North American Carbon Program Coastal CARbon Synthesis (CCARS)

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CCARS Community Workshop

http://www.whoi.edu/website/ccars

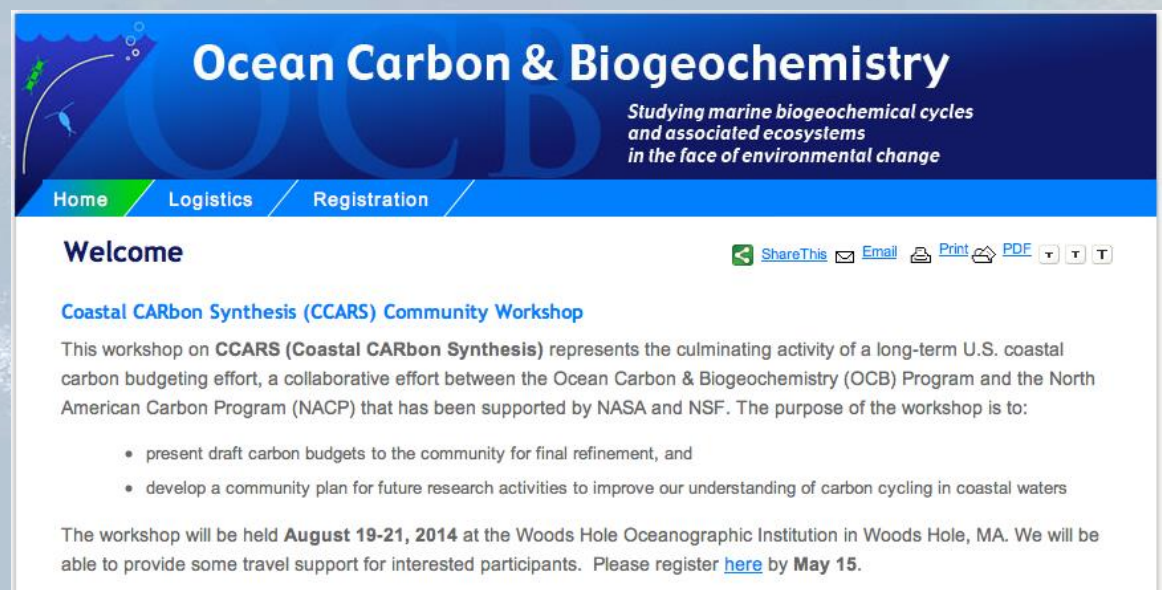
Goals:

- Present draft coastal carbon budgets for final community refinement
- Identify gaps in coastal carbon research
- Develop recommendations for a science plan to help agencies prioritize future investments in coastal carbon cycle research

August 19-21, 2014

Woods Hole, MA

Register by May 15!



Outline

- Historical perspective and motivation
  - Early 2000's
  - North American Continental Margins Workshop (2005)
    - Recommendations from Hales et al. (2008)
- Recent CCARS progress on regional budgets
- Future
  - Summer workshop: Woods Hole, August 2014

Implications of Coastal Carbon Cycling

- Coastal margins are at the interface of terrestrial and ocean ecosystems
- Better constraints on coastal carbon cycles will improve understanding of land-ocean interactions and support decision-making on a variety of issues

Land
Carbon Management
Land Use Practices
Water and Forest Management
Agriculture, Fertilizer
Greenhouse Gases
Energy and Biofuels
Development

Terrestrial Export

Coastal Margin
Nutrients and Hypoxia
Ocean Acidification
Wetlands Loss
Coastal Restoration
Water Quality
Fisheries Habitat
Sea Level Rise

Export

Ocean Carbon Reservoir
Long term Sequestration of Carbon?
Ocean Biogeochemistry and Productivity

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)

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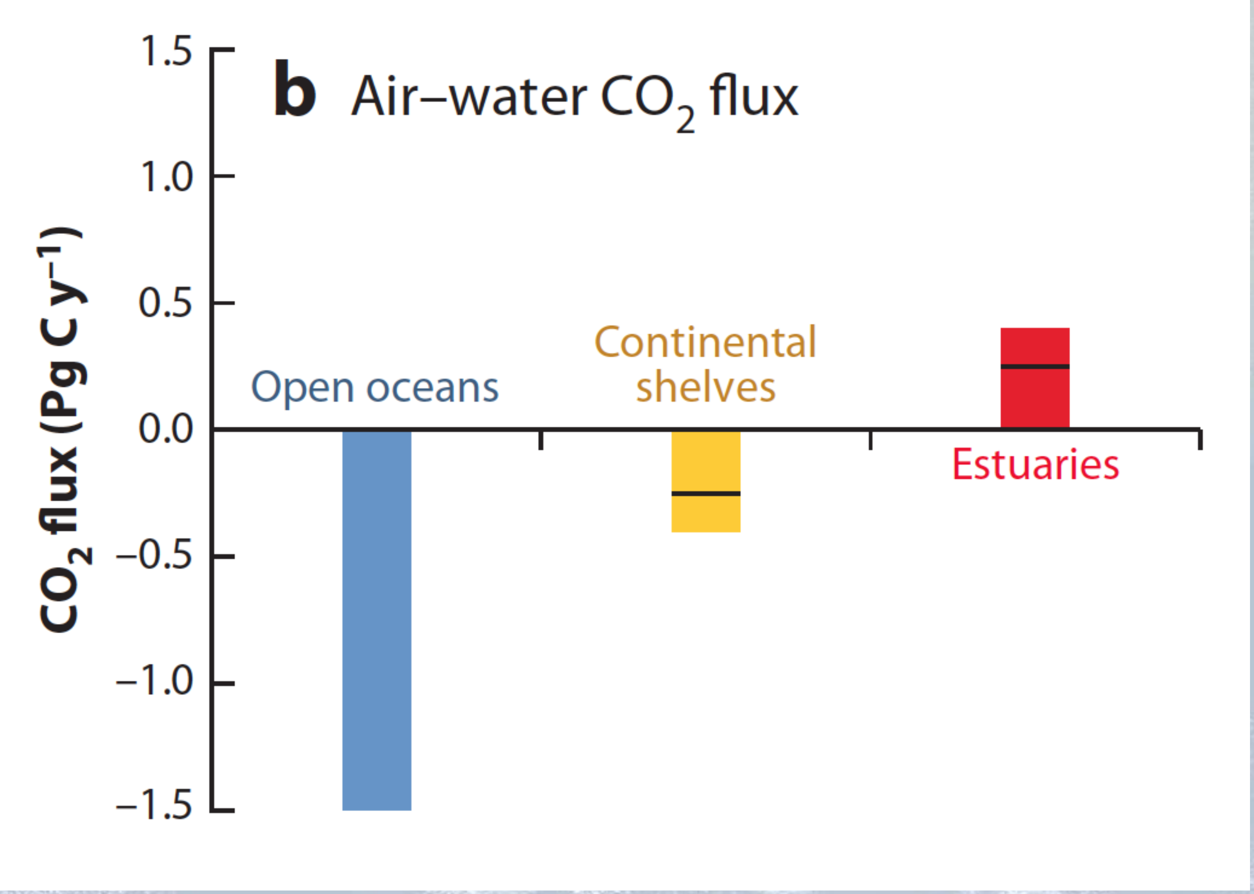
(continental shelves are ~5% of ocean area)



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:

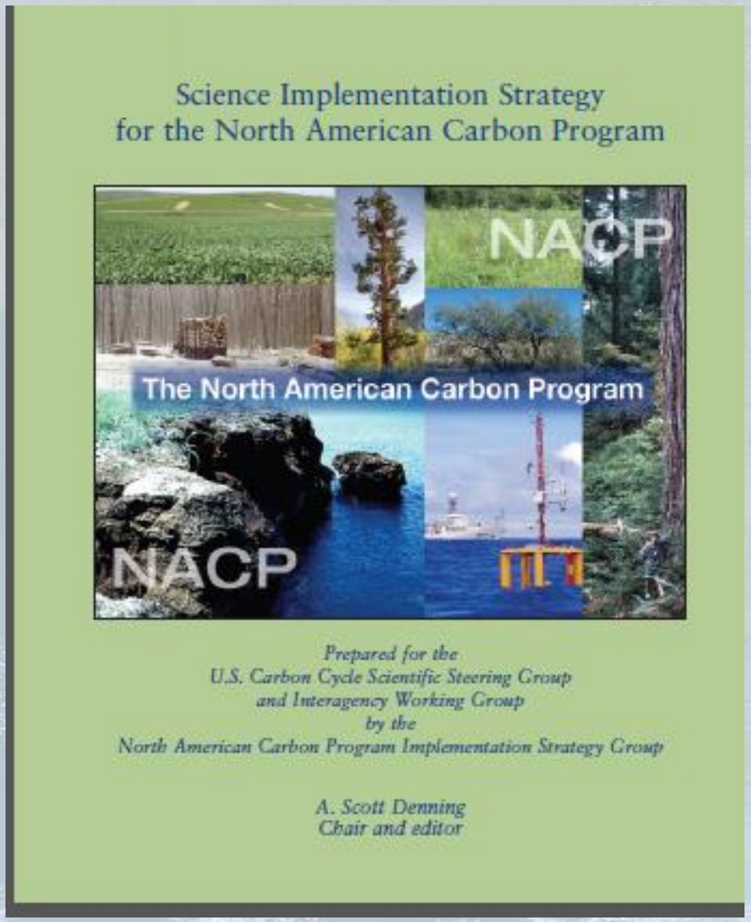
- Limited observations
- Difficult to model (need many regional models)
- Changing human activities on land may affect export of freshwater, sediments, and nutrients to coastal regions
- Effects of human impacts are significant in coastal zones: sea level rise, coastal eutrophication, atmospheric deposition

