# Coastal Carbon Fluxes along the U.S. Eastern Continental Shelf Derived from a Coupled Biogeochemical-Circulation Model

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## USECoS PROJECT OVERVIEW

Although the oceans play a major role in the uptake of fossil fuel $CO_2$ from the atmosphere, there is much debate about the contribution from continental shelves, because many key shelf fluxes are not yet well quantified: the exchange of carbon across the land-ocean and shelf-slope interfaces, air-sea exchange of $CO_2$, burial, and biological processes including productivity. Because of the undersampling typically associated with most observational studies, model-derived carbon flux estimates are likely to be the only viable approach for defining these fluxes in a consistent manner on annual time scales. The goal of the USECoS (U.S. Eastern Continental Shelf Carbon Cycling) project is (1) to quantify these coastal carbon fluxes in this region using models quantitatively evaluated by comparisons with observations, and (2) to establish a framework for predicting how these fluxes may be modified as a result of climate and land use change.

## RESULTS

Until recently, our modeled carbon flux estimates for the U.S. Eastern continental shelf (Fig. 1) have neglected a critical component of the coastal carbon cycle: dissolved organic carbon (DOC) dynamics. Simulations generated with our revised model (Fig. 2) demonstrate that the inclusion of DOC dynamics is key to reproducing the temporal and spatial variability of observed satellite-derived quantities, such as particulate organic carbon (POC), chlorophyll (chl, Fig. 3) and primary productivity (PP, Fig. 4). Additionally, the DOC dynamics play a critical role in our coastal carbon budgets (Fig. 5).

## CONCLUSIONS

Including DOM in the model:

- Lowers (and improves) simulated chlorophyll and productivity
- Reduces the annual variability, but not the mean of air-sea $CO_2$ flux
- Reduces burial of organic carbon by factor of three
- Increases offshore flux of organic carbon by factor of two

We also find that:

- Offshore DOC flux is roughly equal to offshore POC flux in SAB and MAB, but exceeds offshore POC flux in GOM
- Simulated air-sea $CO_2$ flux for the U.S. eastern continental shelf is 6.5 ± 0.9 TgC/yr; Simulated PP is 74 ± 3 TgC/yr

## MODELLED CHLOROPHYLL AND PP COMPARISONS

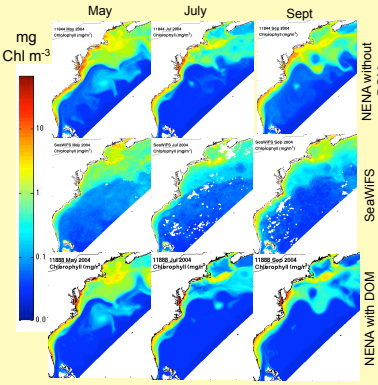


Figure 3. Surface chlorophyll estimates for May, July and September 2004: modeled without DOM (top panels), derived from SeaWiFS data (middle panels) and modeled with DOM (bottom panels). Modeled surface chlorophyll is overestimated when DOM is not included in the model.

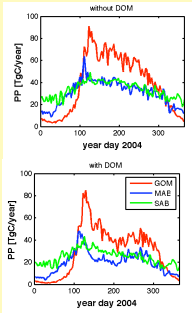


Figure 4. Time-series of PP for the GOM, MAB and SAB without DOM (top) and with DOM (bottom). The total modeled PP for these three regions is:
DOM: ~215±10 $gCm^{-2}y^{-1}$ (or ~74 TgC $y^{-1}$)
noDOM: ~300±10 $gCm^{-2}y^{-1}$ (or ~ 100 TgC $y^{-1}$)

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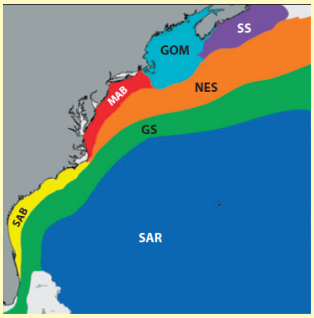


Figure 1. Map of the U.S. East Coast showing the boundaries of the Mid-Atlantic and South Atlantic Bights (MAB & SAB) and the Gulf of Maine (GOM) used in this analysis.

