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Exploring the role of river discharge and temperature regulation in hyporheic exchange processes

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Heat transport within the hyporheic zone strongly affects biogeochemical reactions, and therefore it plays a fundamental role in ecological services, river management, and habitat restoration. With this in mind, we perform a systematic analysis to gain a mechanistic understanding of how the variability of river discharge and temperature impact flow and transport within bedform-driven hyporheic zones. We used time series of river discharge and temperature for stations along the Mississippi River Basin, which are characterized by different degrees of regulation, to force a physics-based model of the hyporheic exchange process. Our modeling results indicate that coupling flow and heat transport significantly affects the dynamic response of hyporheic zones, resulting in substantial differences in the exchange rates and characteristic timescales. We also find that the hyporheic zone acts as a low-pass filter, removing high-frequency temperature oscillations. The importance of this filtering effect depends on the characteristic timescales for surface discharge and temperature variability (the driving forces) and the hyporheic zone's transport timescale (the modulator). This work has important implications for understanding local variability in hyporheic exchange and its implications for thermal refugia and ecosystem functioning.