- 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

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

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

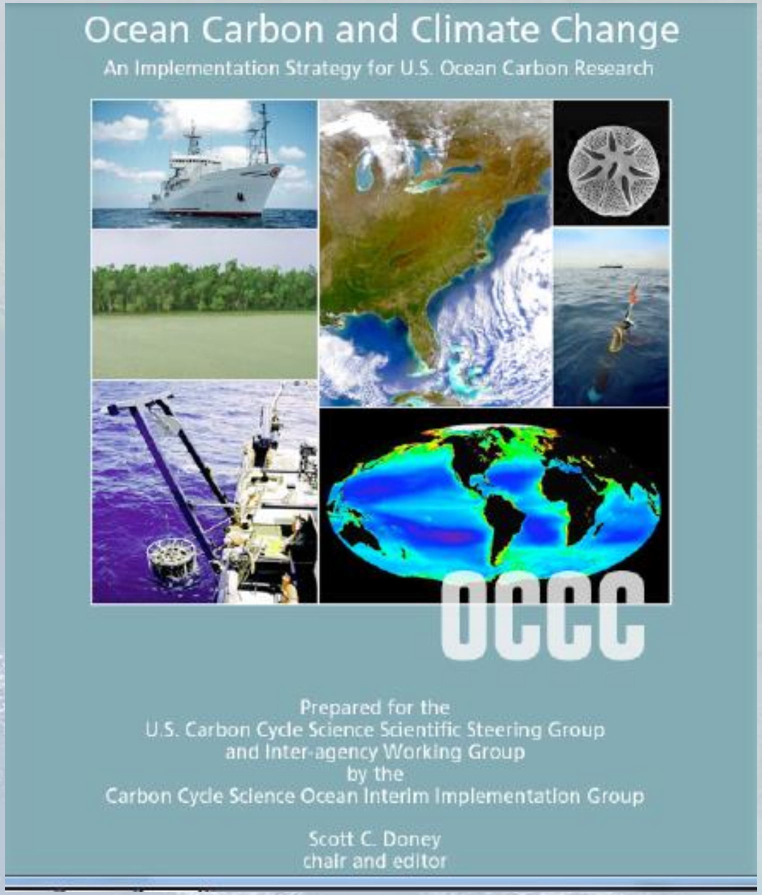


Denning, 2002

Importance of Coastal Margins from the ocean perspective

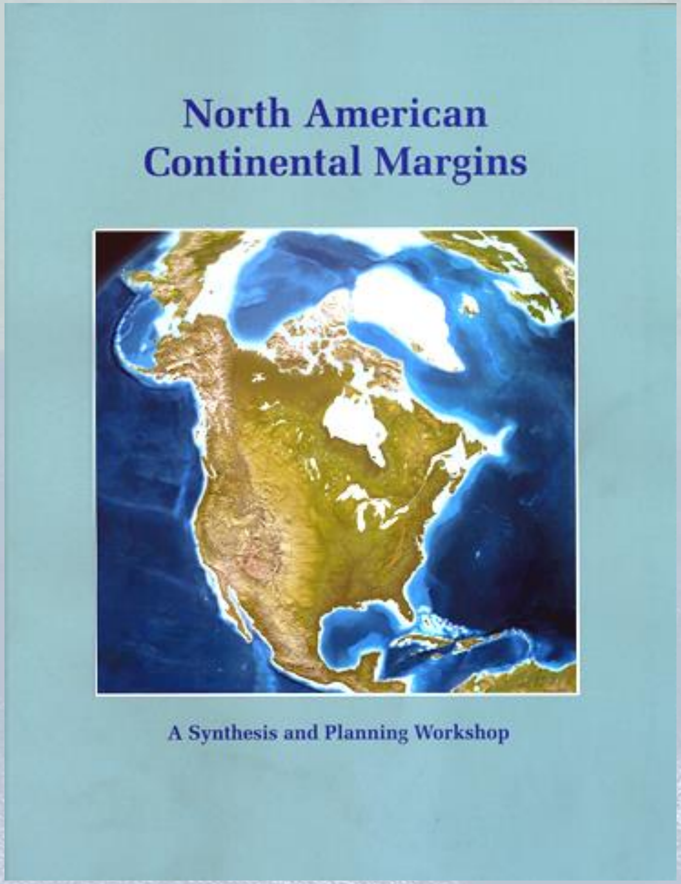
- Need for improved estimates of:

"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: A Synthesis and Planning Workshop September, 2005



Hales et al., 2008

Produced recommendations to guide future carbon cycle research in North American Continental Margins

North American Continental Margins Workshop Recommendations (cont.)

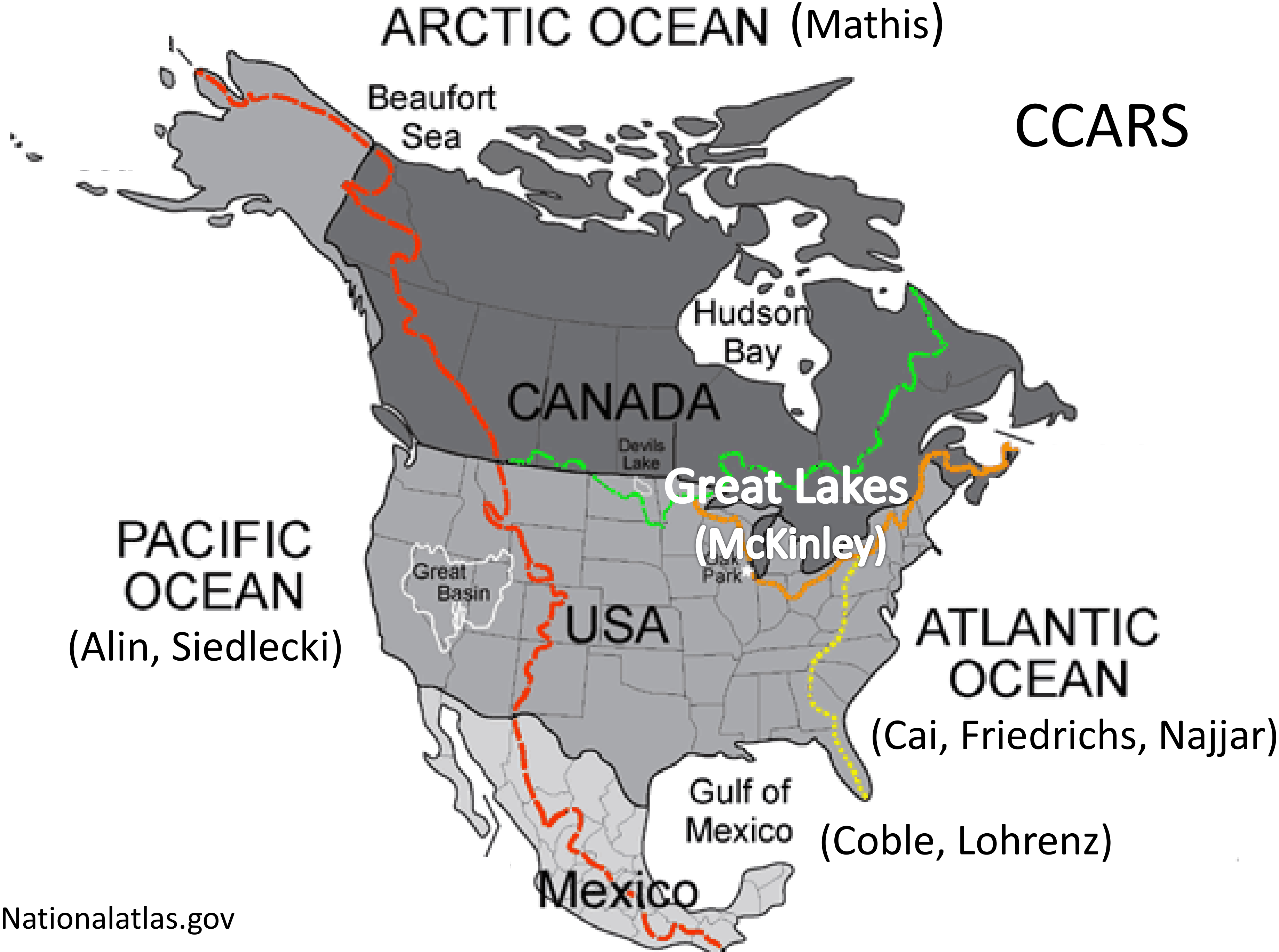
- Improve coastal carbon cycling observational capabilities
  - Expand routine measurements
  - Refine satellite algorithms
  - Develop new technologies
- Synthesize and model existing datasets
  - Create a “database of databases”
  - Model carbon cycle in subregions to quantify sensitivities to forcing and develop predictive capabilities
- Develop plan for obs. + modeling of characteristic regions
  - Determine fluxes for each subregion (not one-size-fits-all)
  - Close mass balances in each region individually
  - Develop detailed biogeochemical models of each region

North American Continental Margins Workshop Recommendations (cont.)

