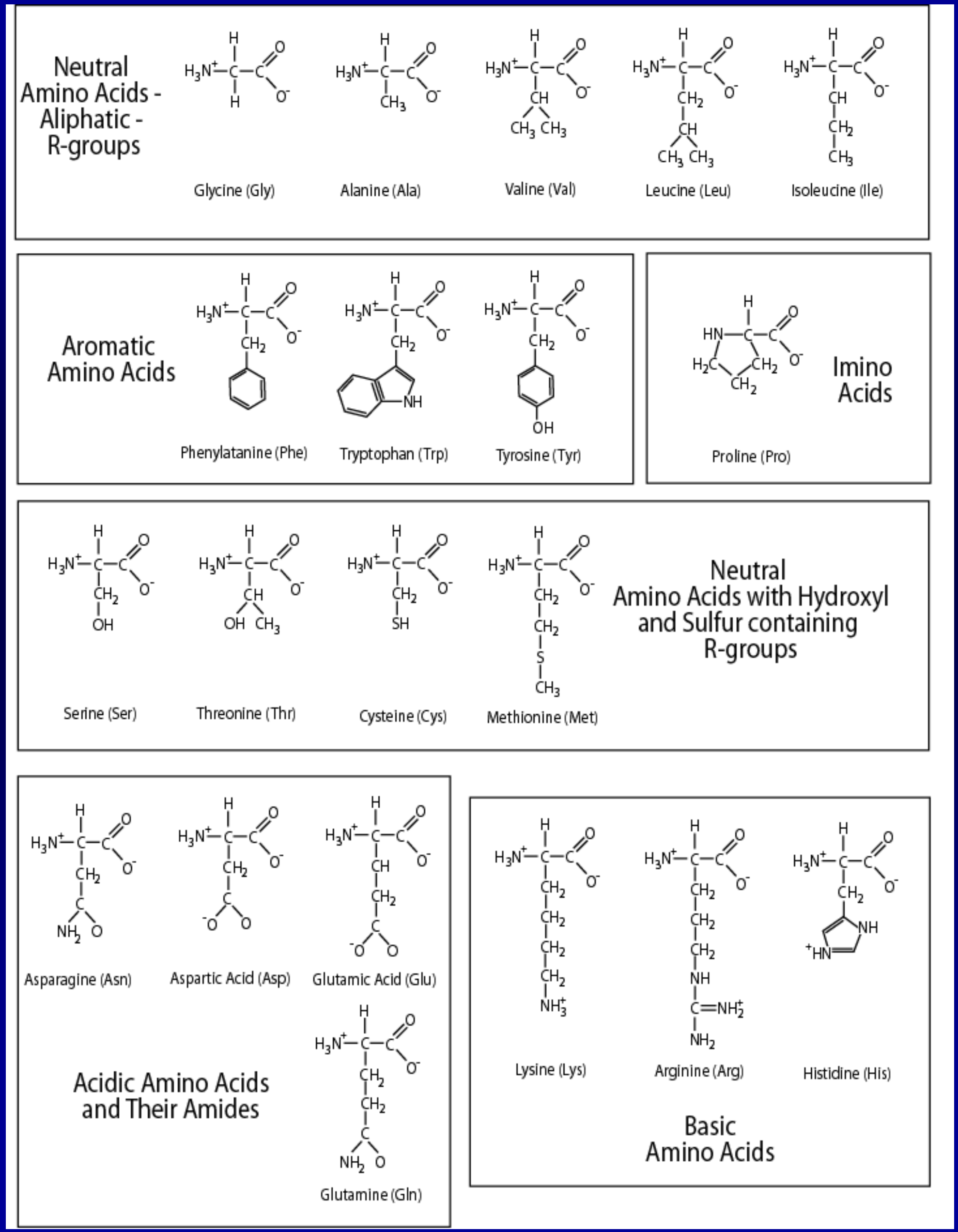


Duan and Bianchi (2006);
Duan et al. 2007)

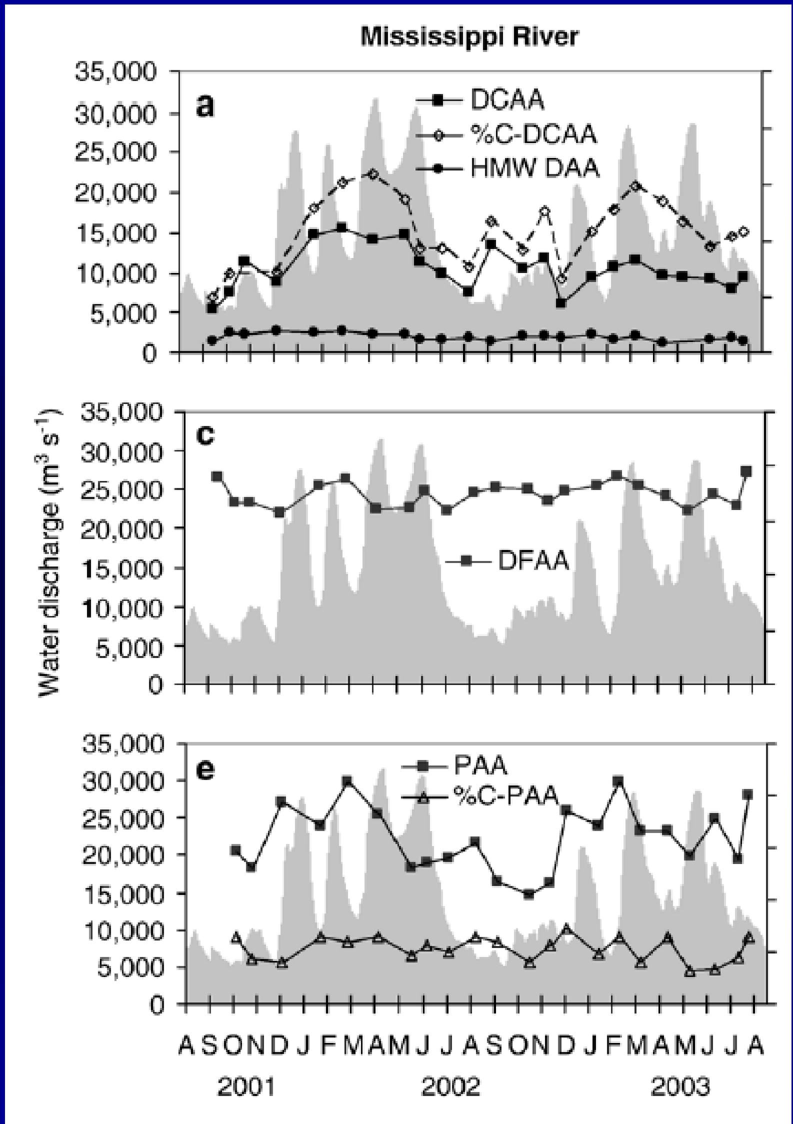
Amino Acids

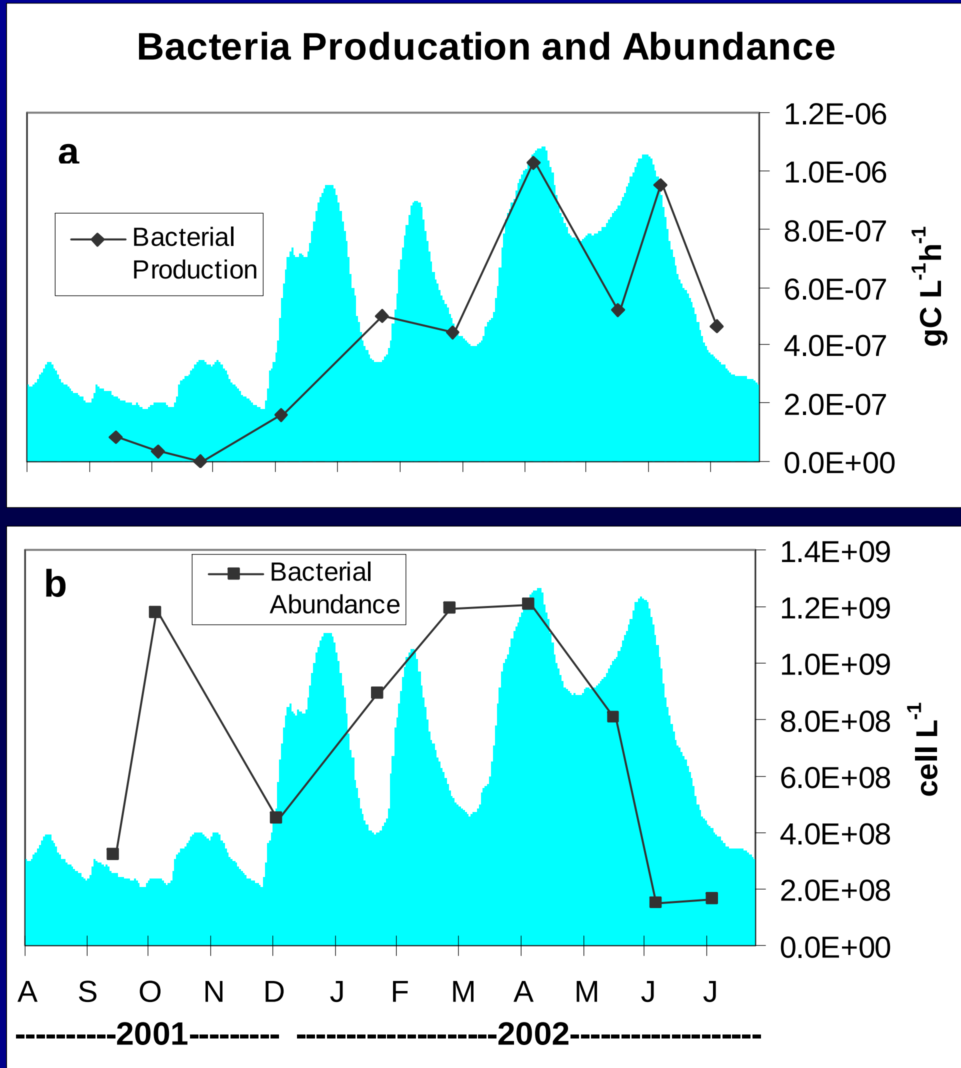


Amino Acids as Tracers of Dissolved Organic Nitrogen (DON)



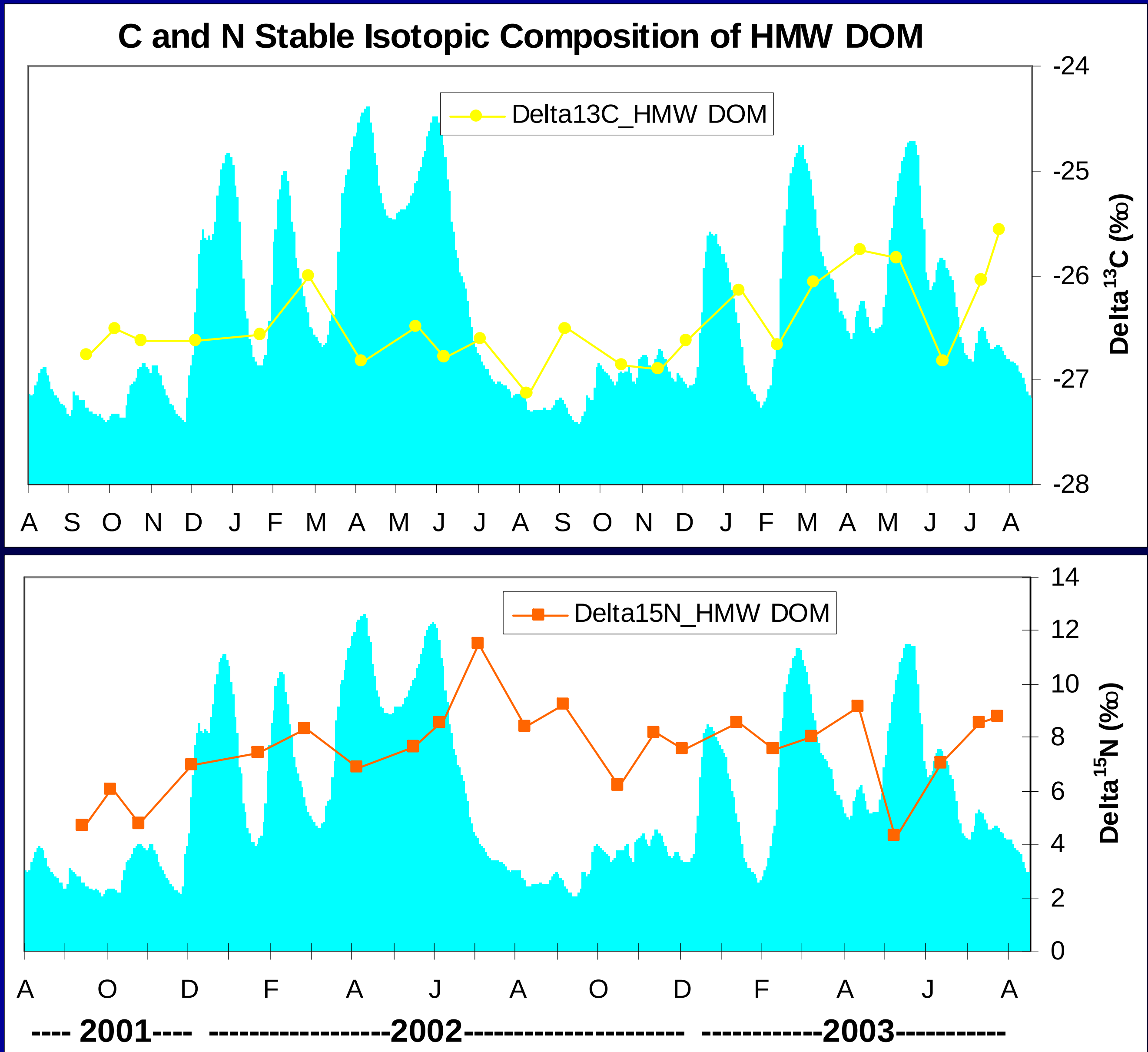
Amino Acids and Bacterial Activity





Duan and Bianchi (2007)

Stable Isotopic Composition of HMW DOM



Isotopic Ranges of Natural Organic Matter

Table 9.2 Published ranges of isotope values of potential organic matter sources to estuaries.

