NACP/OCB Coastal Synthesis Activities: Regional Updates

Paula G Coble, Ray Najjar, Galen McKinley, Jeremy Mathis, (Simone Alin)

Coastal Interim Synthesis Activity

- Initiated at July 2008 OCB
- Five regions preliminary budgets
  - East Coast and Gulf of Maine – Ray Najjar
  - Gulf of Mexico – Paula Coble
  - Great Lakes – Galen McKinley
  - Arctic – Jeremy Mathis
  - West Coast – Simone Alin

Fluxes of interest

Interfacial fluxes:

- Inputs from land of DOC, POC, and DIC
- Air-sea: Exchange of CO_2, rainwater DOC
- Sedimentary fluxes: POC deposition, DOC & DIC exchange, benthic productivity, groundwater, hydrocarbon seeps
- Shelf-break exchange: DIC, DOC, POC

Internal fluxes:

- Primary production
- Respiration
- Net community production

Carbon budget for the continental shelf of the Eastern United States

R. Najjar, D. Butman, W.-J. Cai, M. Friedrichs,
A. Mannino, P. Raymond, J. Salisbury,
and D. Vandemark

+

B. Boyer, K. Fennel, J. Fuentes, M. Kemp, K. Kroeger, R. Striegl, and P. Vlahos

2010 Ocean Sciences Meeting
February 26, 2010

Motivation

- Coastal carbon cycle globally important
- Coasts susceptible to climate, land use
- Model evaluation
- Direction of future work
- North American Carbon Program mid-term synthesis

Study domain

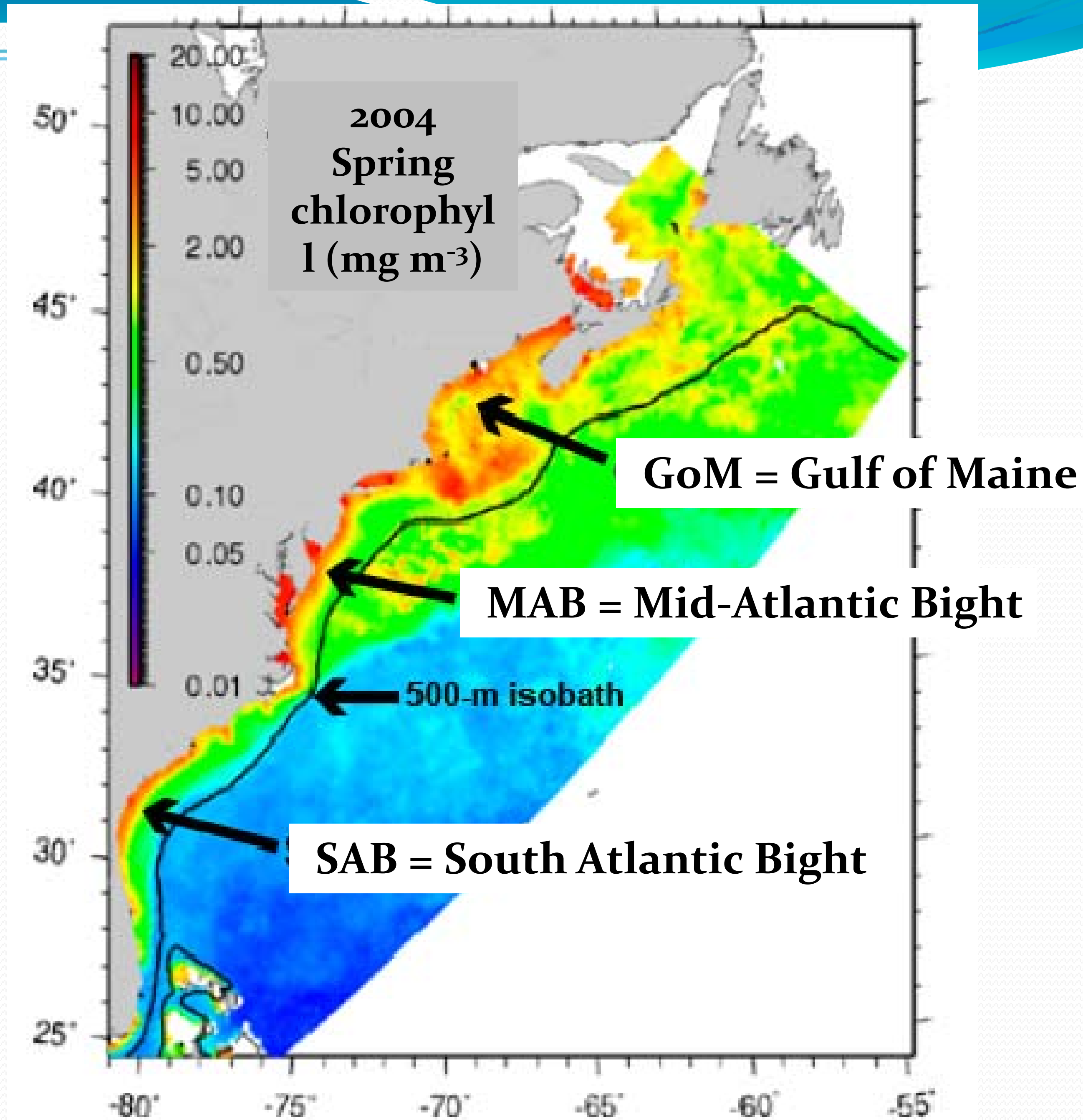
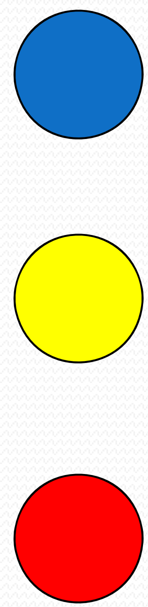


Figure courtesy
S. Signorini

Key for describing level of uncertainty

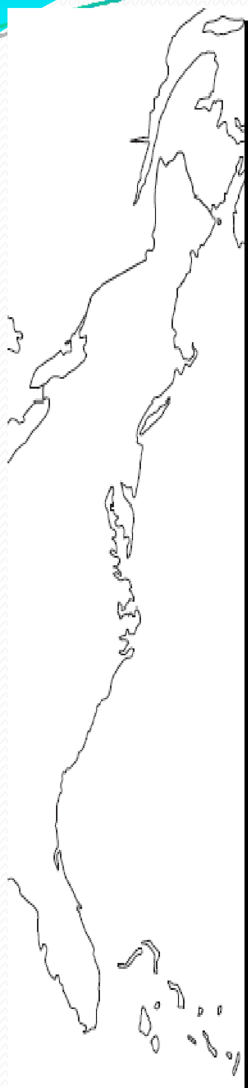


Low

Medium

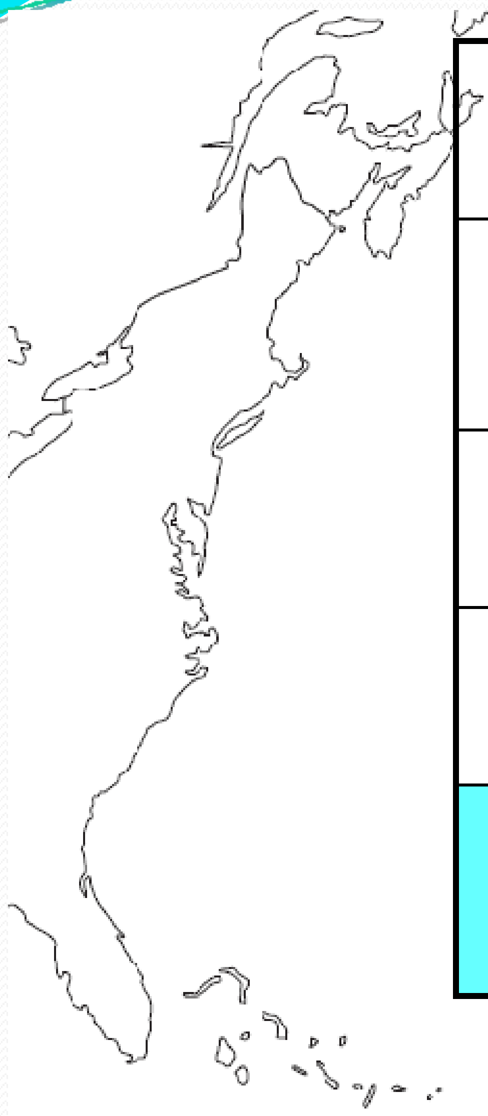
High

Input from land (Tg C yr^{-1})



	DIC	DOC	POC	Reference
GoM	0.5	NA	0.1	DIC, POC: Friedrichs
MAB	1.1	0.59 ± 0.09 (estuary) 0.56 (river) 1-1.5 (TOC)	0.5	DOC: Vlahos et al. (2002), Raymond and Bauer (2000) TOC: Bauer et al. (2008)
SAB	0.6 (river) 0.7 (marsh)	0.75 (river) 2-2.5 (TOC)	0.1-0.15 (river)	DIC: Wang (2003), Cai and Wang (1998) DOC & POC: Cai et al. (2003) TOC: Bauer et al. (2008)
Total	**2.9**	**>~1.6**	**~0.7**	**Total C input from land >~ 5**

Air-to-sea CO_2 fluxes



	Tg C yr^{-1}	mol m^{-2} yr^{-1}	Reference
GoM	NA	-0.38 ± 0.30 (western GOM)	Vandemark and Salisbury (in prep.)
MAB	1.6 ± 1.0	1.1 ± 0.7	DeGrandpre et al. (2002)[1]
SAB	0.52 ± 0.23	0.48 ± 0.21	Jiang et al. (2008)
MAB + SAB	2.1 ± 1.0	0.81 ± 0.39	

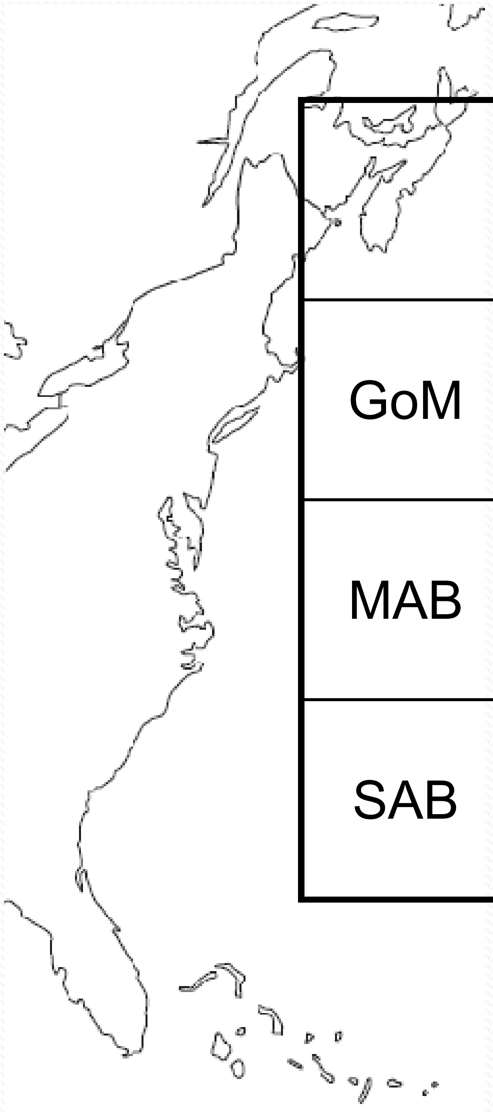
[1]Recomputed by Fennel et al. (2008) using different areas.

Global mean ~0.5 mol m^{-2} yr^{-1}.