## NENA-DOM: OCEAN BIOGEOCHEMICAL CIRCULATION MODEL

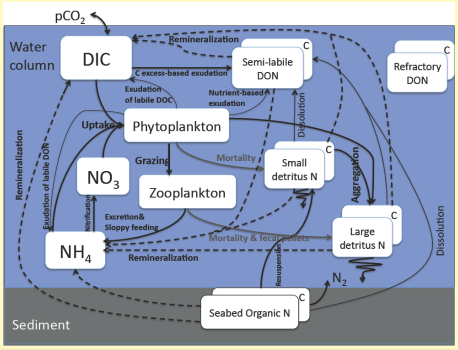


Figure 2. Schematic of biogeochemical and dissolved organic matter (DOM) models incorporated into the Northeast North American (NENA) model, which is based on the Regional Ocean Modeling System (ROMS). The NENA-DOM model is based on Fennel et al. (2006, GBC; 2008, GRL) and Druon et al. (2010, ECSS) and has been modified using measurements from satellites, field studies, historical data, and one-dimensional data assimilative modeling.

## SIMULATED CARBON FLUXES WITH AND WITHOUT DOM

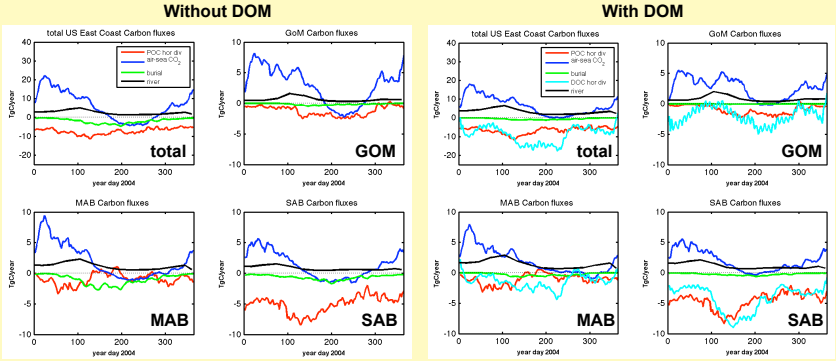


Figure 5. Annual time-series of the rates of carbon input to the GOM, the MAB, the SAB and total (GOM+MAB+SAB; note different scale in this case) via river discharge (black), burial (green), air-sea $CO_2$ flux (blue), and the horizontal divergence fluxes of POC (red) and DOC (cyan). Results shown for model without DOM (left four panels) and with DOM (right four panels). Both models are roughly in steady state, with d/dt (POC+DOC+TIC) ~ 0 when averaged over the year. Note that the addition of DOM to the model decreases burial and increases the annual variability of the air-sea $CO_2$ flux. The mean air-sea $CO_2$ flux is not significantly changed. The net annual fluxes appear in Tables 1 and 2 below.

**Table 1. Net annual fluxes without DOM [TgC/yr]**

| Region | River | Air-sea $CO_2$ flux | Burial | Horiz Div POC | Horiz Div DOC |
|---|---|---|---|---|---|
| Total | 2.6 ± 0.2 | 6.2 ± 0.7 | -1.9 ± 0.1 | -7.3 ± 0.1 | 0 |
| GOM | 0.6 ± 0.1 | 2.9 ± 0.5 | -0.2 ± 0.02 | -1.3 ± 0.1 | 0 |
| MAB | 1.1 ± 0.1 | 2.0 ± 0.5 | -1.1 ± 0.1 | -1.0 ± 0.2 | 0 |
| SAB | 0.8 ± 0.1 | 1.3 ± 0.4 | -0.7 ± 0.1 | -5.1 ± 0.3 | 0 |

**Table 2. Net annual fluxes with DOM [TgC/yr]**

| Region | River | Air-sea $CO_2$ flux | Burial | Horiz Div POC | Horiz Div DOC |
|---|---|---|---|---|---|
| Total | 3.4 ± 0.3 | 6.5 ± 0.9 | -0.5 ± 0.1 | -6.7 ± 0.3 | -8.9 ± 0.8 |
| GOM | 0.8 ± 0.1 | 2.6 ± 0.3 | 0.0 ± 0.0 | -1.0 ± 0.1 | -1.9 ± 0.3 |
| MAB | 1.4 ± 0.1 | 1.9 ± 0.4 | -0.3 ± 0.04 | -1.1 ± 0.2 | -1.4 ± 0.2 |
| SAB | 1.1 ± 0.1 | 1.9 ± 0.3 | -0.2 ± 0.03 | -4.6 ± 0.3 | -4.2 ± 0.4 |

Tables 1 and 2. Net annual carbon fluxes into the GOM, MAB, SAB and all three regions combined (Total). Uncertainties are derived as two standard errors. Note that the inclusion of DOM in the model results in significantly more offshore organic carbon transport and less burial. There is no change in the mean annual air-sea $CO_2$ flux.