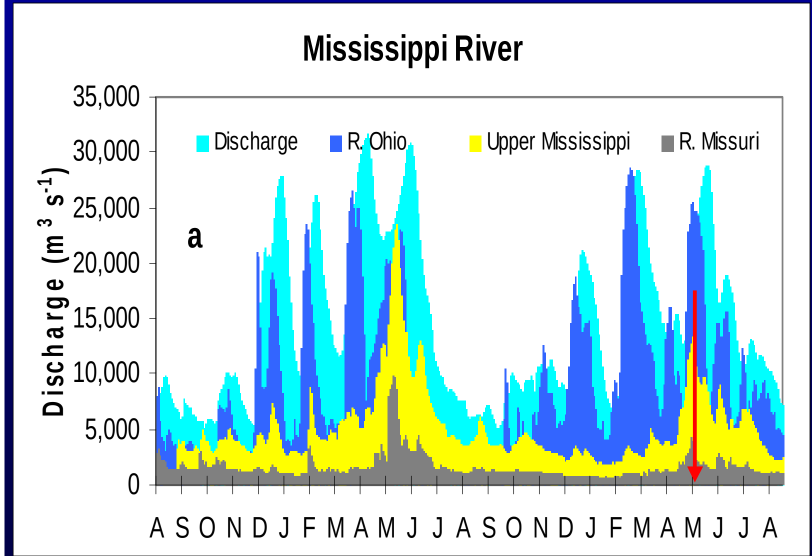
Source	$\delta^{13}C$ (‰)	$\delta^{19}N$ (‰)	$\Delta^{14}C$ (‰)	References
Terrigenous (vascular plant)	-26 to -30	-2 to +2		Fry and Sherr (1984): Deegan and Garritt (1997)
Terrigenous soils (surface)/forest litter	-23 to -27	2.6 to 6.4	+152 to +310	Cloern et al. (2002): Richter et al. (1999)
Freshwater phytoplankton	-24 to -30	5 to 8		Anderson and Arthur (1983): Sigleo and Macko (1985)
Marine/estuarine phytoplankton	-18 to -24	6 to 9		Fry and Sherr (1984): Currin et al. (1995)
C-4 salt marsh plants	-12 to -14	3 to 7		Fry and Sherr (1984): Currin et al. (1995)
Benthic microalgae	-12 to -18	0 to 5		Currin et al. (1995)
C-3 Freshwater/Brackish marsh plants	-23 to -26	3.5 to 5.5		Fry and Sherr (1984): Sullivan and Moncreiff (1990)

Compound-Specific Isotopic Analysis (CSIA) HMW DOM lignin

Sampling Date	Vanillin	Syringic_acid
Aug. 1998	-24.2 ± 1.5	-29.9 ± 1.2
Oct. 1998	-25.6 ± 1.2	-29.5 ± 0.8
Mar. 1999	-24.6 ± 1.8	-30.0 ± 1.1
Apr. 1999	-25.3 ± 1.7	-29.7 ± 0.6

June 20-24, 2003

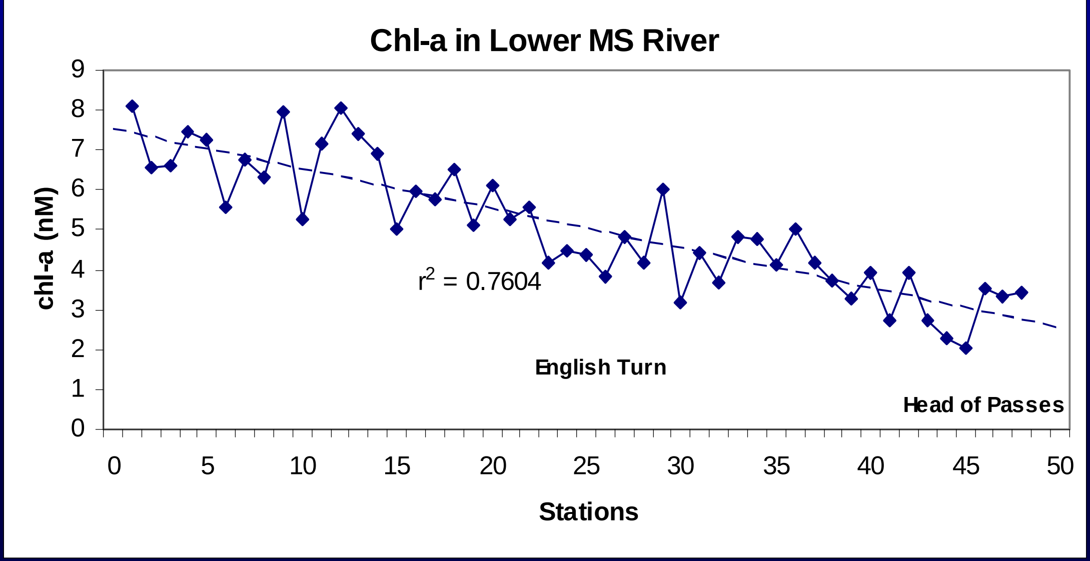
Spatial Sampling

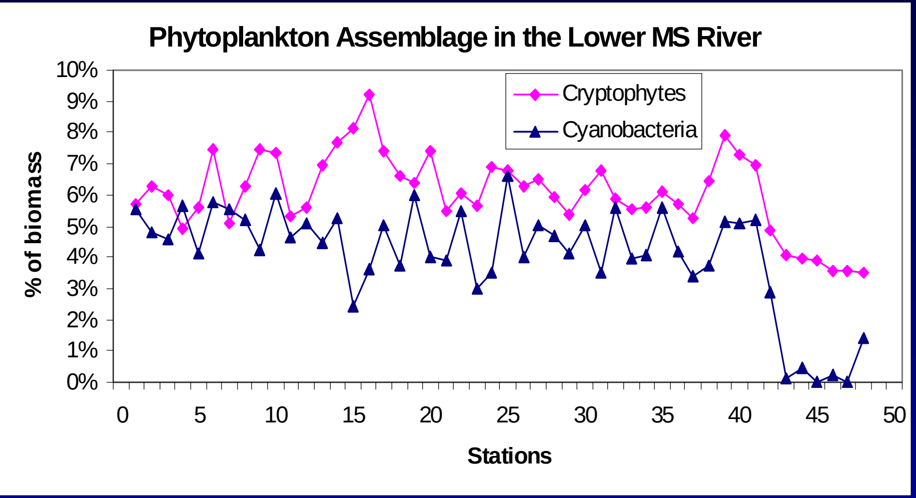


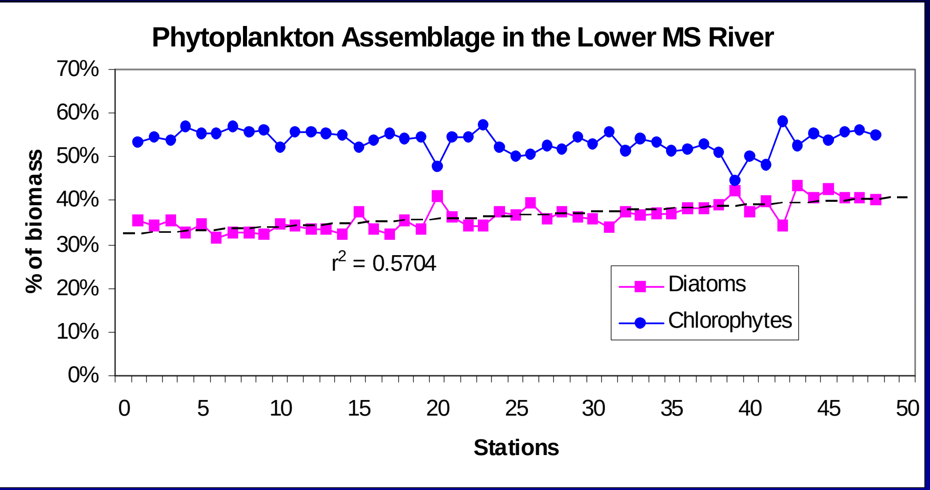
During June 2003, a period of mid-level discharge (17,400 $m^{-3}\ s^{-1}$), a parcel of water in the lower Mississippi River was sampled every 2 h during its 4 d transit from river-mile 225 near Baton Rouge, Louisiana, USA to river-mile 0 at Head of Passes, Louisiana, USA.

Dagg et al. (2006)

Transect of Chlorophyll-*a* and Dominant Carotenoids in lower MR

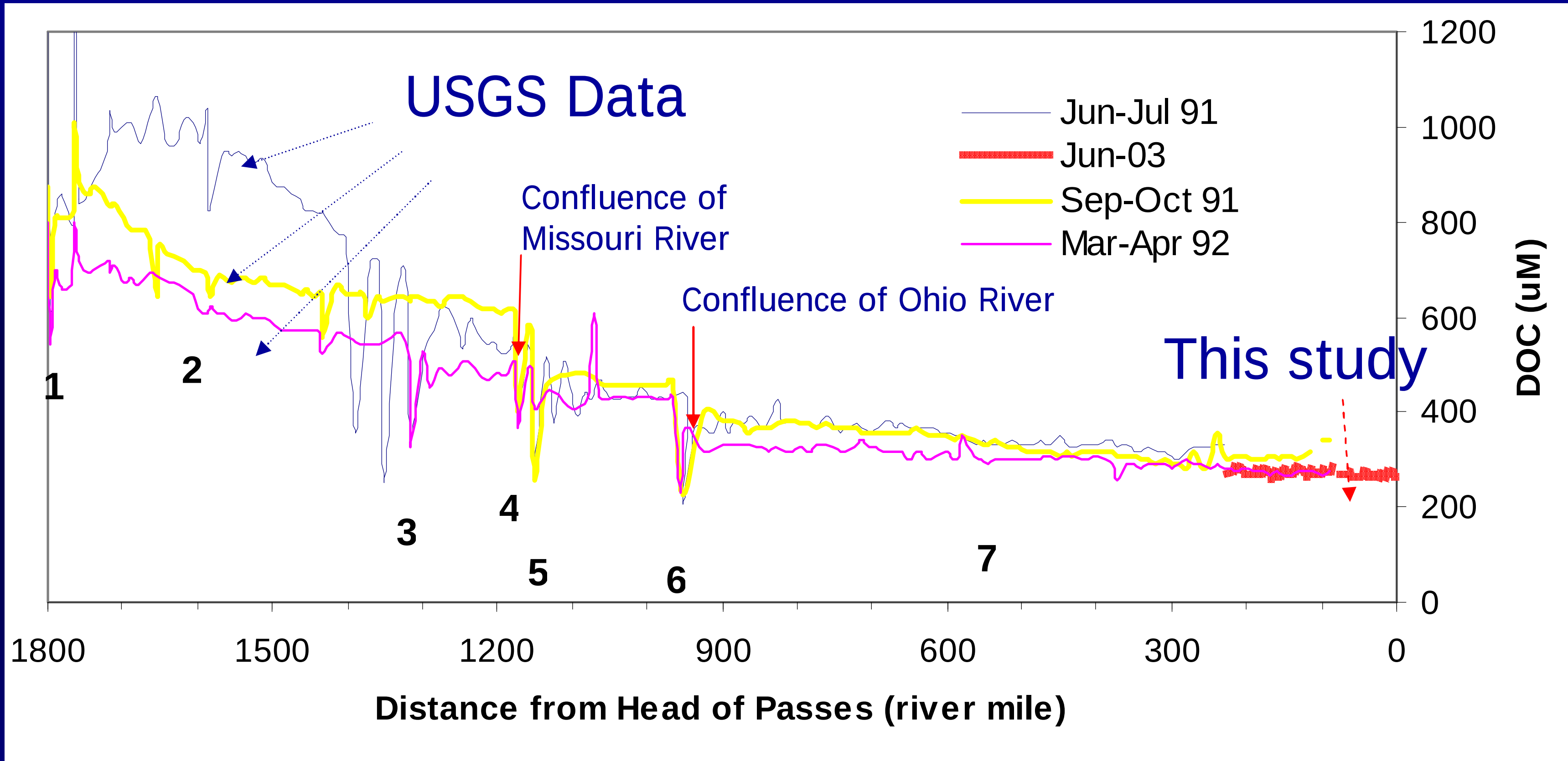






Dagg et al. (2006)

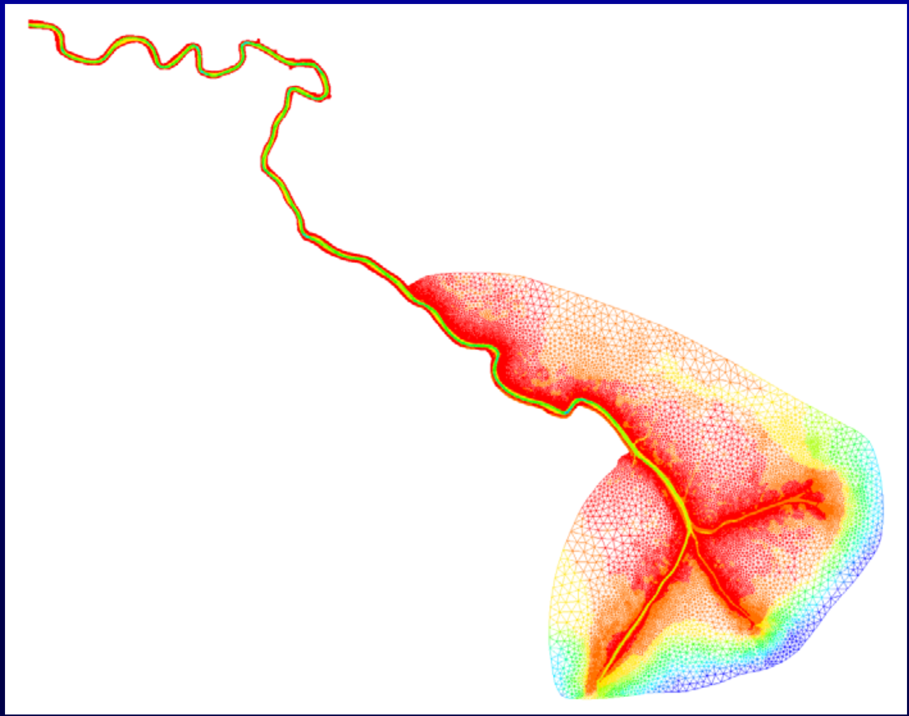
DOC in the Mississippi River From Headwater to Head of Passes



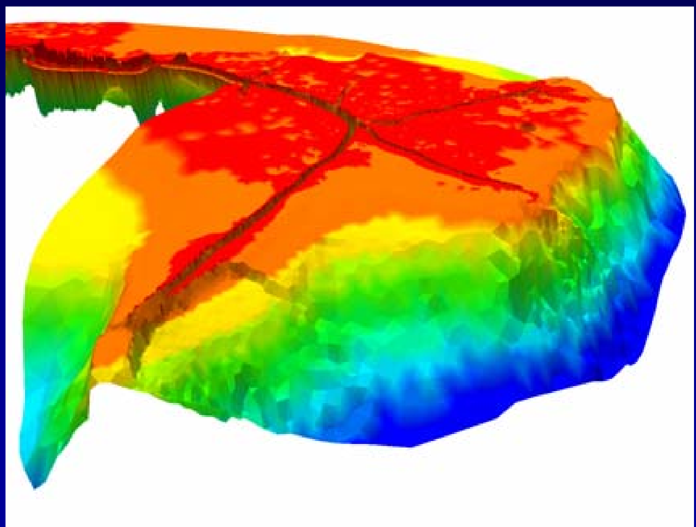
Duan et al. (2007)