Rainwater DOC fluxes

- GoM, MAB precip. ~ 1 m yr^{-1}
- [DOC] in rain ~ 50-100 mmol m^{-3}
- Fluxes ~ 0.05 – 0.1 mol C m^{-2} yr^{-1}
- Total flux to shelf ~ 0.28 ± 0.09 × Tg C yr^{-1}
- DOC in rain has marine component

Sediment-water interface (Tg C yr^{-1})



	DIC	DOC	POC (burial)	
GoM	NA	NA	-0.72 ± 0.22	Charette et al. (2001)
MAB	NA	NA	NA	
SAB	8 ± 11	NA	NA	Jahnke et al. (2005)

Cross-shelf exchange (Tg C yr^{-1})

	DIC	DOC	POC	
GoM	NA	-1.3 ± 2.9 (TOC)	NA	Charette et al. (2001)
MAB	NA	-6.5	-4.8	Vlahos et al. (2002) Falkowski et al. (1994)
SAB	-2.6	NA	NA	Cai et al. (2003), Wang et al. (2005)

Water column primary production

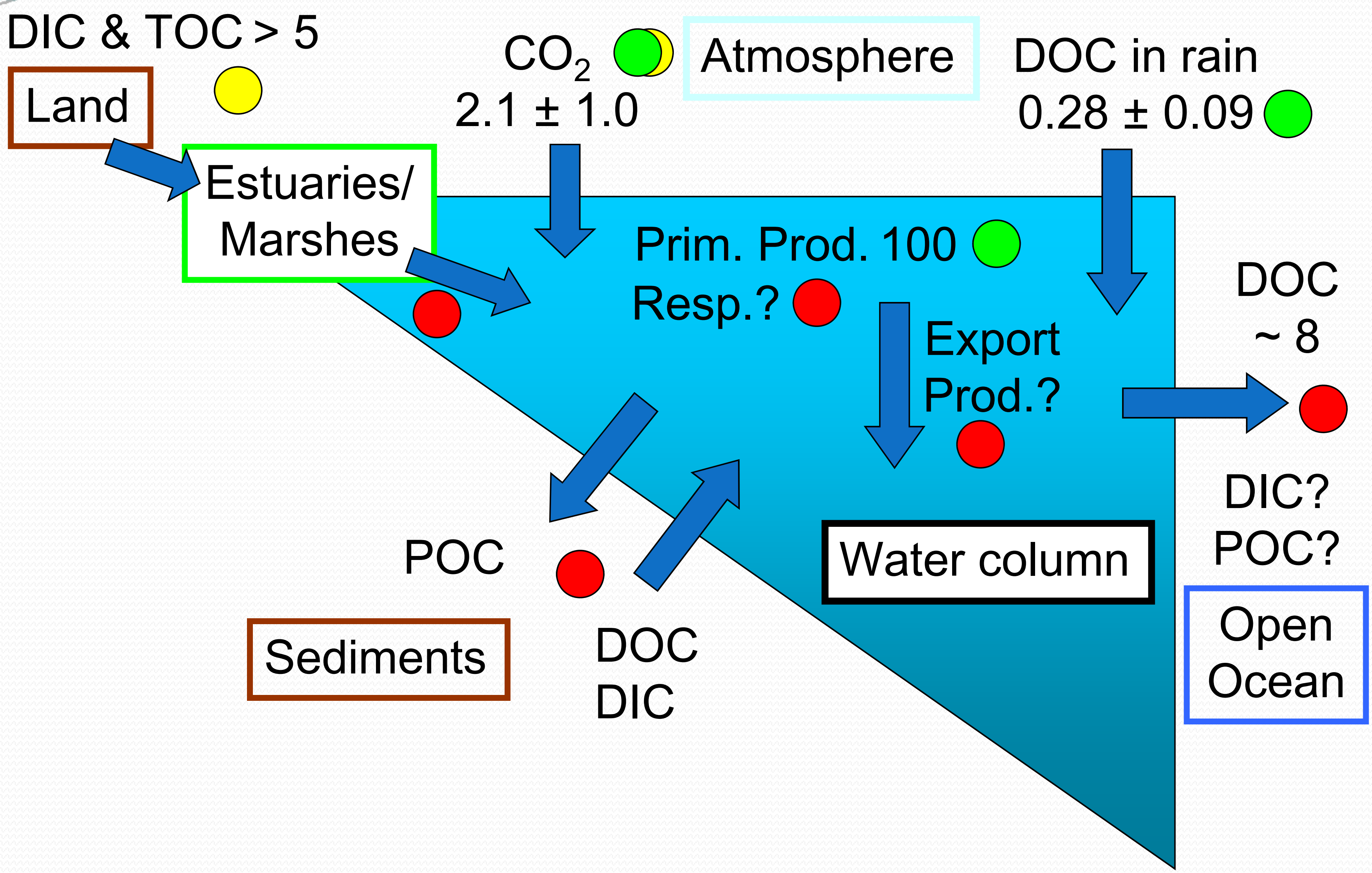
	Tg C yr^{-1}	mol m^{-2} yr^{-1}	
GoM	27 34	22	O'Reilly et al. (1987) Balch et al. (2008)
MAB	39	26	O'Reilly et al. (1987)
SAB	35	32	Menzel et al. (1993)
Total	**100**	26	

(0.2% of global primary production, global areal mean = 12 mol m^{-2} yr^{-1})

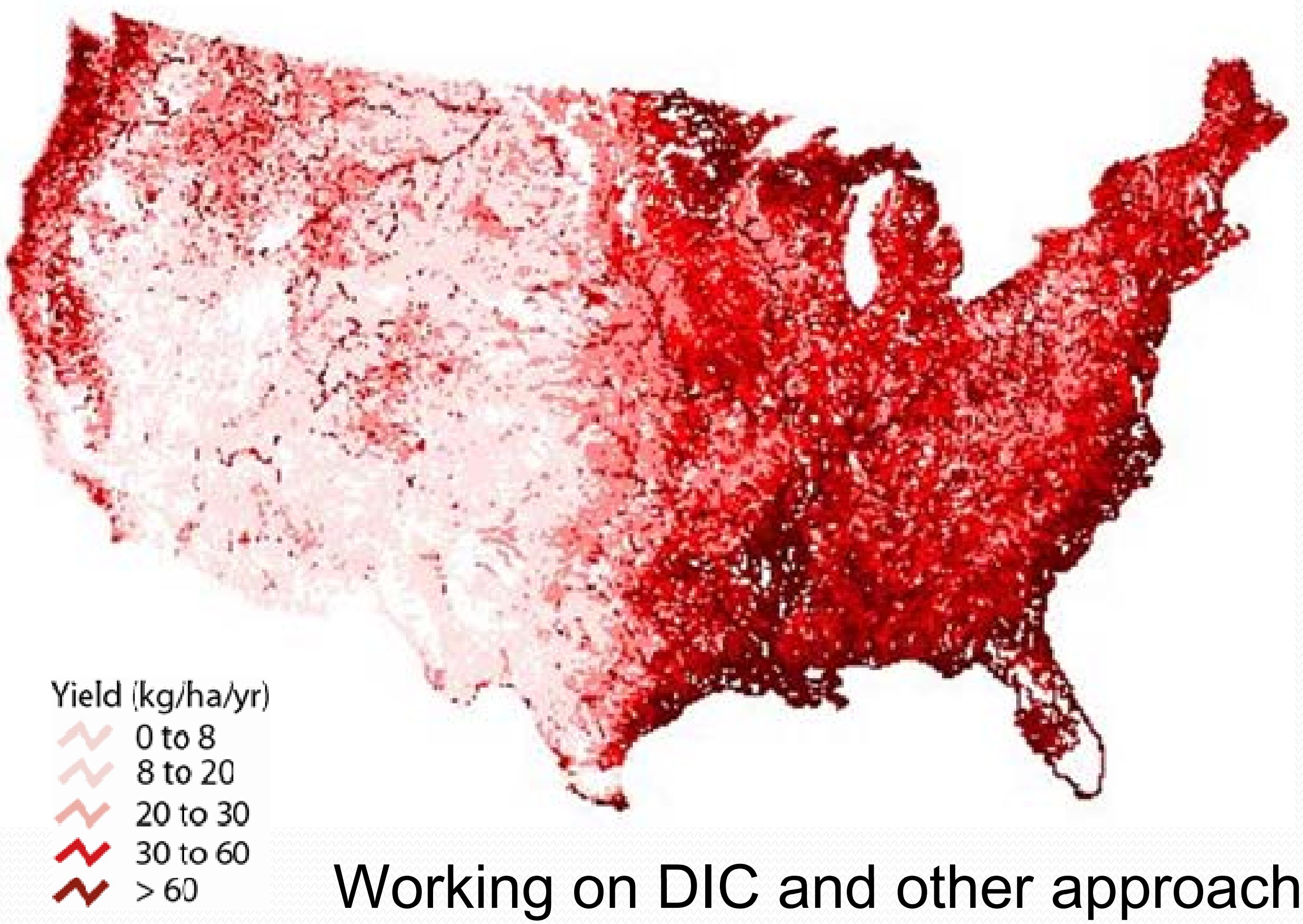
Respiration

- SAB, about the same as primary production (Jiang et al. 2009)
- Few measurements in MAB, GoM

Shelf-wide budget (Tg C yr^{-1})



SPARROW predictions of the incremental TOC yield to streams across the conterminous USA.



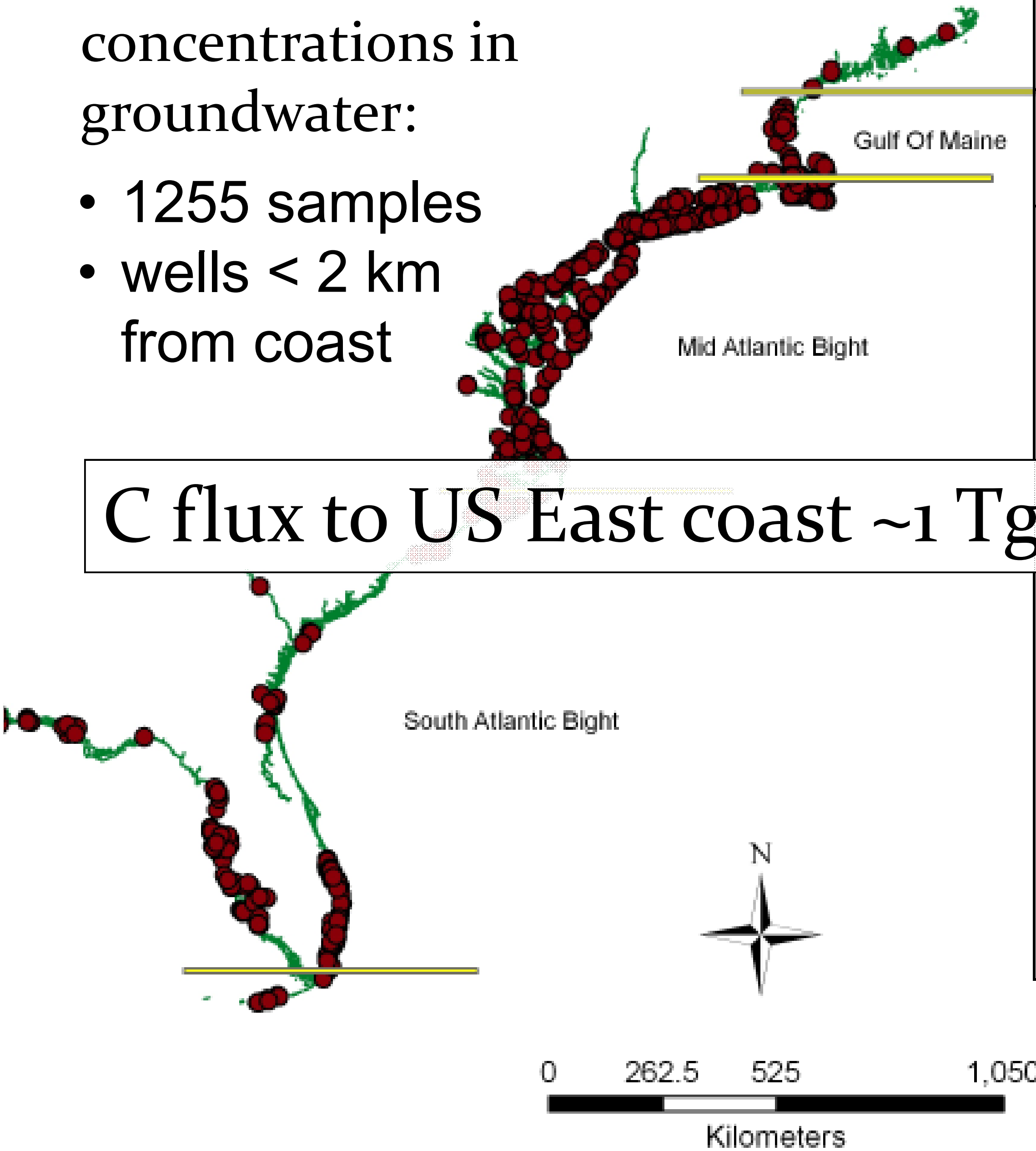
Delivery to Atlantic coastal waters (including W. Florida) = 5.2 Tg C yr^{-1}

Working on DIC and other approaches (LOADEST)

Slide contributed by E. Boyer; Shih et al. in press.

