

A Preliminary Carbon Budget for the Gulf of Mexico

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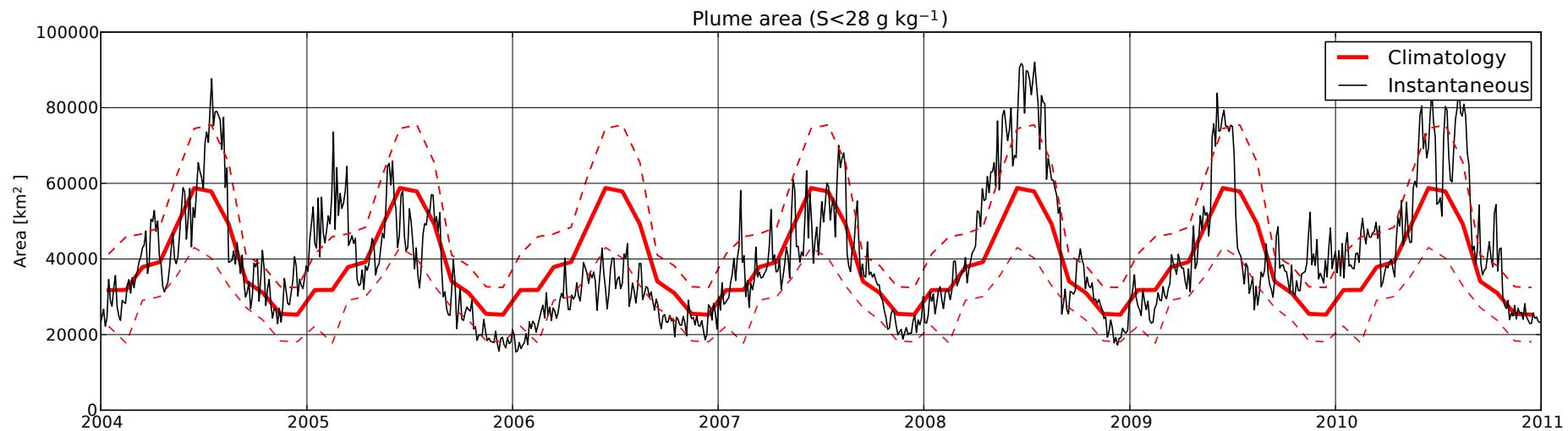
Last updated Aug. 2014



4 coastal and 1 open ocean regions



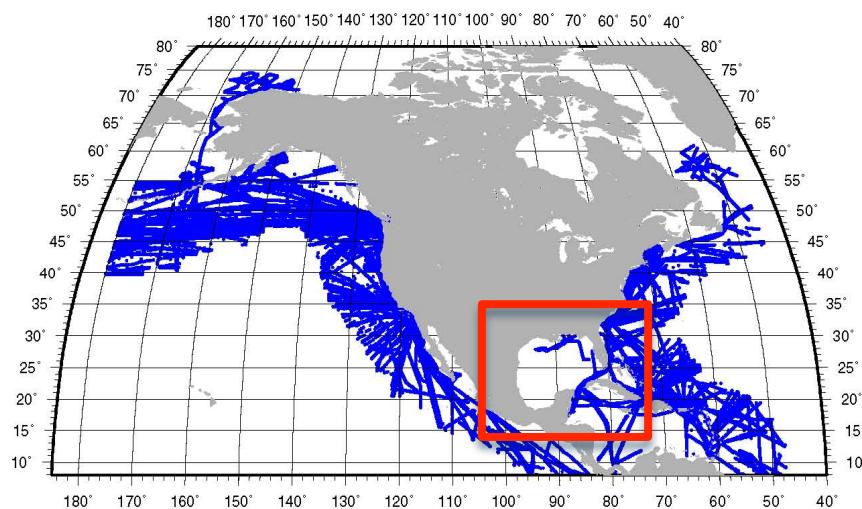
Reduce uncertainty by constraining area of MARS plume = salinity < 28



This can be derived from satellite data!!

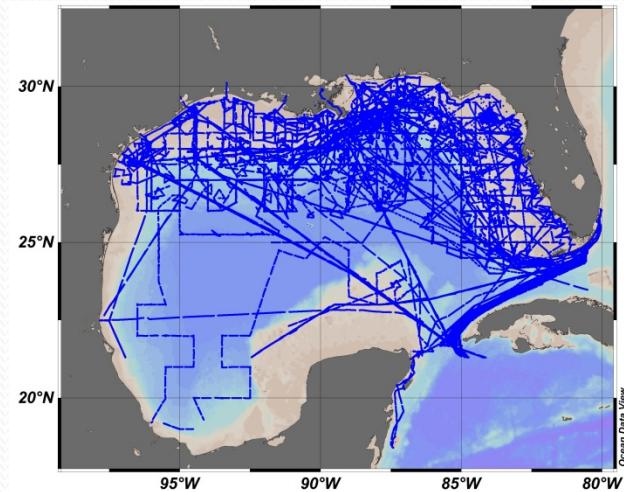
Increase $p\text{CO}_2$ air-sea flux data

Takahashi, 2009
Data up to 2007



Locations where $p\text{CO}_2$ data were obtained around North America as presented in the SOCCR report (Chavez et al., 2007). Note the lack of data in the Gulf of Mexico.