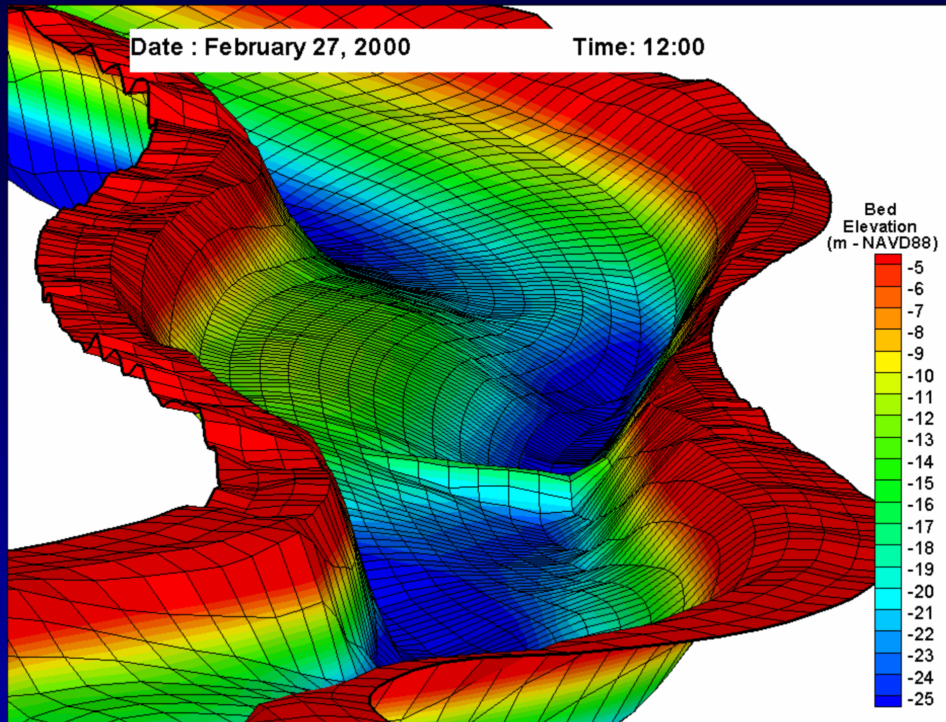
- DOC gradually decreases, most of the decrease occurred in upper MR (by 30-48%), very little (6-8%) in lower river
- Large decrease in DOC below the confluence of the Missouri River and Ohio River, likely from dilution effect and *in-situ* processing

Are dissolved and particulate constituents transformed in lower MR in the presence of the salt wedge during low discharge stages?

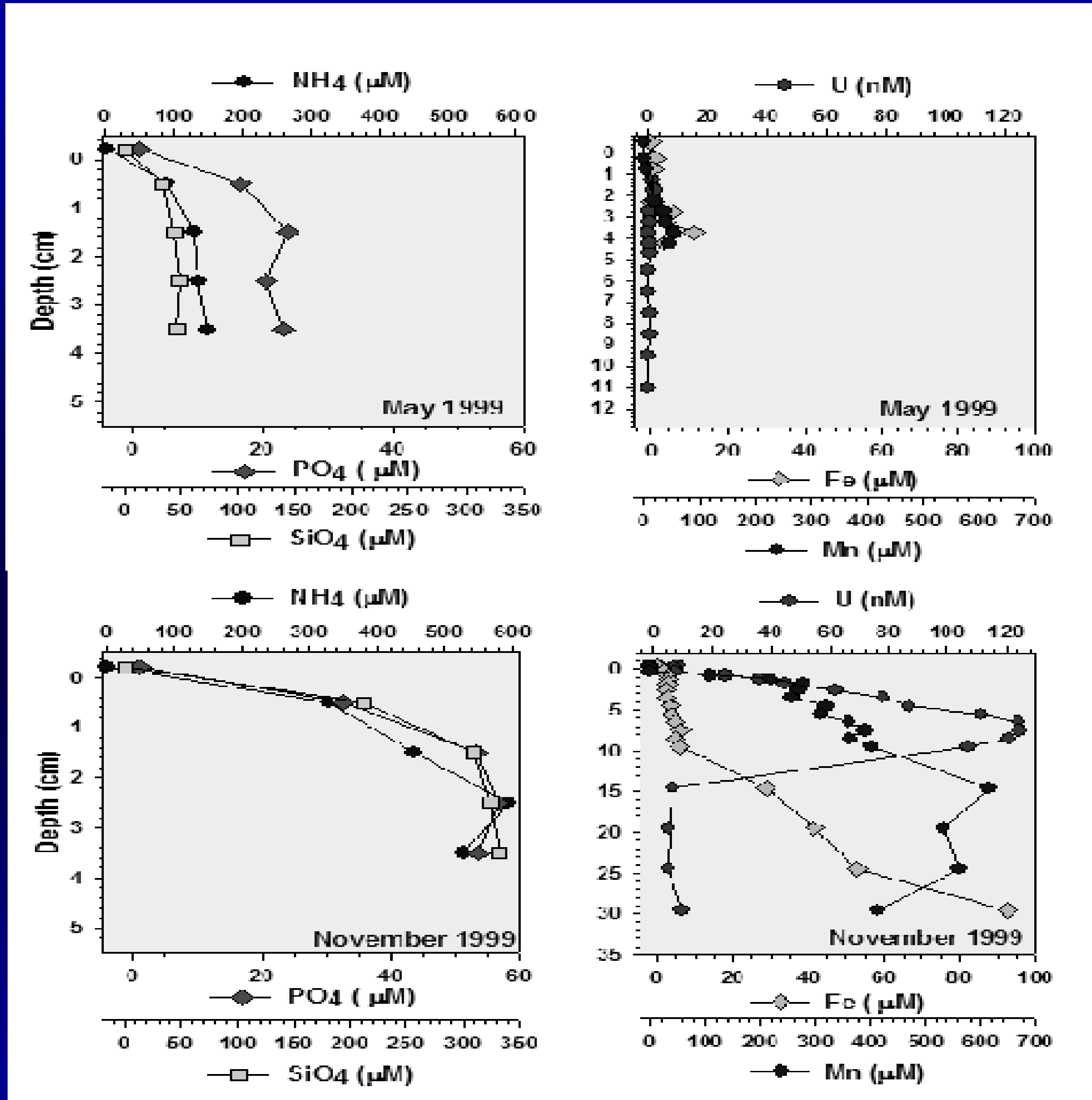


Seismic data used in open source code 3D models, such as the Finite Volume Coastal Ocean Model (FVCOM – Chen et al., 2006)





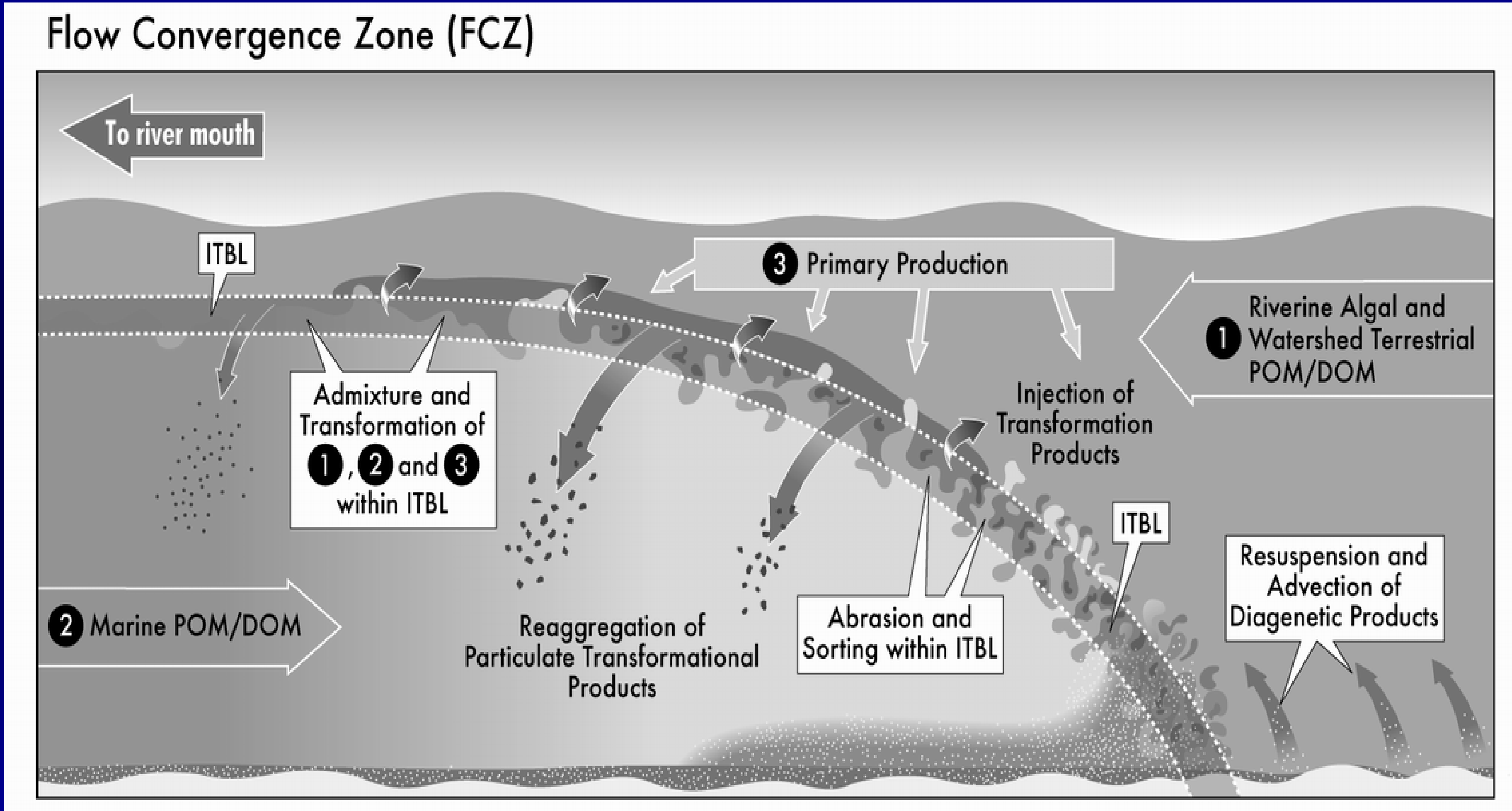
Recharge of dissolved porewater constituents in lower Mississippi River sediments



McKee et al. (unpublished)

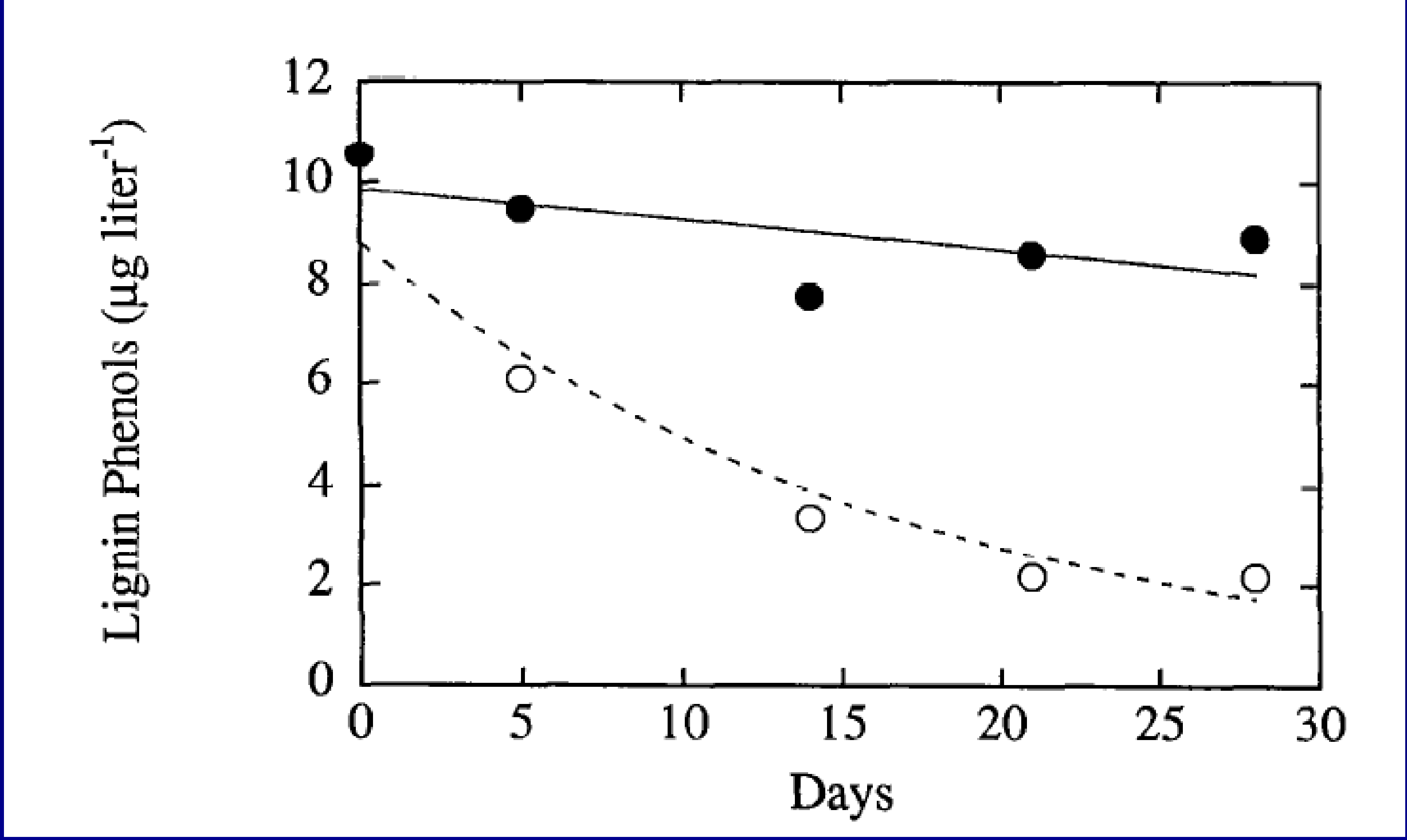
Porewater concentrations of diagenetic products at a lower river location collected before (May) and during (November) a depositional period