Research conducted under such a plan should:

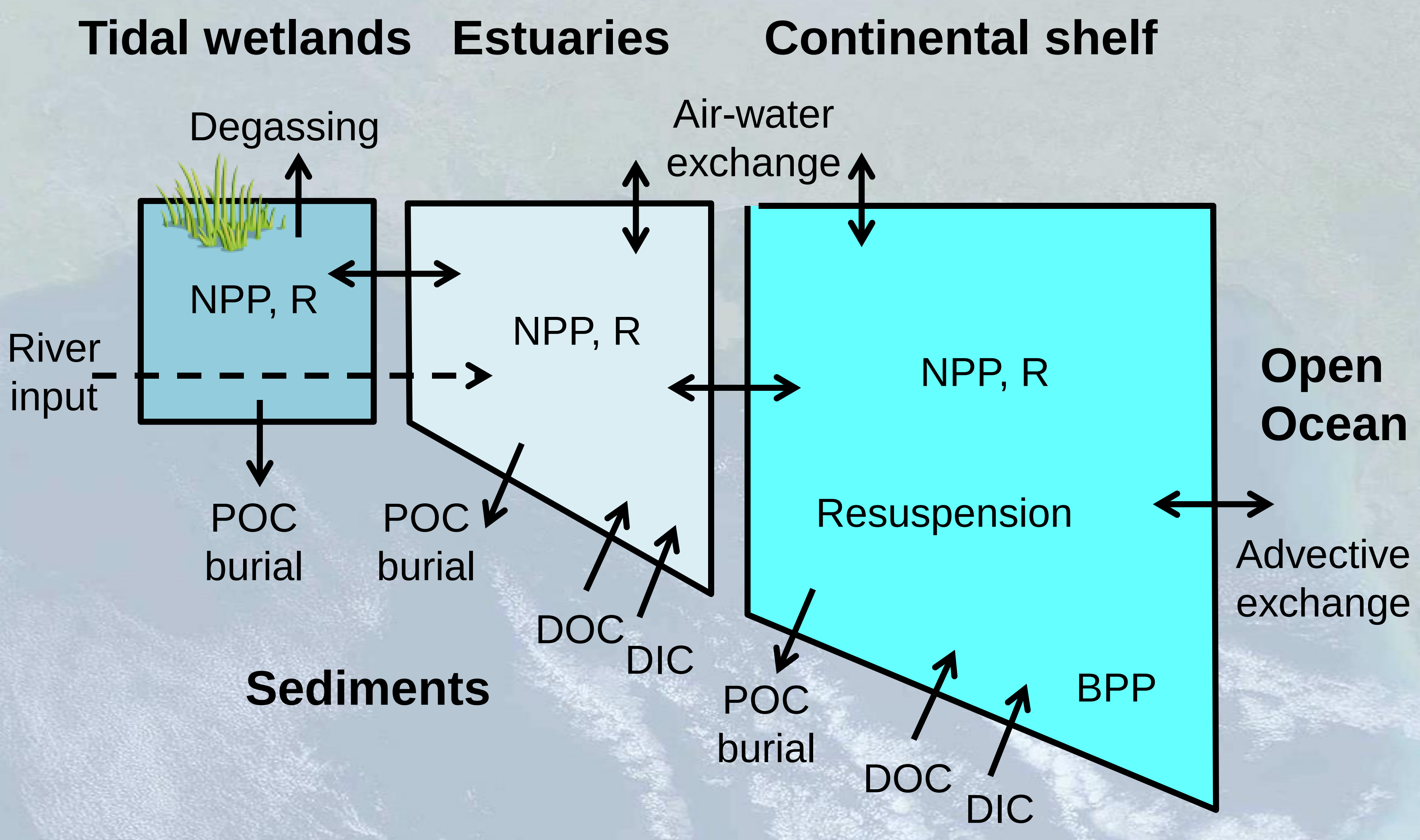
- Quantify carbon fluxes across control volume interfaces, and carbon-relevant processes inside control volumes
- Determine relationships between the fluxes/processes with regularly measured parameters, such that results can be extrapolated to unsampled times/sites
- Parameterize fluxes/processes for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

CCARS



Nationalatlas.gov

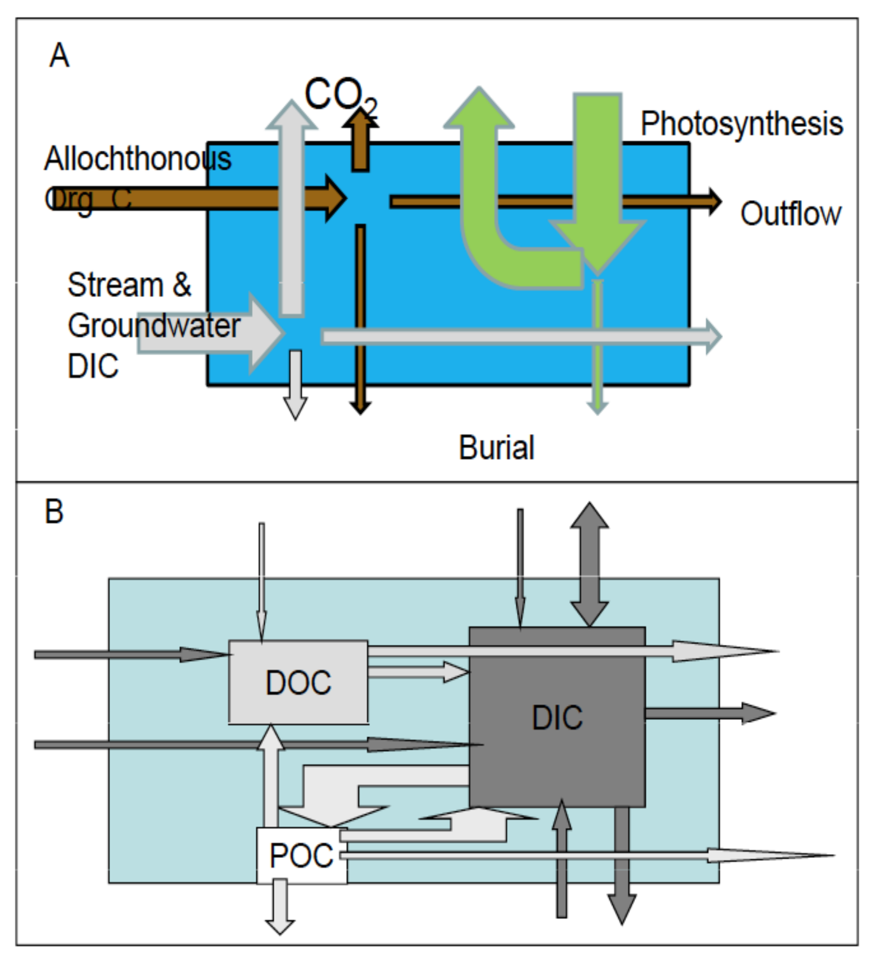
The carbon cycle of the coastal ocean



CCARS timeline

- 2009 Initial Breakout at NACP Meeting
- 2010 NASA Community Workshop
- 2010-2012 Preliminary budgets published in OCB Newsletter issues
- 2012 East Coast Workshop (VA)
- 2013 Gulf of Mexico Workshop (FL)
- 2014 West Coast Workshop (WA)

Great Lakes Carbon Budget



Literature Review:
FLUX = 0.12 TgC/yr (source)

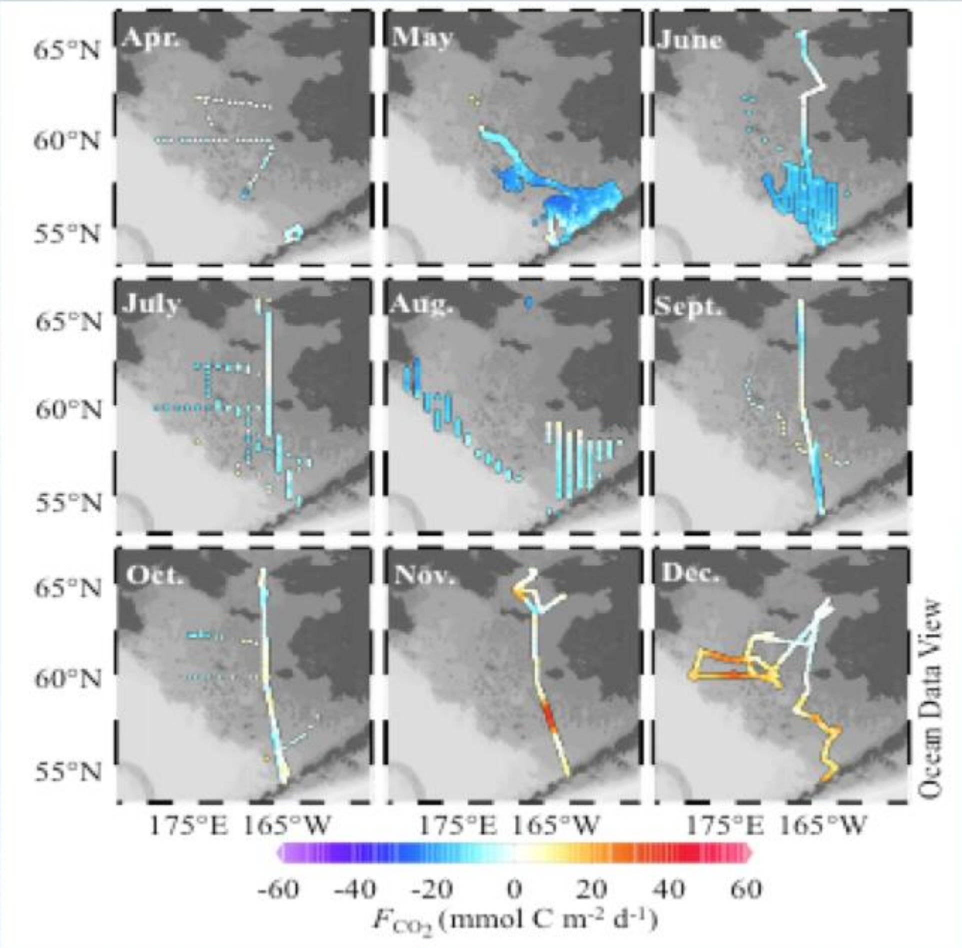
2-D box model:
FLUX = 36 TgC/yr (source)

