History and Overview of the Coastal Carbon Synthesis activities

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CCARS Community Workshop

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A Timeline of U.S. Carbon Cycle Activities

- 1999: U.S. Carbon Cycle Science Plan (Sarmiento & Wofsy, 1999)

- Early to mid-2000s: Formation of **North American Carbon Program (NACP)** and **Ocean Carbon & Biogeochemistry (OCB) Program**

- 2005: The North American Continental Margins Workshop

- Spring 2008: OCB Scoping Workshop *Terrestrial and Coastal Carbon Fluxes in the Gulf of Mexico*

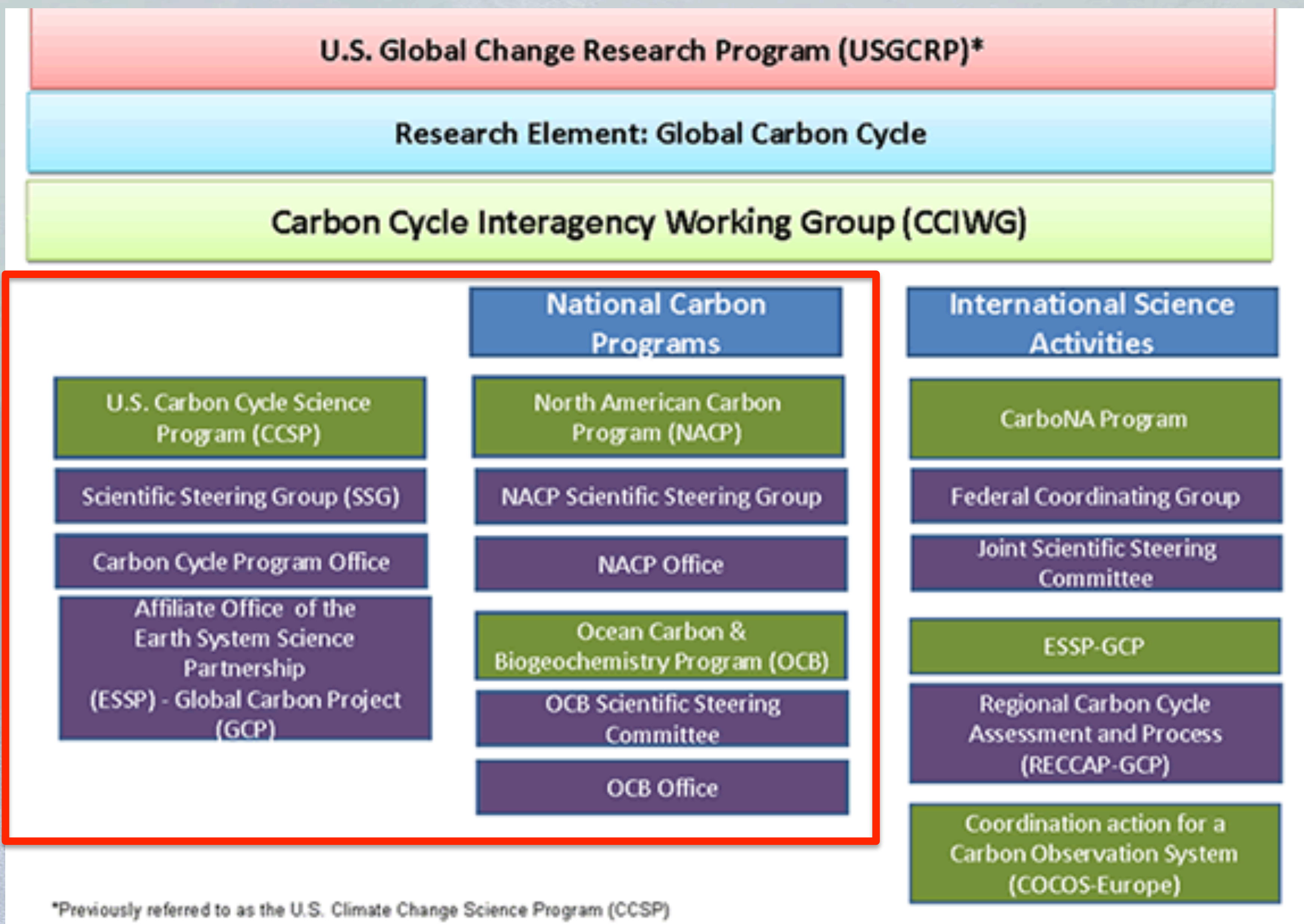
- Summer 2008: The birth of the NACP/OCB Interim Coastal Synthesis Activities (with funding acquired from NASA and NSF thereafter)

- 2010: Kickoff Coastal Synthesis Workshop

A Timeline of U.S. Carbon Cycle Activities

- 2011: New U.S. Carbon Cycle Science Plan (Michalak et al., 2011)
- 2012: East Coast Carbon Cycle Synthesis Workshop
- 2013: Gulf of Mexico Carbon Cycle Synthesis Workshop
- 2014: West Coast Carbon Cycle Synthesis Workshop
- 2014: Culminating CCARS Community Workshop

The Key Players in U.S. Carbon Cycle Activities



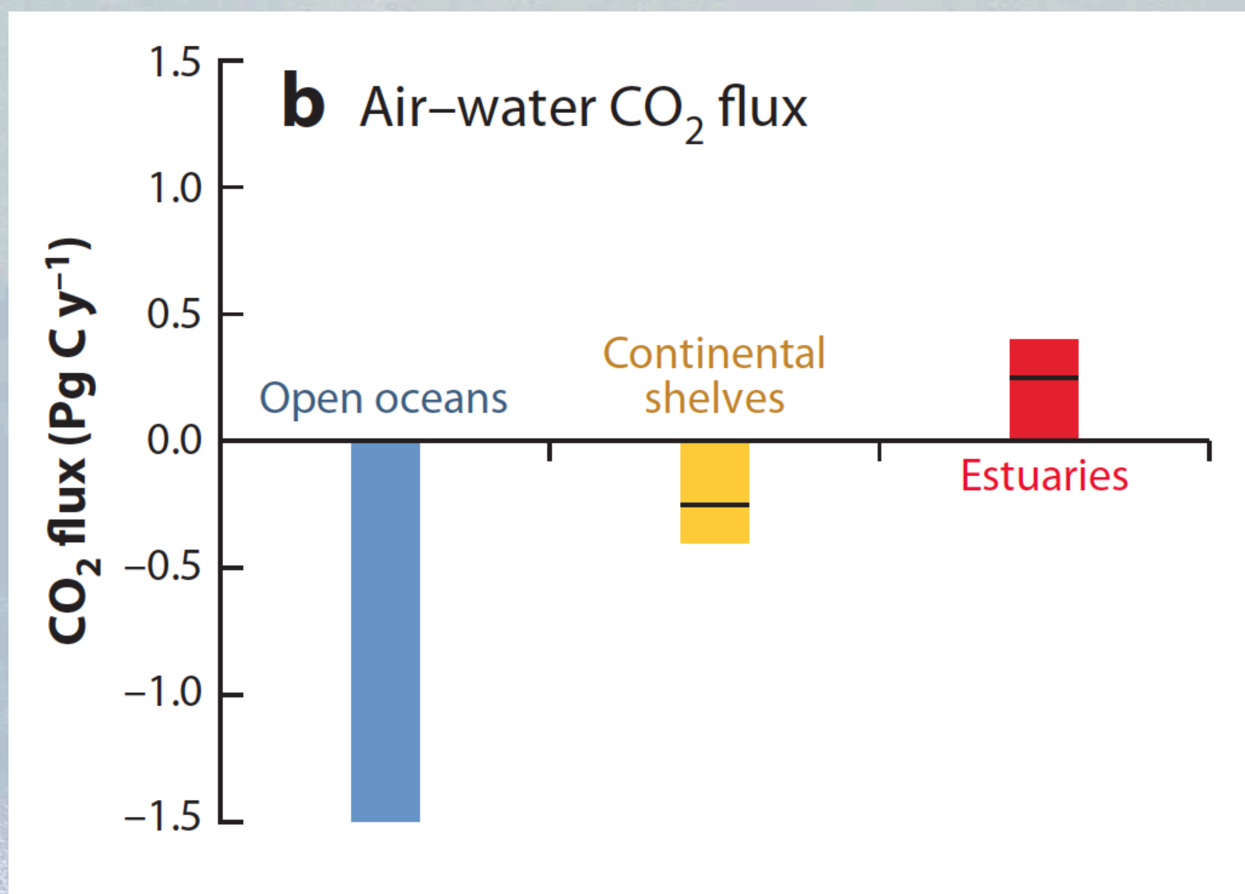
Importance of the coastal ocean
(continental shelves are ~5% of ocean area)