Biogeochemical Dynamics at the Salt Wedge



ITBL – Intensely turbulent boundary layer

Photochemical Breakdown of Lignin



Opsahl and Benner (1998)

Mean Global Fluvial Loadings of Organic Carbon to the Oceans

Reference	DOC	POC	TOC
Smith and Hollibaugh (1993)	164	197	386

Units = 10^{11} mol C yr^{-1}

Mean Annual Fluvial Loadings of Organic Carbon from the Mississippi River

	DOC	POC	TOC
	3.0 (62%)	1.8 (38%)	4.8
Global Percent:	1.8	0.9	1.2

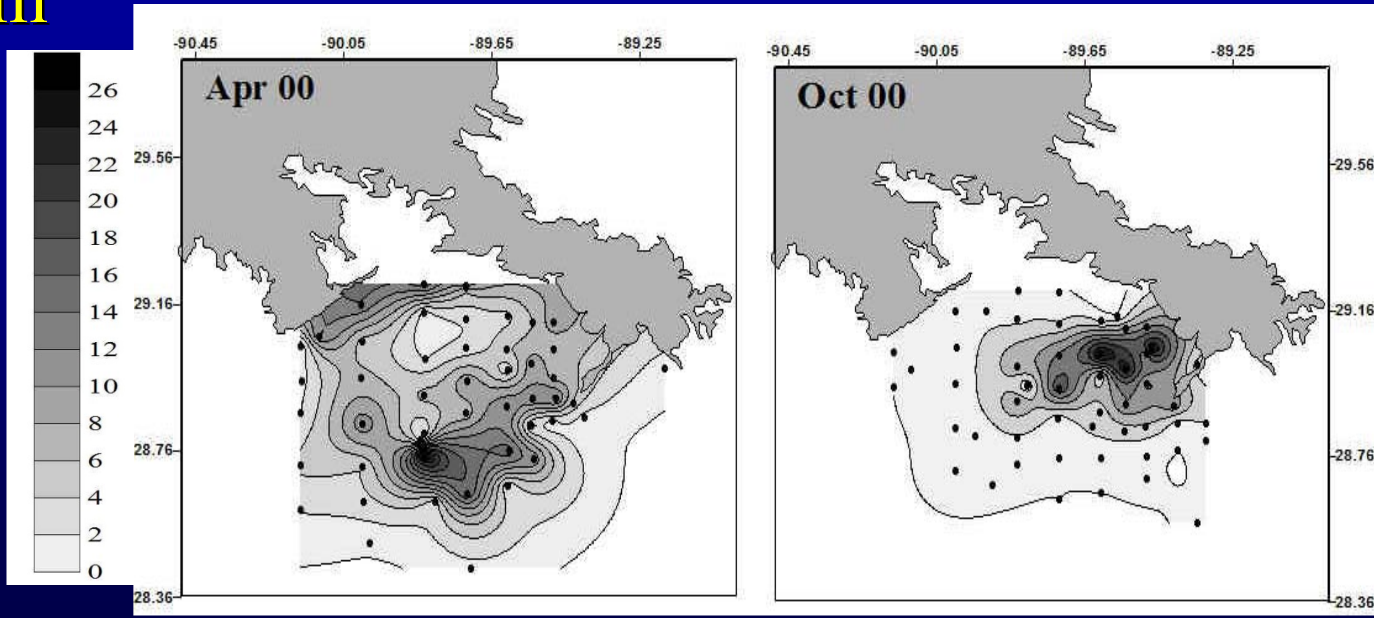
Units = 10^{11} mol C yr^{-1}

Bianchi et al. (2004, 2007)

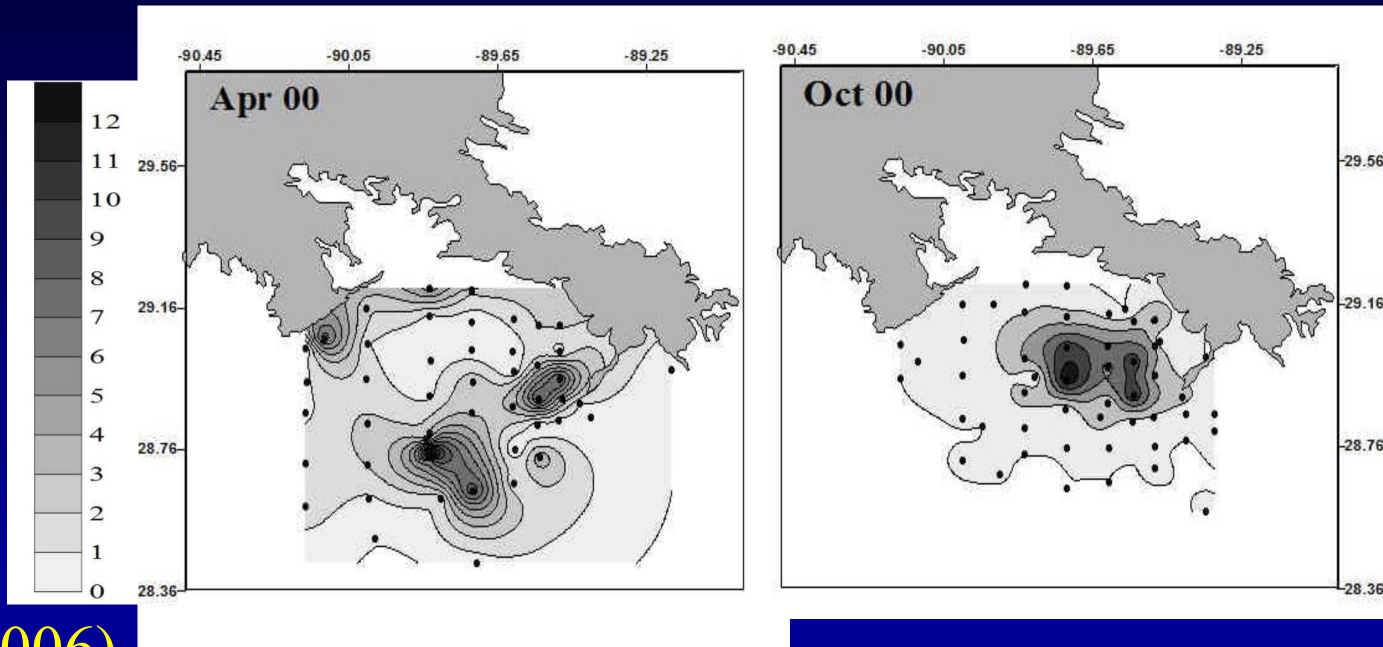
Diversity and Magnitude of Organic Matter Sources and Loading

Nearshore diatom sources?

Chlorophyll-a



Fucoxanthin



Wysocki et al. (2006)

Coastal Wetland Inputs

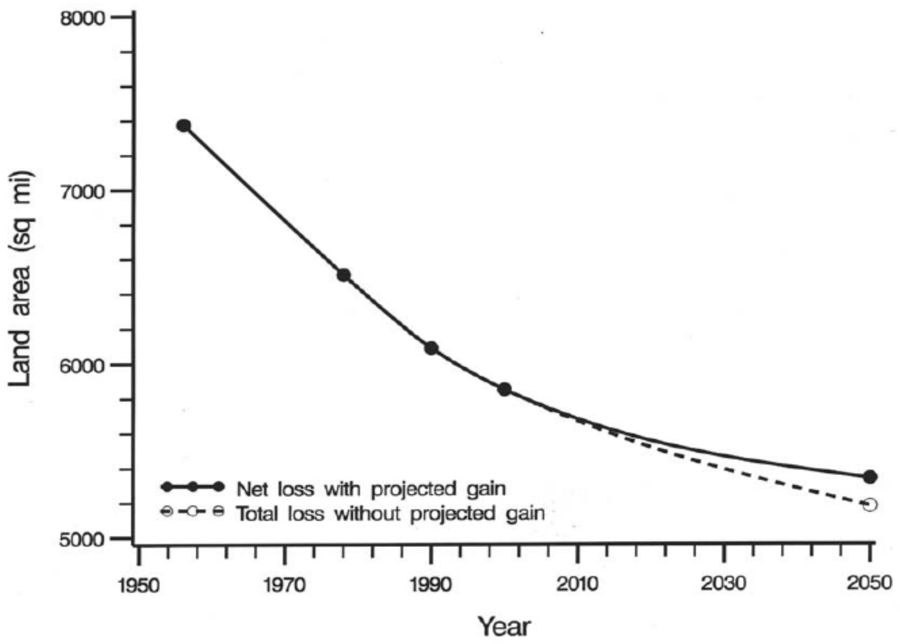
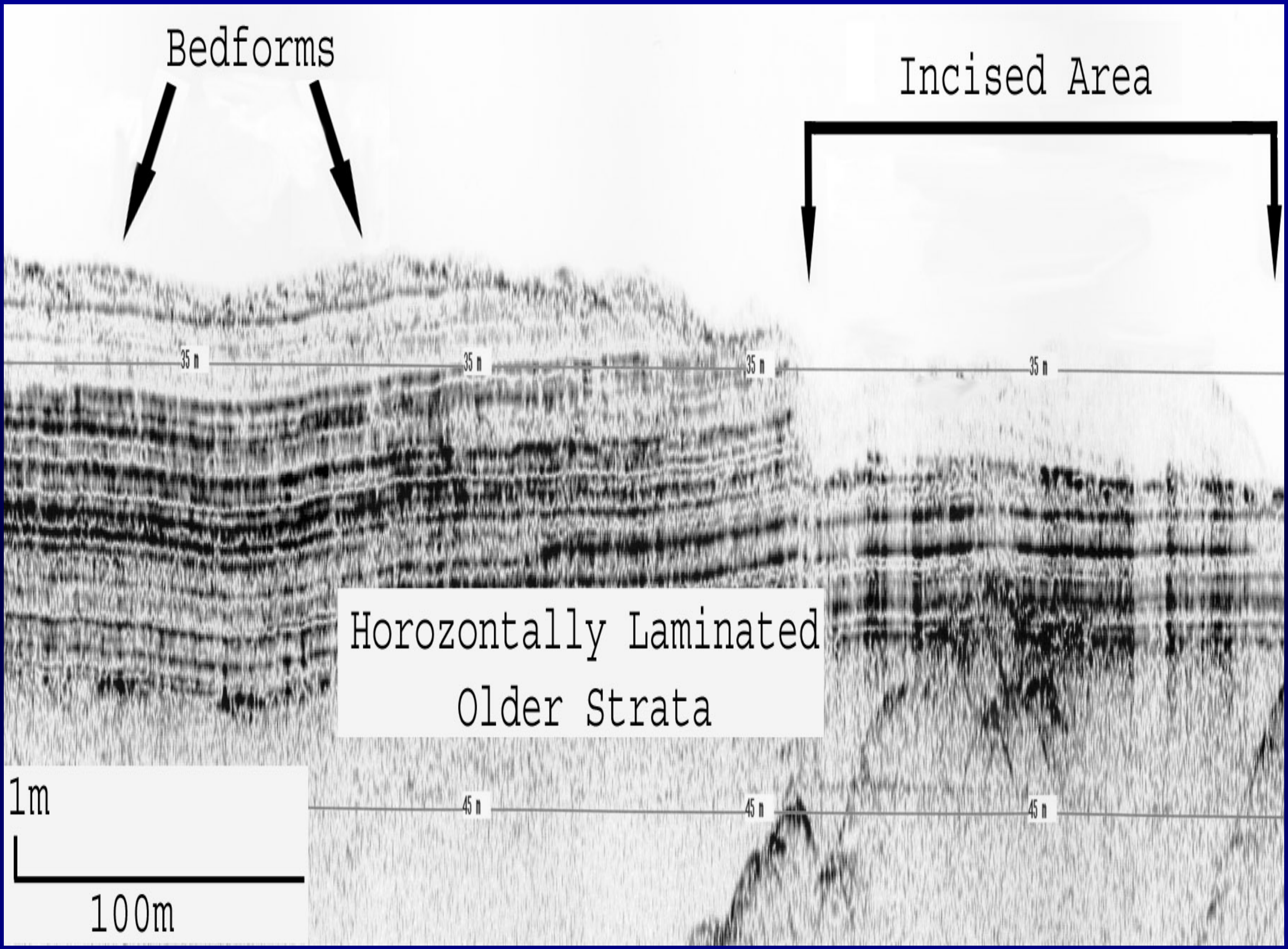


Figure 19. Projected coastal Louisiana land loss from 1956 to 2050.

Note: With the projected gain, the net loss from year 1956 to 2050 is estimated to be 2,038 sq mi (5,278 sq km) whereas without the projected gain, the estimated total loss amounts to 2,199 sq mi (5,695 sq km).

