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Effect of bar topography on hyporheic flow in gravel-bed rivers

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The hyporheic zone is a rich ecotone influencing solute transport and nutrient cycling in rivers. In this study we analyse, by means of a Lagrangian approach, how the hyporheic flow influences solute transport along a river reach. Hyporheic flow is generated by an uneven distribution of the water pressure at the riverbed, which is tied dynamically with the bed topography. We focus here on a gravel-bed river developing free bars, assuming for simplicity that water discharge is constant and that the typical time scale of subsurface flow is small with respect to the morphological time scale controlling bar development and migration. In such a situation the bed topography can be assumed as fixed in time. Furthermore, since in most practical situations hyporheic flow is a small fraction of the total streamflow, surface and subsurface flows can be uncoupled, with the latter reducing to a Darcyan flow controlled by the water head at the riverbed. First we solve analytically the three-dimensional flow equation in a domain of finite thickness and with the reach width and bar wavelength as horizontal dimensions. Then the velocity field is obtained through the Darcy's equation. Finally, solute transport is modeled numerically by particle tracking. We show that the residence time of the solute is Log-Normally distributed. Furthermore, we found that the travel time moments depend on the parameters controlling bedform morphology, suggesting that river morphology influences solute transport and nutrient cycling. The extension of these results to a sequence of bars suggests a possible interpretation of the long tailing observed recently in the breaktrhough curves of passive tracers in headwater streams.