	Pg C yr^{-1}	% ocean total
Primary Production	6.5	12
Export Production	2.0	21
Burial	0.67	86

Dunne et al. (2007)

Importance of the coastal ocean

(continental shelves are ~5% of ocean area)



Cai et al. (2011)

Uncertainties in Coastal Carbon Cycling

Although coastal regions may represent a significant contribution to global carbon cycling, magnitude of many coastal carbon fluxes remain poorly constrained:

- Limited observations
- Difficult to model (need many regional models)
- Changing human activities on land may affect export of freshwater, sediments, and nutrients to coastal regions
- Effects of human impacts are significant in coastal zones: sea level rise, coastal eutrophication, atmospheric deposition

- Reductions in uncertainties in these carbon fluxes & ability to project future changes in response to climate- and human-related activities will benefit carbon management efforts

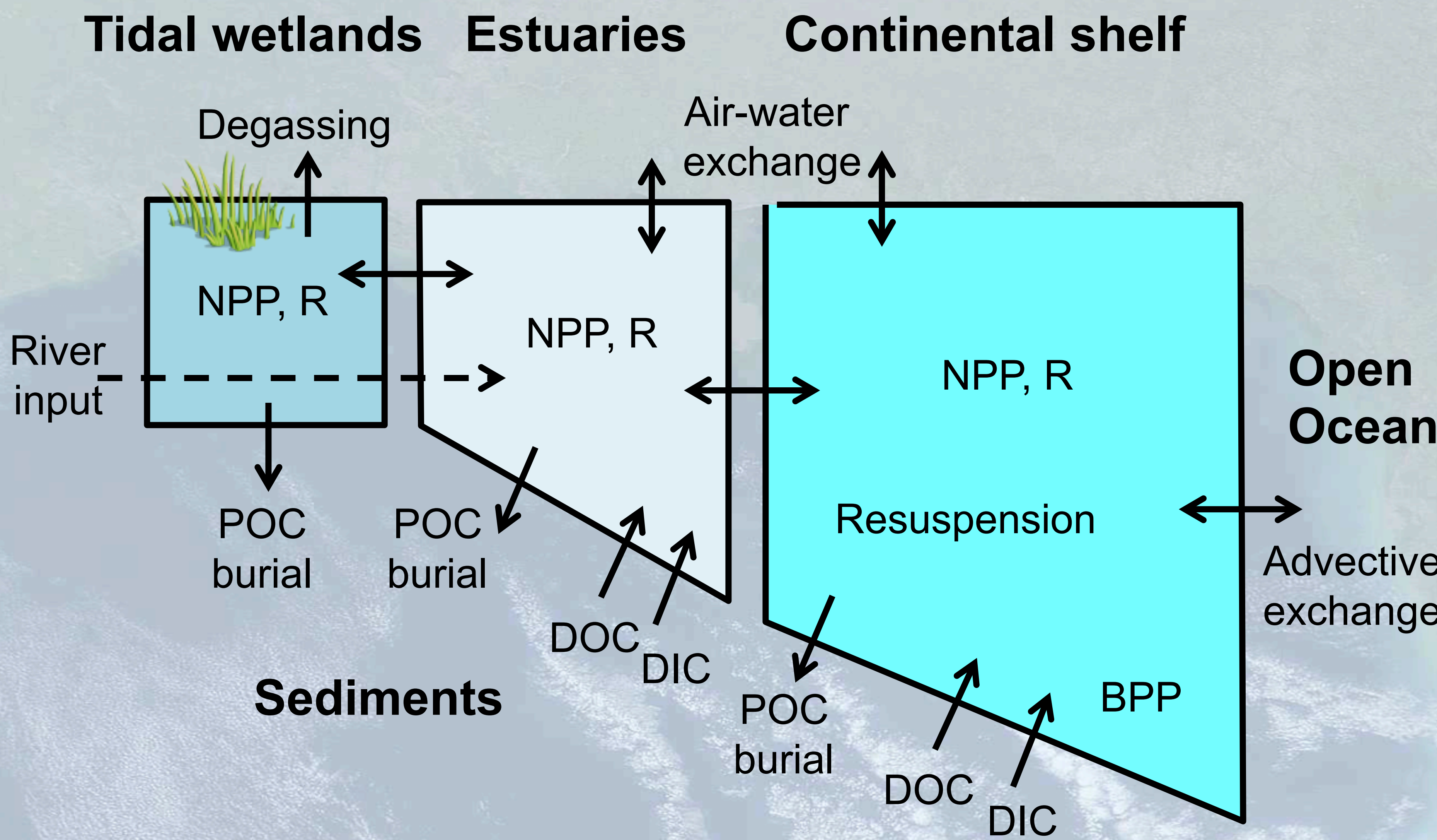
Original CCARS science questions

- How much carbon is stored in the coastal oceans and estuaries of North America?
- How much carbon comes in from North American rivers, and what is the role of estuarine and tidal wetland systems in transforming these carbon sources?
- Are the coastal oceans of North America a net source or sink for atmospheric CO_2?
- How much carbon is buried within estuaries and continental shelves?
- What is the net transfer of carbon between coastal and open oceans?
- How do these carbon fluxes vary on interannual time scales, and how are they influenced by human activities and earth system changes?

CCARS

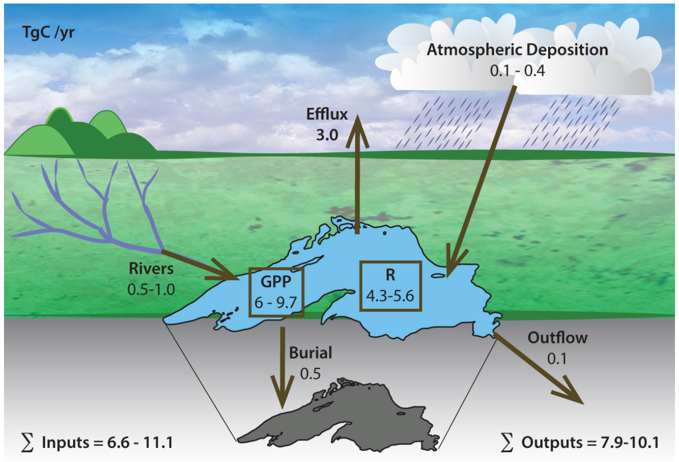
Nationalatlas.gov

The carbon cycle of the coastal ocean



Laurentian Great Lakes

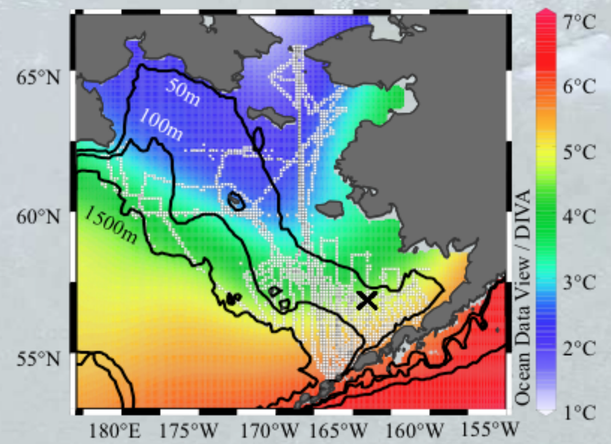
- Leader: Galen McKinley
- Sub-regions: Lake Superior best constrained
- Status: Increasing number of pCO_2 and CO_2 flux observations being made



