

Reactive-Transport processes across scales: A journey from my doorsteps to the modeling of the land-to-ocean loops of the global carbon cycle

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This contribution, dedicated to my colleague and friend Carl Steefel, briefly reviews how concepts of reactive-transport modeling have progressively permeated into the field of climate-carbon cycle science. Our journey will start with selected examples of the surface and subsurface flow processes that connect terrestrial ecosystems to the ocean and atmosphere through Earth's critical zone, watersheds, coastal systems and marine sediments. Regional upscaling will also be showcased, covering the terrestrial-aquatic system's interface in the Amazon basin, the land-river-(estuary) continua of the European continent and US east coast, and/or the imprint of land-river carbon-nutrient fluxes on the Arctic Ocean biogeochemistry. Although still resting on highly simplified representations of coupled reaction-transport, we will then illustrate that the global-scale integration of land-to-ocean processes in Earth system models of the coupled climate-biogeochemical cycles is now at reach, stressing where we stand and what are the key remaining major shortcomings [1,2]. We will conclude by emphasizing how the integration of watershed science and their connected coastal settings modifies our quantitative understanding of the global carbon cycle and its perturbation by human activities [2].

[1] Battin, T., Lauerwald, R. and Regnier P. River ecosystem metabolism and carbon biogeochemistry in a changing world, *Nature*, 613, 449-459, 2023.

[2] Regnier, P., Resplandy, L., Najjar, R., and Ciais, P. The land-to-ocean loops of the global carbon cycle. *Nature*, 603, 401-410, 2022.