Chen and Gardner (2004) reported significant outwelling of chromophoric dissolved organic matter (CDOM) from wetlands

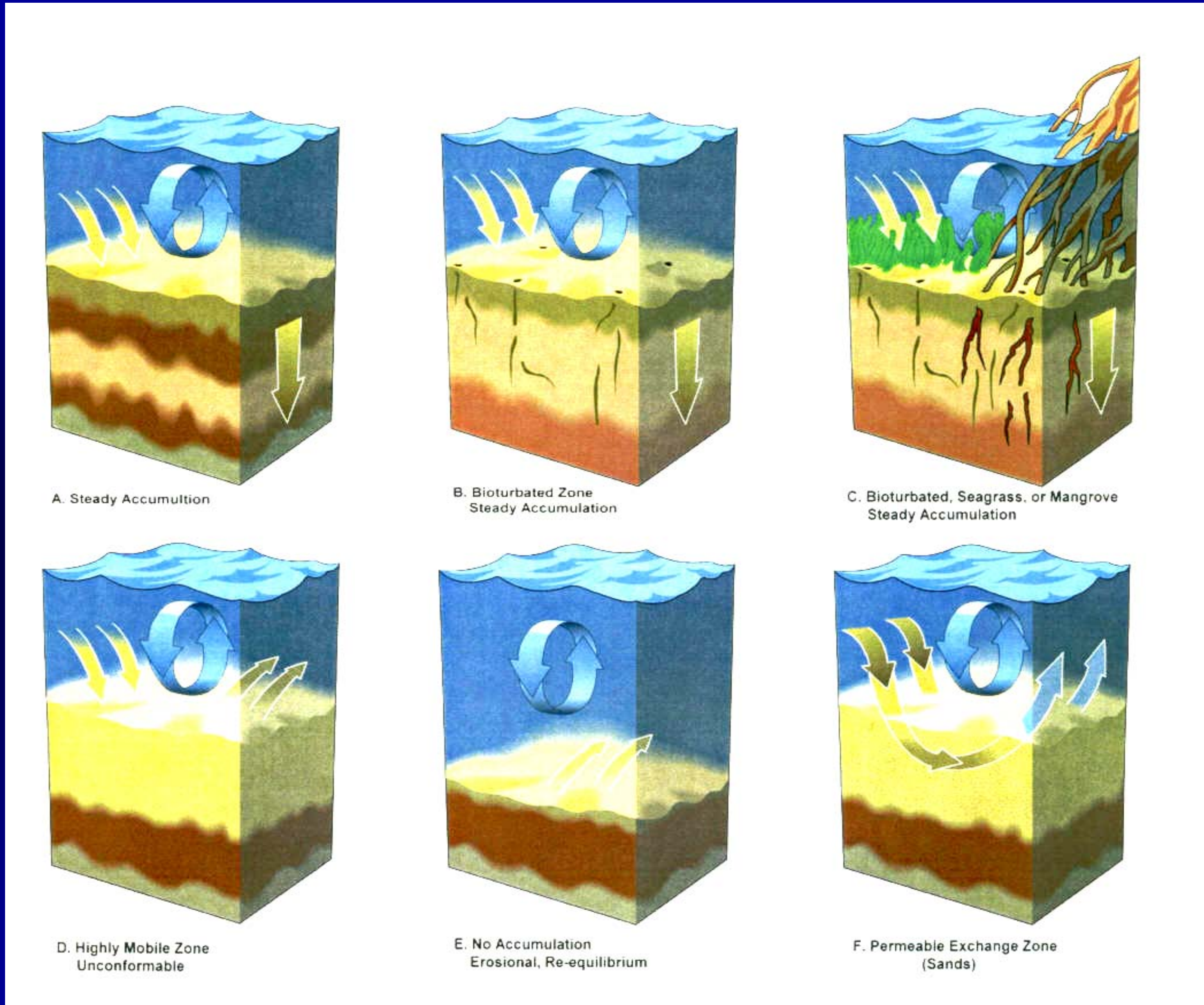
Barras et al. (2003)



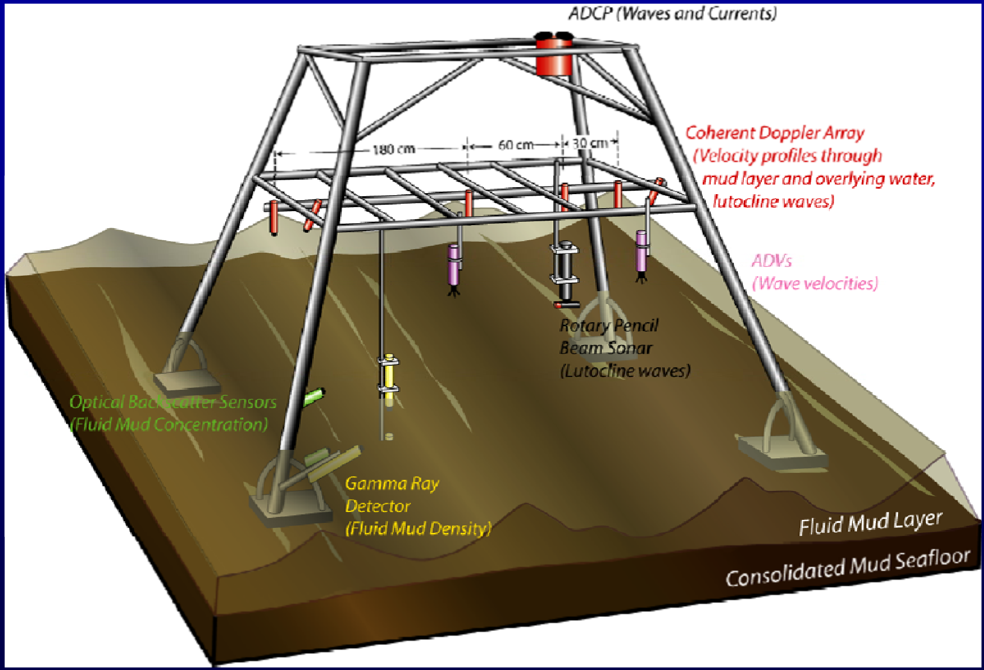
Radiocarbon ages of this peat material ranged from 2,140 to 4,210 yr BP in to 32,580 yr BP in Pleistocene clay layers below.

Galler et al. (2003)

Rates and Efficiency Organic Matter Diagenesis in Mobile Muds



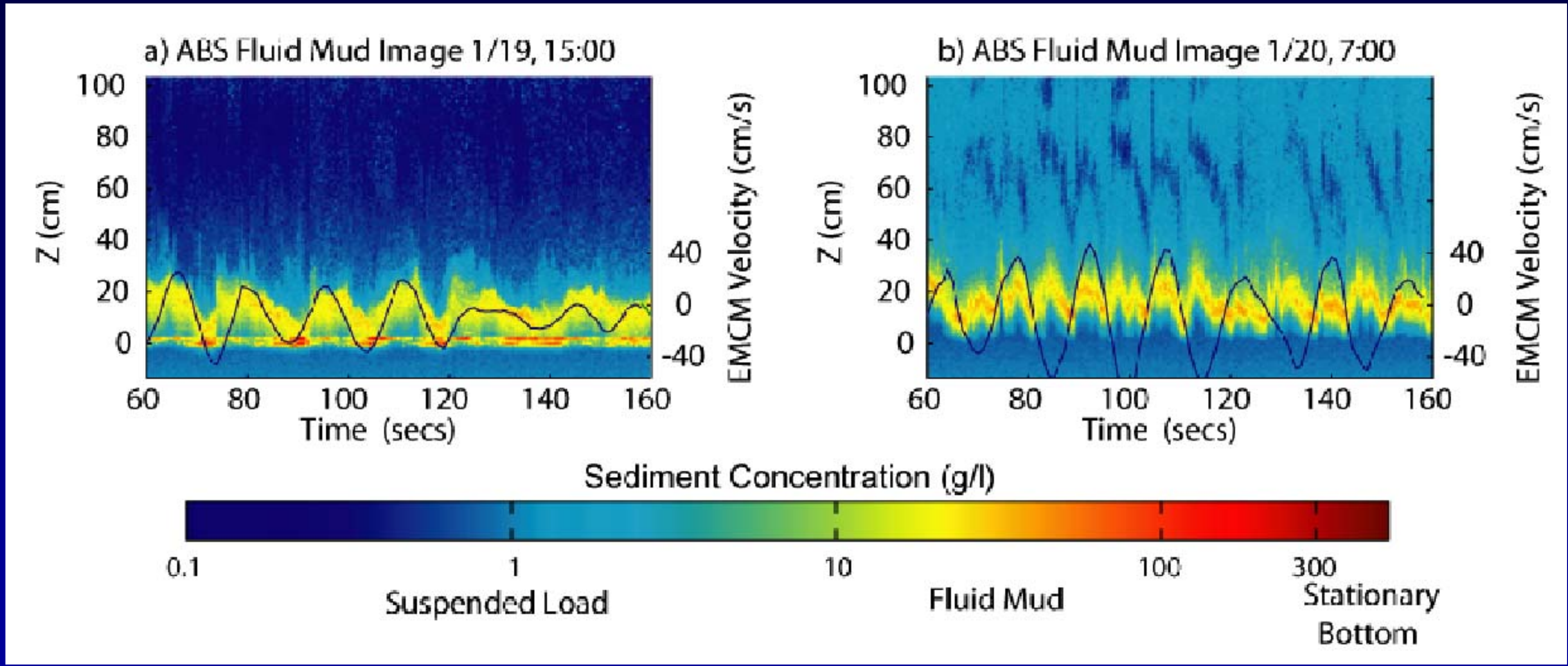
Aller R.C. (2002) - modified by McKee et al. (2003)



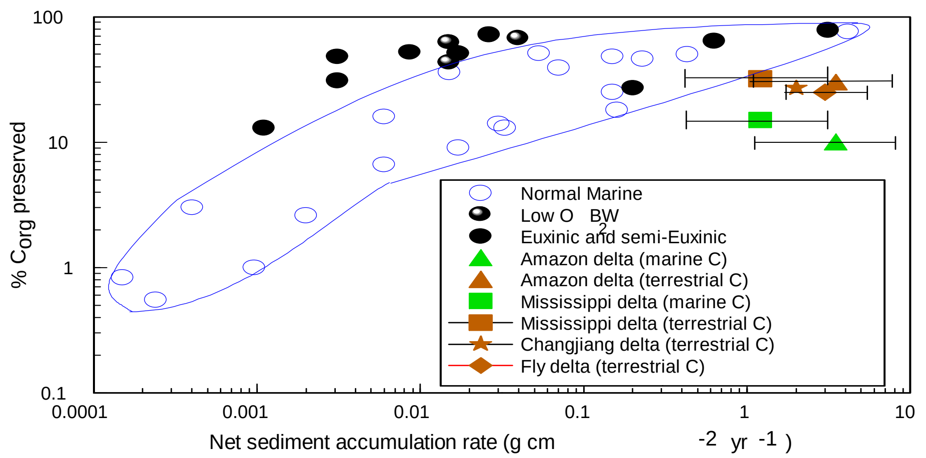
Mobile/Fluid Muds

(Traykovski, 2000)

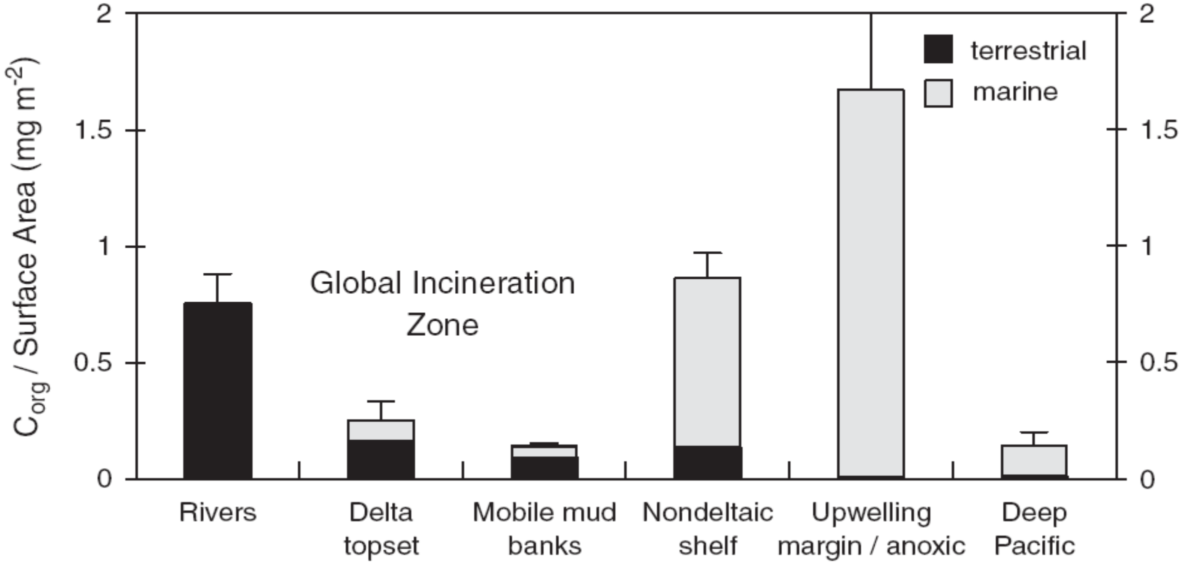
Acoustic Backscatter Sensor (ABS)
Electromagnetic Current Meter (EMCM)
Acoustic Doppler Current Profiler (ACDP)



Diagenesis in Mobile Muds



Aller (1998)



Aller and Blair (2006)

Transport of Mobile Muds

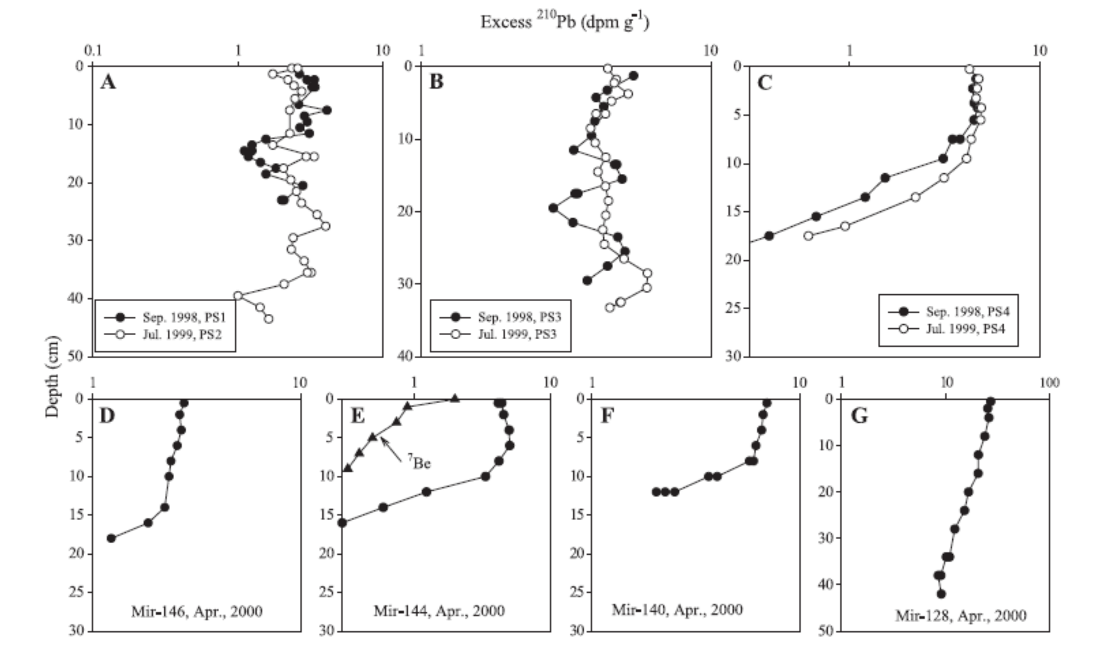


Fig. 2. Excess ^{210}Pb concentrations (dpm g^{-1}) in sediments from the river and shelf sites collected in September 1998 and July 1999, and from a cross-shelf transect collected in April 2000.