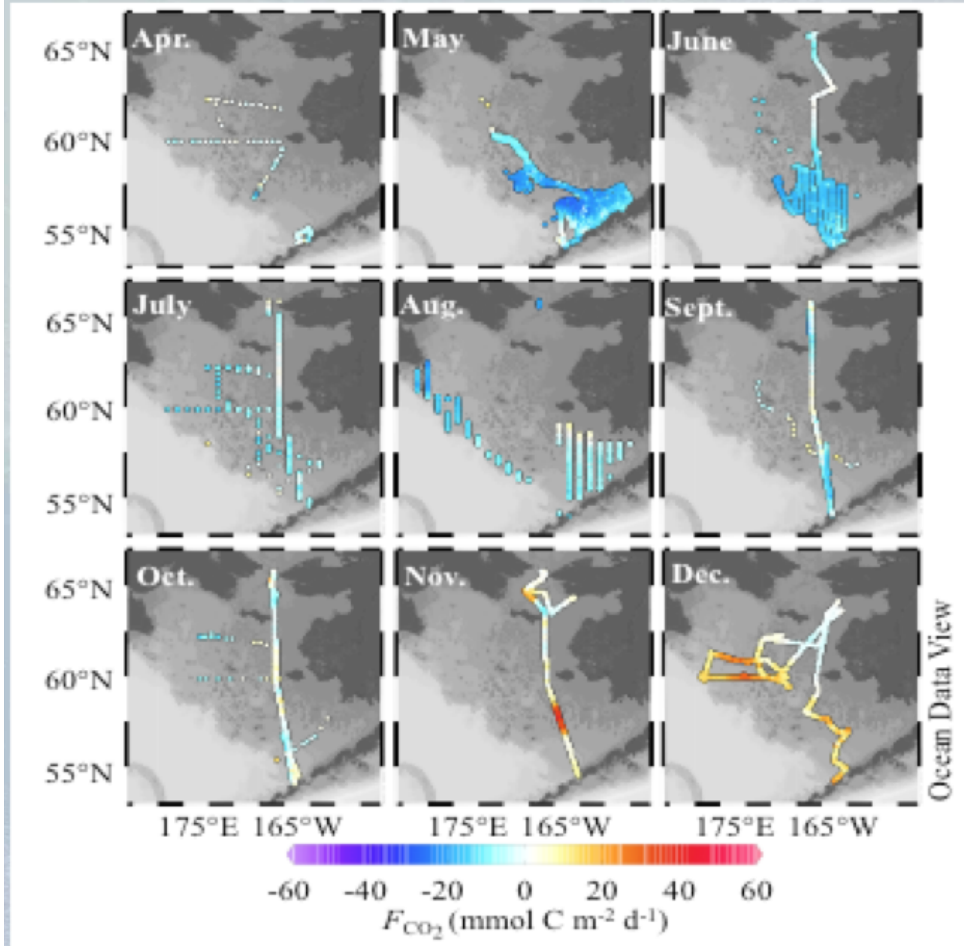
Great Lakes Carbon Budget Summary

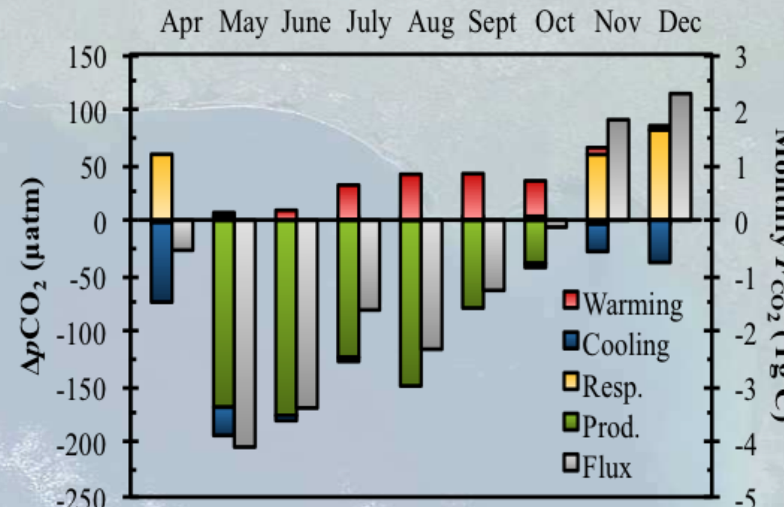
- CO_2 efflux = 0.1-2.0 TgC/yr (high uncertainty)
- Key unknowns: NPP, R, pCO_2
- Priorities: Surface pCO_2, winter observations, satellite algorithms, model-data fusion to address spatio-temporal variability

Bering Sea CO_2 Flux Synthesis



Monthly sea-air CO_2 flux for the Bering Sea shelf



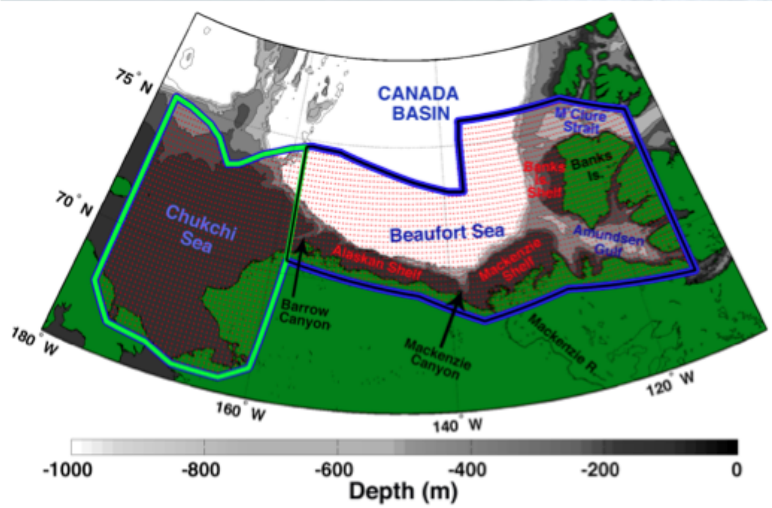


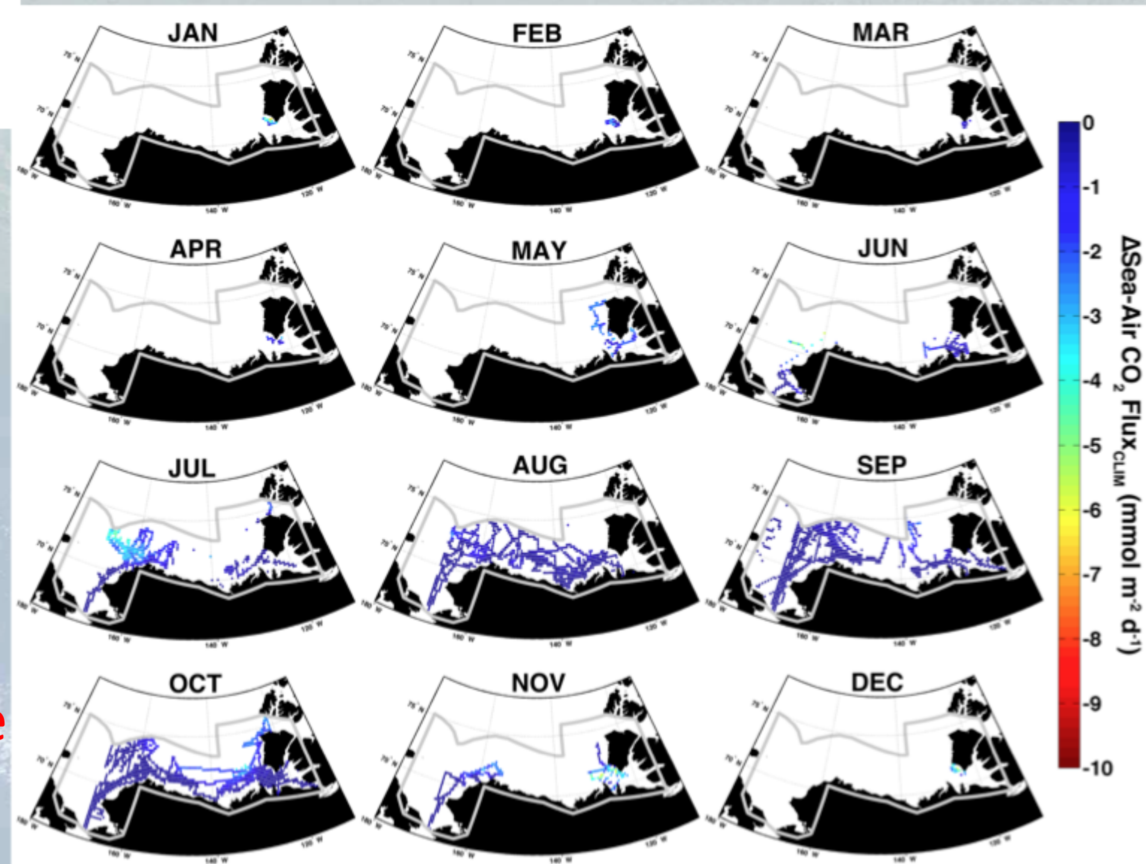
Area-weighted monthly average fluxes and flux drivers for the Bering Sea shelf.