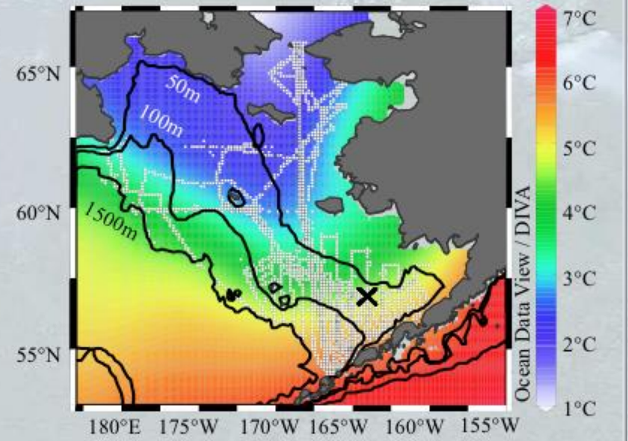
Large uncertainties in air-sea CO_2 flux

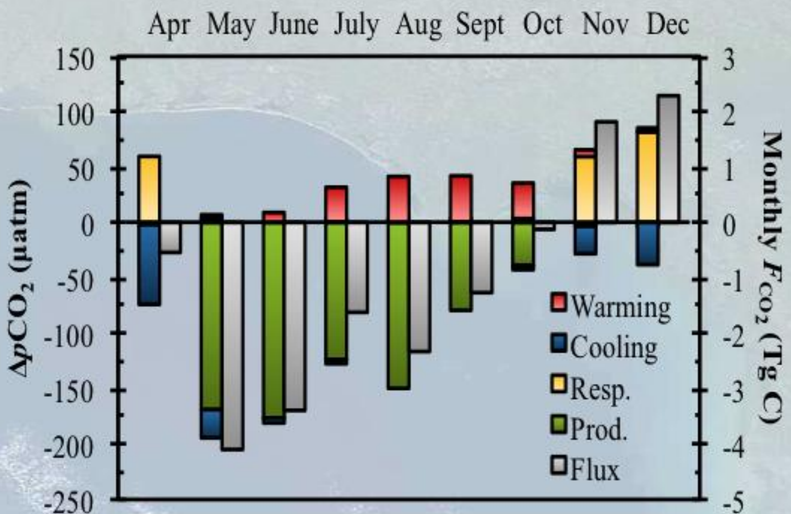
McKinley et al. 2011; Atilla et al., 2011; Urban et al. (in prep)

Bering Sea CO_2 Flux Synthesis

Monthly sea-air CO_2 flux for the Bering Sea shelf





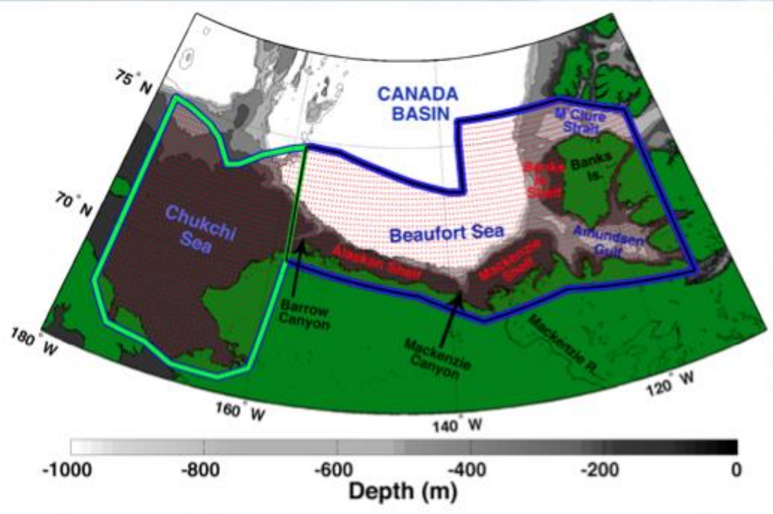


Area-weighted monthly average fluxes and flux drivers for the Bering Sea shelf.

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

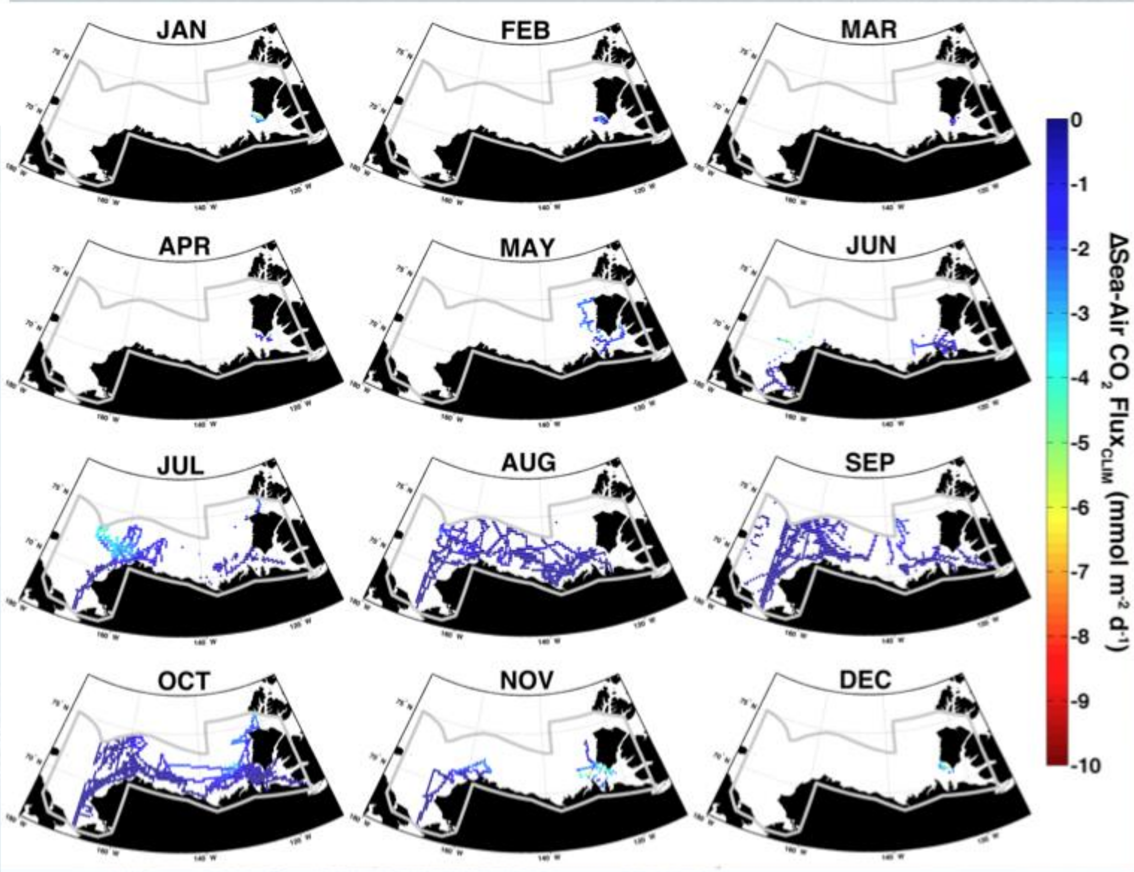
Cross et al., in review (JGR-Oceans)

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}

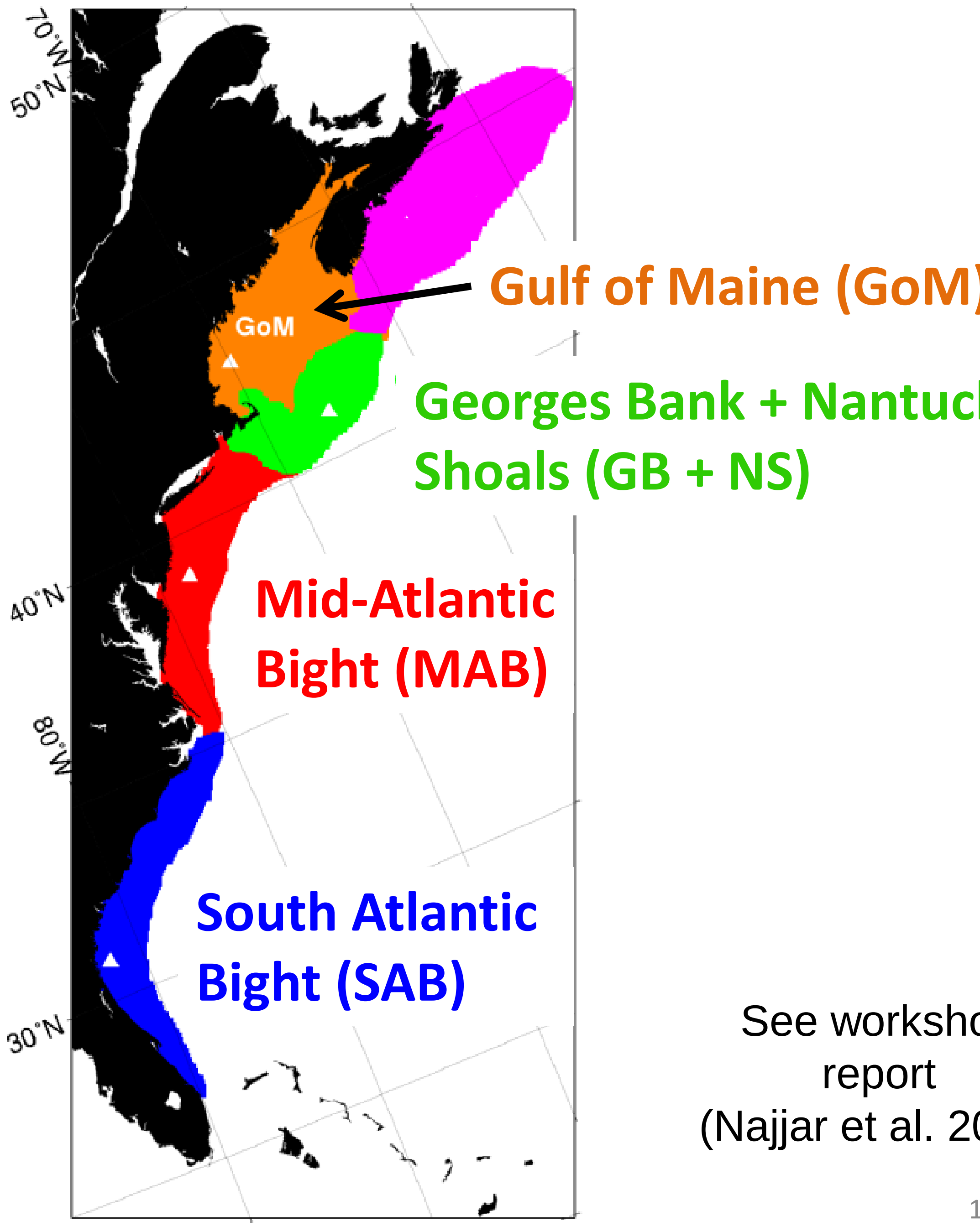


Evans et al., in prep. (Continental Shelf Research)