DOC concentrations in groundwater:

- 1255 samples
- wells < 2 km from coast

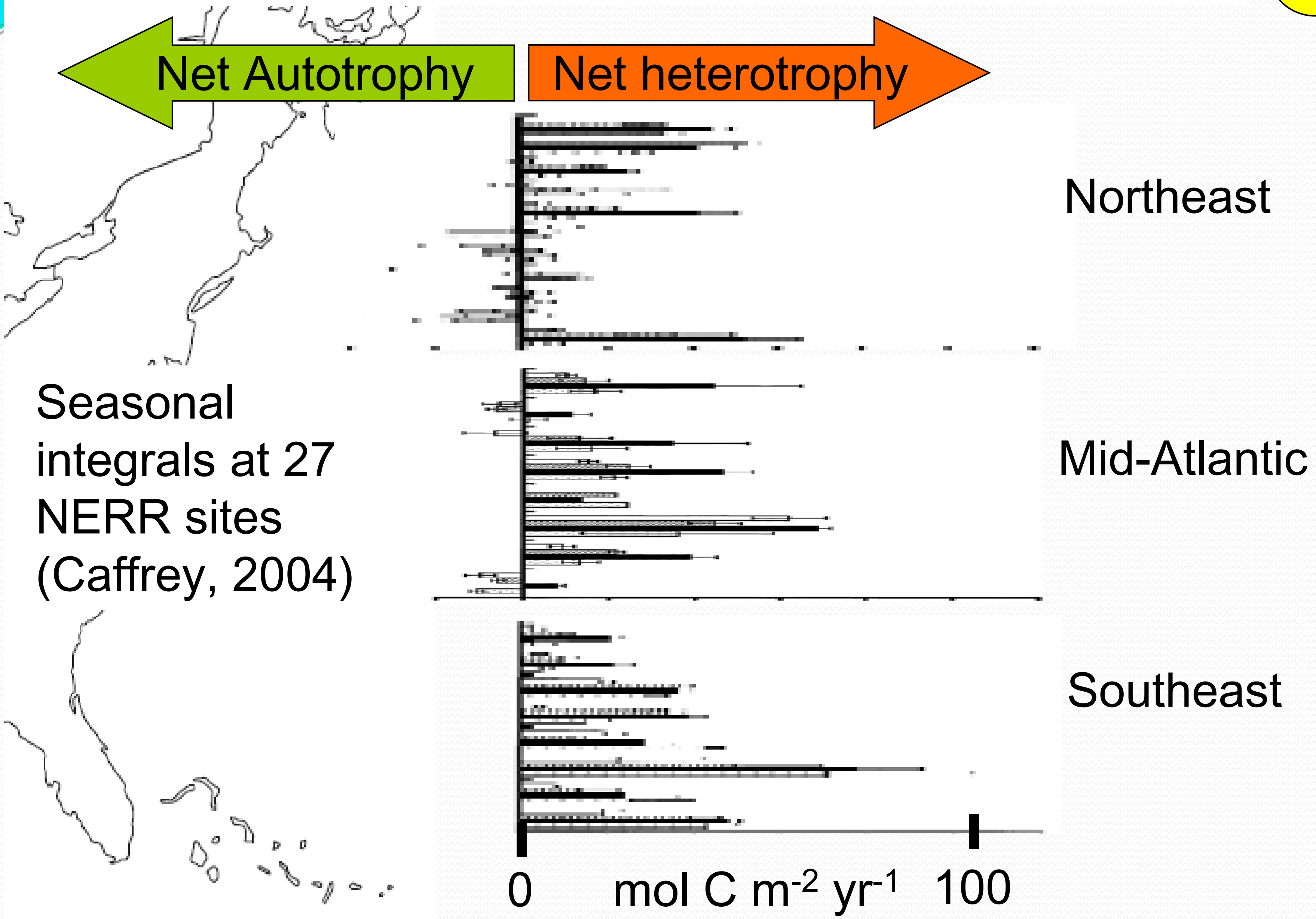


Mean ± $\sigma/N^{1/2}$ (μM)
132 ± 16
694 ± 159
1785 ± 223

C flux to US East coast ~1 Tg C yr^{-1}

Source: K. Kroeger

Estuarine Net Ecosystem Metabolism



Seasonal integrals at 27 NERR sites (Caffrey, 2004)

Important but poorly known:

Short-term outlook:

- Estuarine C processing
- Groundwater fluxes

- Water column respiration
- Shelf sediment fluxes
- Marsh C processing

- Cross shelf fluxes

A Preliminary Carbon Budget for the Gulf of Mexico

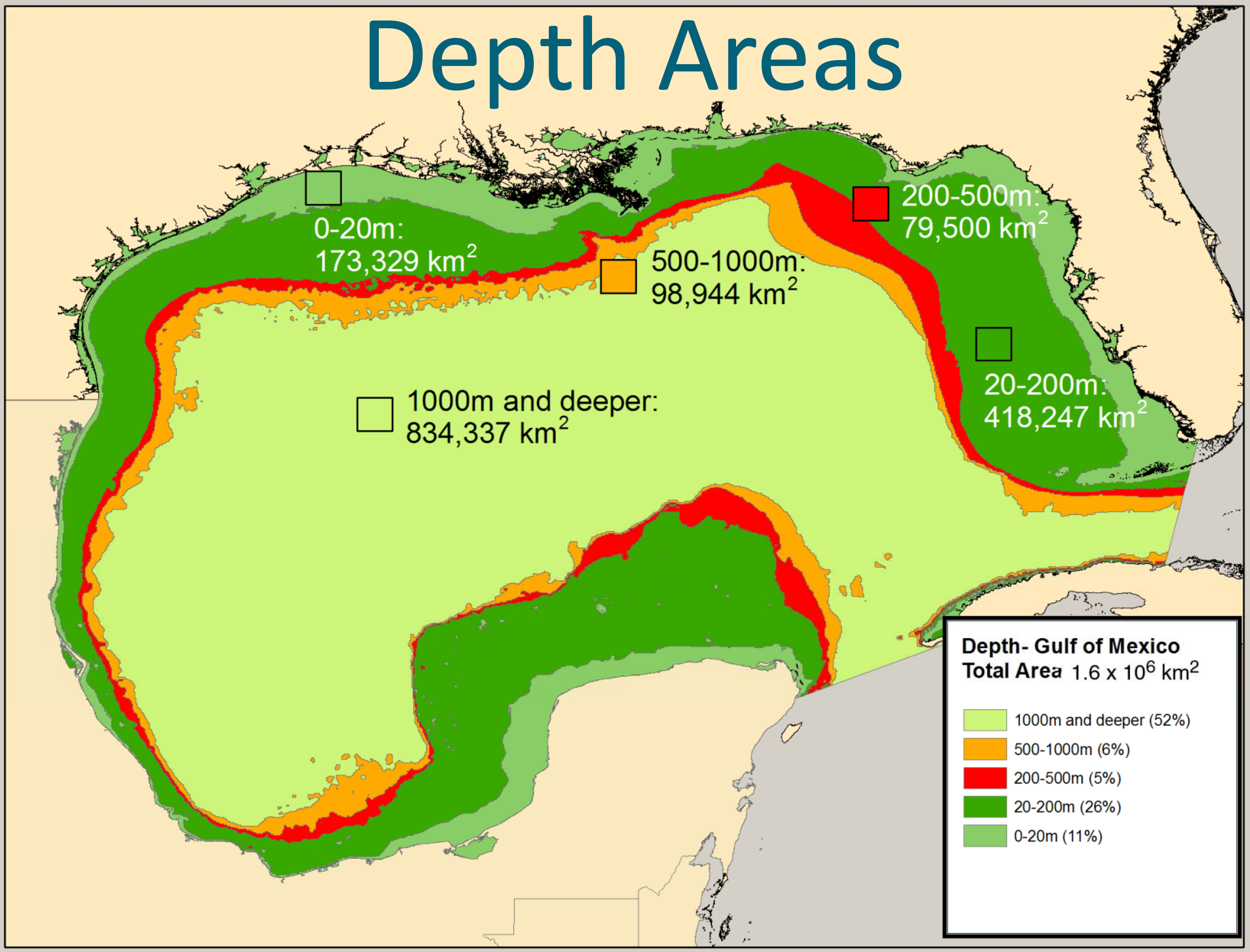
Paula G Coble, Lisa L Robbins, Kendra L Daly, Wei-Jun Cai, Katja Fennel, Steven E Lohrenz

2010 Ocean Sciences Portland, OR Feb. 26,2010

Semi-enclosed basin with major terrestrial inputs

- Basin covers 40% US, 40% Mexico

Depth Areas

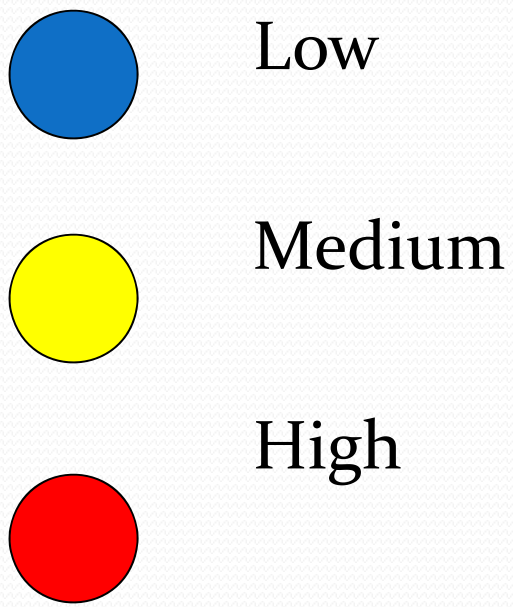


0-20m:
173,329 km²
200-500m:
79,500 km²
500-1000m:
98,944 km²
20-200m:
418,247 km²
1000m and deeper:
834,337 km²
Depth- Gulf of Mexico
Total Area 1.6 x 10⁶ km²
1000m and deeper (52%)
500-1000m (6%)
200-500m (5%)
20-200m (26%)
0-20m (11%)

Data sources

- Modeled rates –
  - Walsh et al. 1989 – water column fluxes
    - 2-layered physical, 21-layered biochemical model
    - 3 coastal areas, open gulf, and plume values calculated
  - Wanninkhof – air-sea flux
- Measured rates
  - Primary productivity, sediment trap fluxes, sediment community oxygen consumption (Rowe)
- Fluxes – rates times depth interval areas

