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Exploring the dynamics of hyporheic zones

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Hyporheic zones (HZs) are characterized by the exchange of water, solutes, momentum and energy between streams and aquifers. Stream stage fluctuations and streambed topography induce pressure gradients along the sediment-water interface and drive hyporheic exchange flow (HEF).

With this in mind, changes in time-dependent hydrologic forcing can have significant effects in the hydrodynamic and transport characteristics of HZs. While previous research has improved our understanding of the drivers and controls of HEF, little attention has been paid to the potential impacts of transient dynamic hydrologic forcing. In this study, we developed a two-dimensional, homogeneous flow and transport model with a time-varying pressure distribution at the sediment-water interface to explore the dynamic development of HZ characteristics in response to discharge fluctuations. With this model, we explore a wide range of plausible scenarios for discharge and bed geometry (such as dunes, ripples, alternating bars). Our modelling results show that a single flood pulse alters the area and depth of the HZ, though quantitatively different, when investigated using hydrological (streamlines/flow field) and geochemical (>90% of surface water in streambed) approaches of HZ. We summarize the results of a comprehensive sensitivity analysis where the effects of hydraulic geometry (slope, amplitude of the streambed), flood characteristics (duration, skewness and magnitude of the flood wave) and biogeochemical timescales (time-scale for oxygen consumption) on the HZ's extent, mean age, and oxic/anoxic zonation are explored. Taking into consideration these multiple morphological characteristics along with variable hydrological controls has clear potential to facilitate process understanding and upscaling.