East Coast

Head-of-tide to shelf break (~200 m)

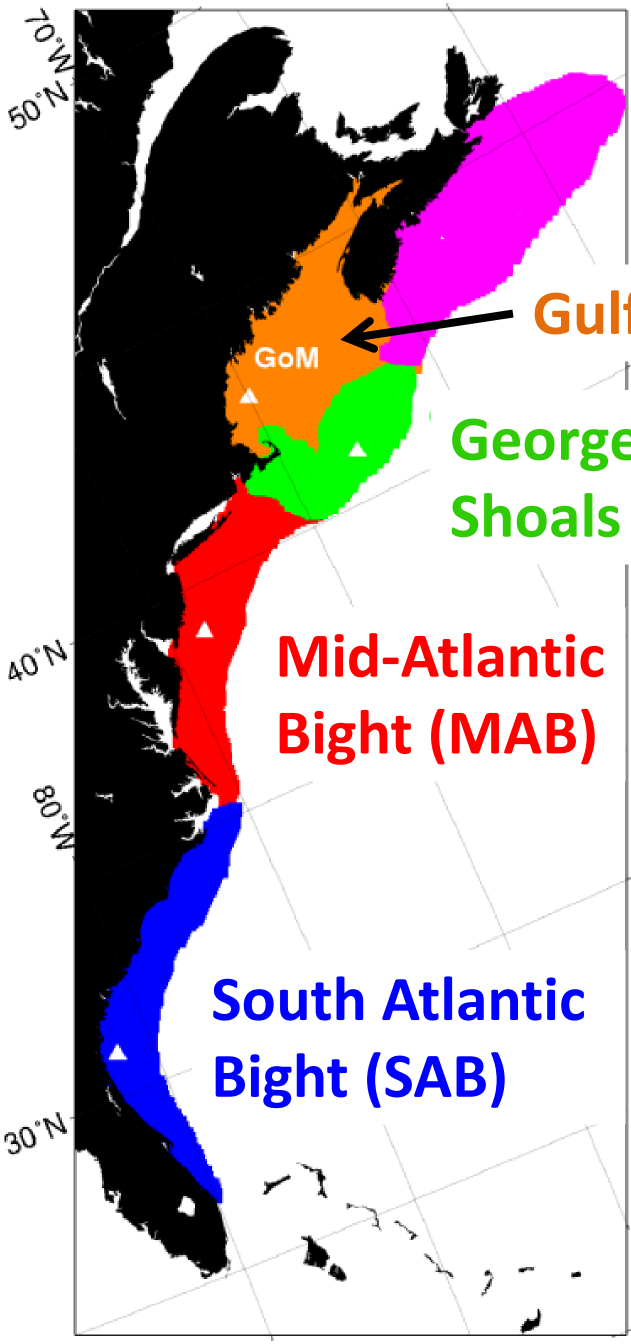
	% Area
Tidal wetlands	3
Estuaries	14
Shelf waters	83



See workshop report (Najjar et al. 2012)

Primary production:

120 ± 30 Tg C yr^{-1}



Gulf of Maine (GoM)

Georges Bank + Nantucket Shoals (GB + NS)

47 ± 20

Mid-Atlantic Bight (MAB)

34 ± 10

South Atlantic Bight (SAB)

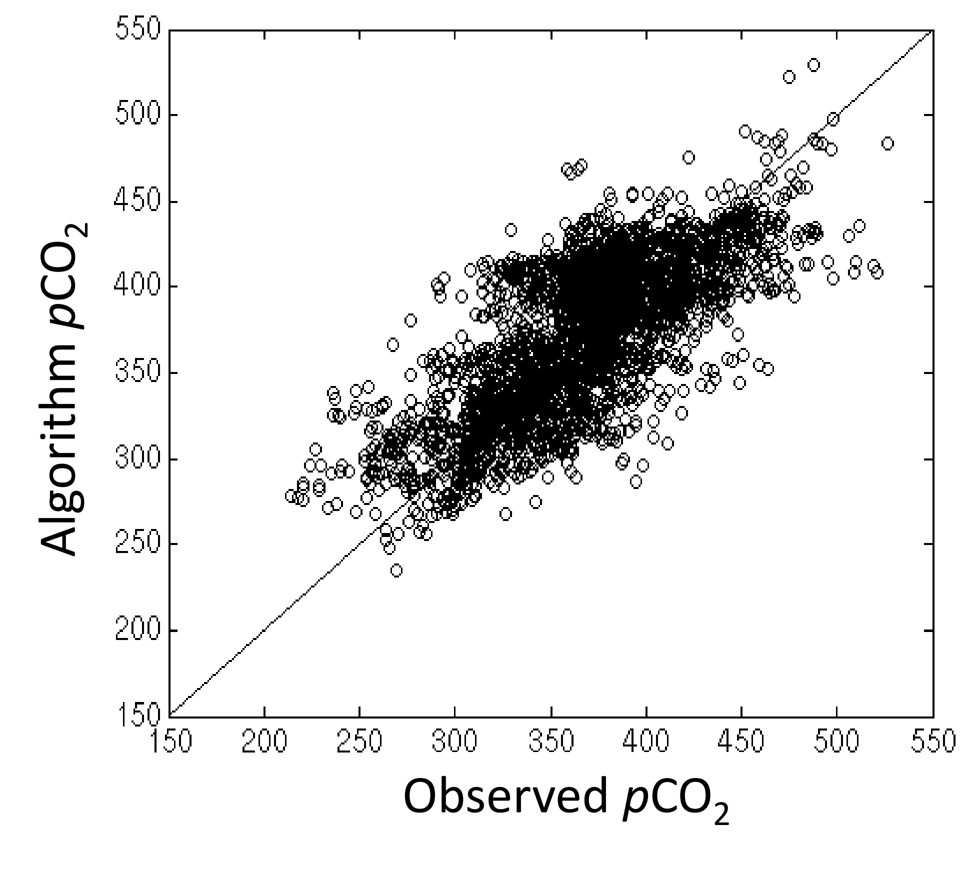
35 ± 10

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

Continental shelf air-sea exchange

(Signorini et al., 2013)

Surface pCO_2 algorithm exploiting satellite data

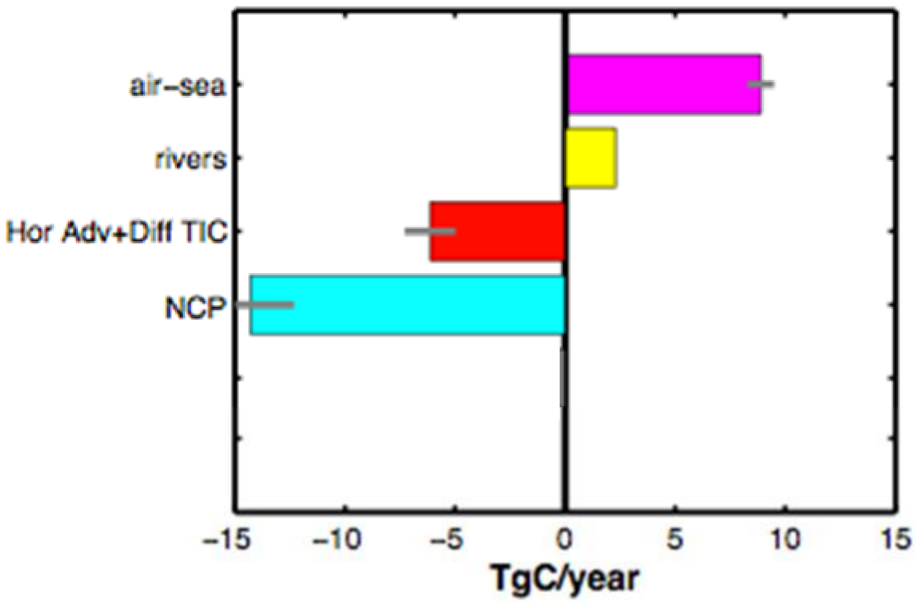


Flux = f(ΔpCO_2, wind, SST)

