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The importance of hydrology in routing terrestrial carbon to the atmosphere via global streams and rivers

SHAODA LIU[1], CATHERINE KUHN[2], GIUSEPPE AMATULLI[3], KELLY AHO[3], DAVID BUTMAN[2], GEORGE ALLEN[4], PEIRONG LIN[5], MING PAN[6], DAI YAMAZAKI[7], CRAIG BRINKERHOFF[8], COLIN GLEASON[8], XINGHUI XIA[1] AND PETER RAYMOND[3]

[1]Beijing Normal University
[2]University of Washington
[3]Yale University
[4]Texas A&M University
[5]Peking University
[6]Princeton University
[7]Tokyo University
[8]University of Massachusetts

Presenting Author: liushaoda@bnu.edu.cn

The magnitude of stream and river carbon dioxide (CO_2) emission is affected by seasonal changes in watershed biogeochemistry and hydrology. Global estimates of this flux are, however, uncertain, relying on calculated values for CO_2 and lacking spatial accuracy or seasonal variations critical for understanding macroecosystem controls of the flux. Here, we compiled 5,910 direct measurements of fluvial CO_2 partial pressure and modeled them against watershed properties to resolve reach-scale monthly variations of the flux. The direct measurements were then combined with seasonally resolved gas transfer velocity and river surface area estimates from a recent global hydrography dataset to constrain the flux at the monthly scale. Globally, fluvial CO_2 emission varies between 112 and 209 Tg of carbon per month. The monthly flux varies much more in Arctic and northern temperate rivers than in tropical and southern temperate rivers (coefficient of variation: 46 to 95 vs. 6 to 12%). Annual fluvial CO_2 emission to terrestrial gross primary production (GPP) ratio is highly variable across regions, ranging from negligible (<0.2%) to 18%. Nonlinear regressions suggest a saturating increase in GPP and a nonsaturating, steeper increase in fluvial CO_2 emission with discharge across regions, which leads to higher percentages of GPP being shunted into rivers for evasion in wetter regions. This highlights the importance of hydrology, in particular water throughput, in routing terrestrial carbon to the atmosphere via the global drainage networks. Our results suggest the need to account for the differential hydrological responses of terrestrial–atmospheric vs. fluvial–atmospheric carbon exchanges in plumbing the terrestrial carbon budget.