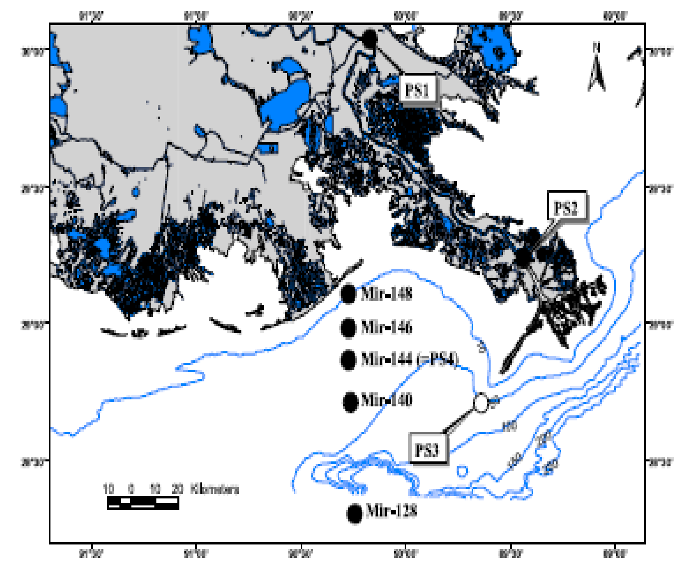
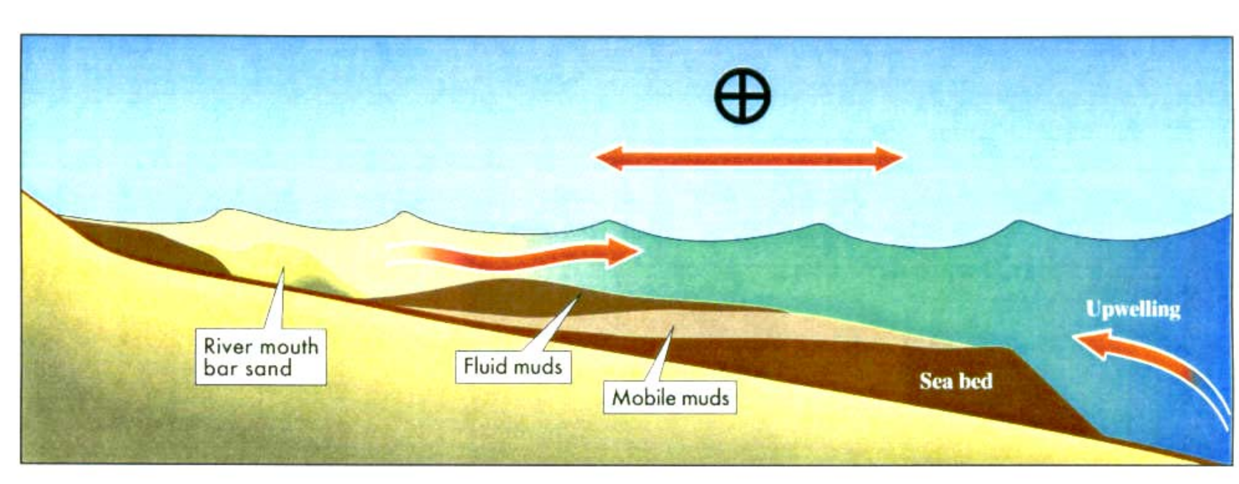
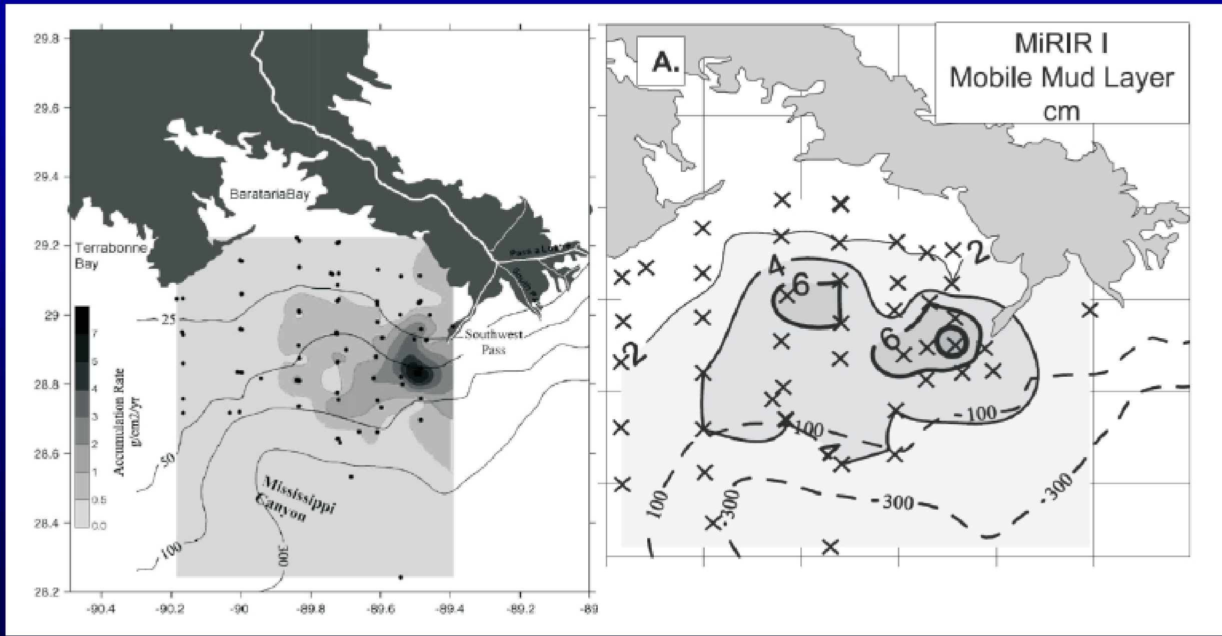


Fig. 1. Map showing the sampling sites in lower Mississippi River and the Louisiana shelf.

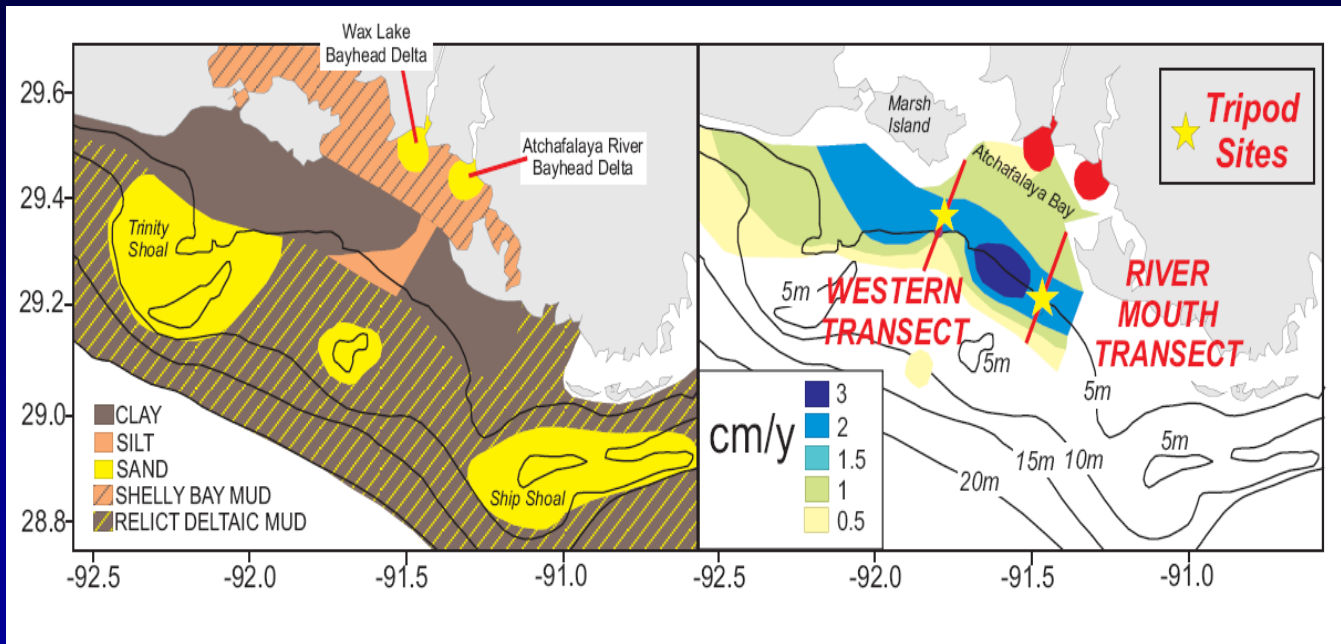
Chen et al. (2005)



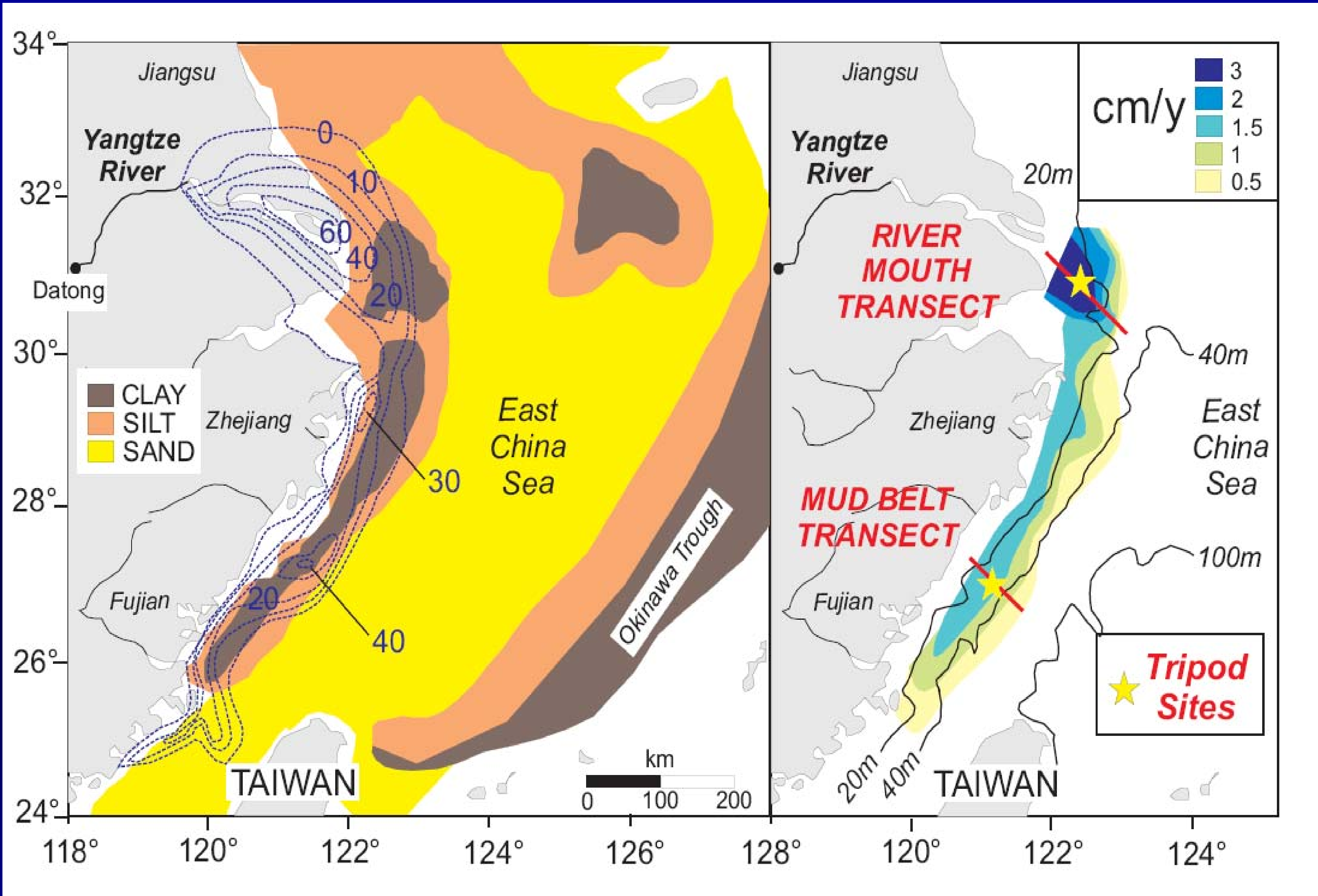
(Aller, unpublished)



^{210}Pb-derived sediment accumulation rates (left) and extent of "mobile" muds in high discharge (April 2003, right) (from Corbett et al., 2004, 2006).

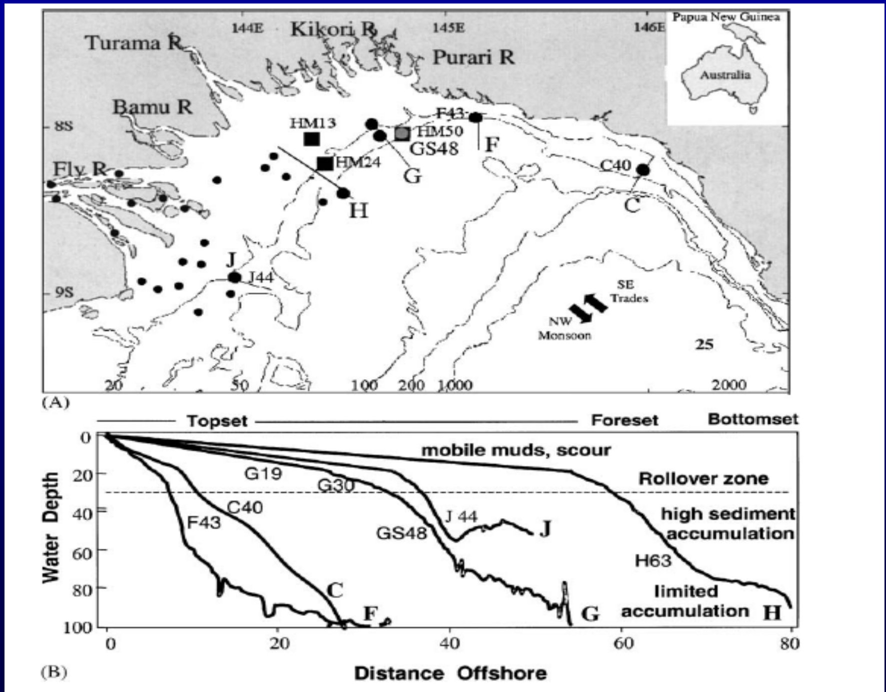


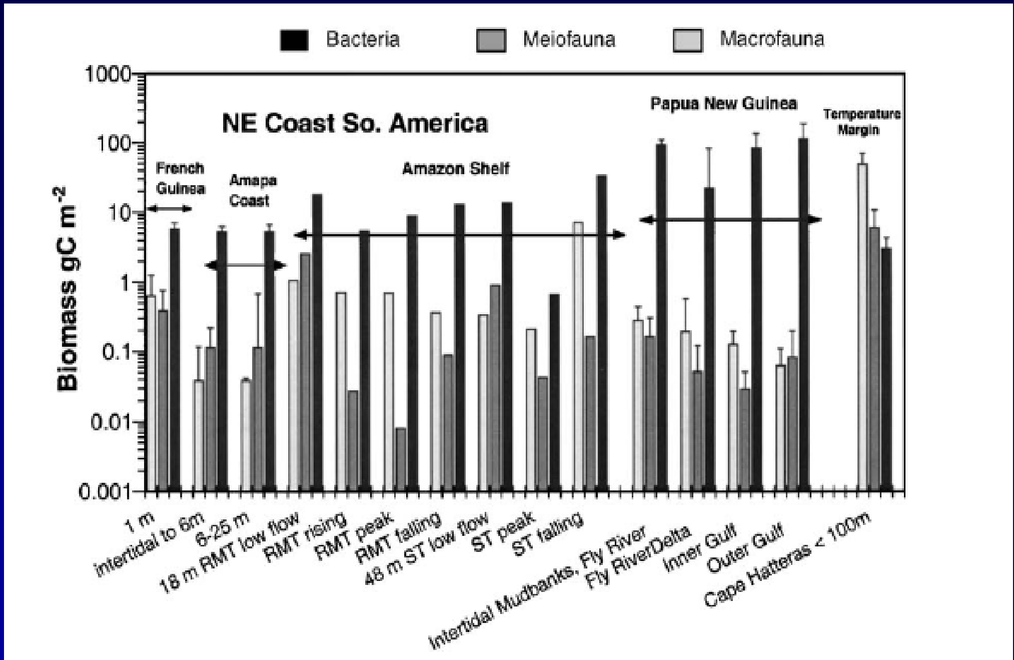
The Atchafalaya surficial sediments (left) and the Pb-derived linear accumulation rate (right) (from Jaramillo et al., 2009, Neill and Allison, 2005).

