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Quantifying Carbon Cycling across the Groundwater-Stream-Atmosphere Continuum Using High-Resolution Time Series of Multiple Dissolved Gases

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The transport and transformation of carbon across the groundwater-stream-atmosphere continuum (GSAC) is a crucial component of regional and global carbon cycling [1]. Recently, quantifying carbon cycling across GSAC gained much scientific interest [2, 3]. However, this quantification is challenging as many physical and biogeochemical processes that shape carbon dynamics in GSAC are highly intertwined.

In the present study, we disentangled carbon cycling in a typical groundwater-stream-atmosphere transect by determining and numerically simulating high-resolution time series of dissolved He, Ar, Kr, O_2, CO_2, and CH_4 concentrations. We estimated the gas exchange rates at groundwater-stream and stream-atmosphere interfaces by fitting the high-resolution time series of dissolved noble gas (Ar and Kr) concentrations observed in the stream. We further integrated the high-resolution time series of dissolved O_2, CO_2, and CH_4 concentrations into the constrained numerical flow model to interpret the carbon biogeochemical processes.

Our results reveal that groundwater discharge is the dominant and constant carbon source for the stream, supporting stream CO_2 and CH_4 emissions to the atmosphere. Strong diurnal variation in stream metabolism (-0.6 - 0.6 mol O_2 m^{-2} d^{-1}) induced carbonate precipitation during the day and dissolution at night. Our study shows that dissolved gases are promising environmental tracers for discerning and quantifying carbon cycling across the GSAC with high spatiotemporal resolution.

[1] Goldschmidt, Battin et al. (2023), *Nature* 613, 449-459;

[2] Goldschmidt, Duvert et al. (2018), *Nat. Geosci.* 11, 813-818;

[3] Goldschmidt, Marx et al. (2017), *Rev. Geophys.* 55, 560-585