From a source to a sink: the role of biological activities on atmospheric CO$_2$ exchange along the river-ocean continuum.

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Freshwater transports organic and inorganic carbon (C) from the terrestrial biosphere to the coastal ocean, yet this transfer is not conservative, as freshwater ecosystems produce, degrade, store organic C and exchange carbon dioxide (CO$_2$) with the atmosphere. Freshwater ecosystems are often reported as net heterotrophic, whereby the organic C respiration is higher than the autochthonous production of organic C, and excess organic C consumption is maintained by inputs of allochthonous organic C. Net freshwater heterotrophy promotes the emission of CO$_2$ to the atmosphere, with global emission from continental waters being significant for global CO$_2$ budgets. Coastal waters further process the matter received from rivers, and can either act as source or a sink for atmospheric CO$_2$. A mechanistic chain of biogeochemical models, taking into account the transfer and transformation of C, N, P, Si, was implemented to study the C cycle and the air-water CO$_2$ flux in river, estuarine and coastal environments. For this application, the model was applied to the anthropized Scheldt basin and the Belgian coastal zone and the evolution of the pCO$_2$ and air-sea CO$_2$ flux was simulated for the year 2006. Results show that two processes control the value and seasonal evolution of water pCO$_2$: exchange of CO$_2$ with the atmosphere and net ecosystem production (NEP). In both the Scheldt River and its estuary, whereas the emission of CO$_2$ to the atmosphere sets the overall background pCO$_2$ values, NEP controls the seasonal variations. In the Belgian coastal zone, on the contrary, the pCO$_2$ levels and seasonality are mainly controlled by NEP while the exchange of CO$_2$ with the atmosphere has a minor role in pCO$_2$ dynamics. This is related on one hand to the very high pCO$_2$ values brought by ground waters in the river, leading to very intense emissions of CO$_2$ to the atmosphere, and on the other hand on the higher buffering capacity of saline compared to brackish and freshwaters. On an annual basis, biological activities lead to a source for atmospheric CO$_2$ in the river and the estuary and as a sink or a source for CO$_2$ in the coastal environment depending on the relative importance of C and nutrient inputs. Model results are also used to compute annual air-water CO$_2$ budgets.