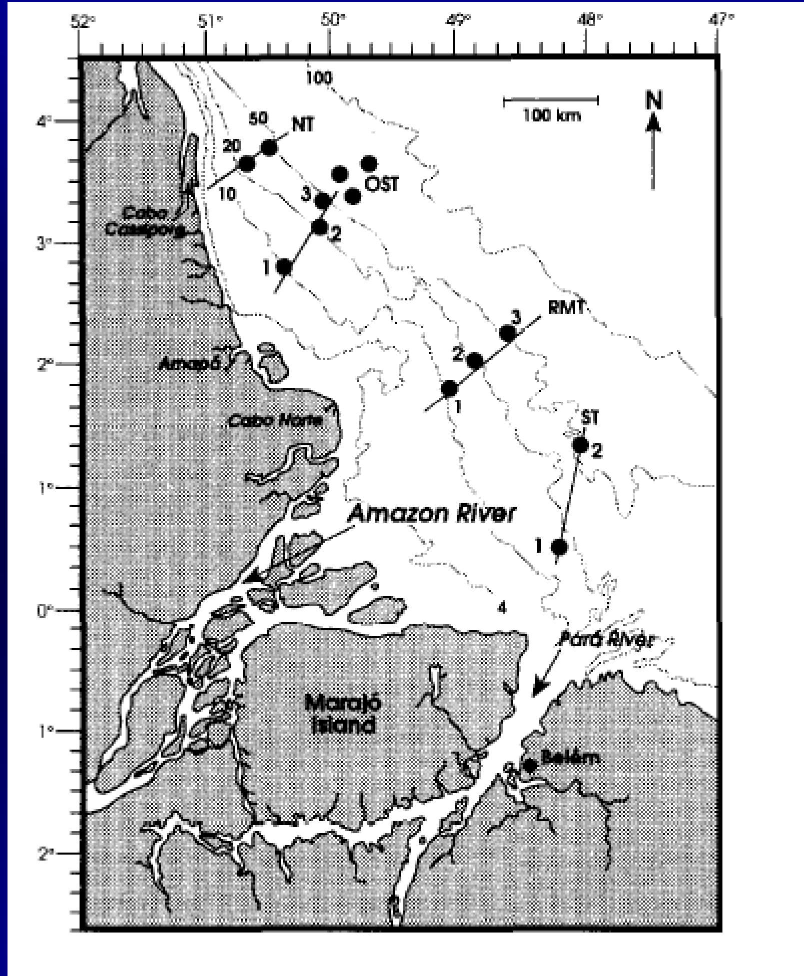


Chanjiang grain size distribution of surficial sediments and 0-7 ky isopach sediment map (left), and the ^{210}Pb-derived linear sediment accumulation rates (right) (from Liu et al., 2006, 2007).

Heterotrophy in Mobile Muds







Aller and Aller (1994, 2006);
Aller andn Stupekoff (1996)

Louisiana Shelf Benthos

TABLE 2. Community biomass at the location studied (Fig. 1). Number of replicates are in parentheses.

Sites and Dates	Macrofauna (g C m^{-2})	Meiofauna (g C m^{-2})	Bacteria (g C m^{-2} 8 cm depth)	Total Biomass (g C m^{-2})
July 1991				
C6A (1)	0.68	1.1	2.67	4.45
C6B (1)	0.16	0.43	7.12	7.71
C7 (1)	0.56	0.76	30.49	31.81
D2 (1)	0.11	0.21	22.22	22.54
Mean biomass	0.38 ± 0.29	0.66 ± 0.34	15.6 ± 12.9	16.7 ± 12.9
April 1991				
GC1	0.23 ± 0.62 (4)	0.37 ± 0.08 (2)	1.67	2.3
4	0.01 ± 0.01 (3)	0.55 ± 0.51 (2)	4.18	4.7
C6A	1.24 ± 0.7 (3)	0.55 ± 0.3 (2)	1.72	3.5
D2	0.49 (1)	0.07 ± 0.03 (2)	1.85	2.4
Mean biomass	0.49 ± 0.54	0.38 ± 0.23	2.36 ± 1.22	2.81 ± 0.99
August 1994				
1	0.19 ± 0.18 (3)	—	2.81 ± 1.1 (3)	3.4
2	0.20 ± 0.18 (3)	—	3.41 ± 1.1 (3)	3.7
3	0.11 ± 0.07 (3)	—	3.8 ± 1.1 (8)	4.0
4	0.12 ± 0.1 (3)	—	2.6 ± 1.3 (8)	2.8
C6B	0.04 ± 0.01 (3)	—	1.7 (1)	1.8
Mean biomass	0.15 ± 0.1	0.09 ± 0.1	3.1 ± 0.9	3.1 ± 0.9

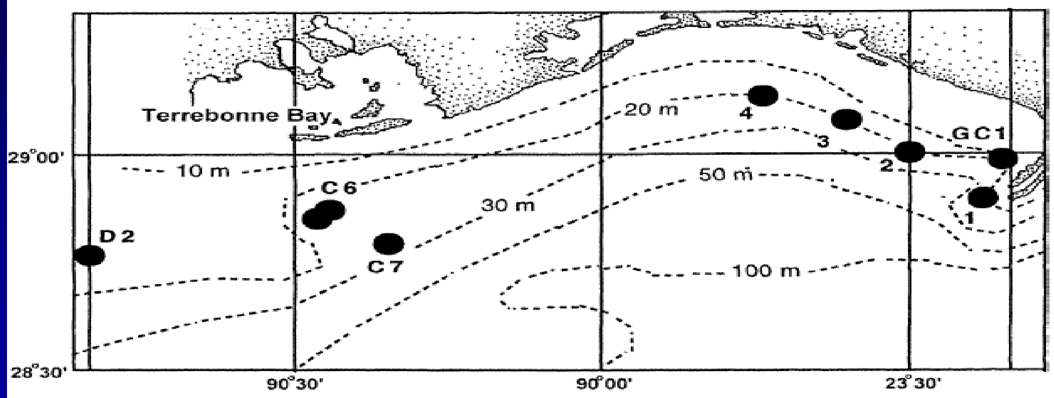
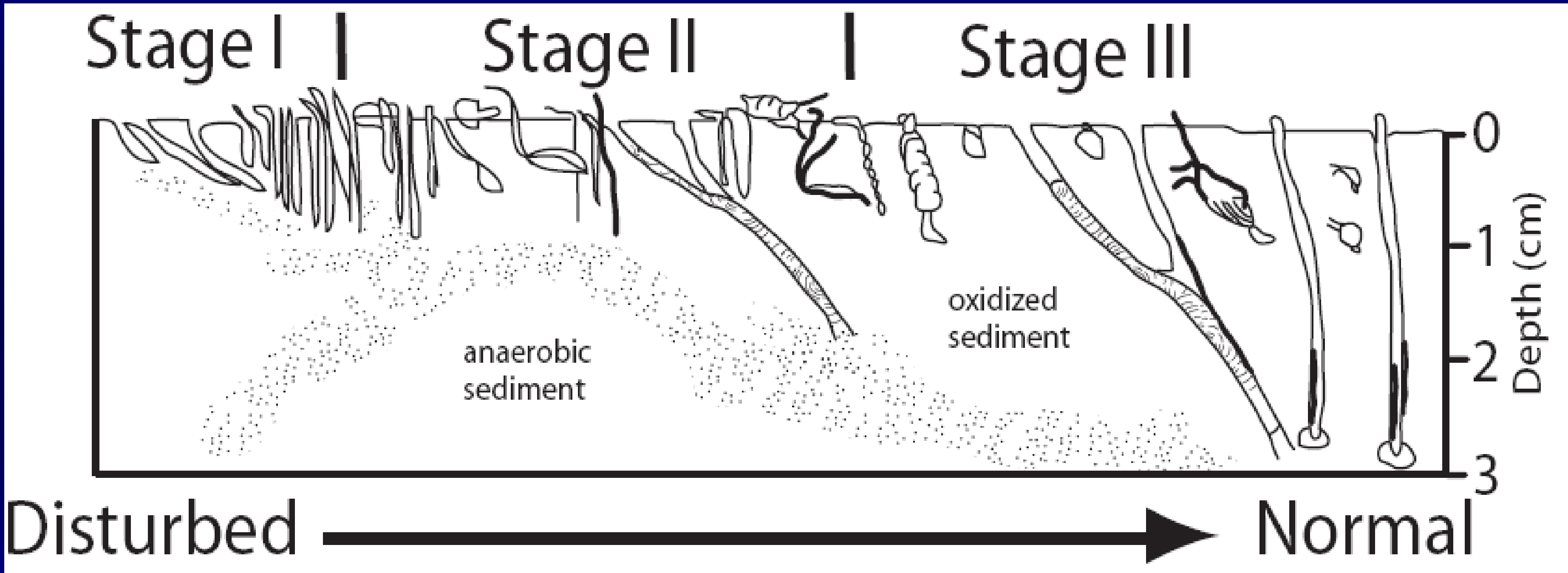


Fig. 1. Map of northern Gulf of Mexico showing the location of the sites studied.

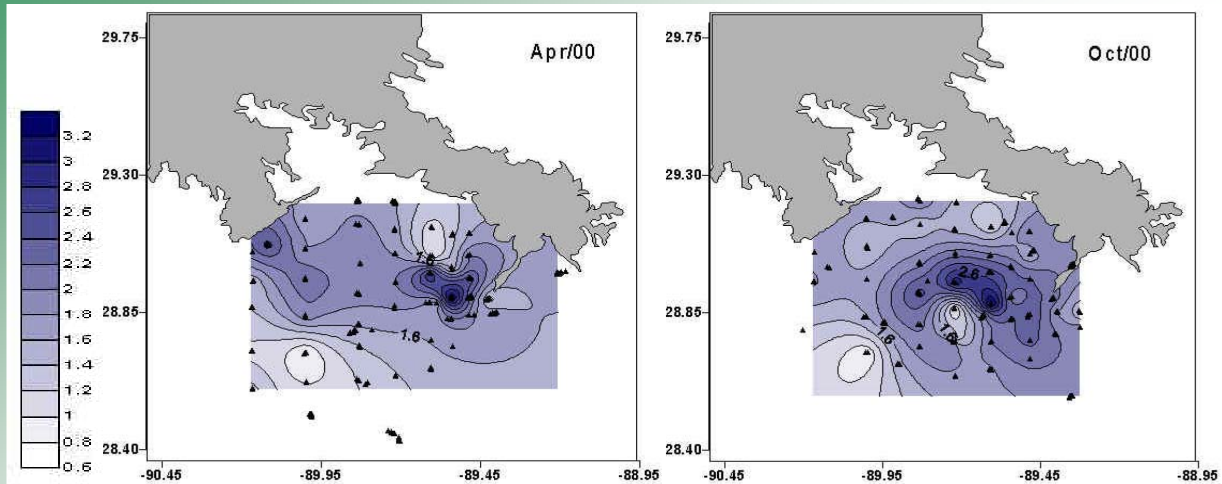
Rowe et al. (2002)

Benthic Macrofaunal Succession

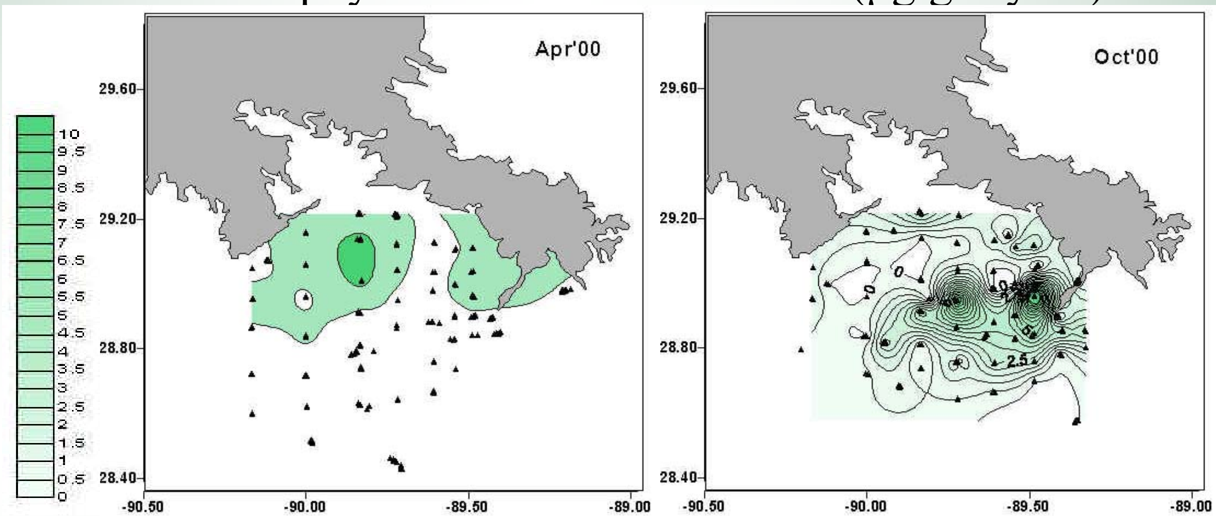


Zajac (2001)

Ad/Al ratios in surface sediments



Chlorophyll *a* in surface sediments (µg/g dry wt)



