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Heat transport in the hyporheic zone as controlled by interaction of a turbulent current with bedforms

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The thermal regime of sediments underlying a flowing water column is regulated by the competing effects of heat conduction and advection, with heat advection governed by a combination of local effects, due to current-bedform interaction, and larger-scale effects due, for example, to stream configuration and surrounding topographically-controlled groundwater flow. We use mathematical models to investigate the particular situation where fluid exchange between a water column and underlying sediments is forced by spatially varying head gradients along the sediment-water interface (SWI), caused to current-bedform interaction, and by ambient groundwater discharge (AGD) due to larger-scale hydrologic processes. The bedforms are dunes with a one meter wave-length. Heat transport is forced by a diel variation of temperature in the water column. Coupled models simulate turbulent flow in the water column and Darcy flow and heat transport within sandy sediments. Current-bedform induced fluid flow in the sediments results in a complicated but predictable interfacial exchange zone (IEZ) pattern and transient heat distribution. When AGD is present, the influence of current-bedform induced advection becomes subdued until, at higher rates of AGD, fluid flow and heat transport becomes essentially vertically one-dimensional. For lower AGD rates, with the complex IEZ pattern, strong diel temperature variations may be found horizontally adjacent to zones lacking any substantial temperature variations. The zones with weak temperature variations are found close to crests of dunes where pore water is upwelling from deeper areas of the sediments. Strong temperature variations are observed underneath areas along the lower part of the stoss face of the dunes, where water is recharging the IEZ from the water column. This complex pattern of temperature variation is important for more permeable sediments. Less-permeable

sediments are dominated by heat diffusion, and heat transport becomes essentially one dimensional. Current-bedform induced fluid flow and AGD substantially affect the thermal regime of permeable sediments and thus should influence important hyporheic ecological and biogeochemical processes.