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Modeling of global plastic dynamics and their relation to biogeochemical cycles in terrestrial-aquatic-estuarine continuum

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Recent research has shown that inland water plays some role in carbon cycling, although its contribution has remained uncertain (Battin et al., 2009). In addition, contamination of plastic materials has received more attention during the last few decades (Kooi et al., 2018). Some models succeeded to simulate transport and fate of plastic debris in freshwater systems (Meijer et al., 2021), but a complete model is under development to elucidate the whole picture of plastic dynamics in continental scale. The author has developed a process-based eco-hydrology model, NICE (National Integrated Catchment-based Eco-hydrology) (Nakayama and Watanabe, 2004), and applied it to various basins. NICE can simulate iteratively nonlinear interactions between hydrologic, geomorphic, and ecological processes (Nakayama, 2020). Recently, this model was extended to biogeochemical cycle in terrestrial-aquatic-estuarine continuum (Nakayama, 2022, 2023), and to couple with plastic debris model (Nakayama and Osako, 2023a, 2023b, 2024).

In this study, the author extended NICE to model plastic dynamics and their relation to biogeochemical cycles in terrestrial-aquatic-estuarine continuum. New model used Dirichlet boundary condition at the downstream of global major rivers. Generally, CO_2 degassing decreased and POC increased in most rivers. The simulated result also showed estuarine carbon cycle was sensitive to intense anthropogenic disturbances reflected by nutrient load, seawater temperature, sea level rise, and ocean acidification. In addition, the result showed seasonal variations of plastic fluxes, and flood events have a great impact on plastic mobilization (van Emmerik et al., 2019). NICE was further extended to incorporate biofouling (with algae and phytoplankton) and heteroaggregation (with suspended particulate matter) to improve the accuracy of global plastic dynamics in global river basins and the amount of plastic flows from land into rivers and finally into the ocean. The result implied the plastic dynamics are related to this carbon cycles, particularly in terrestrial-aquatic-estuarine continuum.

These results help to improve estimates of plastic dynamics and their relation to carbon budgets in inland water, thus emphasizing the effect of estuary should be explicitly included in plastic dynamics and biogeochemical cycles to minimize uncertainty of the model.