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Editorial: Carbon Cycling in Aquatic Critical Zones

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Editorial: Carbon cycling in aquatic critical zones

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Editorial on the Research Topic
Carbon cycling in aquatic critical zones

Understanding the processes and mechanisms controlling carbon biogeochemistry in aquatic ecosystems, under the influence of human activities and climate change, is essential in global change studies and Earth System Models. New physicochemical boundaries in aquatic systems, created in the Anthropocene, are providing corridors for rapid biogeochemical and organismal change. Here, we define such aquatic critical zones (ACZs) as the interfaces where crucial geological, chemical, biological and physical processes operate together to sustain systematic functionalities of aquatic systems (Bianchi and Morrison, 2018). Natural ACZs have always existed, such as fjords, lakes, reservoirs, river reaches below dams, river confluences, river plumes, riverine floodplains, irrigation ditches, wetlands, mobile mud belts, and estuarine turbidity maximum zones (Figure 1). However, land-use and climate change have in some cases enhanced biogeochemical gradients in ACZs and in other cases created new types of ACZs such as hypoxic and harmful algal bloom (HAB) regions. Some of these changes have resulted in unusually steep concentration gradients in abiotically and biotically derived dissolved and/or particulate constituents that have significantly altered elemental cycling from micro-to mesoscales. The highly dynamic character of ACZs provides unique opportunities for examining the global impact of human activities on carbon cycling across land-ocean boundaries.

Carbon composition and transport behavior in ACZs have changed greatly due to anthropogenic and climate effects in recent decades. For example, global estimates of the erosion and transport of higher plant detritus and soil carbon from land to rivers *via* surface water runoff are highly variable, in part due to spatial heterogeneity of land-use change, deforestation, water and soil conservation, droughts, and storms (Lal, 2003). Similarly, the production of autochthonous organic carbon (OC) has dramatically increased in rivers, lakes, reservoirs, estuaries, and marginal seas, where OC

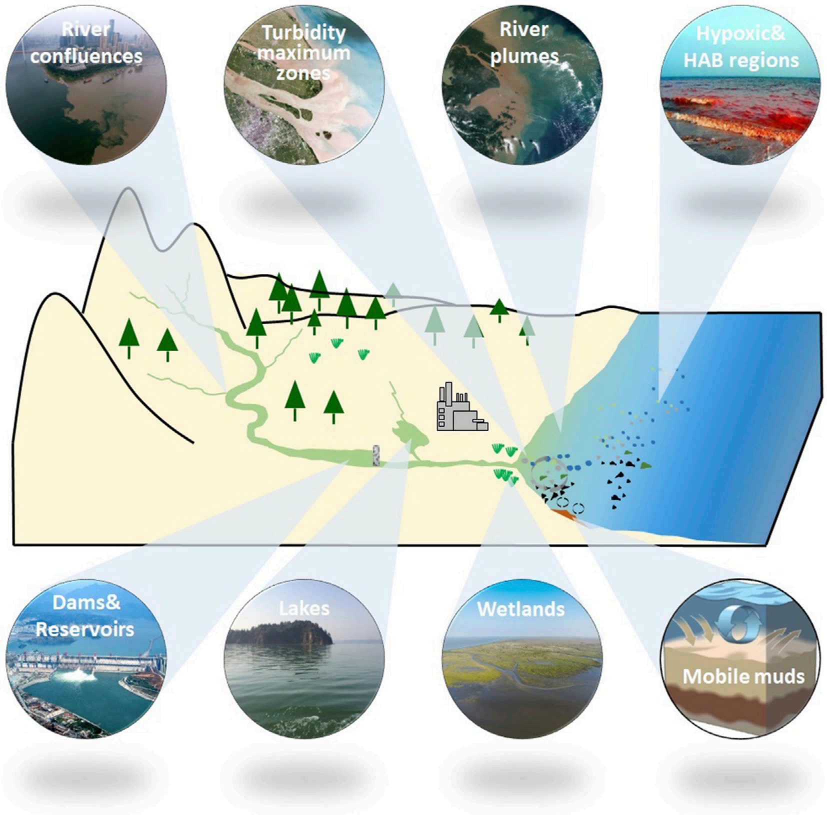

FIGURE 1
Typical aquatic critical zones (ACZs) along the aquatic continuum.

processing rates are unusually high (Cloern et al., 2014; Maavara et al., 2017; Mendonça et al., 2017; Gao et al., 2021). A better understanding of the controls on water residence time and biotic/abiotic decay kinetics of organic matter in these ACZs is key to improving predictions by Earth System Models (Li et al., 2017). In this Research Topic, six studies provide a broad range of spatial-temporal data on carbon cycling in ACZs, from drainage basins to estuaries, coastal bays, coral islands, and the deep sea.