Key for describing level of uncertainty



Water column primary production

	$g\ C\ m^{-2}\ yr^{-1}$	$10^{12}\ g\ C\ yr^{-1}$	
Central Gulf	190* 30-150	191.5 (63%)	Walsh et al. 1989 Lohrenz & Verity 2010
TX	156* 160	13.2 (5%)	Walsh et al. 1989 Lohrenz & Verity 2010
LA	260*	45.8(11%)	Walsh et al. 1989
WFS	270* 30-180	47.5 (11%)	Walsh et al. 1989 Lohrenz & Verity 2010
MX	265? 100-120	46.6(11%)	Lohrenz & Verity 2010
Plume	3060* 584	5.7	Walsh et al. 1989 Cai & Lohrenz 2009
Total	105 - 210	Σ = 336	Walsh et al. 1989

*f = 0.10 (global areal mean = 144 $g\ C\ m^{-2}\ yr^{-1}$)

Primary Productivity

	g C m^{-2} yr^{-1}	10^{12} g C yr^{-1}	Reference
Benthic GMx	109.5	19 (0-20m)	Murrell et al. 2009
Benthic MAB	146	25.7 (0-20m)	Jahnke et al. 2000
Total WC		336	
Total PP		358	

Export from upper layer

	g C m^{-2} yr^{-1}	10^{12} g C yr^{-1}	
Central Gulf	12.7	12.8 (63%)	*Walsh et al. 1989
TX	12.4		*Walsh et al. 1989
LA	18.1 109.5		*Walsh et al. 1989 Redalje et al. 1994
WFS	14.7		*Walsh et al. 1989
Plume	56.7 365	?	*Walsh et al. 1989 Redalje et al. 1994
0- 200m	Ave = 15.1	8.9 (37%)	
Total		Σ = 21.7 (6.4% PP)	Walsh et al. 1989

Sediment-water interface (10^{12} g C yr^{-1})

	g C m^{-2} yr^{-1}	10^{12} g C yr^{-1}	
Central Gulf	1.3* 0.5 1.4	0.83 (52%)	*Walsh et al. 1989 Escobar-Briones Rowe et al. 2008
TX	7.1*		*Walsh et al. 1989
LA	9.5* 30 12.7		*Walsh et al. 1989 Eadie et al. 1994 Rowe et al. 2008
WFS	7.9*		*Walsh et al. 1989
Plume	36.2* 50 1	?	*Walsh et al. 1989 Eadie et al. 1994 Cai & Lohrenz 2009
MX Slope/rise	1 - 2	0.26 (11%)	Escobar-Briones
0- 200m	Ave = 8.2*	4.83 (37%)	*Walsh et al. 1989
Total		2.06 Σ = 5.92	Walsh et al. 1989 1.7% PP

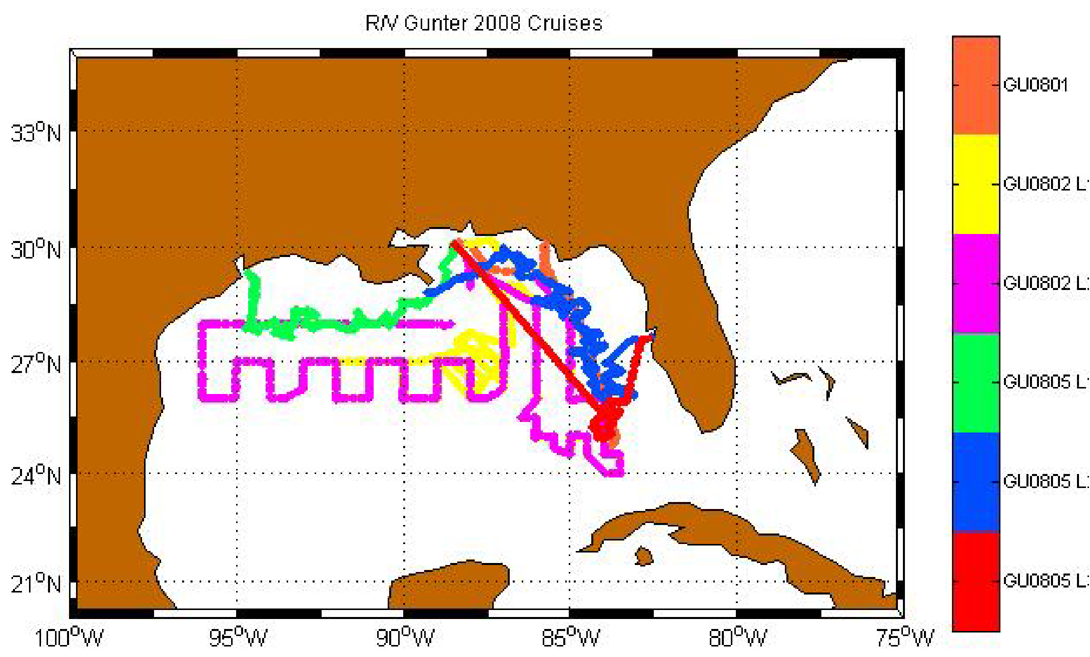
*50:1 C:chla

Input from land (1012 g C yr-1)

	DIC	DOC	POC	Reference
MARS	21	2.5	2.5	Cai & Lohrenz 2009
Other rivers	?	?	?	Robbins, in prep.
Total				

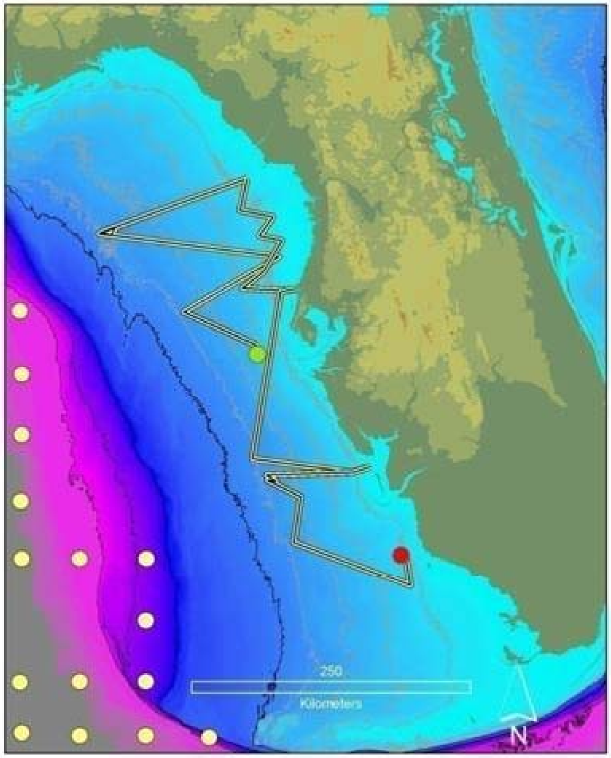
Air-sea flux data

2008 R/V Gunter cruises



Wanninkhof 2009

2009 USGS cruises



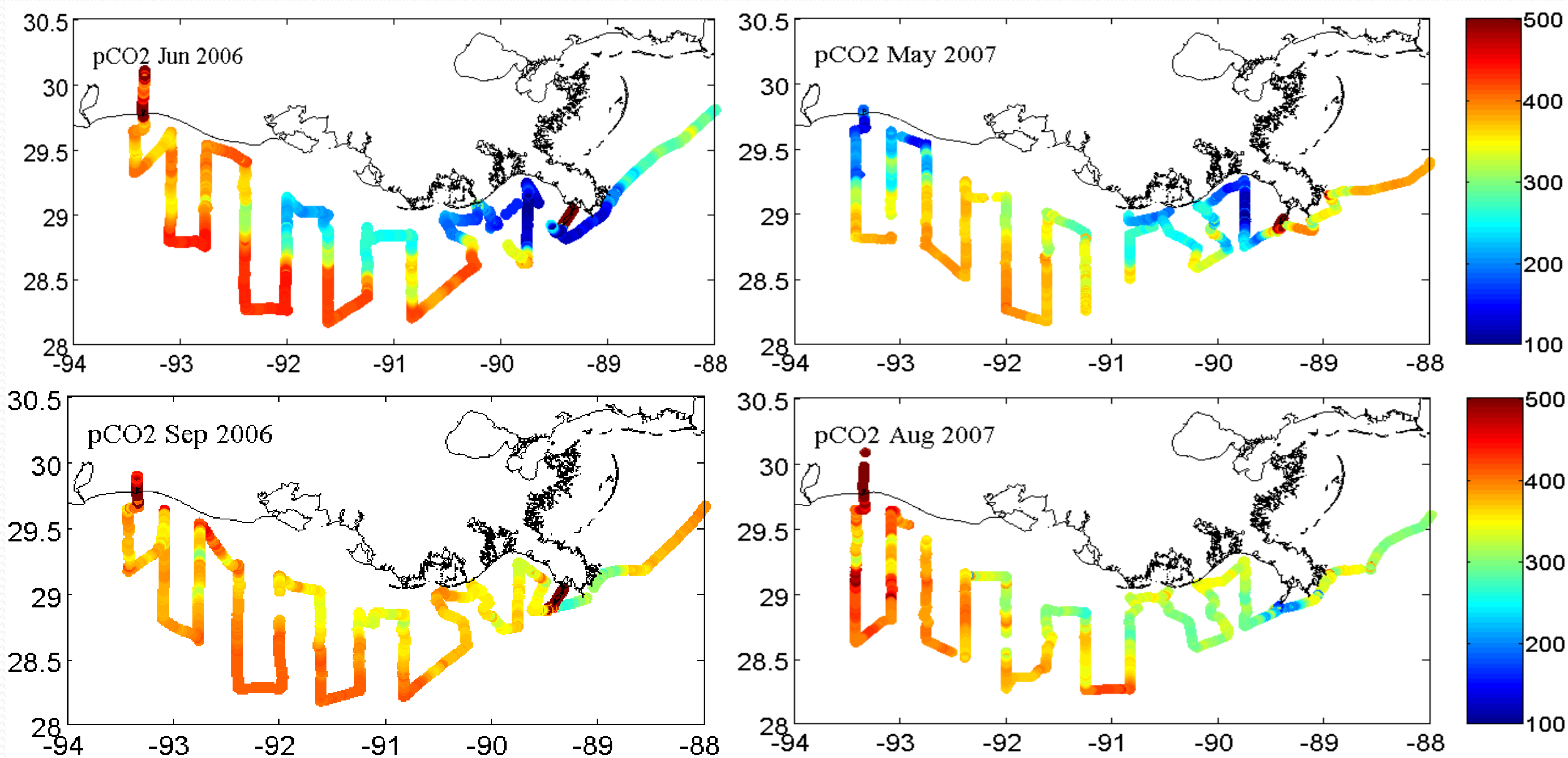
Robbins, unpub.