The average annual Bering Sea CO_2 sink is ~6.6 Tg C yr^{-1}

Cross et al., in review (JGR-Oceans)

Western Arctic CO_2 Flux Synthesis

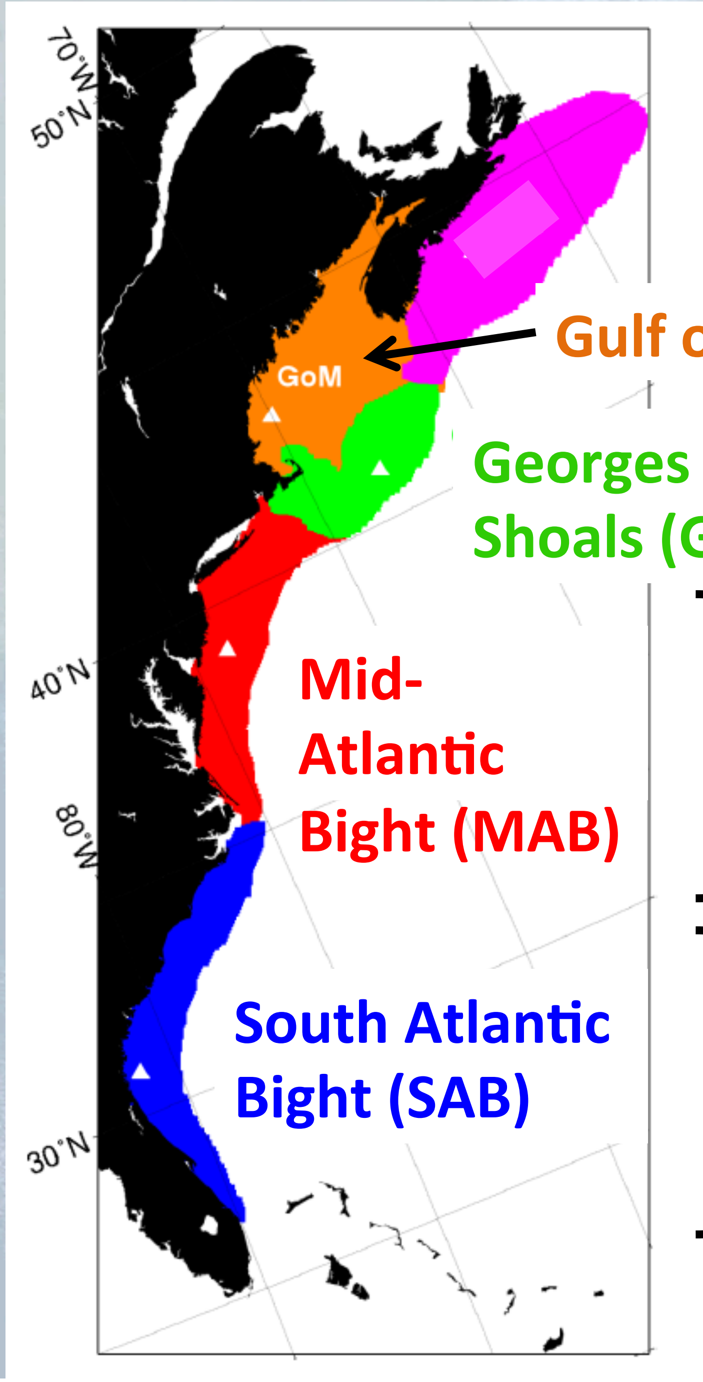




Synthesized available 2003-2012 data for western Arctic coastal ocean

First comprehensive data-based carbon sink estimate for this region: 12 Tg C yr^{-1}

Evans et al., in prep. (Continental Shelf Research)



East Coast

Primary production:
120 ± 30 Tg C yr^{-1}

47 ± 20

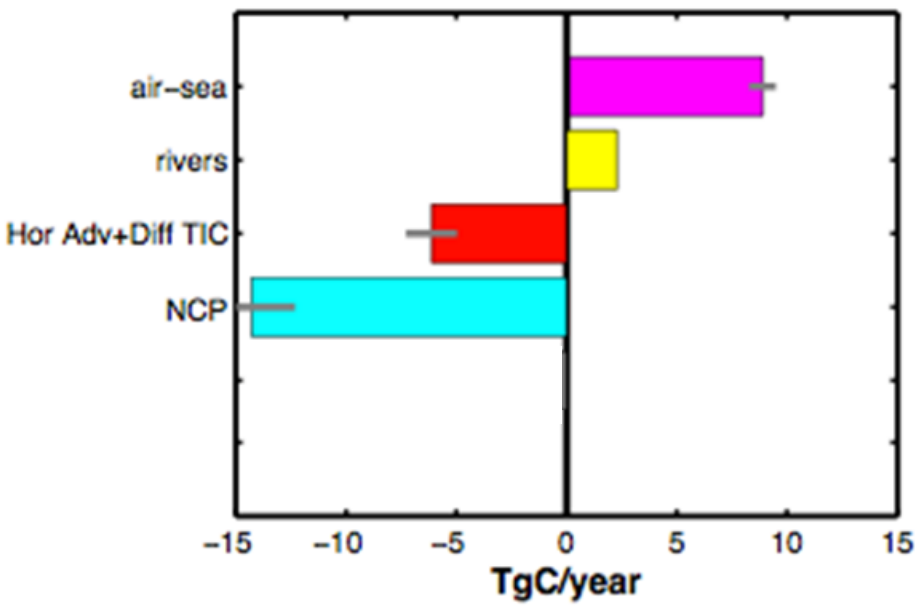
34 ± 10

35 ± 10

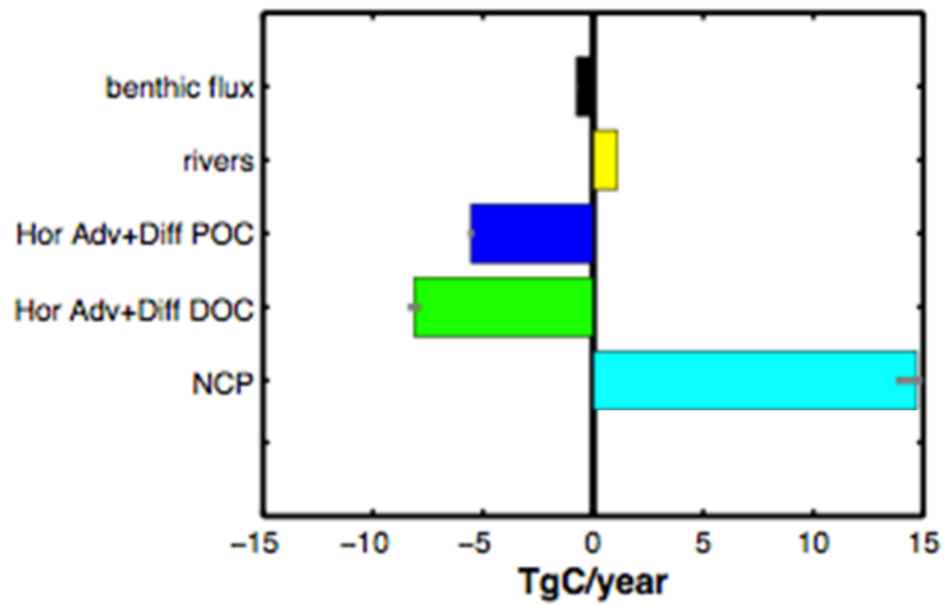
- Currently a literature synthesis
- Also using satellite algorithms and numerical models
- Respiration poorly constrained