April	October
range: 0 – 2 µg/g	range: 0– 12 µg/g
mean: 0.44 ± 0.09	mean: 1.75 ± 0.67

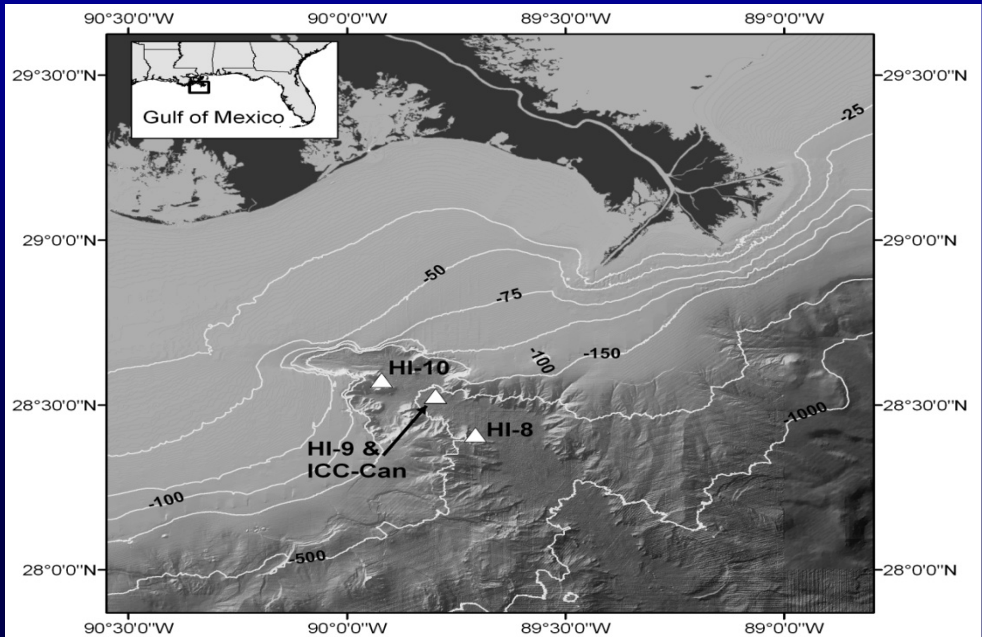
Wysocki et al. (2006)

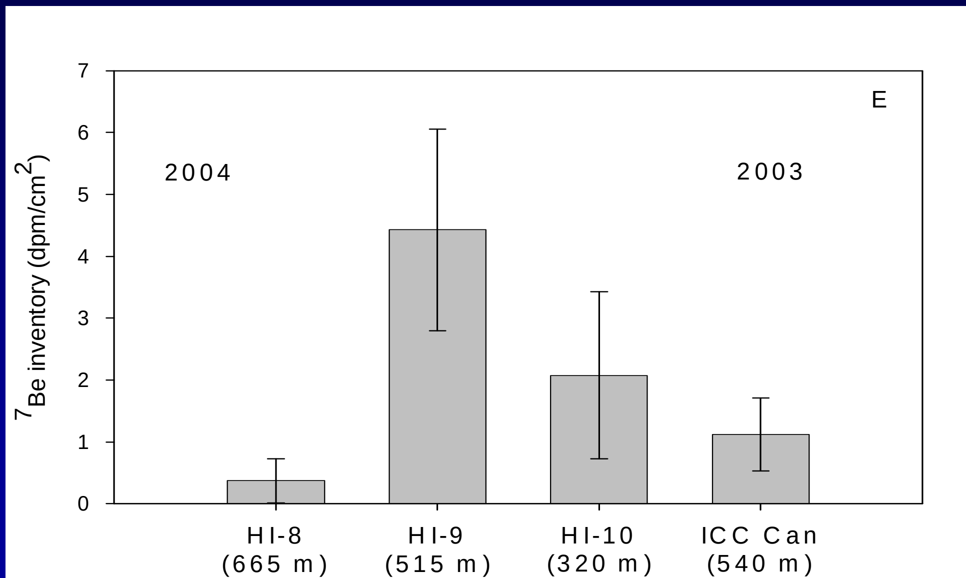
Co-metabolism: the set of processes whereby refractory organic material (e.g. terrestrial OC) is broken down more efficiently when mixed with labile material (e.g. marine OC),via higher microbial turnover rates

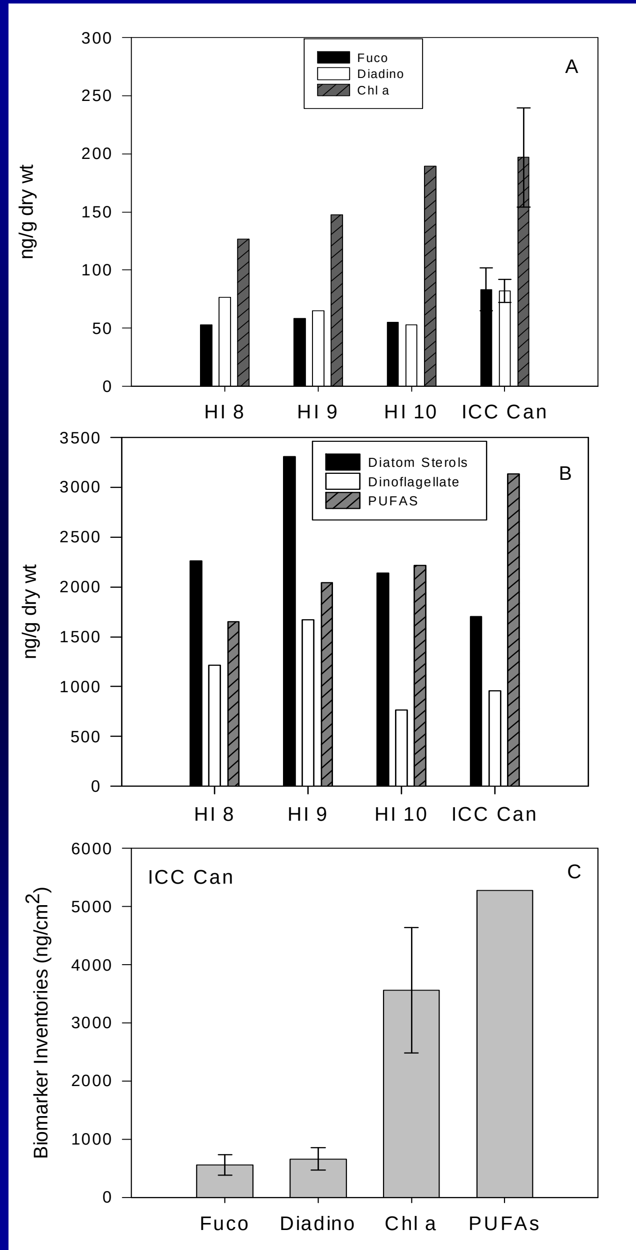
Lohnis (1926); Canfield (1993); Aller (1998)

Rapid Transport of Labile Shelf-Derived Organic Matter to the Mississippi River Canyon

Rapid Export of Organic Matter from the shelf to the Mississippi Canyon

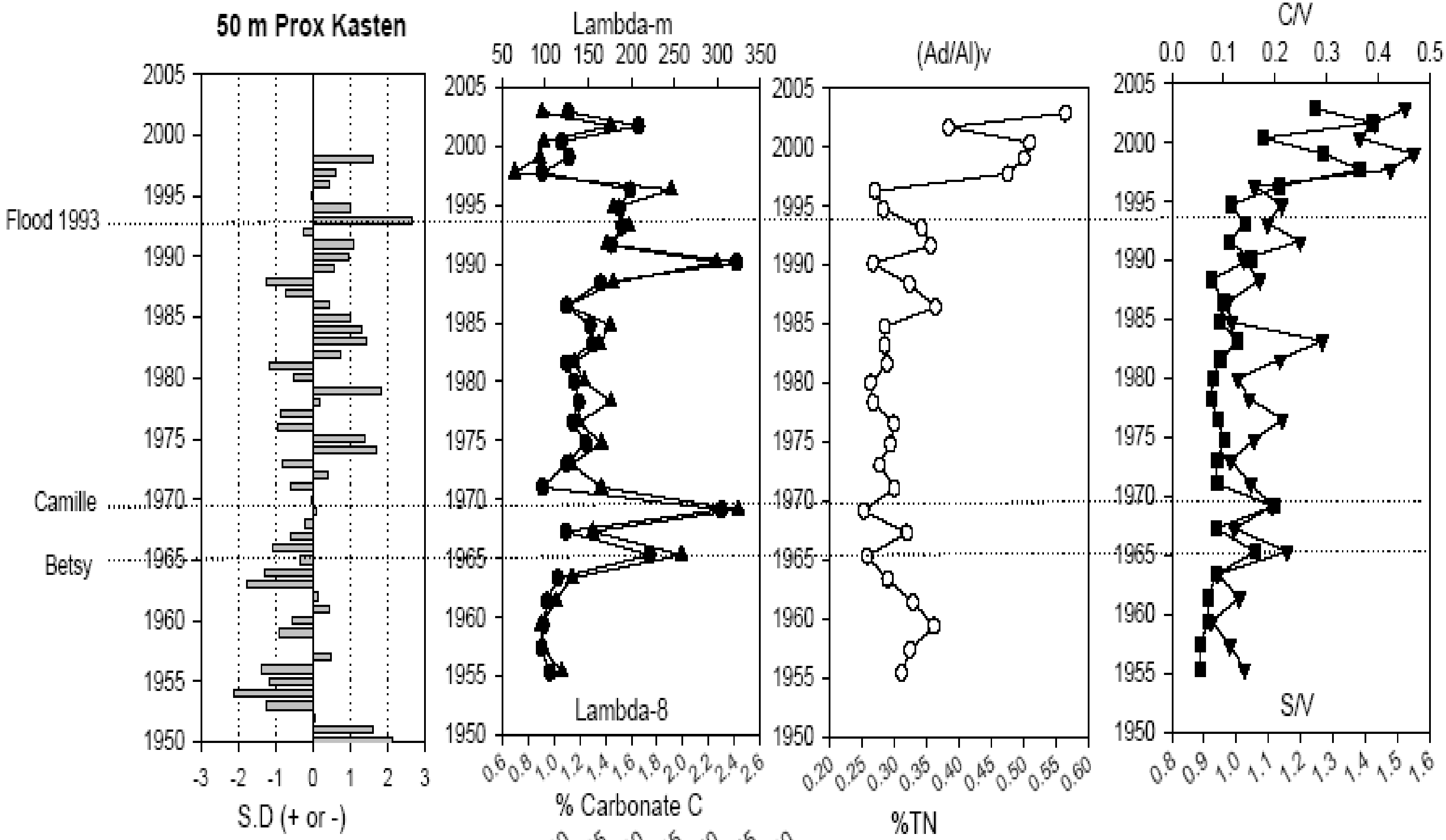






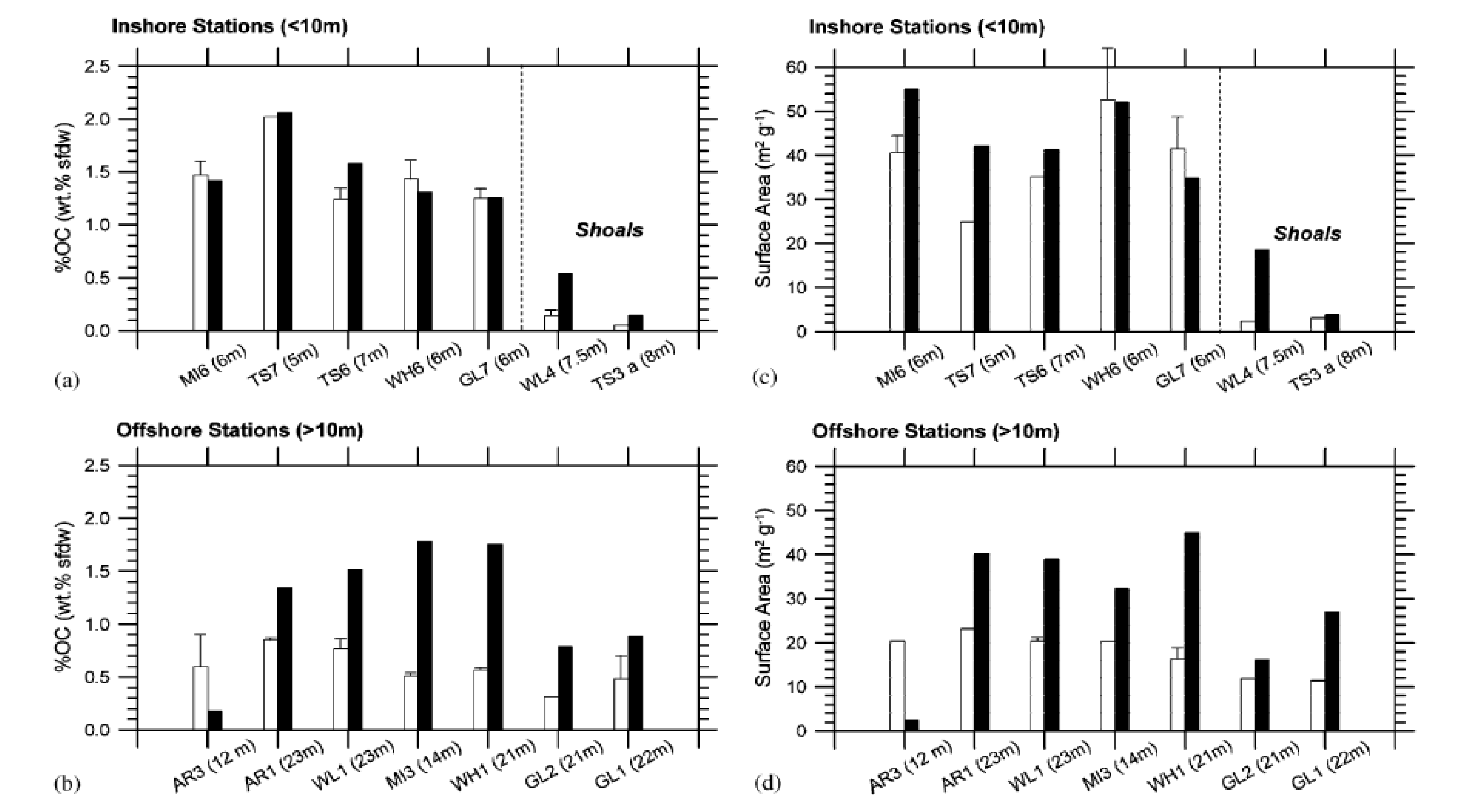
Bianchi et al. (2006)

Historical Records of Hurricane in Louisiana Shelf Sediments



Sampere et al. , submitted (JGR)

Effects Hurricane Lili on Organic Matter Distribution



Goni et al. (2006)