GulfCarbon: A Comprehensive Study of Carbon Dynamics in the Northern Gulf of Mexico

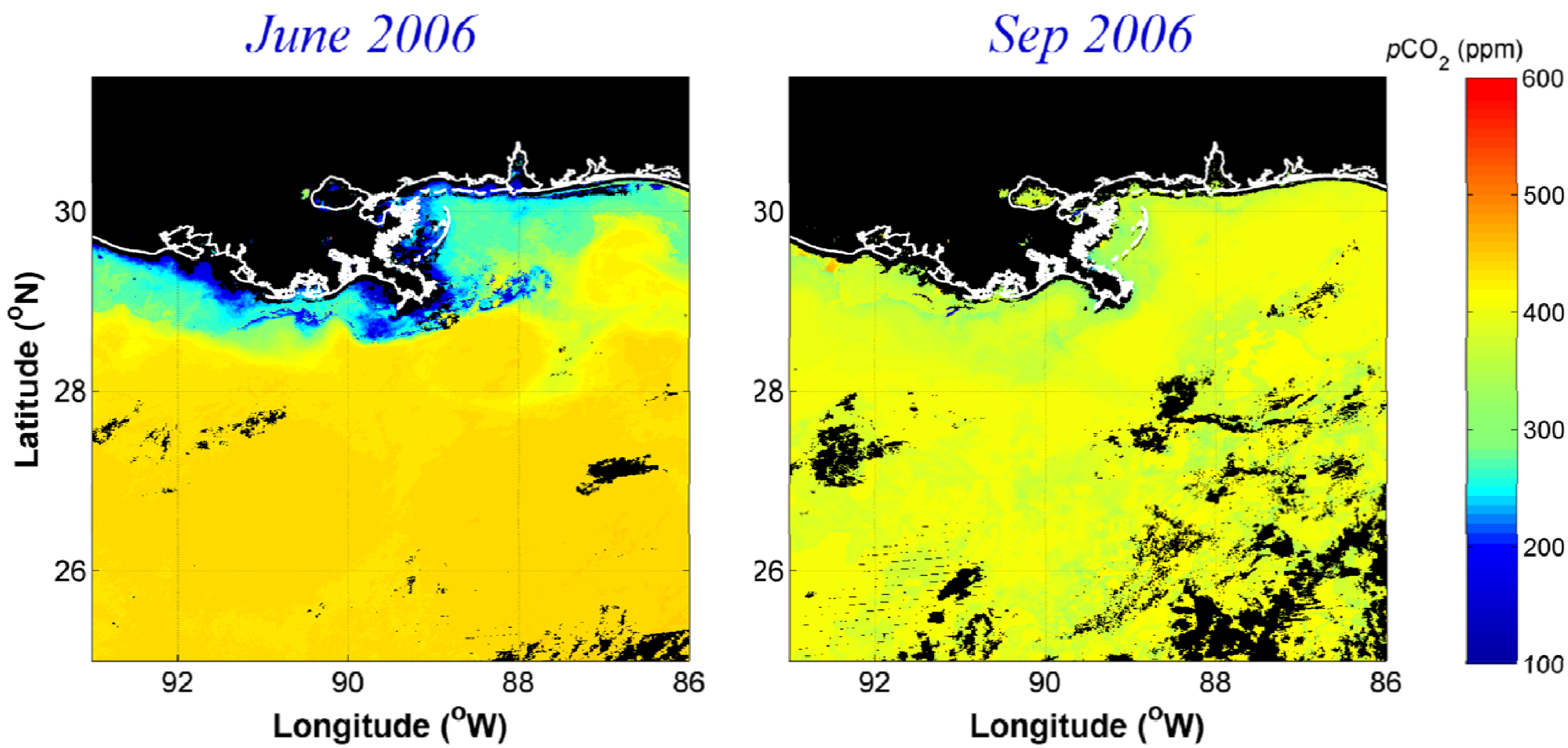
Steven E. Lohrenz, Wei-Jun Cai, Kevin Martin, Sumit Chakraborty, Sarah Epps, Kjell Gundersen, Wei-Jen Huang, Yongchen Wang

Preliminary Findings

EPA survey cruises shown strong influence of freshwater inputs

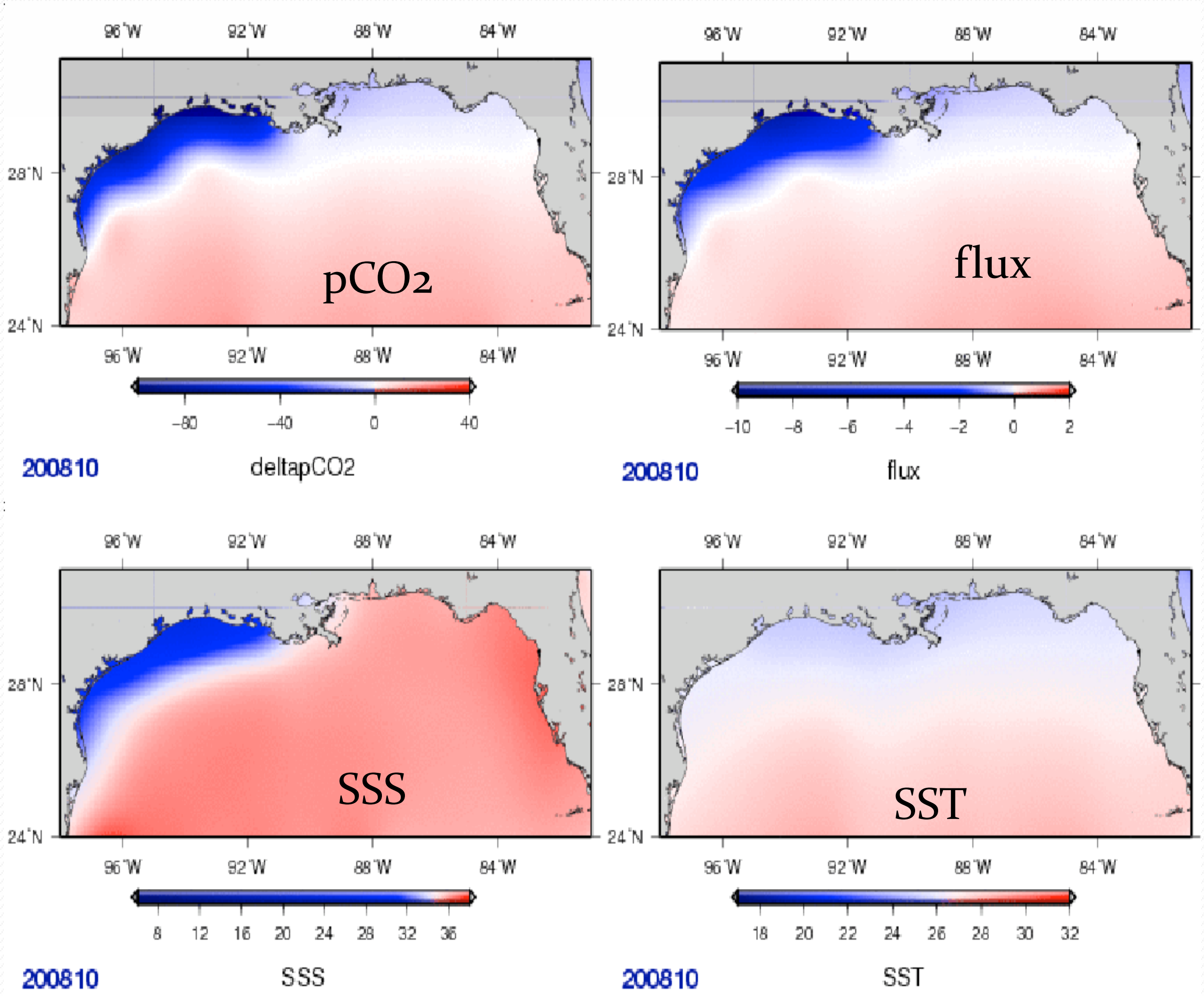


Satellite-derived pCO2



- Net sink inshore in June
- Net source offshore source in Sep

Air-sea flux



- MR plume sink all year
- Open water source only in late summer
- pCO2 correlates with temperature

North of 24°N = -11.8 Tg C yr^{-1}

Wanninkhof 2009

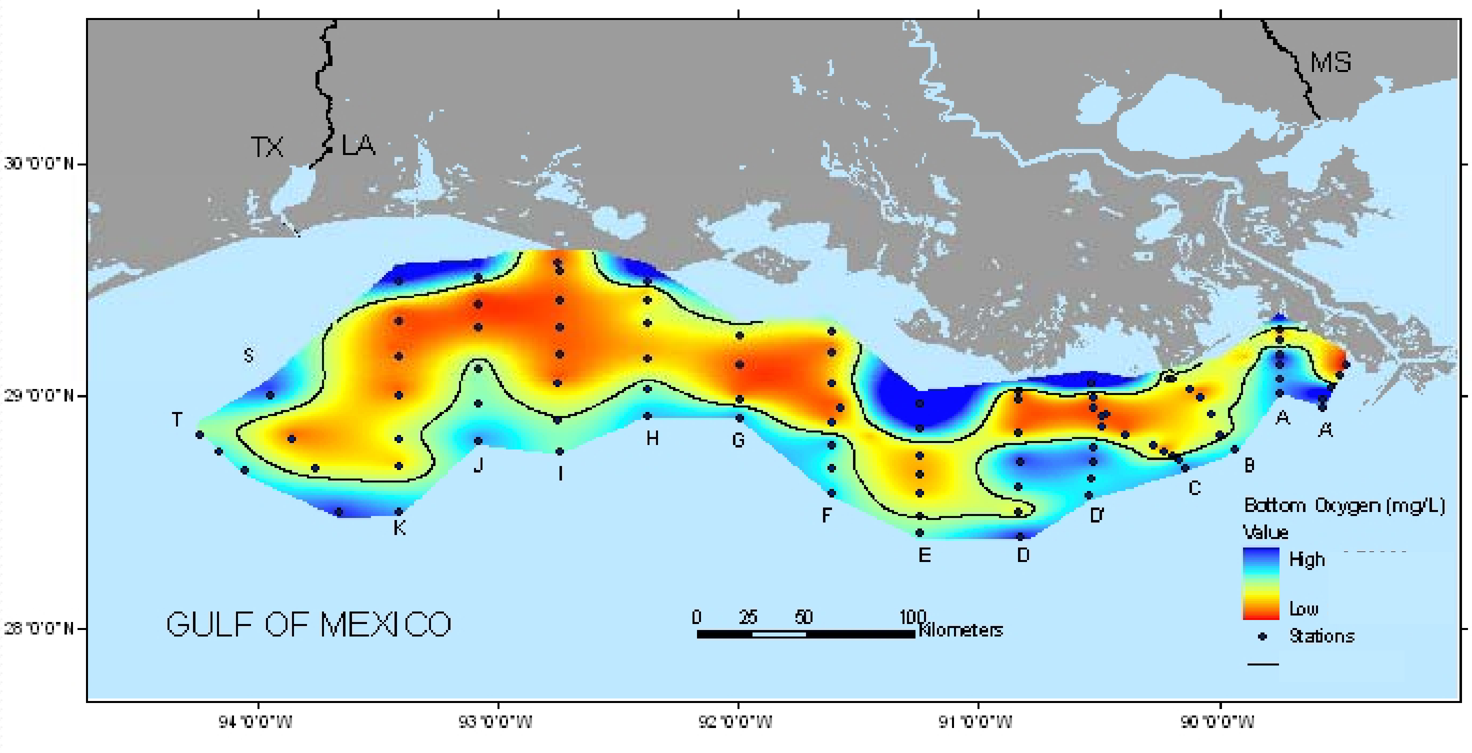
Air-to-sea CO_2 fluxes

	10^{12} g C yr^{-1}	mol m^{-2} yr^{-1}	Reference
Summer		0.48 0.186-0.230(Aug.'04) 2.71-3.32 (Oct. '05)	Robbins, unpub. Lohrenz et al. 2010 Lohrenz et al. 2010
Winter		-0.22 -0.97 - -1.18	Robbins, unpub. Lohrenz et al. 2010
N of 24°	-11.8		Wanninkhof (unpub.)
Total?	-23.6		