Modeled carbon flux estimates

Inorganic Carbon Budget for 2004



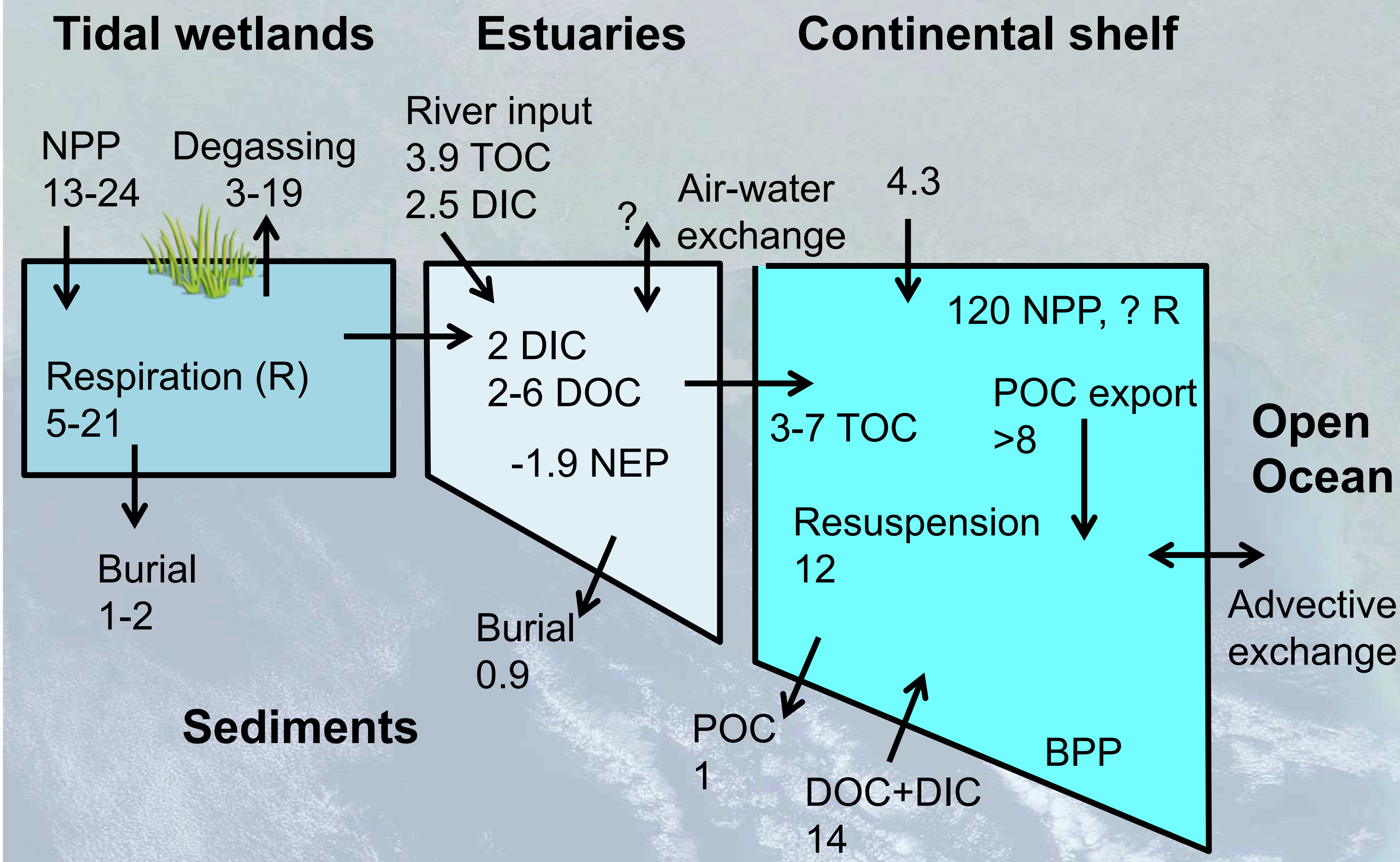
Organic Carbon Budget for 2004



- Mass is conserved; budgets close
- Need long model spin-up
- Need interannual runs