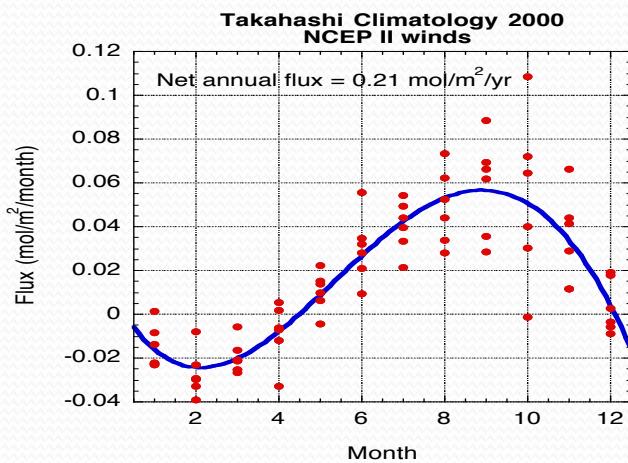
Our newly compiled data,
up to 2012



- Over 375+K data points
- Years 1996-2012
- 196 cruises, (more to be added shortly)
- Combined result of Ships of Opportunity and dedicated research cruises

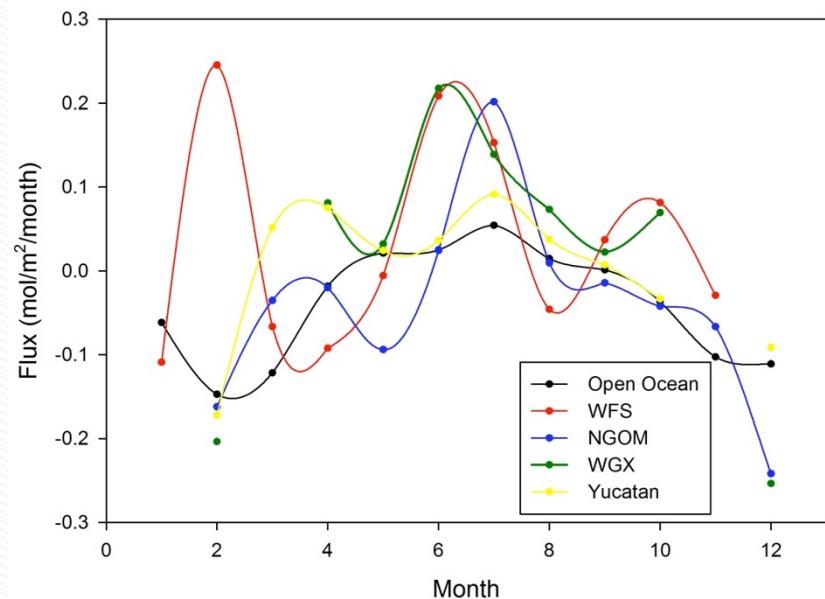
Flux Monthly Variability

The Gulf is a sink with a Net Annual Flux of -0.19 mol C/m²/year
(-3.57 Tg C/year)