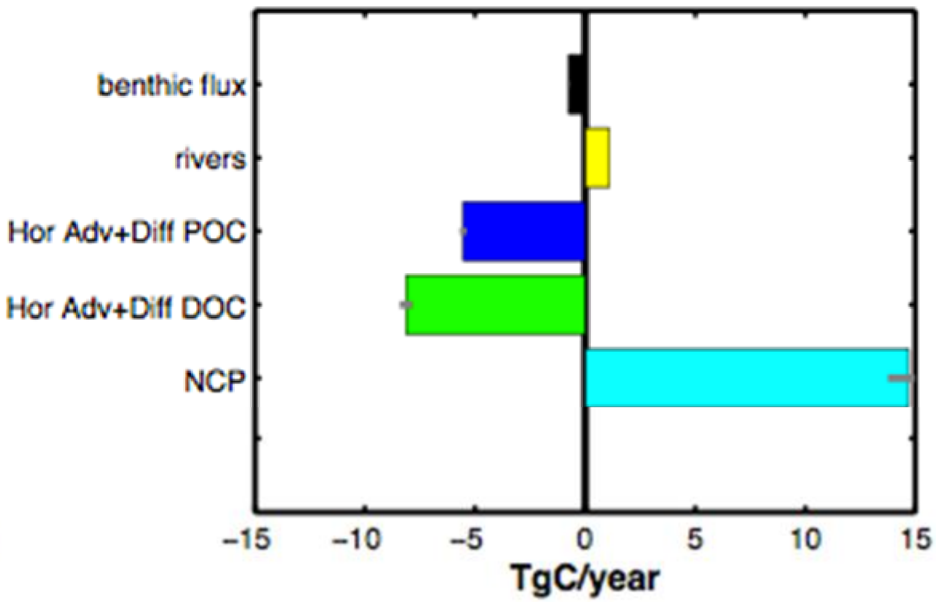
	Uptake Tg C yr^{-1}
GoM	-0.1
GB+NS	1.3
MAB	2.1
SAB	1.0
East Coast	~4

Modeled carbon flux estimates

Inorganic Carbon Budget for 2004



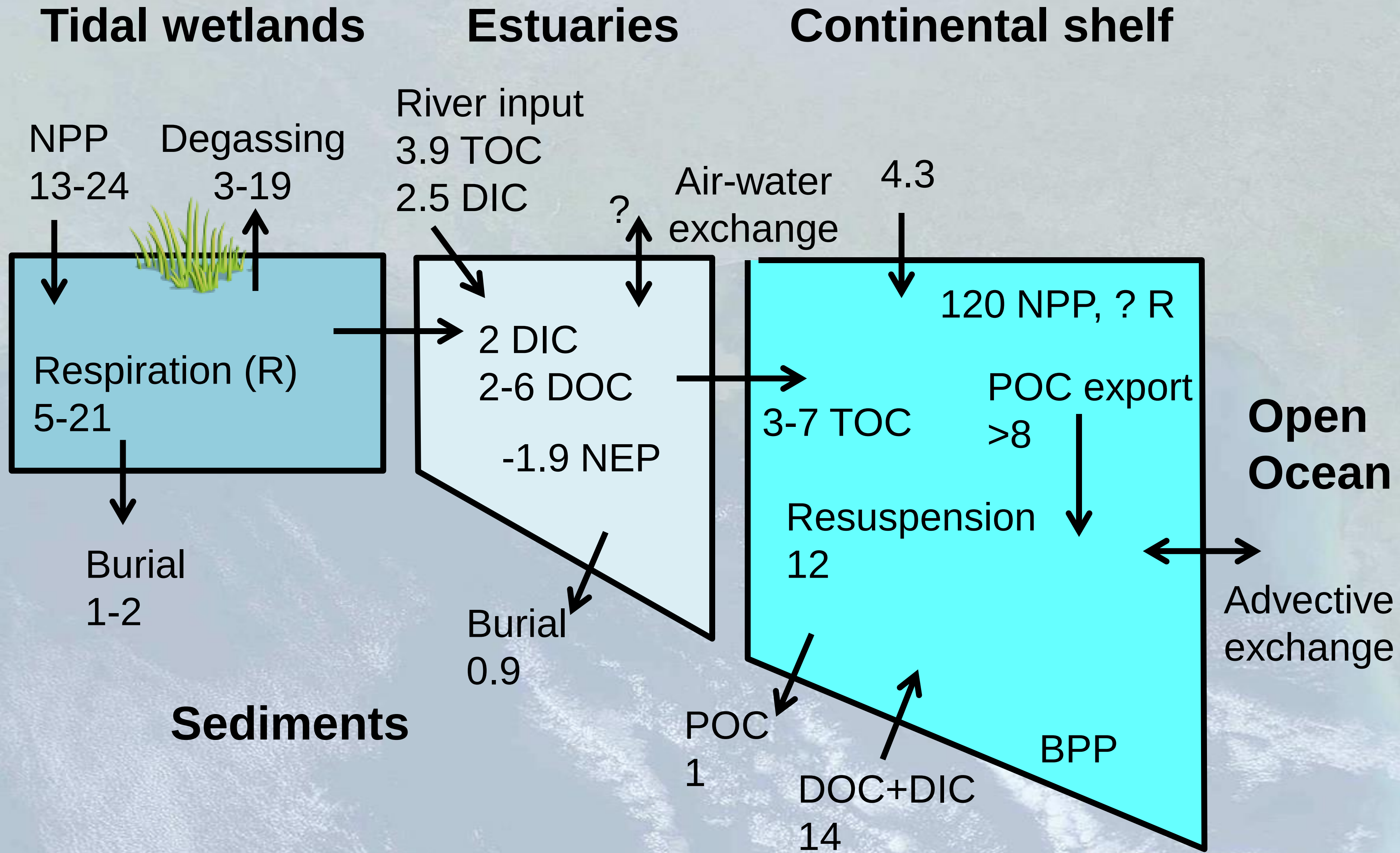
Organic Carbon Budget for 2004



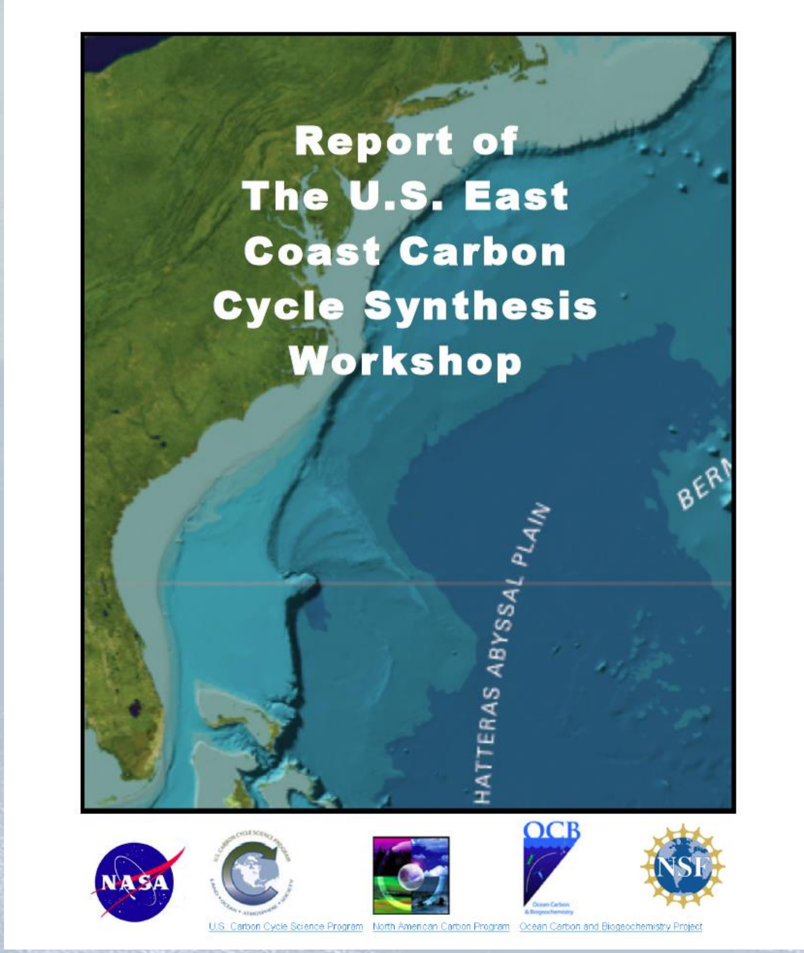
- Mass is conserved; budgets close
- Need long model spin-up
- Need interannual runs