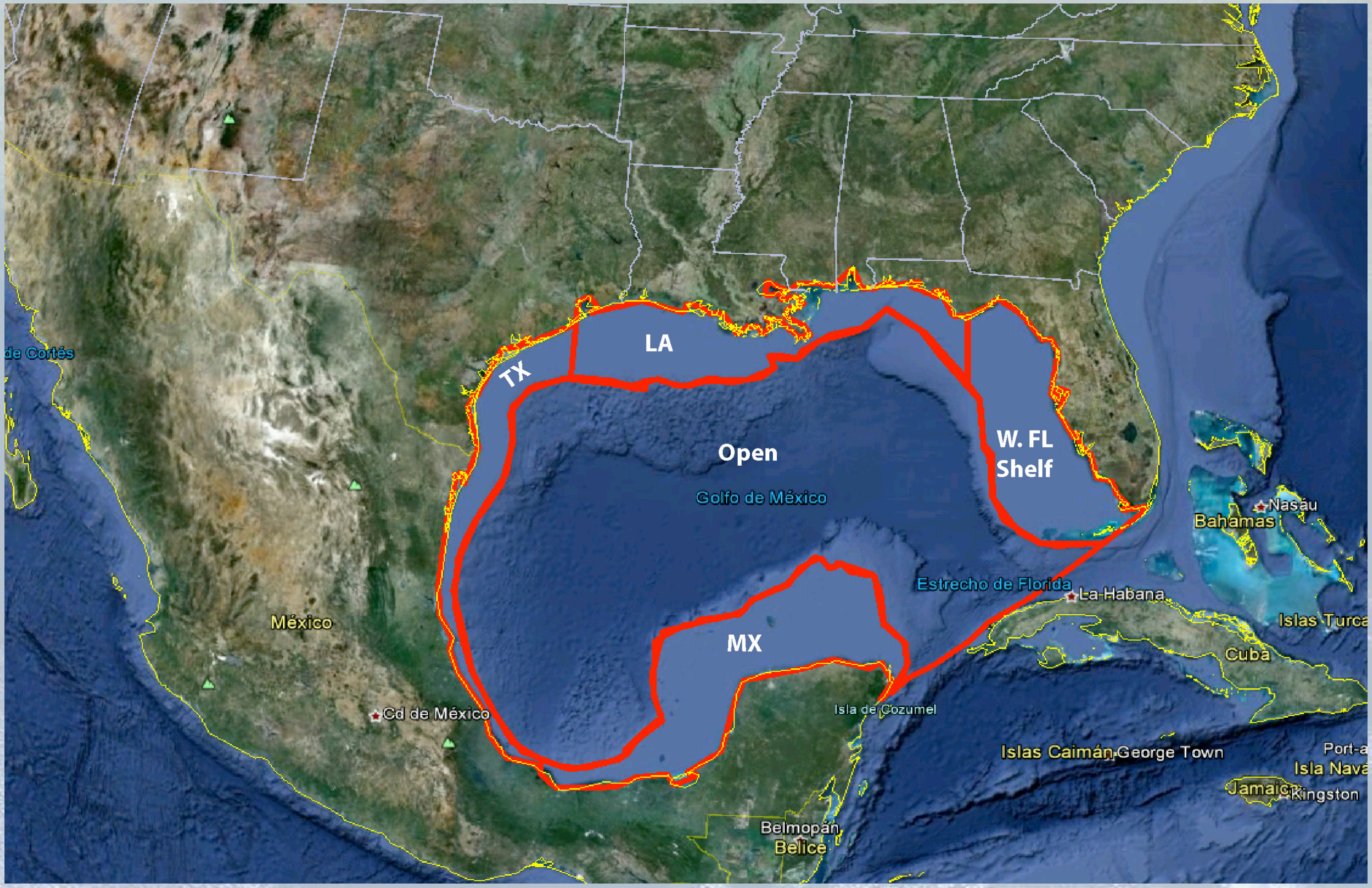
USECoS modeling team

Overall East Coast Carbon Budget



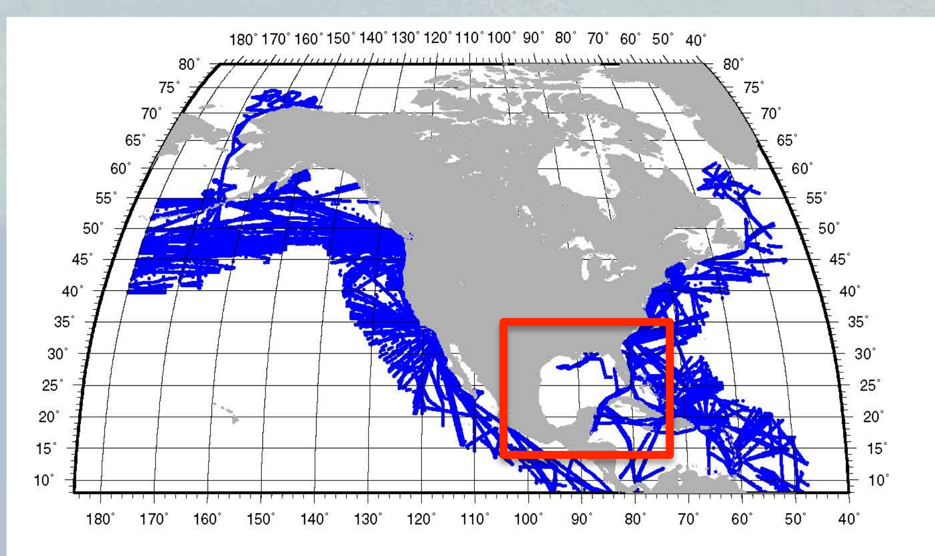
Gulf of Mexico

4 coastal and 1 open ocean regions



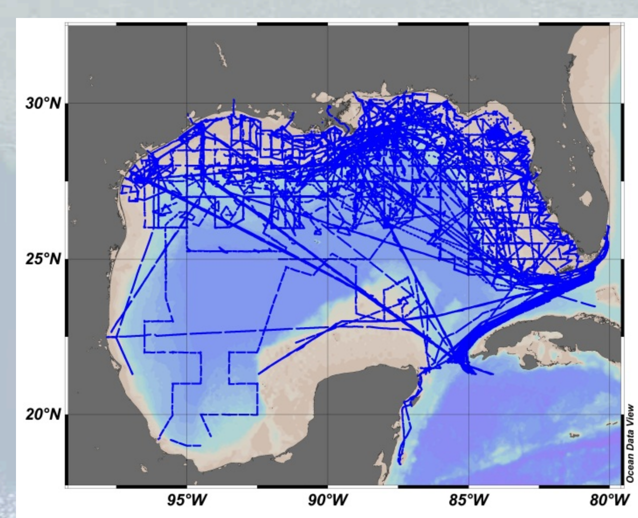
Increase pCO_2 air-sea flux data

Takahashi, 2009
Data up to 2007



Locations where pCO_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.

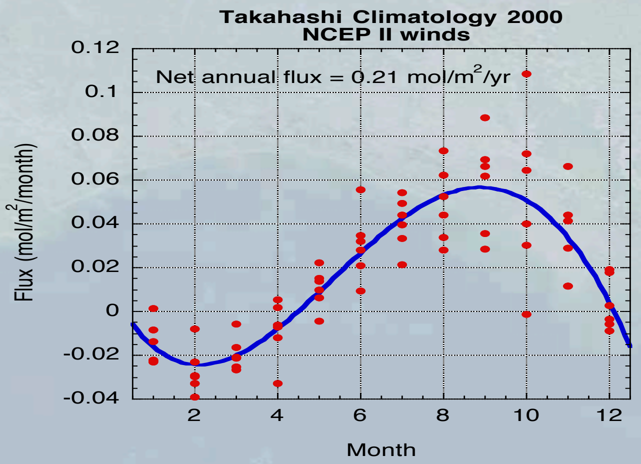
Our newly compiled data, up to 2012



- 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

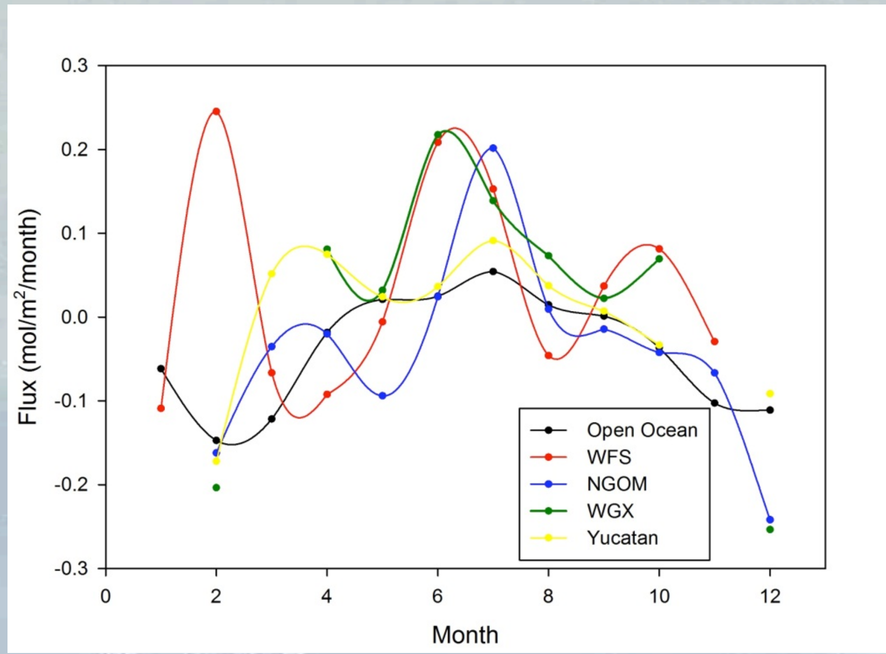
Flux Monthly Variability

The Gulf is a sink with a Net Annual Flux of -0.19 mol C/m^2/year
(-3.57 Tg C/year)