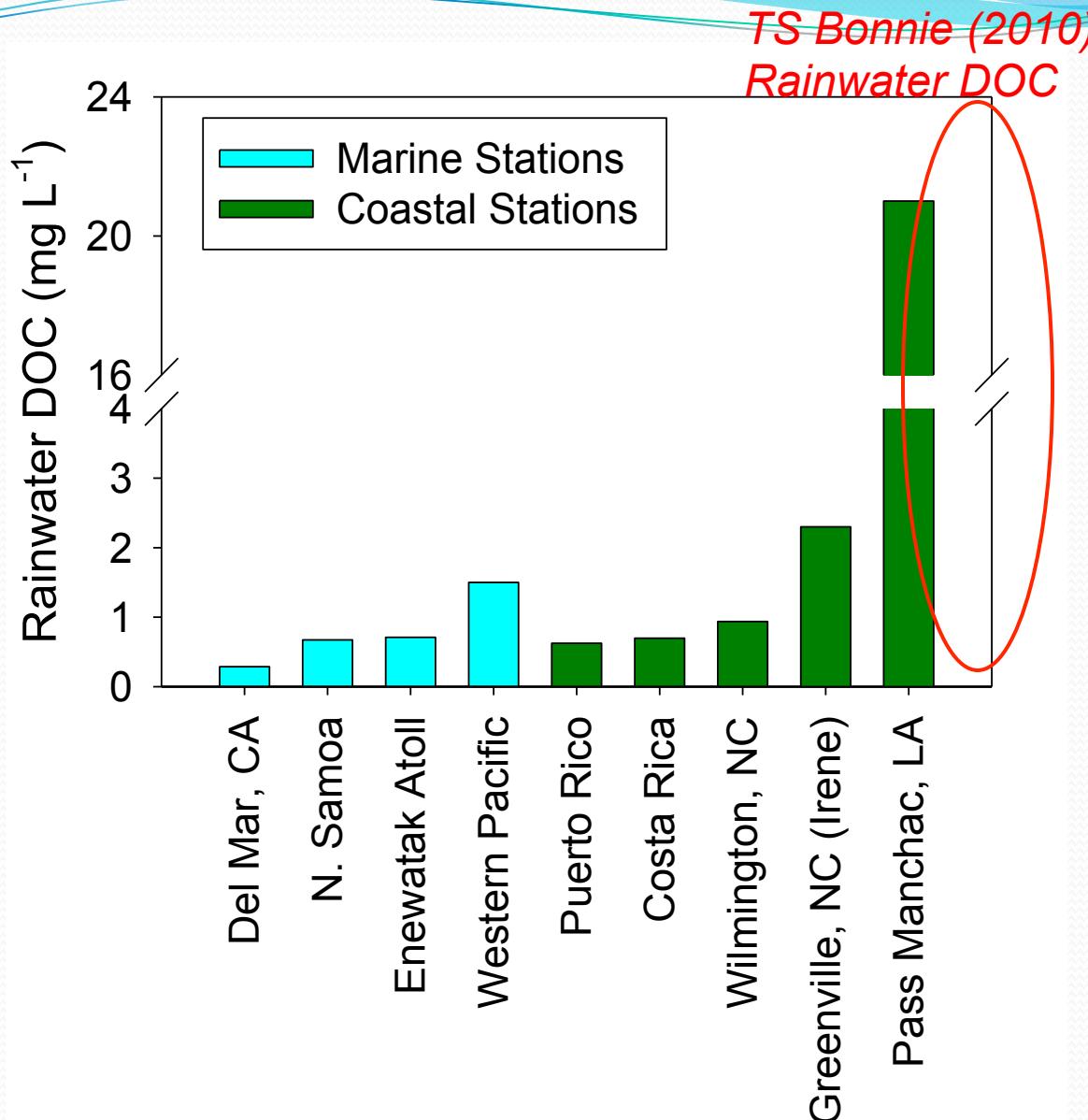
Net Annual Flux:
+0.21 mol C/m²/year

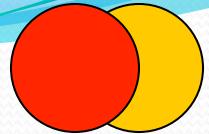
-2 cruises
-summer data



Net Annual Flux (including coastal regions):
- 0.19 mol C/m²/year

Dissolved Organic Carbon in Rainwater





Air-Sea POC flux

- Available coastal and marine [POC] from Gulf (5 refs) 0.32-15.2 ug/m³
- Dry deposition flux=[vd]*[Cp-oc]
 - Dry aerosol flux: 0.0094 – 14.9 TgC/yr
- Wet deposition flux=I*[Wp]*[Cp-oc]; I=ppt rate (m/d), Wp=washout ratio, Cp-oc=aerosol particulate carbon
 - Wet aerosol deposition: 0.0898 - 8.05 TgC/yr
- Total (dry + wet) = 0.0094 – 22.95 TgC/yr

