Net ecosystem production and organic carbon balance of U.S. East Coast estuaries: A synthesis approach

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Objectives:

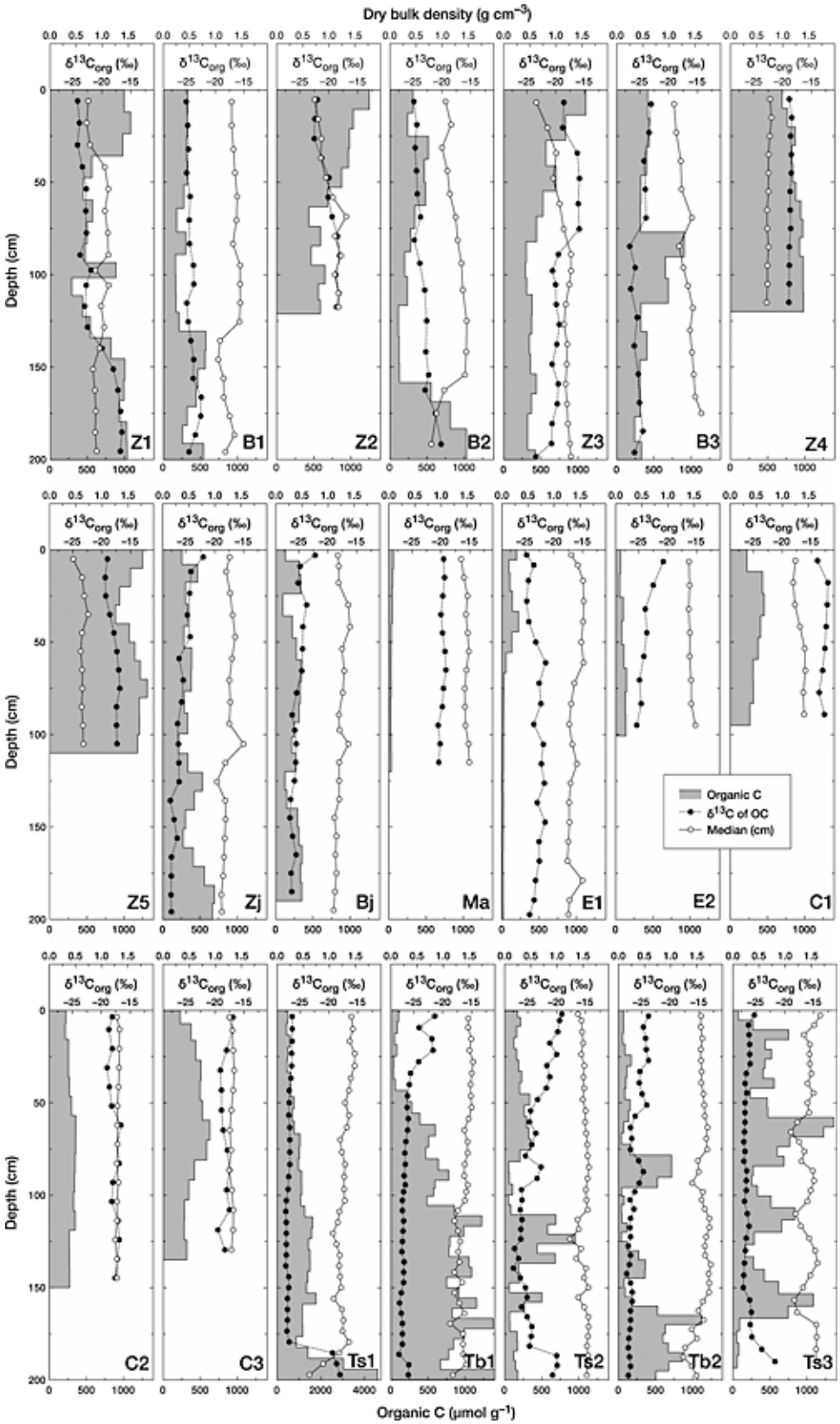
- This paper describes a synthesis approach to the estimation of Net Ecosystem Production (NEP: defined as gross primary production minus community respiration) and the overall organic carbon budget for the estuaries along the East Coast of the United States.
- The study used 52 estuarine drainage areas (EDA) grouped into the following sub-regions: Gulf of Maine (GOM), Mid-Atlantic Bight (MAB), and South Atlantic Bight (SAB).
- With the aim of describing the dominant vectors of organic carbon cycling in the estuaries, the four major terms of the budget used were 1) input across the landward boundary 2) burial in estuarine sediment, 3) estuarine net ecosystem production and 4) export to the ocean.
- The authors developed empirical models relating: 1) NEP to loading ratios of dissolved inorganic nitrogen to total organic carbon, and 2) carbon burial in the sediment to estuarine water residence time and total nitrogen input across the landward boundary.
- Output from a data-constrained statistical water quality model (Spatially Referenced Regression on Watershed Attributes – SPARROW) was used to estimate inputs of total nitrogen and organic carbon to the estuaries across the landward boundary, including fluvial and tidal-wetland sources.
- Given a paucity of data of reliable NEP estimates (i.e. annually and spatially averaged), the authors developed an empirical algorithm for scaling up the local flux estimates to regional scales.
- Net export of organic carbon across the seaward boundary was estimated by difference, assuming steady state.
- Uncertainties in the carbon budget were estimated by allowing uncertainties in the supporting model relations.