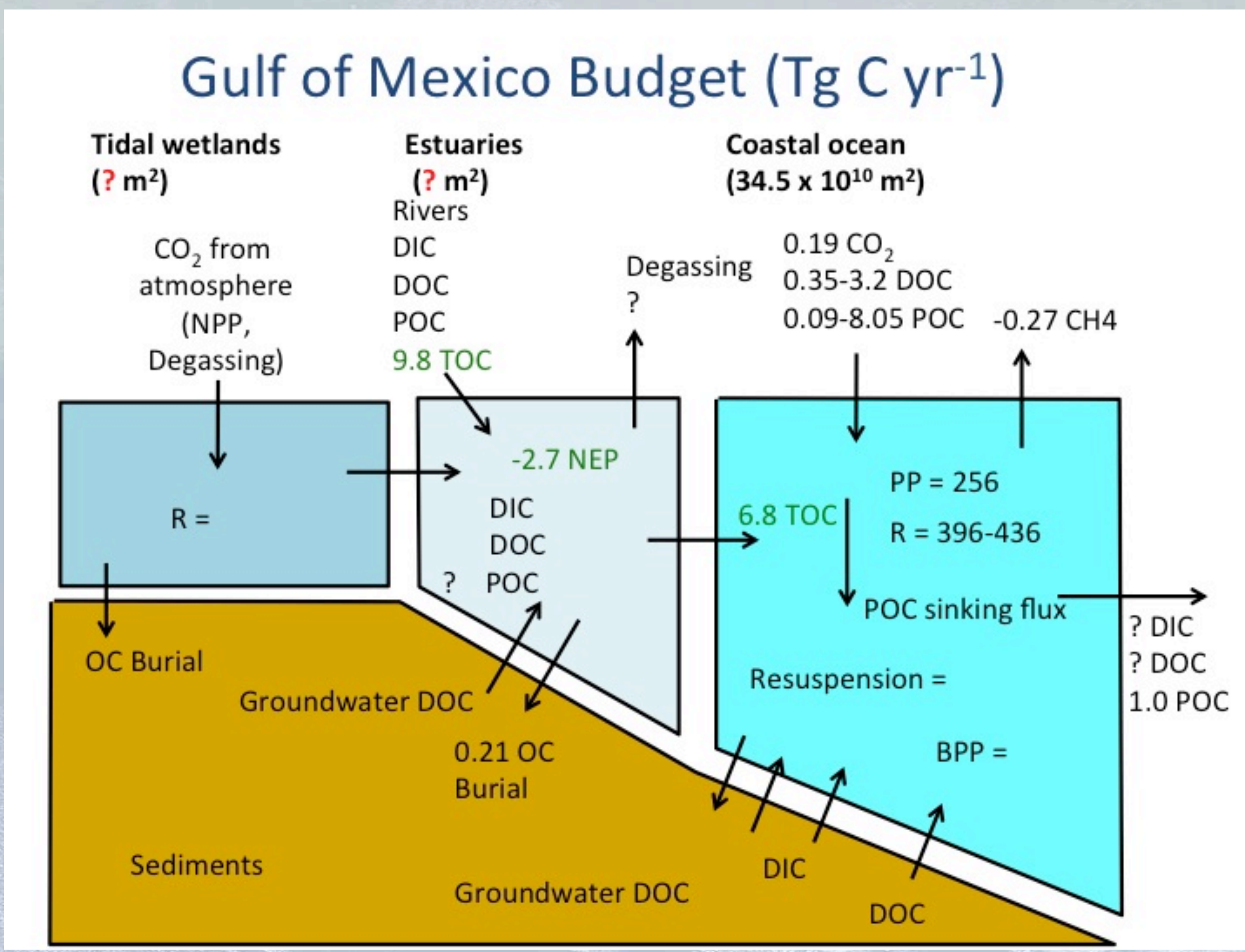
Net Annual Flux:
+0.21 mol C/m2/year

-2 cruises
-summer data

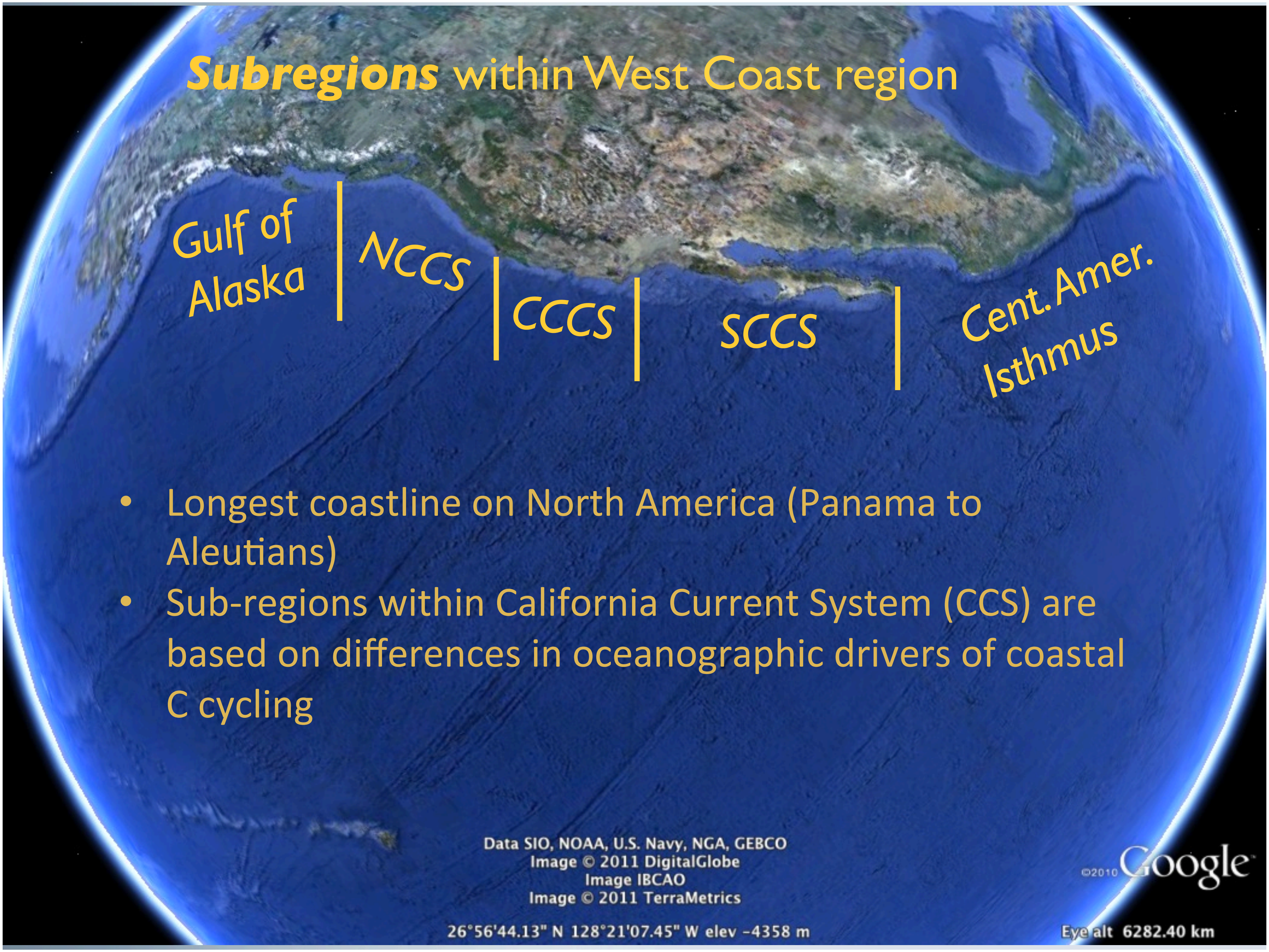


Net Annual Flux (including coastal regions):
- 0.19 mol C/m^2/year

Overall Gulf of Mexico Carbon Budget



Subregions within West Coast region

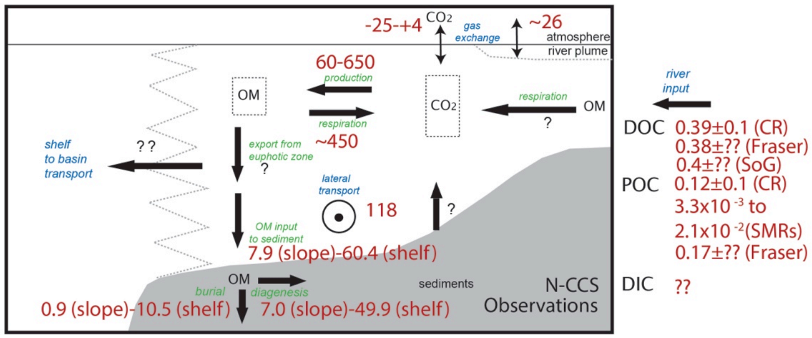


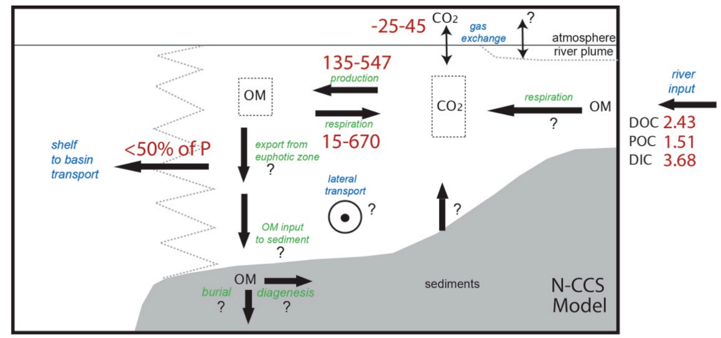
- Longest coastline on North America (Panama to Aleutians)
- Sub-regions within California Current System (CCS) are based on differences in oceanographic drivers of coastal C cycling