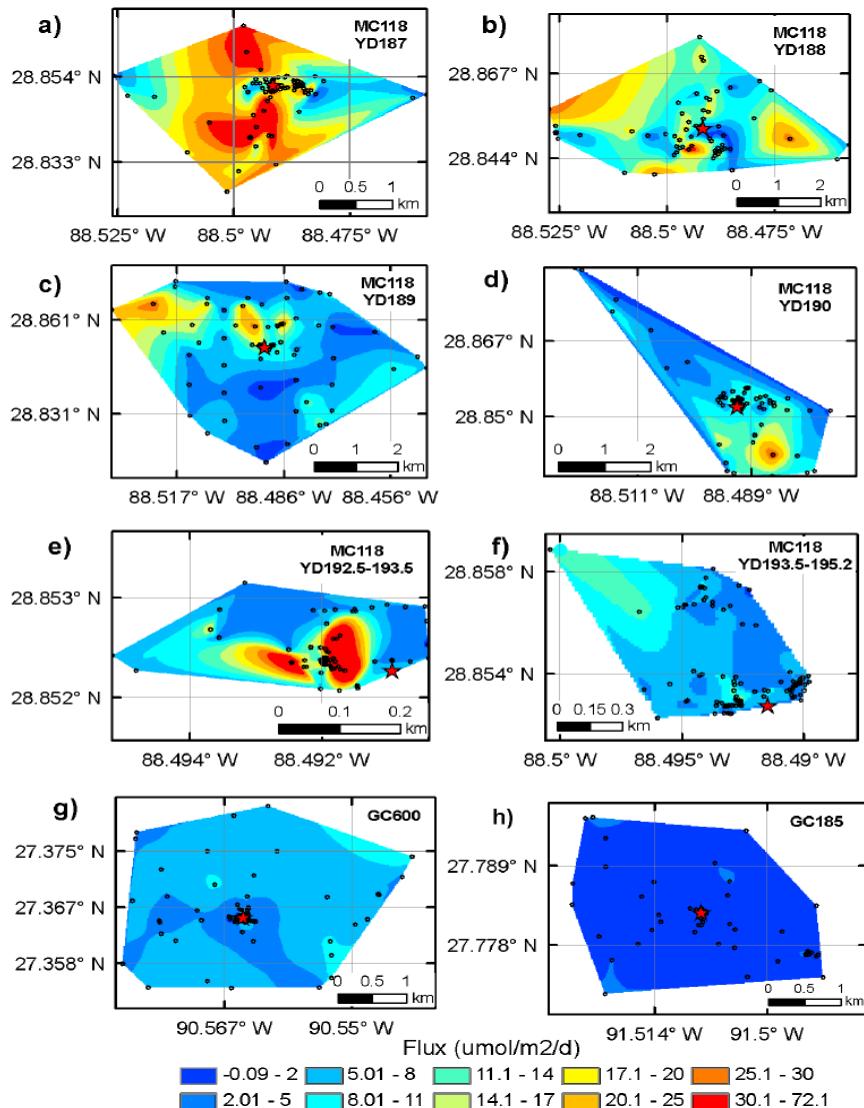
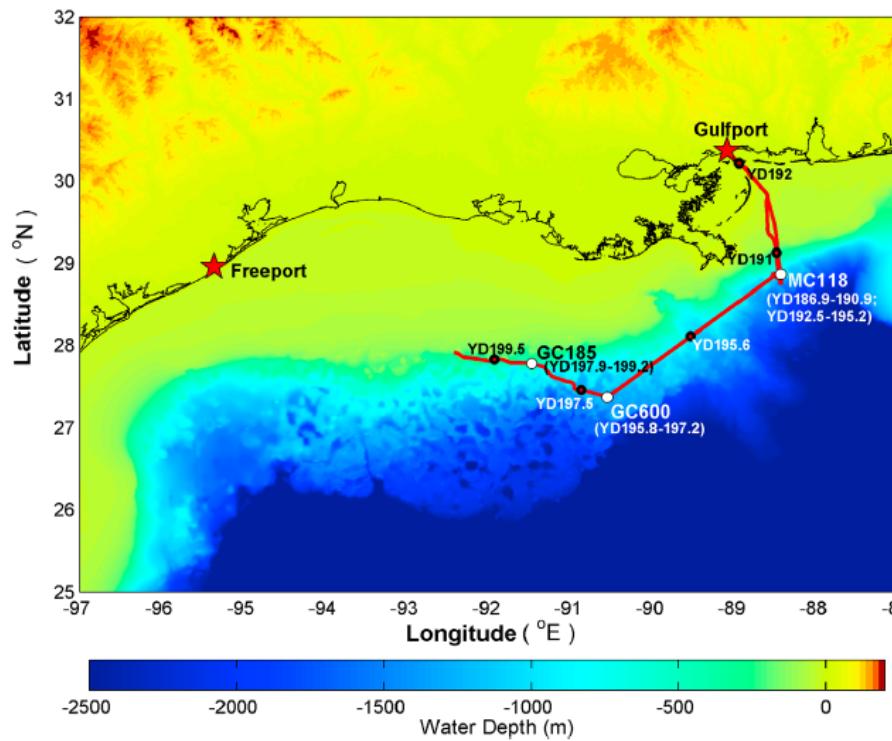
VOC flux

- Few data sets, VOCs not significant other than CH₄

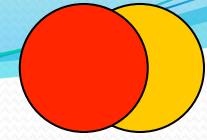
Cruise	PI	Dates	VOC available	
Milagro	various	Mar 1-30, 2006	Atm VOC	
TexAQS/ GoMACCS	various	Aug 2- Sept 11, 2006	Atm VOC	
TexAQS/ GoMACCS	various	Aug 31 –Oct 6, 2006	Atm VOC	
CalNex	various	June 6-8, 2010	Atm VOC	
HYFLUX	S. Yvon- Lewis	July 4-19, 2009	Underway CH ₄ , C ₂ H ₆ , C ₃ H ₈	
PLUMES	S. Yvon- Lewis	June 2010	Underway CH ₄ , depth profiles C ₂ H ₆ , C ₃ H ₈	