River restoration aimed at rewetting the valley floor has the potential to increase OC stocks in the form of floodplain soil carbon, downed wood, and riparian vegetation. To quantify the carbon sequestration potential of different restoration approaches in diverse geographic settings (Hinshaw and Wohl), developed a conceptual framework to identify the conditions that maximize carbon storage in relation to characteristics of the river corridor and specific restoration practices. This conceptual model may help to identify levels of hydrologic connectivity, channel and floodplain dynamics, floodplain vegetation, and other variables that may optimize carbon storage at treatment sites.

An estimation for inland waters showed that autochthonous production (AP) has been strengthened during recent decades, due chiefly to increasing aquatic photosynthesis caused by global warming and intensifying human activities (Liu et al.). The increasing AP resulted in the decreasing of CO_2 emissions from inland waters and the increasing of dissolved OC storage and/or OC burial in inland waters. The residual land sink (or missing carbon sink) associated with the strengthening AP in inland waters may range from 0.38 to 1.8 Gt C yr^{-1}, indicating that AP may play an important role in the further evolution of the global carbon cycle.

Anthropogenic inputs have significant Influences on particulate and dissolved OC (POC and DOC) cycling in estuaries and coastal seas, including coastal bays. An investigation on the characteristics and distributions of DOC in three costal bays (Jiaozhou Bay, Sishili Bay, and Taozi Bay) in North China showed that the optical and isotopic characteristics of DOC in these coastal bays were regulated by multiple sources (river inputs, aquaculture activities, waste dumping, and sewage discharge) and processes (biological production and photodegradation), with river inputs as the main factor that causes the variation of DOC in these coastal bays (Li et al.

). Similarly, riverine discharge was also identified as the major source for particulate and dissolved black carbon (PBC and DBC) in another two coastal bays (Bohai Bay and Laizhou Bay) in North China. The quantity and quality of PBC and DBC in these two bays varied seasonally and interannually due to significant changes of fluvial hydrological regimes, solar radiation and sediment dynamics (Fang et al.).

Submarine groundwater discharge (SGD) can be an important source of carbon to coastal regions. Lui et al. found that the SGD of two isolated coral islands (Liuqiu Island and Dongsha Island), located in the northern South China Sea discharge high dissolved inorganic carbon (DIC) and low pH water to surrounding areas all year round. This acidic SGD waters may cause observable dissolution of carbonate skeletons or shells of some marine organisms, especially those with high Mg:Ca ratios. This work indicated that the impact of SGD on coastal biogeochemical cycles and ecosystems deserves further investigation.

Climate change and human activities can impact OC cycling in deep ocean waters. The Tropical Western Pacific Ocean (TWPO) is one of the most sensitive areas in response to global change, and the oxygen minimum zone (OMZ) in this region has expanded greatly during past decades. According to an investigation in the Kocebu seamount area of the TWPO, the presence of an OMZ in the water column of 590–1,350 m reduced the decomposition rate of POC, causing more POC to sink into deeper waters (Ma et al.). The interaction between OMZ and POC sinking flux has far-reaching influence on deep sea carbon cycling and burial in the context of global change.

In summary, both inorganic and organic carbon in ACZs are characterized by steep concentration gradients and diverse processes, and the spatial-temporal evolution of carbon cycling in ACZs has been significantly modified by climate change and human activities. Multidisciplinary approaches to trace carbon cycling in ACZs from source to sink are necessary to better understand transport and transformation of carbon species in diverse habitats along the aquatic continuum and land-ocean margin in the Anthropocene.

Author contributions

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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