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Modelling flow-dependent CO_2 emissions from stream metabolism in contiguous US rivers

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River metabolism controls CO_2 emissions along the land-ocean aquatic continuum yet remains highly uncertain in large-scale carbon budgets. Using a machine learning approach, we modelled estimates of gross primary productivity (GPP) and ecosystem respiration (ER) for rivers across the contiguous United States (CONUS). We evaluated metabolic responses to extreme hydrological conditions like drought and flooding, and identified the ranked importance of drivers of stream metabolism. Our model predicts annual GPP in CONUS rivers of 10.1 Tg-C yr^{-1} and ER of 18.7 Tg-C yr^{-1}, implying that net ecosystem productivity (NEP = GPP – ER) may be a small contributor to river CO_2 emissions at the national scale. More than 70% of river metabolism occurs in western states, where regions of both extreme heterotrophy and autotrophy exist. We find autotrophy to be more prominent across the western US, with an annual average of 25% of western US rivers experiencing autotrophy on monthly timescales, compared with 11% of rivers in the east. Autotrophy is especially prominent in biomes like arid environments including deserts, grasslands and shrublands, which may suggest that global riverine uptake of CO_2 is higher than hypothesized, given the understudied nature of arid rivers in freshwater biogeochemistry. Our results show that at the CONUS scale, ER is less sensitive to changes in flow, while increases in GPP occur in response to drought.