Methane Fluxes to the Atmosphere (Northern Gulf of Mexico)

HYFLUX (2009)

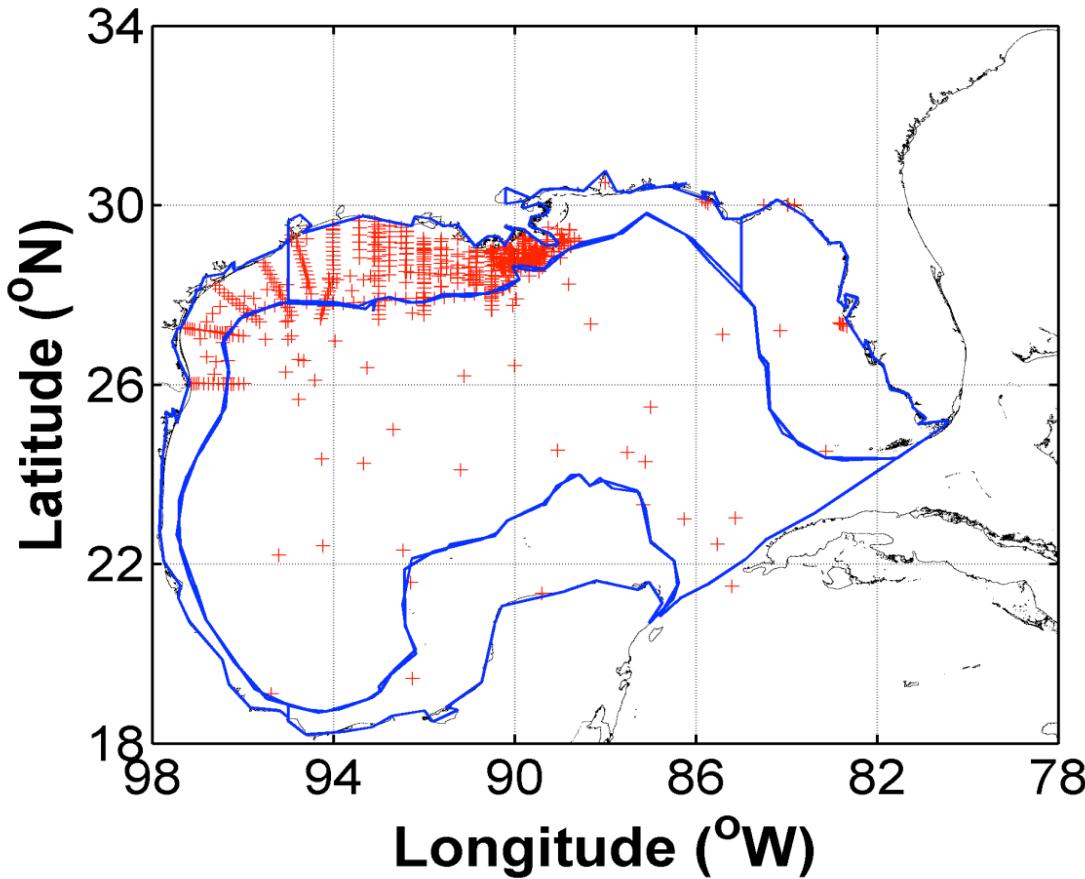


Methane in Northern Gulf of Mexico (Regions 3 and 1)



Study Region	Surface Concentration (nmol L ⁻¹)	Flux (μmol m ⁻² d ⁻¹)	Reference
Mississippi/Alabama Shelf	22		Brooks (1975)
Northern Gulf of Mexico	2.4		Kelley and Jeffery (2002)
Northern Gulf of Mexico	9.9 - 343		Kelley (2003)
Northern Gulf of Mexico	0.8 - 1609	200 - 10,500	Solomon et al. (2009)
DWH	3.3	-0.055 - 1.83	Yvon-Lewis et al (2011)
HYFLUX	1.72 - 156	-4.19 - 86.1	Hu et al. (2012)

