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Evaluating thermal diffusivity in stream-beds from temperature spectra

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Recent studies utilize the analogy of heat and solute transport in streams to extend the amount and type of data that can be used to interpret stream-mixing processes. Particularly the exchange of heat and solutes with the hyporheic zone has great implications for water quality and stream ecology and has therefore been the subject of extensive investigations the past couple of decades. Heat transport in aquatic sediments has been studied specifically to evaluate the vertical mixing properties as well as their longitudinal variation along a river. Here a new methodology is proposed by which the power spectra of in-stream temperature are related to the power spectrum of the temperature at a specific sediment depth by means of exact solutions of a physically based formulation of the vertical heat transport. Data for this evaluation was obtained by installing temperature sensors at different depths in the sediment of Säva Brook, Sweden. Measurements were performed down to about one meters depth at seven measuring stations distributed along a 16 km stream reach. The feasibility of the approach was evaluated using variants of the exact solution that account for vertical conduction-convection, layered thermal diffusivity and a segmentwise evaluation of the vertical variation in thermal diffusivity. It is shown that any frequency (ω) of in-stream temperature fluctuation scales with thermal diffusivity (κ_e) and vertical separation distance between temperature (ε) data as $\omega \propto \kappa_e/(2\varepsilon^2)$, which implies an decreasing weight to higher frequencies (shorter periods) with depth. The ratio of the power spectra of the temperature time-series at two different depths is given by $\mathrm{P}_1(P_2)^{-1} = exp[-(2\omega/\kappa_e)^{0.5}\varepsilon]$. Furthermore, the spectral ratio varies along Säva Brook and as a function of stream water depth (i.e. over time). This behaviour can be explained from the change of stream water depth causing variation in the hyporheic exchange and the apparent (effective) thermal diffusivity.