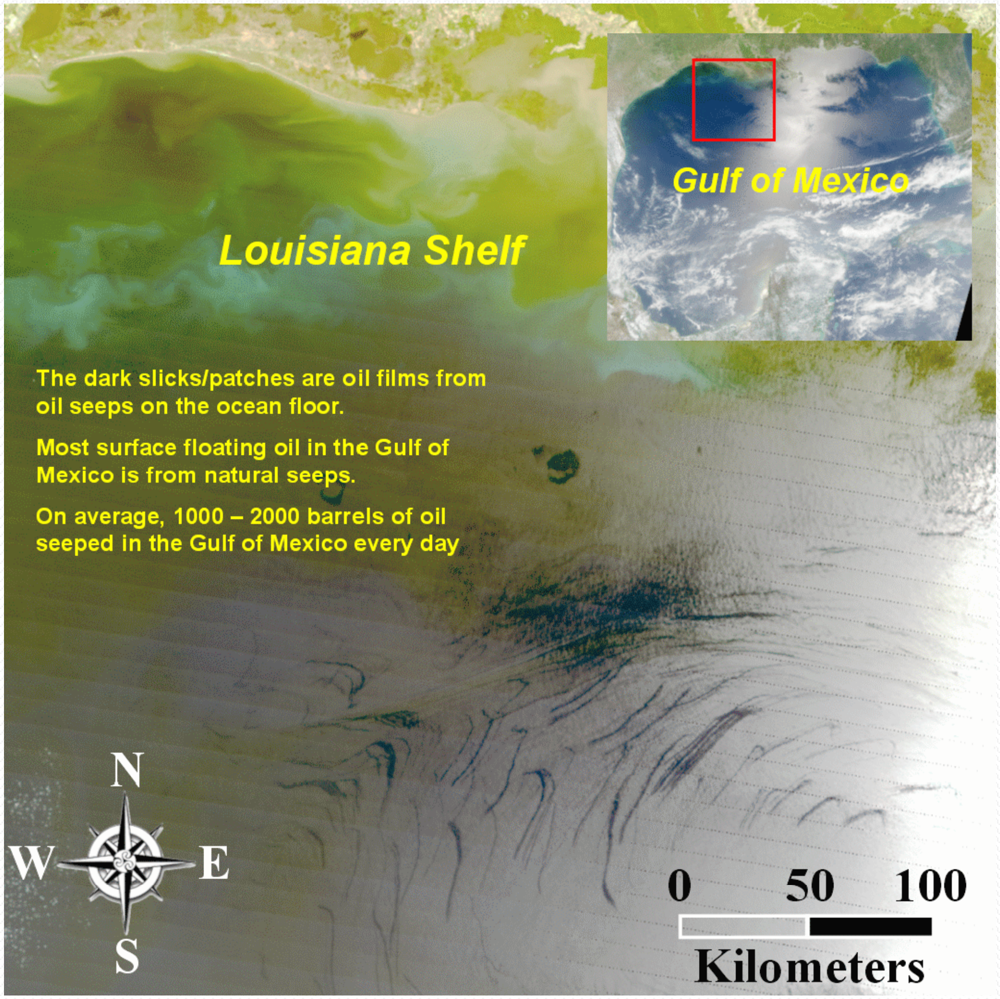
Red numbers are sinks

Other fluxes - Hypoxia

21 – 28 July 2007
Hypoxia
(N. Rabalais, LUMCON)



Other fluxes - Crude oil



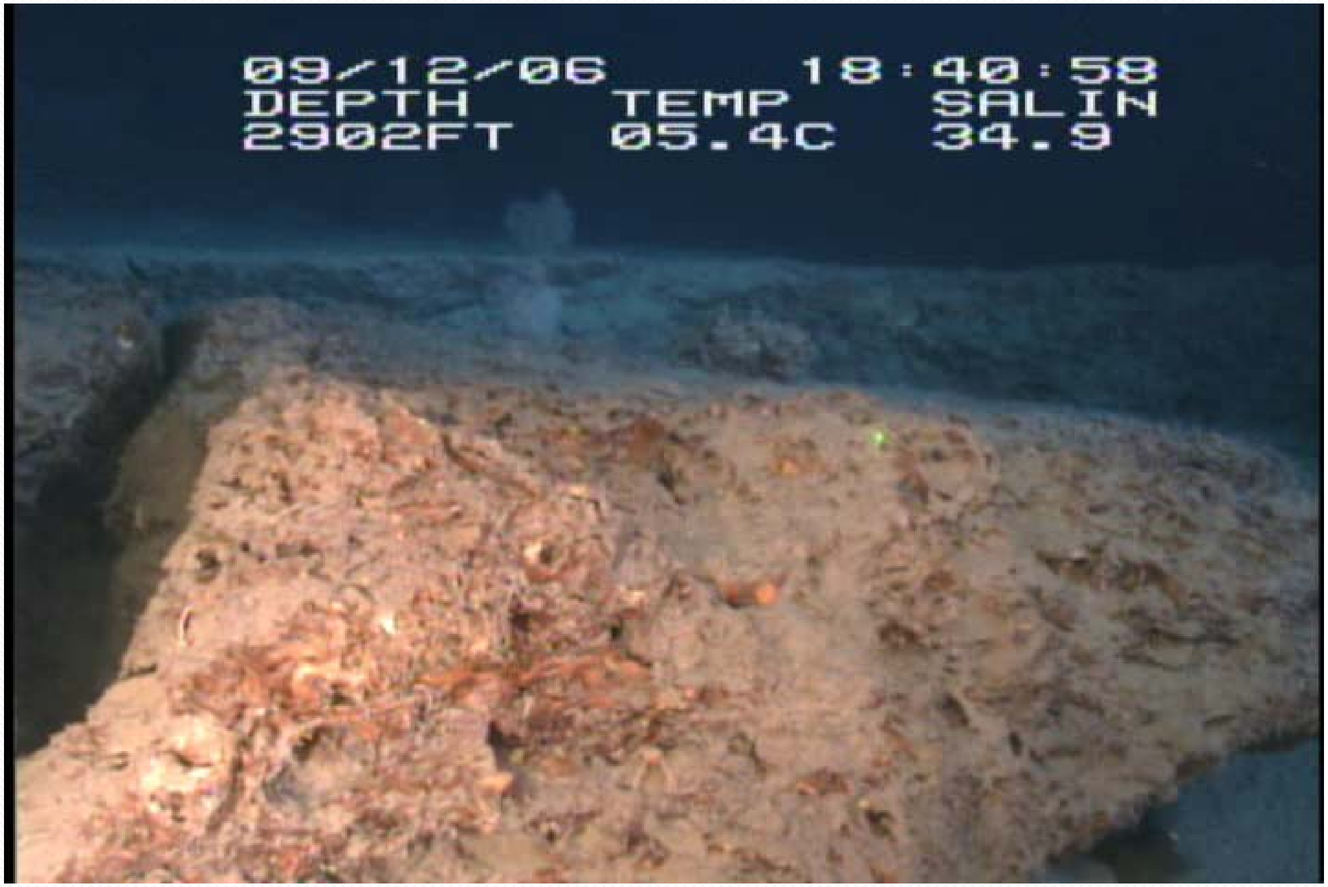
1000 – 2000 barrels/d = 0.04 – 0.08 Tg C/yr

DWH spill total 2.24-4.48 M barrels = 024 – 0.49 Tg C

Thanks to C. Hu

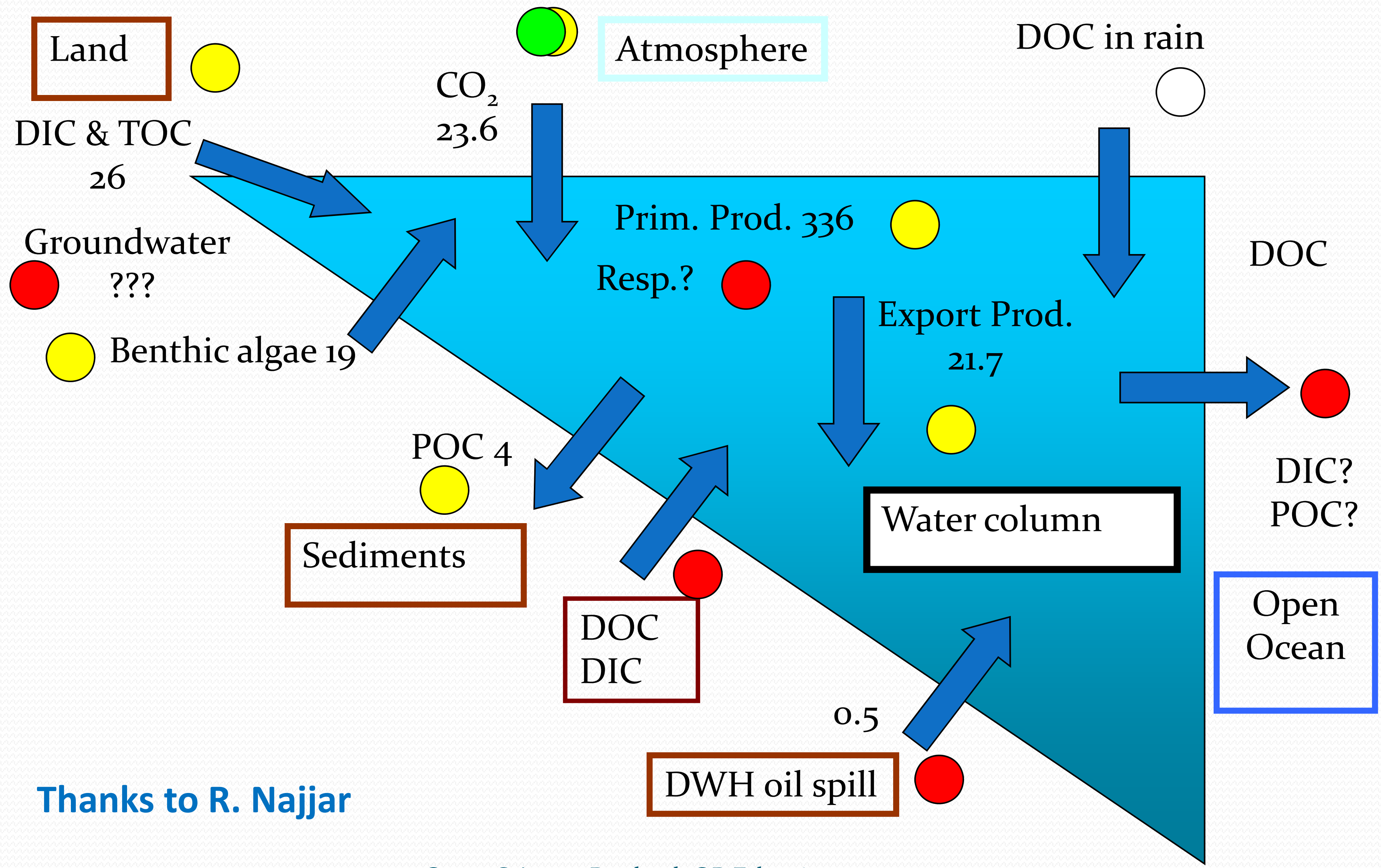
Other fluxes - Volatile HC seeps

chemotrophic bacterial carbonate pavements



Thanks to V. Asper

Shelf-wide budget (10^{12} g C yr^{-1})



