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Using wavelet analysis to derive seepage rates from thermal records

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The use of thermal records to detect loosing and gaining reaches of streams and also to determine water fluxes between surface water and groundwater has attracted researchers in hydrological sciences worldwide. This method is attractive due to the high resolution and quality of the temperature data and the relatively low costs of the equipment needed to collect the data in the streambed and therefore is widely applied.
Stream water temperature fluctuates on different time scales, with strong diurnal and seasonal fluctuations. When the temperature signal propagates into the aquifer, it is attenuated and shifted in time, where the degree of signal attenuation and its shift are determined by the fluid flow velocity, thermal properties of the sediment matrix, and the frequency of the temperature signal. High-frequency signals (diurnal or smaller) are damped more than low-frequency signals (seasonal or annual). Vertical fluxes can be estimated from the amplitude ratios of temperature oscillations measured between two depths in the stream bed by using the one-dimensional heat transport equation by STALLMAN (1965) when the sediment properties between this two depths are assumed to be homogeneous.
However, before this calculations can be performed a time-frequency analysis has to be performed. In contrast to the Fourier transform, which is most common, the use of wavelets allows also to capture non steady-state frequency responses. This, of course, is a huge advantage of the wavelet analysis for hydrological applications as most environmental signals are non steady-state. Wavelet transform decomposes a signal into a time-frequency space and therefore localized intermittent periodicities in the signal can be detected. The wavelet power spectrum that is yielded then allows to separate these different periods, e.g. daily cycles and seasonal signals.
To test this method, temperature data that was recorded for a period of 2 years in a stream and its riverbank at a field site in Luxembourg (BANZHAF et al., 2011) was used. By filtering the temperature raw data with the wavelets, a daily component of temperature variation was isolated and used to calculate daily seepage rates.

BANZHAF, S., KREIN, A. & SCHEYTT, T. (2011). Investigative approaches to determine exchange processes in the hyporheic zone of a low permeability riverbank. Hydrogeology Journal 19 (3), pp. 591-601.
STALLMAN, R. W. (1965). Steady one-dimensional fluid flow in a semi-infinite porous medium with sinusoidal surface temperature. Journal of Geophysical Research 70 (12). pp. 2821-2827.