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Using spectral decomposition to investigate CO_2 concentration patterns and soil-stream linkages in a boreal headwater stream

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The export of terrestrial carbon (C) to inland waters is a key control on aquatic ecosystems as well as the large scale cycling of C. Historically, the temporal resolution of aquatic CO_2 concentration observations have been too low to capture the spectrum of time scales over which the governing C processes occur. However, the development of new technologies to obtain high frequency observations using in-situ sensors has provided new possibilities to monitor and analyze the C cycling in inland waters. Here, we investigated CO_2 concentration dynamics along an upslope-riparian-stream transect in a boreal headwater stream in the Krycklan Catchment, located in the northern part of Sweden. We utilized a set of spectral methods and analyzed a high-frequency (hourly resolution) dataset for aquatic C with the aim to identify spatiotemporal patterns in CO_2 concentration fluctuations and soil-stream linkages.

The spectral methodology decomposes the observed time series into a spectrum of periodicities and the analyses revealed a high spatiotemporal variability in predominant periodicities of CO_2 concentration fluctuations across the soil-stream transect. In addition, the spectral coherence between time series of CO_2 concentration and water levels were used to explore soil-stream linkages affecting the in-stream CO_2 concentration. The hydro-chemical connectivity along the soil-stream transect was found to be far more complex and intermittent than the hydrological connectivity, which had a very high and consistent coherence across a wide spectrum of periods Moreover, the spectral coherence between the riparian groundwater level and in-stream CO_2 concentration, highlighted a strong control of hydrology on in-stream CO_2 dynamics. However, during specific hydrological events the simple concentration dilution relationship in the stream was obscured. We hypothesize that flow dependent riparian source areas as well as in-stream processes caused the variabilities in the hydrochemical connectivity between the stream and the riparian soil.

This work emphasizes the relationship between stream CO_2 and riparian soil hydrology and highlights the power of decomposing hydrochemical time series to test hypotheses about the connectivity and biogeochemical transformation along pathways that link aquatic and terrestrial systems.