Thanks to R. Najjar

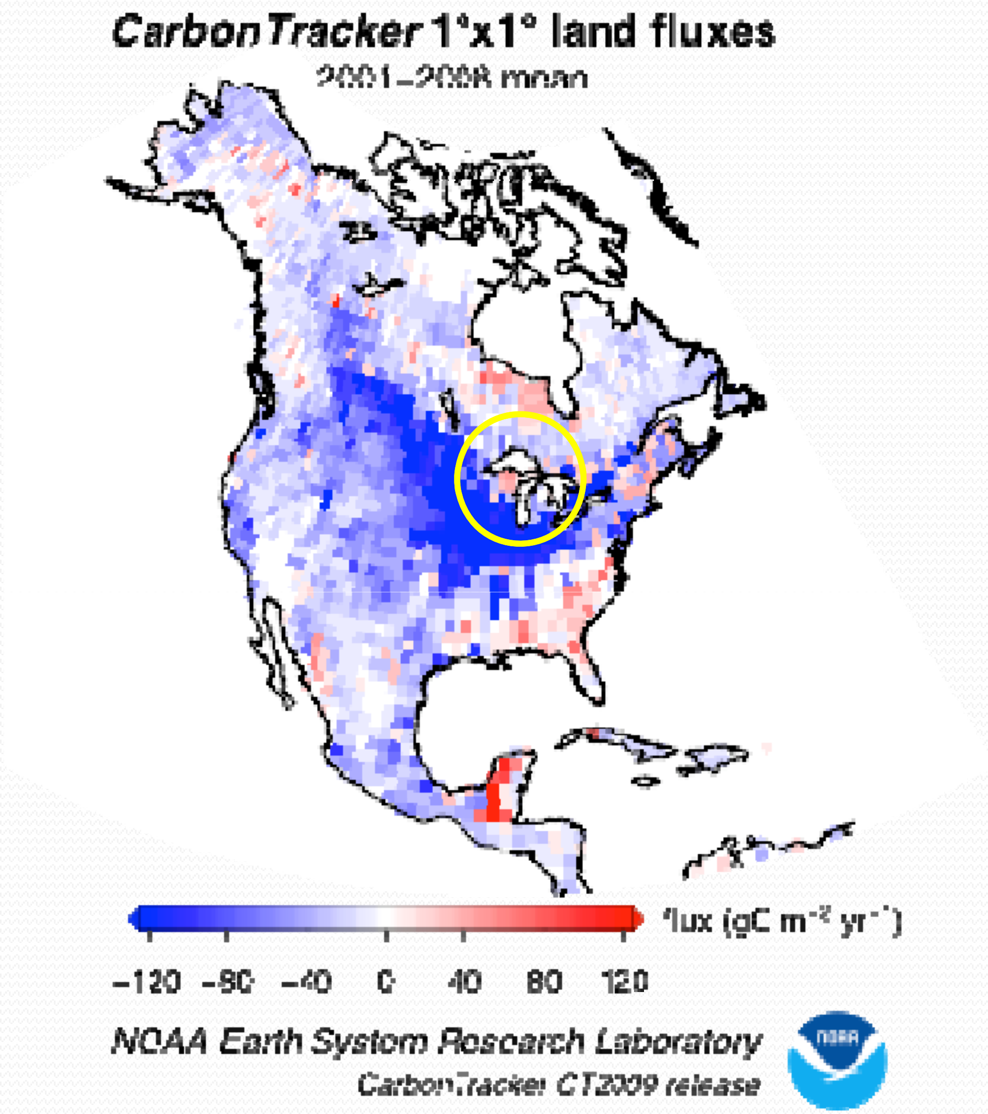
Conclusions

- Many rates missing
  - Some not available, some still under construction
- Need data from southern GMx
  - Unknown availability
- Need DIC and DOC internal flux data
  - Potentially can be modeled from existing concentration data
- Need data for fluxes GMx – Caribbean
- Potentially can be modeled from existing concentration data

Great Lakes

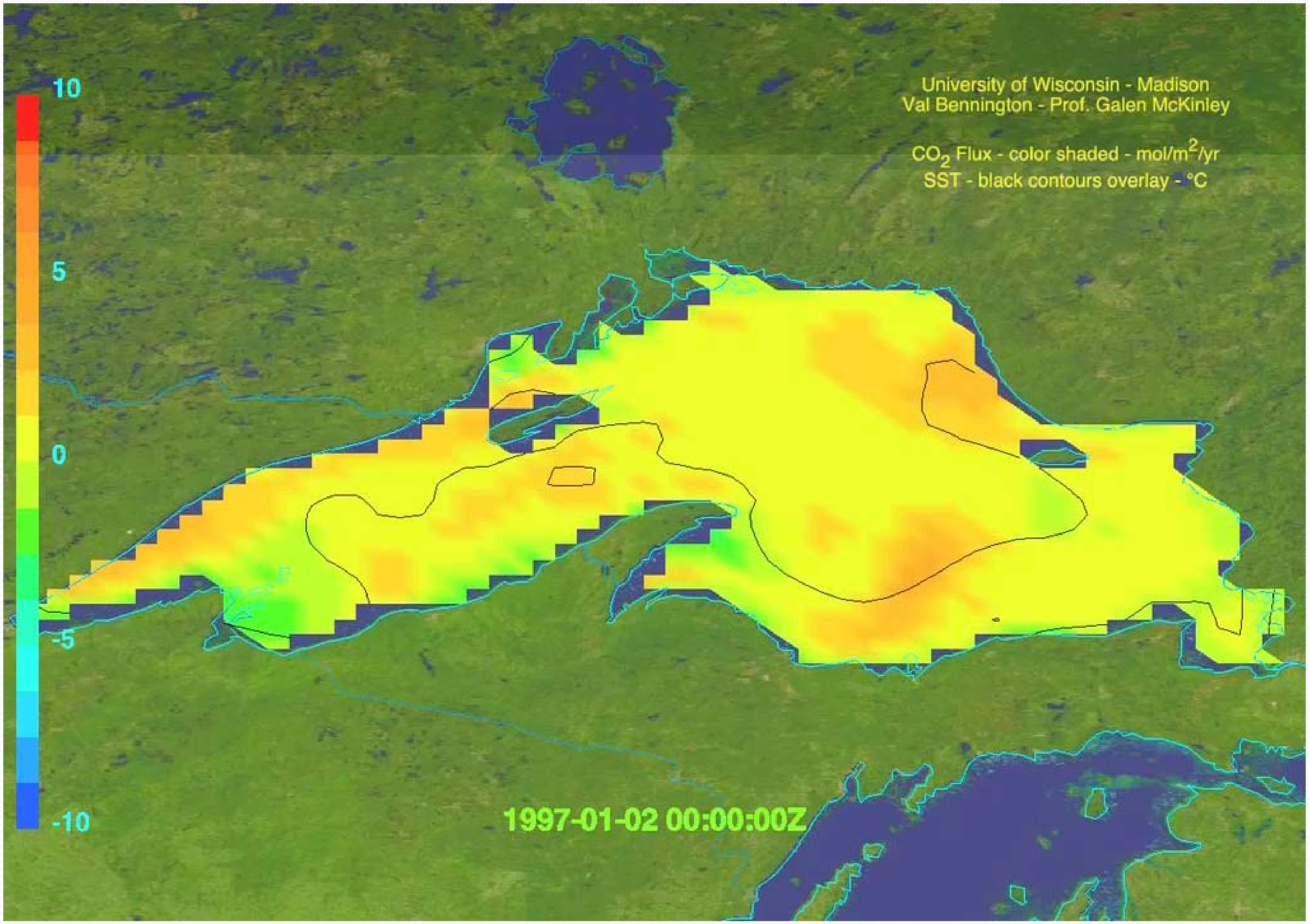
Galen McKinley

Do coastal fluxes impact regional carbon budgeting?



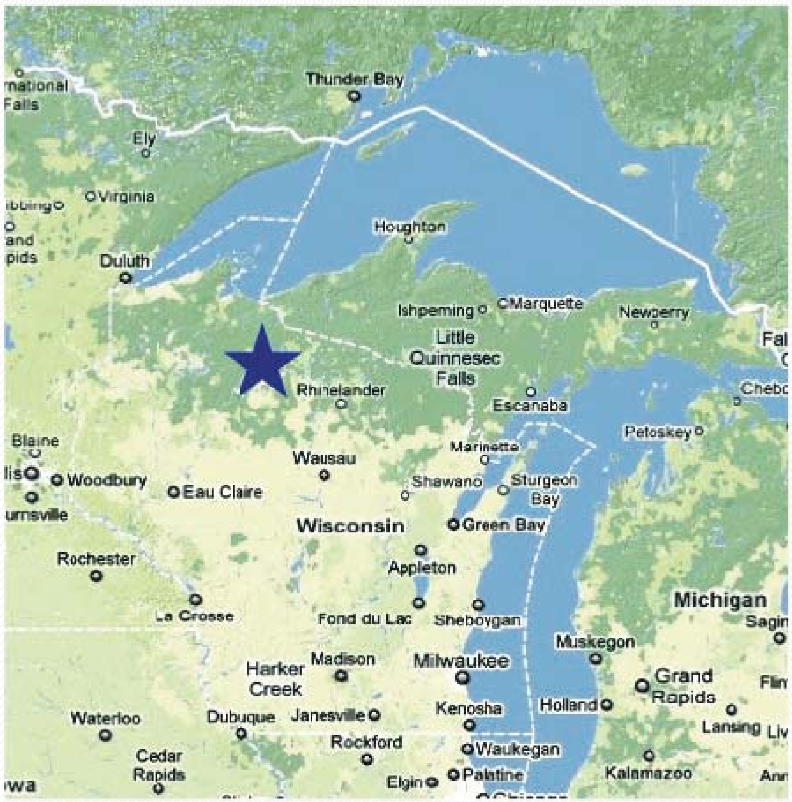
North American Carbon Program
www.nacarbon.org

Modeled CO_2 flux

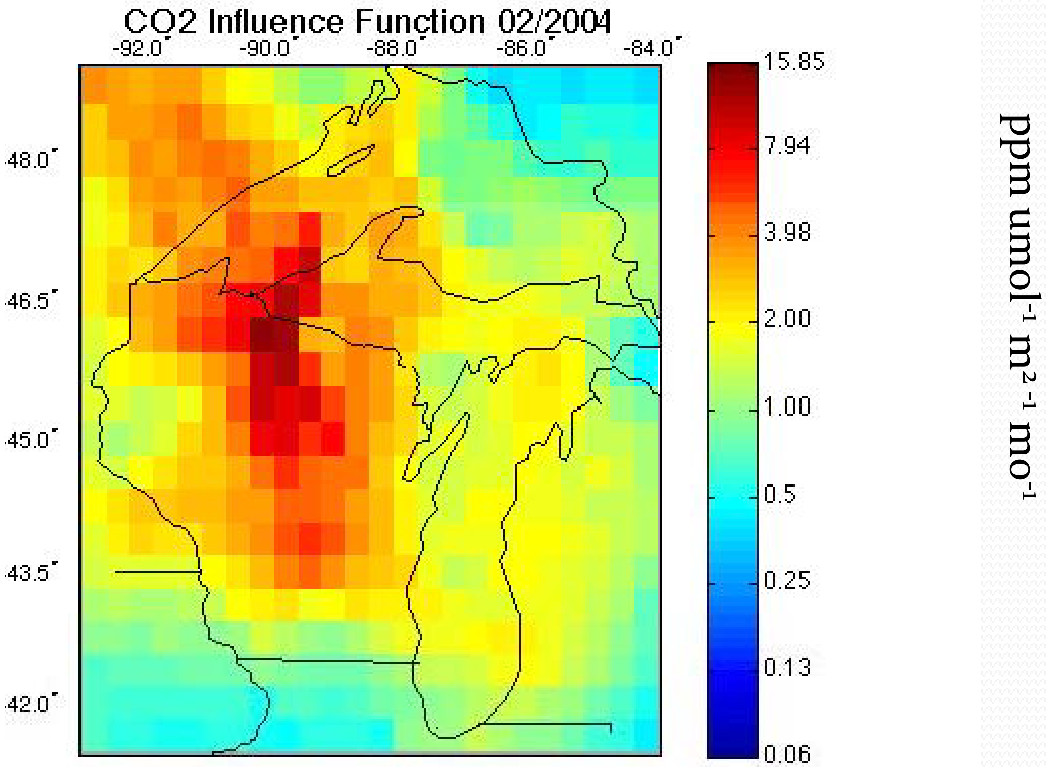


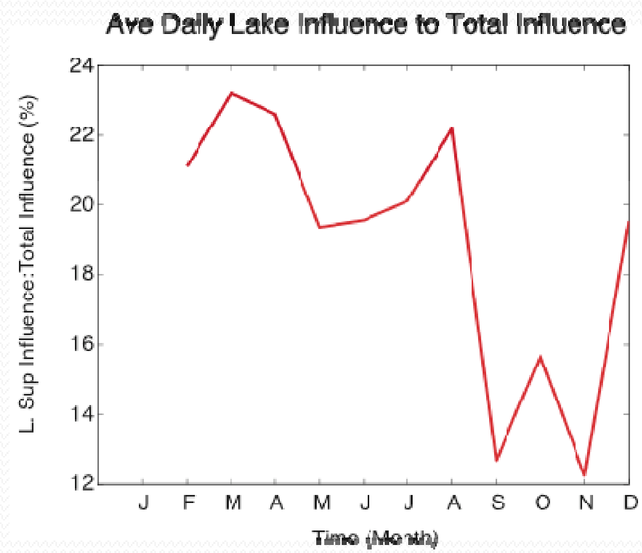
McKinley et al. *in prep*

Influence of Lake Superior CO_2 flux on the WLEF tower in Park Falls, WI?