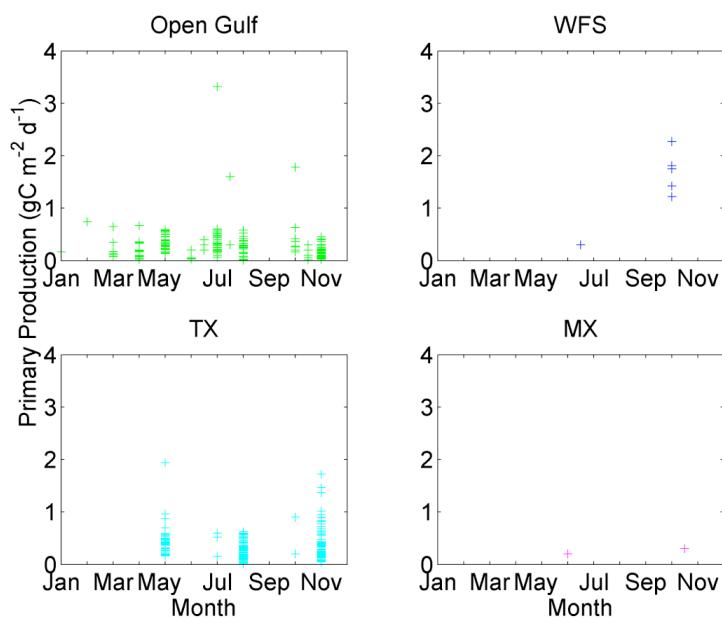
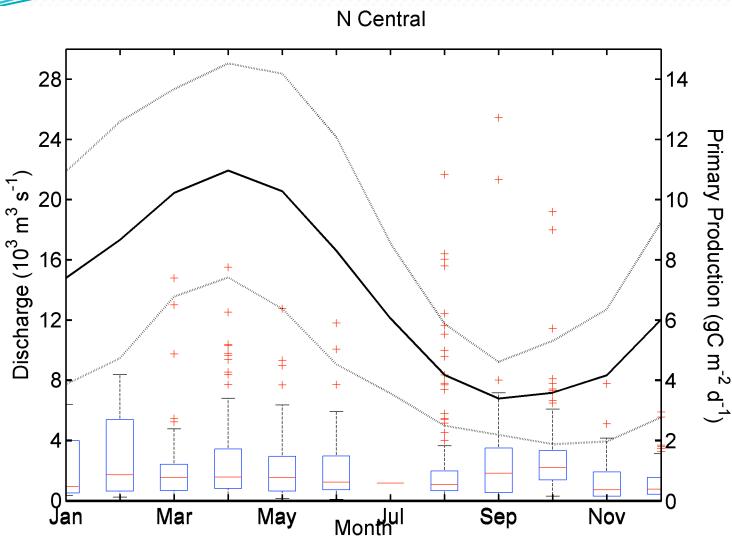
Primary Productivity



1. ^{14}C -based:
 - bottle incubations
 - P-E based
 - *In situ*
 - Simulated *in situ*
2. Oxygen-based primary production estimates
3. Satellite-derived
 - Vertically Generalized Production Model, VGPM
 - Carbon-based Productivity Model, CbPM
4. Numerical ecosystem models of primary production

Primary Productivity

- Rates are 7-fold higher in MARS than in other regions per meter, but area of plume is highly variable
- Sparse data for WFS and MX region, more data are likely available for both



Primary Productivity - from measurements

Table 6.1. Annual regional water column primary production based on median estimates for the different regions.

<i>Region</i>	Daily PP gC m ⁻² d ⁻¹	Annual PP gC m ⁻² y ⁻¹	Area km ²	Regional PP Gt C y ⁻¹
Open	0.28	102.2	9.89E+05	0.101
TX	0.33	120.45	8.68E+04	0.010
N Central	1.1	401.5	1.47E+05	0.059
WFS	1.3	474.5	1.47E+05	0.070
MX	0.23	83.95	1.83E+05	0.015
		Total	0.256	

- Regional annual rates based on CbPM compare favorably with measurement-based rates for the North Central region.
- Annual rates are 50% to 200% higher for other regions, with the Mexican shelf (MX) exhibiting the greatest deviation (0.23 gC m⁻² d⁻¹ vs. 0.75 m⁻² d⁻¹).

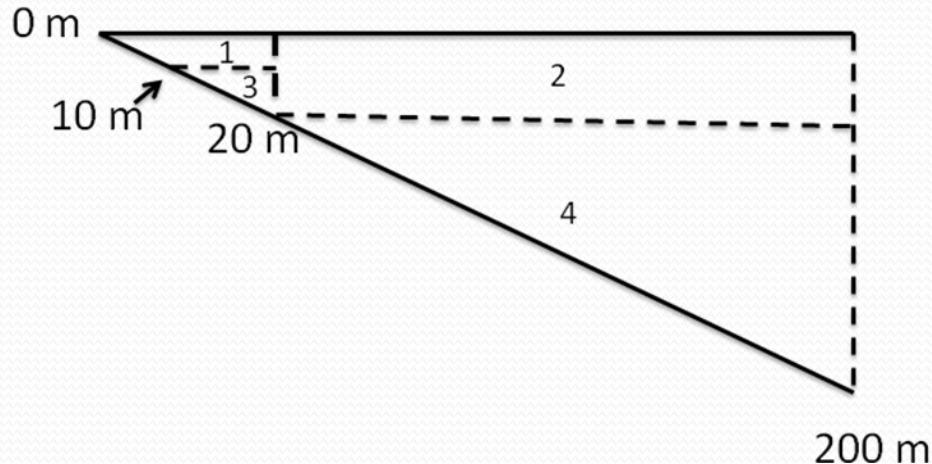
Benthic Primary Productivity

Table 6.4. Estimates of Benthic Primary Production (BPP)