New Science:

- The study finds that, collectively, the U.S. East Coast estuaries are net heterotrophic, remineralizing more organic carbon that what is produced by photosynthesis, with the area-integrated NEP of -1.5 (-2.8, -1.0) Tg C yr^{-1} (best estimate (95% confidence interval)) and the area-normalized NEP of -3.2 (-6.1,-2.3) mol C m^{-2} yr^{-1}.
- East Coast estuaries serve as a source of organic carbon to the shelf exporting 3.4 (2.0, 4.3) Tg C yr^{-1} or 7.6 (4.4, 9.5) mol Cm^{-2} yr^{-1}.
- Organic carbon inputs from fluvial and tidal-wetland sources for the region are estimated at 5.4 (4.6, 6.5) Tg C yr^{-1} or 12 (10, 14) mol Cm^{-2} yr^{-1}.
- Carbon burial in the open estuarine waters at 0.50 (0.33, 0.78) Tg C yr^{-1} or 1.1 (0.73, 1.7) mol Cm^{-2} yr^{-1}.
- The results suggest that, in aggregate, U.S. East Coast estuaries assimilate (via remineralization and burial) ~40% of organic carbon inputs from fluvial and tidal-wetland sources and allow ~60% to be exported to the shelf.
- Approximately 35% of total organic carbon input to the East Coast estuaries comes from tidal wetlands, which account for less than 1% of the total drainage area.

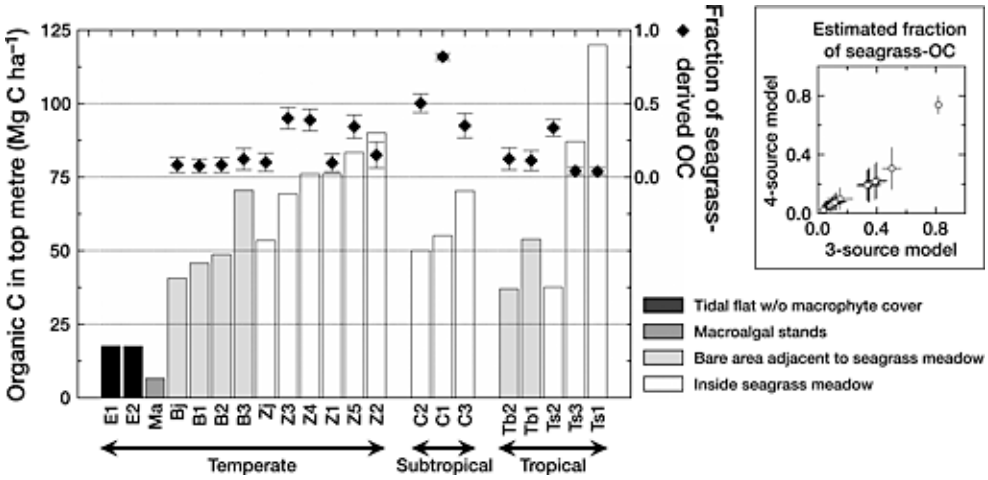
Significance:

- Coastal regions cover a small fraction of the Earth's surface and yet have a major function in the global carbon cycle, because they receive large inputs of carbon from land, and because coastal rates of carbon fixation, respiration and burial tend to be much higher than the global averages.
- Although carbon cycling in inland and coastal waters is a major component of the global carbon budget it has been neglected in past IPCC assessments and often is not included in Earth system models, largely due to limited data availability and the extreme heterogeneity of coast systems, which makes regional and global interpretations particularly difficult.
- Complete carbon budgets for estuaries are critical for a predictive understanding of how such systems will respond to future alternations as a result of human activity and climate change, but are currently only available for a few individual systems, not on the regional scales relevant to the global carbon cycle.
- Challenges for computing fluxes at the regional scale include a high degree of heterogeneity, the lack of sufficient data across system types, and the incomplete understanding of controls on the rates.
- The synthesis approach presented in this paper provides a method of estimation of carbon budgets which addresses the challenges and is suitable for regional upscaling despite parsimonious data inputs.


Dry bulk density (g cm^{-3})
$\delta^{13}C_{org}$ (‰)
Depth (cm)
Organic C (μmol g^{-1})
Z1
B1
Z2
B2
Z3
B3
Z4
Z5
Zj
Bj
Ma
E1
E2
C1
C2
C3
Ts1
Tb1
Ts2
Tb2
Ts3
Organic C
$\delta^{13}C$ of OC
Median (cm)

(a)The empirical model of net ecosystem production (NEP) as a function of riverine loading ratio of dissolved inorganic nitrogen to total organic carbon ($R_{DIN:TOC}$); the shading shows the model uncertainty envelope; the data and the sources are given in Table 2 in the paper, as are the model equations and parameters. The dotted vertical line shows the Redfield nitrogen to carbon ratio for reference.

(b)The empirical model of the buried fraction of total nitrogen input as a function of water residence time (tau); the shading shows the model of uncertainty envelope; open circles show data from Dettman [2001]; data points marked as "other" show burial estimates from literature sources given in section 2.2 and are intended to illustrate the model performance against observations. See paper for model equation and parameters.



(a)Area-integrated budget for the entire U.S. East Coast. Organic carbon fluxes in Tg C yr^{-1} are shown as the best estimate (bars) and the 95% confidence intervals (whiskers). The burial and export terms from the equation (described in detail in the paper) are shown as negative numbers to emphasize that these fluxes represent loss of TOC from the estuaries. (b)Relative contribution of the subregions to the total area-integrated U.S. East Coast fluxes; note that MAB does not contribute to remineralization because the best estimate for the NEP flux is positive (net autotrophic). (c)Area-normalized fluxes by subregion and for the entire U.S. East Coast; note the differences in scales to emphasize the comparisons.