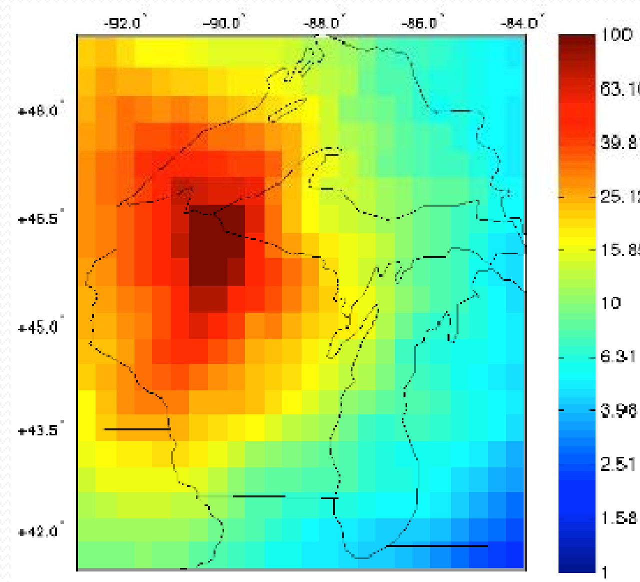


Lake influence on WLEF tower



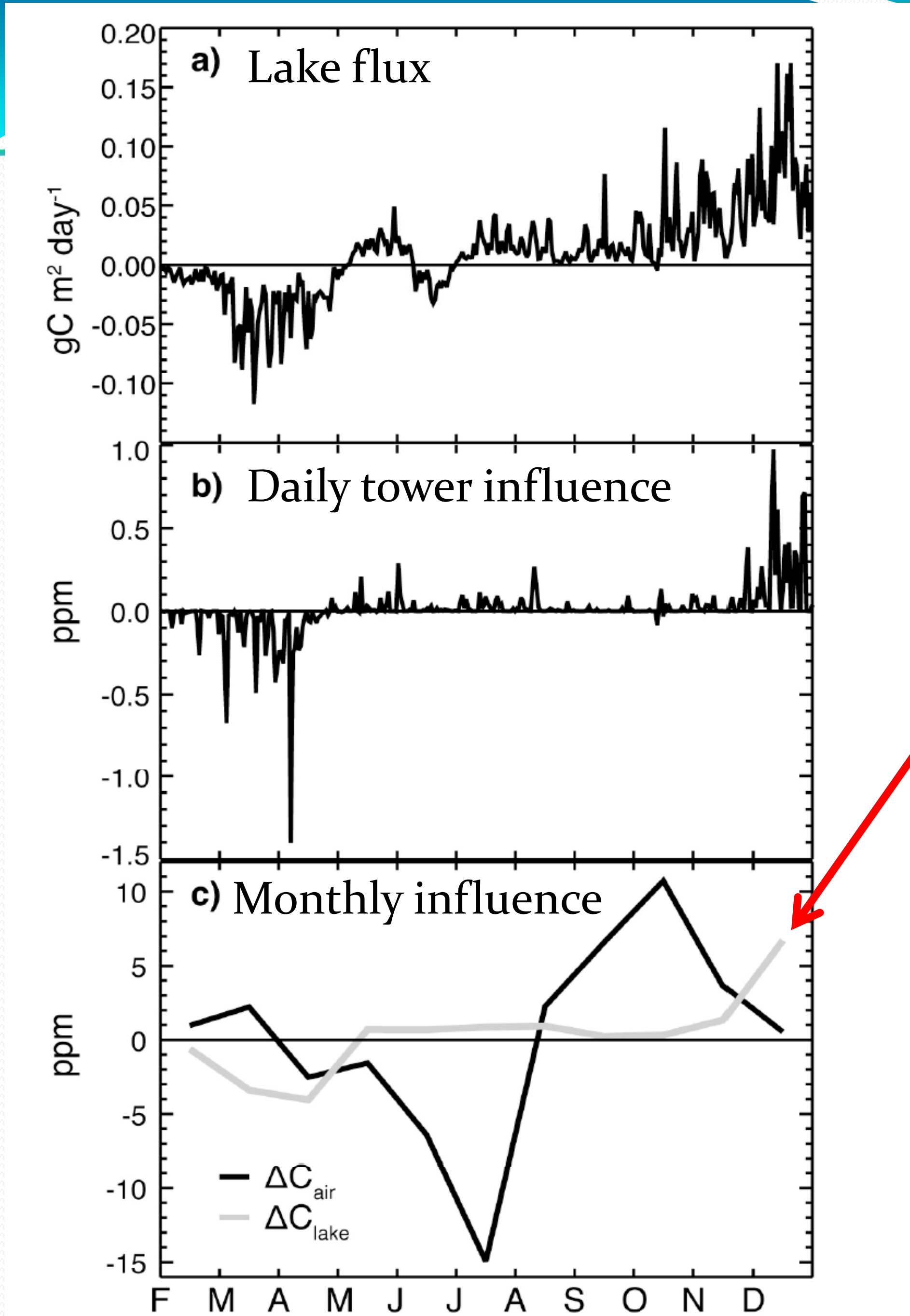


Annual Mean function



72-hour particle backtrajectory analysis for 2004
(WRF model with STILT – *A. Michalak, Michigan*)

Influence seasonally variable

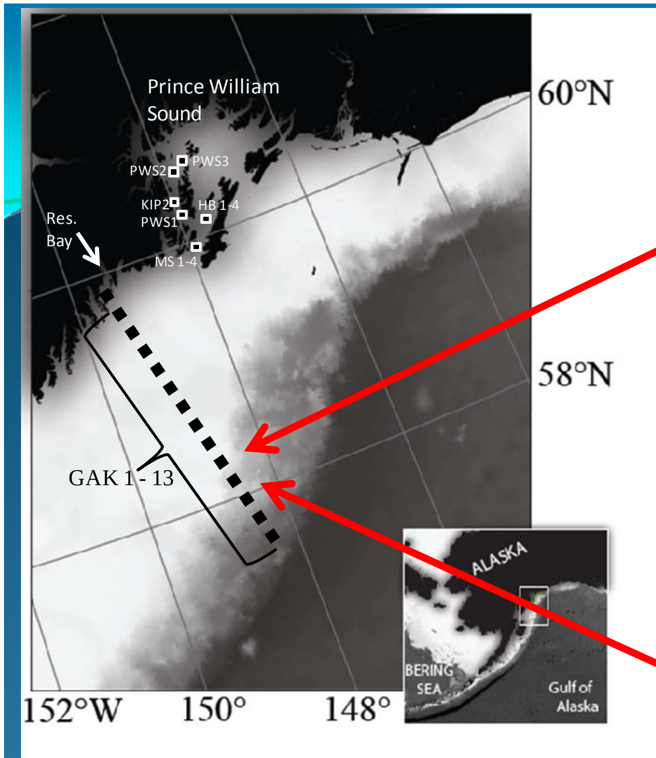


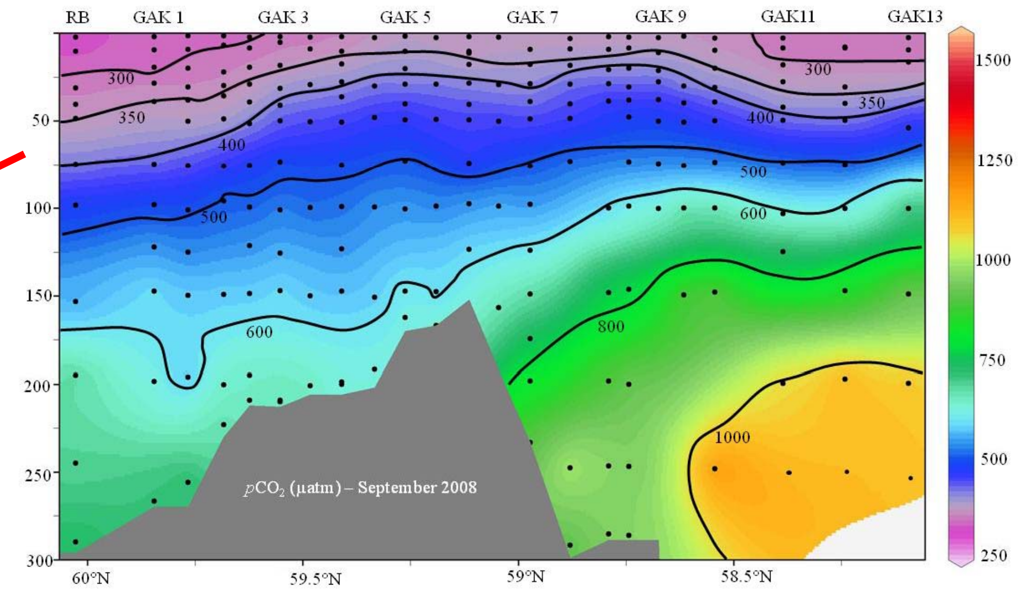
In winter and spring, Lake significant to observed pCO_2^{air} changes

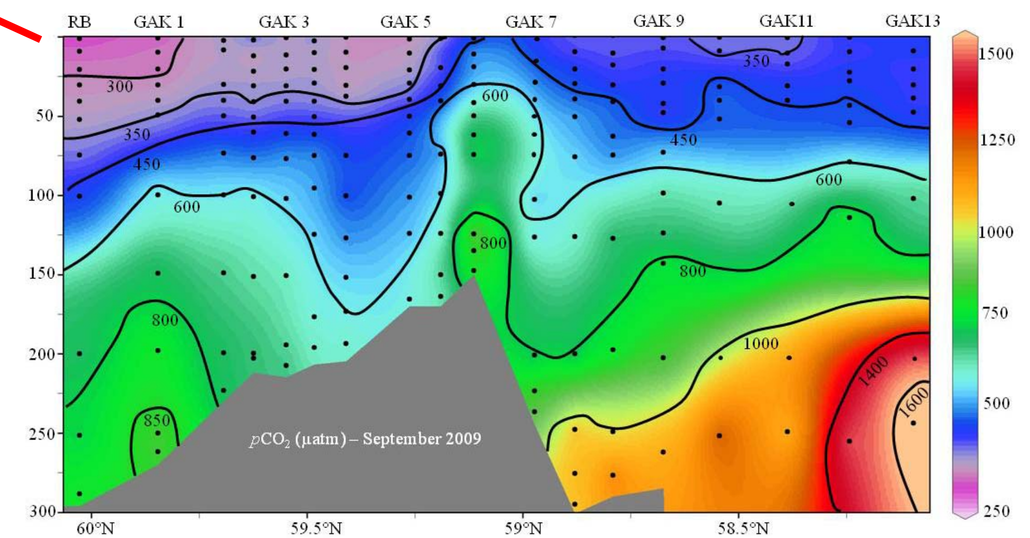
Vasys et al. *submitted to GRL*

Arctic

Jeremy Mathis







In September of 2008 pCO_2 had been drawn down over the shelf creating an average net sink of ~31 mmol C m^{-2} d^{-1}

In September of 2009 downwelling favorable winds were relaxed allowing high pCO_2 deep water to penetrate to the surface creating regions of supersaturations (souces) and lowering the regional net sink.

Mathis, J.T., Trahanovsky, K., Stockwell, D., Weingartner, T.J., Whitledge, T., Carbon Biogeochemistry of the Northern Gulf of Alaska and Prince William Sound Part II: Primary Production and the Controls on Seasonal CO2 Fluxes (Continental Shelf Research, In Prep).

Summary

- Preliminary carbon budgets in two regions
- Significant progress in other regions
- Gaps identified
- Much work needed
- Please contribute!