California Current System Carbon Budget

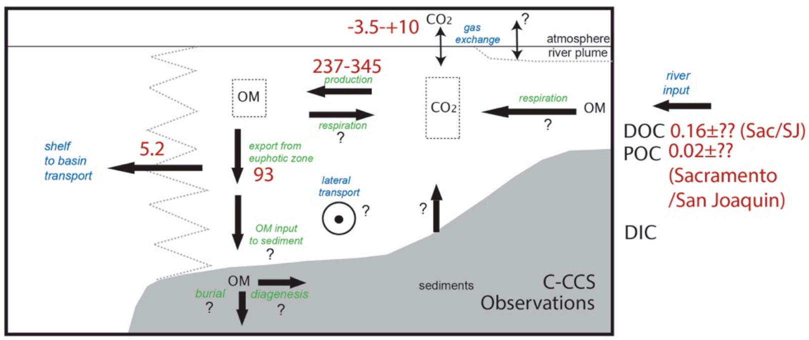
Observations | Models

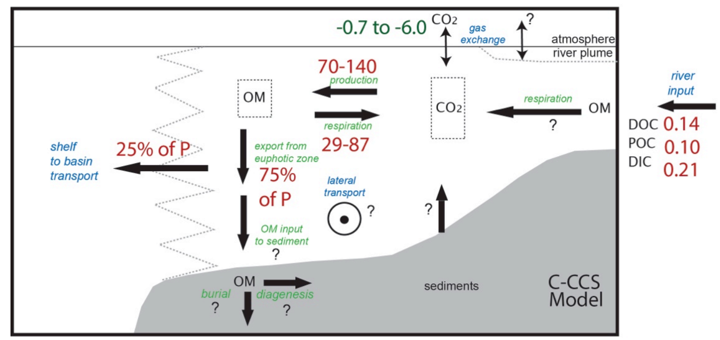
North CCS



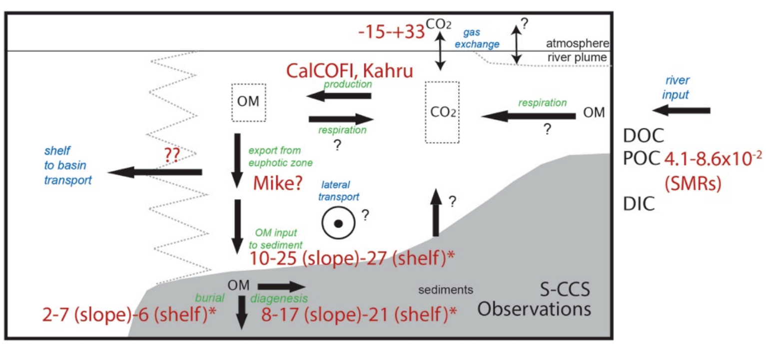


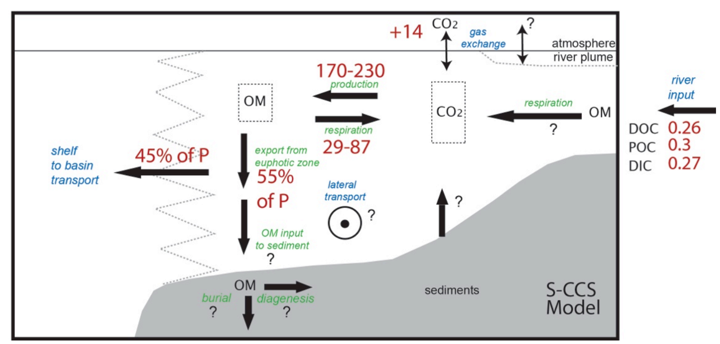
Central CCS





South CCS





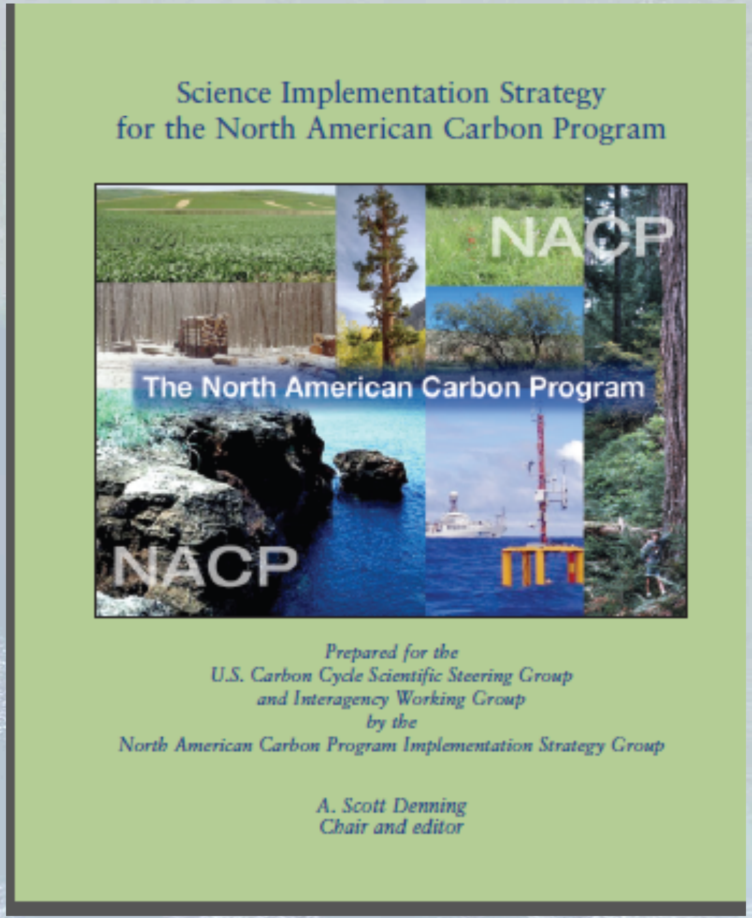
NACP/OCB Coastal Synthesis Informational Resources

- NACP and OCB websites
- Coastal Carbon Wiki – regional progress, meetings, reports, relevant literature, etc.
- OCB Newsletter – series of articles on regional coastal carbon budgets and synthesis activities

Importance of Coastal Margins in the North American Carbon Program (NACP) 2002

Coastal objectives included improved:

- ✓ estimates of air-sea fluxes and their impact on the CO_2 concentrations of continental air masses
- ? estimates of carbon burial & export to open ocean
- – elucidation of factors controlling the efficiency of solubility and biological pumps in coastal environments
- ✓ the development of coupled physical biogeochemical models for different types of margins

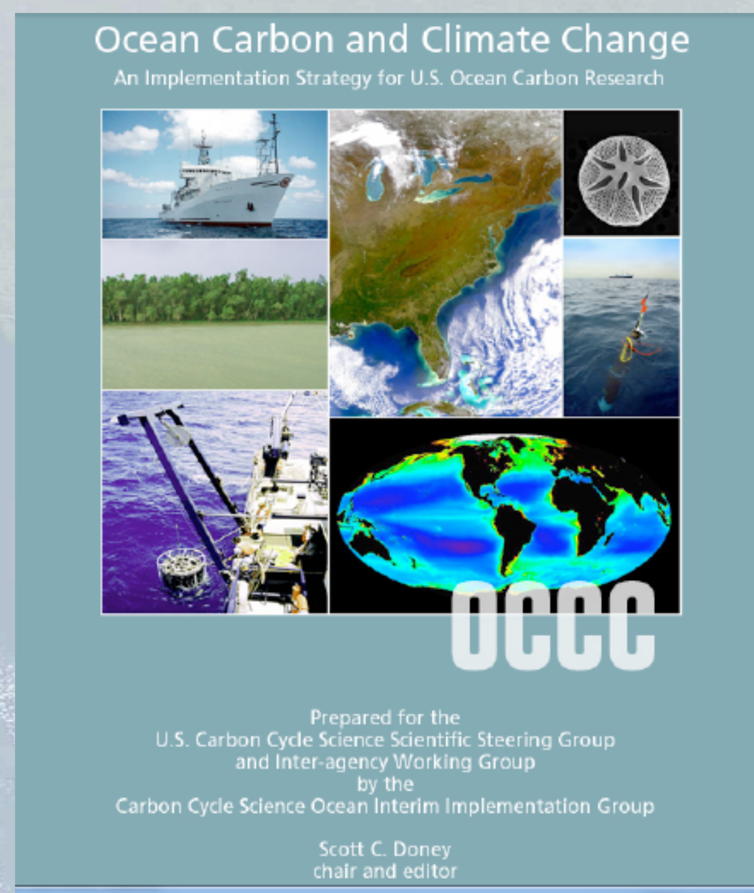


Denning, 2002

Importance of Coastal Margins from the ocean perspective

- Need for improved estimates of:

"North American coastal ocean and continental margin air-sea fluxes, land-ocean and coastal open ocean exchange, and biogeochemical cycling…in order to close the carbon budget over North America"



Doney, 2004

North American Continental Margins Workshop Recommendations (cont.)

Research conducted under such a plan should:

- ✓ Quantify carbon fluxes across control volume interfaces, and carbon-relevant processes inside control volumes
- Determine relationships between the fluxes/processes with regularly measured parameters, such that results can be extrapolated to unsampled times/sites
- ✓ Parameterize fluxes/processes for use in models
- ~ Develop detailed biogeochemical models of subregions, to initially guide fieldwork and ultimately assimilate field data

NACP Questions

1. What is the carbon balance of North America and adjacent oceans? What are the geographic patterns of fluxes of CO_2, CH_4, and CO? How is the balance changing over time? ("***Diagnosis***")

2. What processes control the sources and sinks of CO_2, CH_4, and CO, and how do the controls change with time? ("***Attribution***")

3. Are there potential surprises (could sources increase or sinks disappear)? ("***Prediction***")

4. How can we enhance and manage long-lived carbon sinks ("sequestration"), and provide resources to support decision makers? ("***Decision support***")

Overall CCARS achievements

- Existing data has been synthesized and revised carbon budgets now exist for each of five geographical domains, with specified uncertainties
- Air-sea flux estimates from models and observations are converging
- Coastal carbon cycling models are sophisticated enough to start directly comparing with observations
- Enough observations to begin to synthesize seasonal and interannual variability of fluxes
- Highlighted where additional information is needed

Remaining Unknowns

- Role of tidal wetlands and estuaries in modifying exchange between land and ocean
- Understanding of processes controlling fluxes adequate for prediction and decision support
- … tbd

Workshop Goals

- Present draft carbon budgets to the community for final refinement
  - What do we know?
  - What don't we know?

- Develop a community plan for future research activities to improve our understanding of carbon cycling in coastal waters
  - Finalize Draft plan
  - Formulate concise science questions
  - Develop prioritized research needs
- Go beyond past plans and proposals

Proposed Science Questions

1. What changes can we expect in the coastal carbon cycle and associated ecosystems in the face of accelerating global change?

2. How do carbon fluxes in the coastal zone help us reconcile land and ocean carbon budgets?

Additional Slides