Benthic Primary Producer	Total BPP Gt C yr ⁻¹	Std dev Gt C yr ⁻¹	Area (m ⁻²)	Convert to g C yr ⁻¹	Std dev g C yr ⁻¹	Avg. BPP g C m ⁻² yr ⁻¹	Std dev g C m ⁻² yr ⁻¹
Microphytobenthos (avg upper 100 m)	0.038	0.038	4.58E+1 1	3.79E+13	3.78E+13	83	83
Microphytobenthos (avg upper 20 m)	0.025	0.023	1.73E+1 1	2.45E+13	2.31E+13	142	133
Seagrass (area from seagrass atlas)	0.005	0.003	1.93E+1 0	4.93E+12	2.68E+12	255	139
Macroalgae (area from seagrass atlas)	0.003	0.001	1.93E+1 0	3.00E+12	1.00E+12	155	52
Total Gulf phytobenthos upper 100 m	0.062	0.038	4.58E+1 1	6.19E+13	3.78E+13	135	83
Total Gulf phytobenthos upper 20 m	0.049	0.023	1.73E+1 1	4.85E+13	2.31E+13	280	133

- Need to convert units to TG/yr
- Microphytobenthos 10 x more than SAV
- 80-100 m zone adds 25% to 0-20 m flux

Respiration



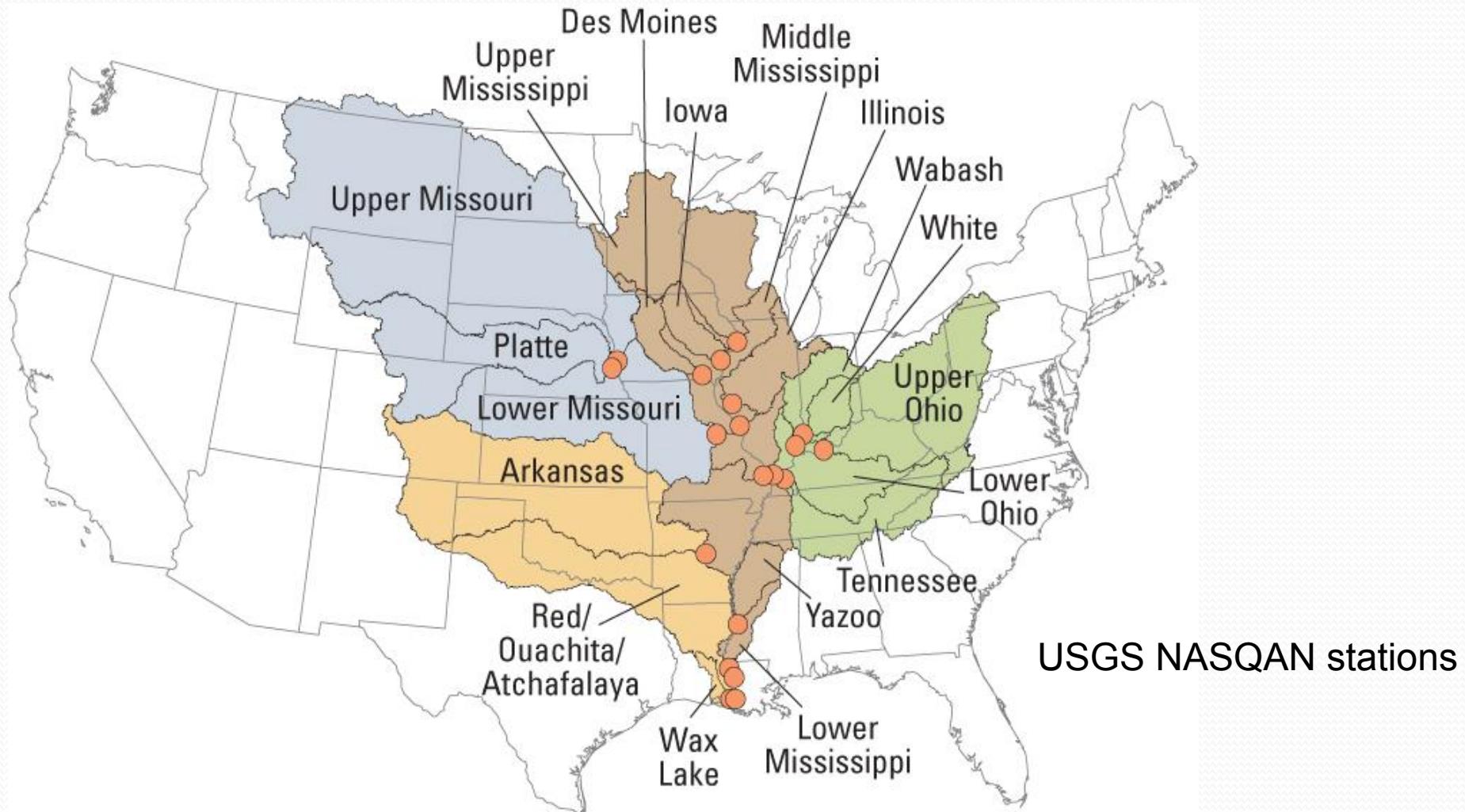
- N Central region
nearshore euphotic zone
subdivided to improve
accuracy