USECoS modeling team

Overall East Coast Carbon Budget



Overall East Coast Carbon Budget

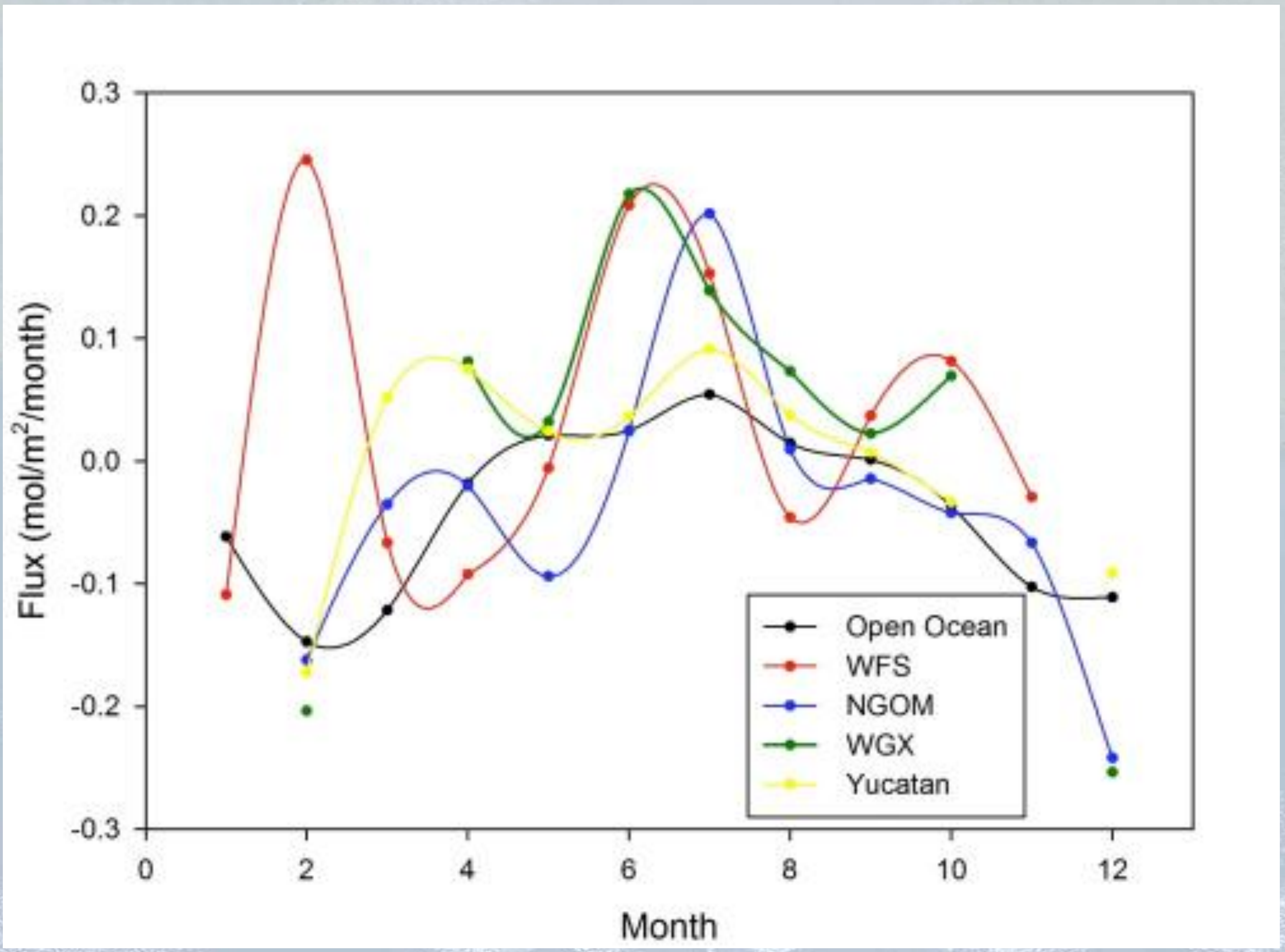


For each carbon flux:

- Short term plans
- Long-term recommendations
  - NPP, R in wetlands/estuaries
  - Advective fluxes
- Overarching themes
  - Innovative methods required for scaling up local flux estimates
  - Need many independent estimates of a given flux
  - Mechanistic numerical models of coastal zone biogeochemistry are a powerful complement to observational studies

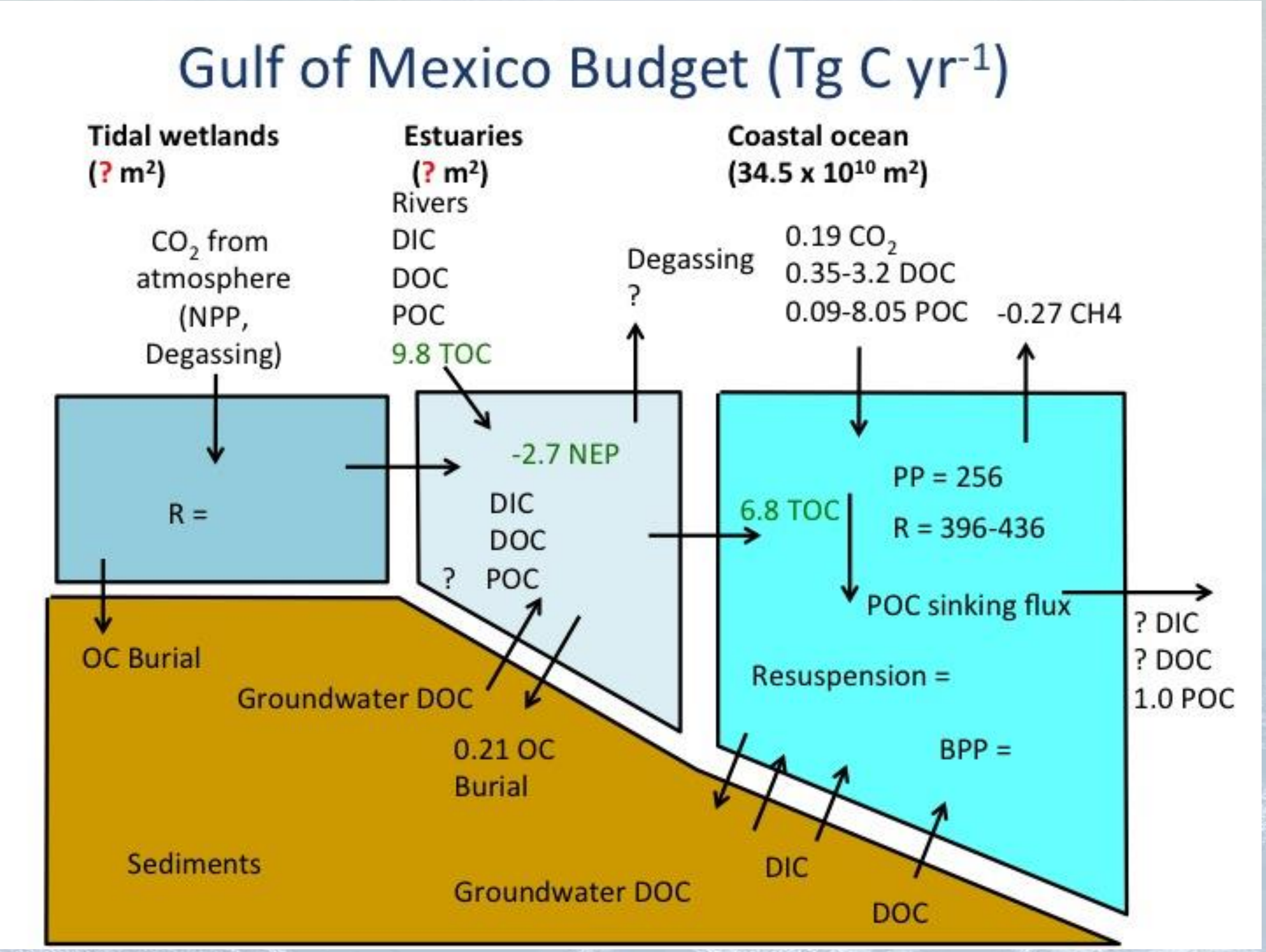
Najjar et al., 2012

Gulf of Mexico air-sea exchange



New data set indicates Gulf is sink of CO_2: uptake for entire Gulf = ~4 Tg C y^{-1}

Overall Gulf of Mexico Carbon Budget



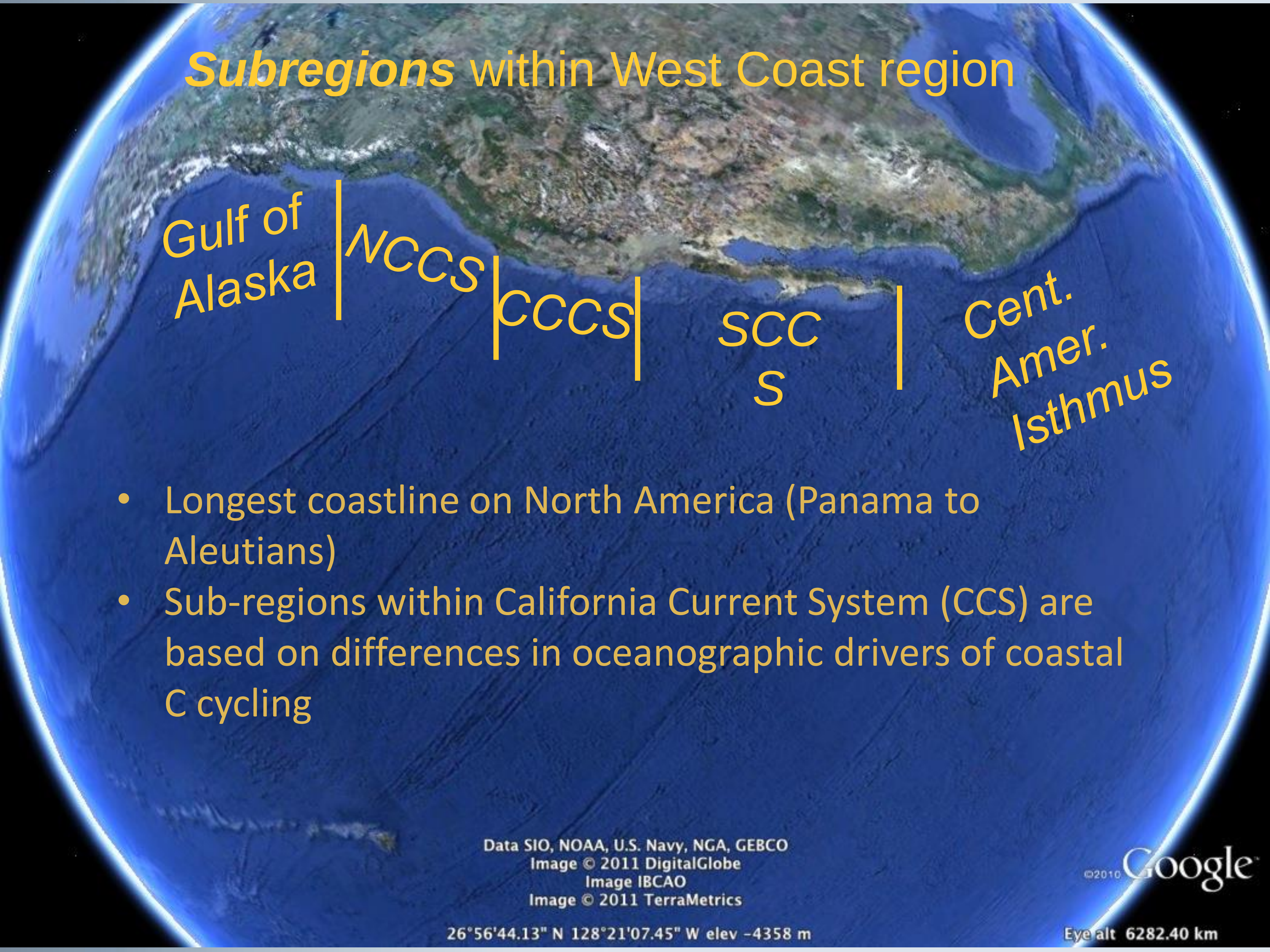
Overall Gulf of Mexico Carbon Budget

Knowledge gaps:

- Lacking data in Mexican waters; more collaborations needed
- Nitrogen fixation
- Sediment-water carbon fluxes
- Tidal wetlands & interface between rivers and estuaries
- Model-observation and model-model comparisons needed
  - Regional
  - Entire Gulf

Benway and Coble, 2013

Subregions within West Coast region



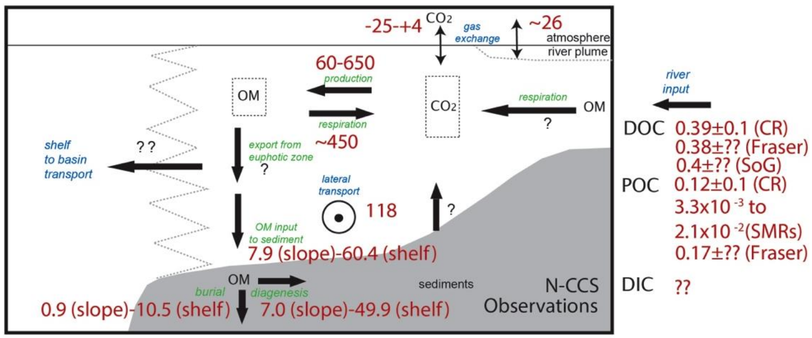
- Longest coastline on North America (Panama to Aleutians)
- Sub-regions within California Current System (CCS) are based on differences in oceanographic drivers of coastal C cycling

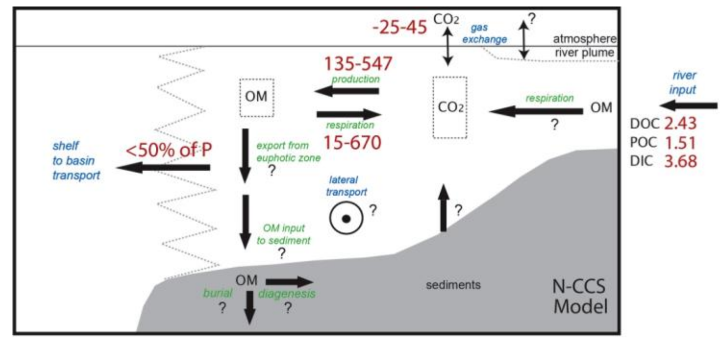
California Current System Carbon Budget

Observations

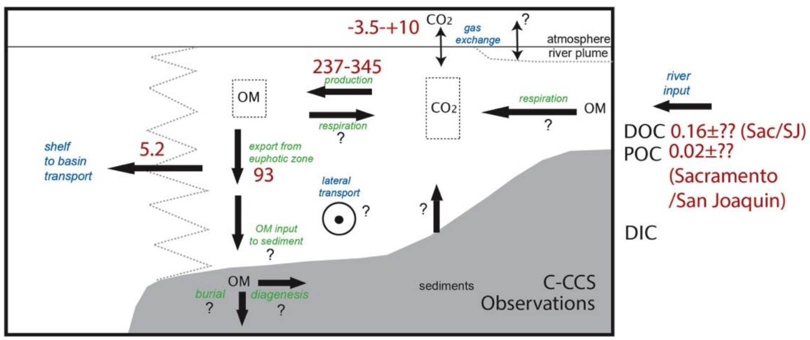
Models

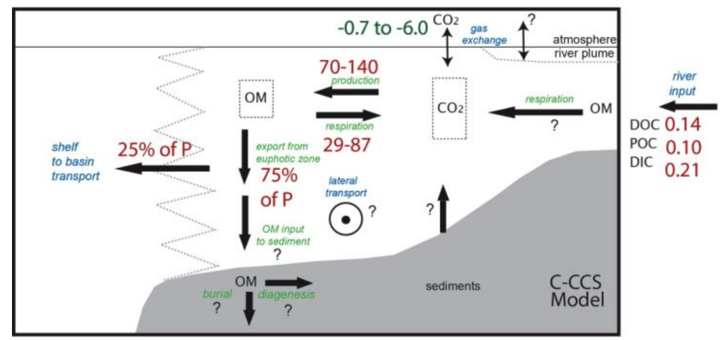
North CCS



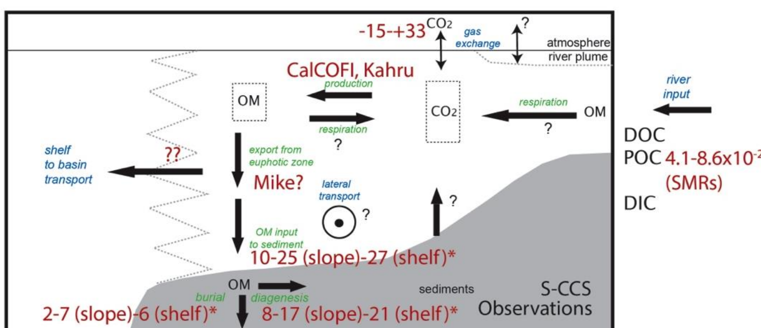


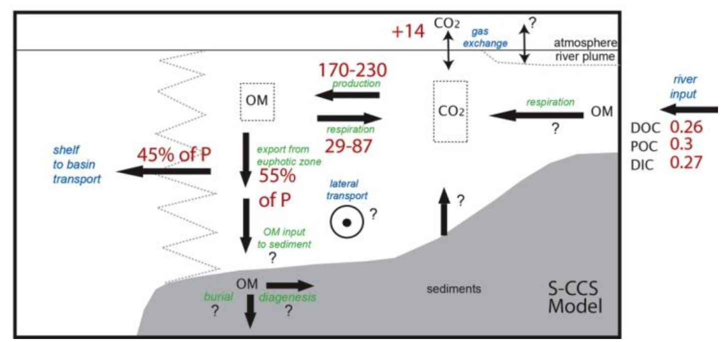
Central CCS





South CCS





California Current System Carbon Budget

Remaining knowledge gaps:

- Estuarine processing—how much of what comes into the estuary enters the coastal ocean?
- Winter observations—not a lot of them.
- Missing net community production—where does it end up?
- Most C cycle terms in the Gulf of Alaska and Central American Isthmus sub-regions are poorly constrained.
- Models are required to make predictions as to how coastal carbon cycles will change in future; process studies required to test hypotheses generated by them

Overall CCARS achievements

- Existing data has been synthesized and revised carbon budgets now exist for each of five geographical domains, with specified uncertainties
- Highlighted where additional information is needed
- 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

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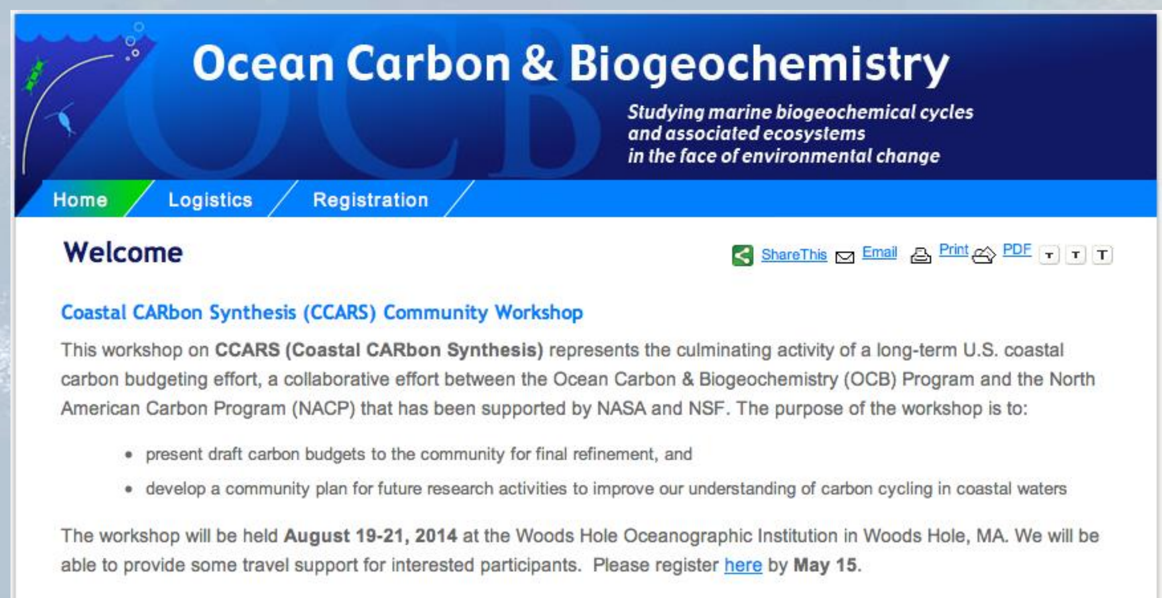

Additional Slides

Remaining 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?