	VOLUME (m^3)	R_{vol} ($g\text{ C m}^{-3}\text{ y}^{-1}$)	R ($10^{12}\text{ g C y}^{-1}$)
R1	3.96×10^{11}	46.6	18.5
R2	17.6×10^{11}	29.7	52.2
R3	1.44×10^{11}	31.9	4.59
R4	35.9×10^{11}	16.2	58.2

Respiration

REGION	DAILY R ($\text{gC m}^{-3} \text{ d}^{-1}$)	AREA (10^9 m^2)	ANNUAL R ($10^{12} \text{ gC yr}^{-1}$)
Northern	0.044 – 0.128	147	133
WFS	0.076 – 0.918	147	55.9
Open	0.009 – 0.012	989	130-168
Texas	(0.076 – 0.152) ^a	8.68	(26.7) ^b
Mexico	(0.076) ^a	183	(52.8) ^b
		TOTAL	396 to 436

Terrestrial Fluxes



SPARROW modeling

Region	Drainage Area (km ²)	TOC Flux (Tg/yr)	TOC Yield (kg/km ² /yr)	DOC Yield (kg/km ² /yr), estimated as 0.78% TOC
West Florida Shelf	149,561	2.13	14,209	11,083
Northern Gulf (LA)	6,487,201	10.42	1,606	1,253
Western Gulf (TX – south to US-Mexico border)	810,420	0.78	962	750
Mexico- Yucatan	?	?		
Open Gulf	?	?		

DIC estimates missing

DLEM modeling (Tian et al.)

	Western Gulf (TX)	Northern Gulf (LA)	West Florida Shelf
DOC (Tg C/yr)	0.49	3.49	0.68
POC (Tg C/yr)	0.317	3.563	0.21
DIC (Tg C/yr)	2.04	19.96	0.82

MX and open gulf estimates missing

NEWS modeling (Mayorga et al.)

region	drainagearea	discharge	TSSload	DICload	DOCload	POCload
NACP GoM	Global NEWS km2	Global NEWS km3/yr	Global NEWS Tg/yr	Hartmann Tg/yr	Global NEWS Tg/yr	Global NEWS Tg/yr
West Florida Shelf	77,770	26.1	1.3	0.63	0.18	0.05
Northern Gulf (LA)	3,602,661	789.4	54.4	9.64	3.82	1.94
Western Gulf (TX)	1,428,650	71.2	60.1	1.61	0.30	0.41
Mexico-Yucatan	299,449	203.3	144.4	3.49	0.81	0.94
Open Gulf	22,800	6.2	5.4	0.08	0.03	0.04
Total:	5,431,330	1096.2	265.5	15.45	5.13	3.38

Lateral TOC Flux from 3 models

Region	Sparrow TOC	NEWS TOC	DLEM TOC
WFS	2.13	0.23	0.89
LA	10.42	5.76	7.0
TX	0.78	0.71	0.81
MX		1.75	
Open		0.07	

Note that areas for flux estimates are different

Carbon component comparisons from 2 models

Region	DLEM DOC	NEWS DOC	DLEM DIC	NEWS DIC	DLEM POC	NEWS POC
WFS	0.68	0.18	0.82	0.63	0.21	0.05
LA	3.49	3.82	19.96	9.64	3.563	1.94
TX	0.49	0.30	2.04	1.61	0.317	0.41
MX		0.81		3.49		0.94
Open		0.03		0.08		0.04

Well, they are not in perfect agreement, but this is not bad!

Gulf of Mexico Budget (Tg C yr^{-1})

