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Using a spectral approach to compare dynamic and static head driven hyporheic exchange

Anders Wörman, Ida Morén, and Joakim Riml
The Royal Institute of Technology, Division of River Engineering, Stockholm, Sweden (worman@kth.se)

Hyporheic exchange is an important process controlling the transportation and fate of solutes in natural streams. The exchange is driven by the hydraulic head gradients over the stream bottom and occurs on a wide range of spatial scales. The hydraulic head gradient is either dominated by the static head, originating from water surface elevation differences or it is dominated by the dynamic head that is created when the velocity head of the stream is transformed to pressure variations along an uneven bed surface. This article uses a power spectral approach to compare the exchange due to the static and dynamic head occurring over a range of spatial scales in the Tullstorps Brook.
Prediction of hyporheic exchange is restrained by the complications of performing measurements of high quality and quantity in the field. In this study bottom elevation and water depth was measured with a levelling instrument every 2.56 – 16.83 m along a 500 m long reach of the Tullstorps Brook. The velocity head was calculated at the same sections based on the measured cross section area of the stream and the average discharge during the day when the measurements were done. Parallel to the head investigations a Rhodamine WT tracer test was performed in the reach and the parameters controlling hyporheic exchange was estimated through inverse modelling. These tracer test parameters were compared with theoretical parameters obtained from a spectral model.
Hyporheic exchange is often modelled by assuming the head variations to be harmonic with a certain wavelength and amplitude. In the reality the head variation cannot be represented by a single harmonic function, but the representation of head geometry can be improved by superimposing a large number of harmonic functions. Here, to be able to include the whole range of harmonics, we used a power spectral approach to analyse the hydraulic head measurements from the field. The Fourier power spectrum of the data was calculated for the water surface and bed elevation and related theoretically to the expected exchange velocity caused by the static exchange – related to the power spectrum of the water surface – and the dynamic exchange – related to the bed surface power spectrum. Also the velocity field for the bed was defined through the superimposition of all calculated velocities in the spectra and the residence time distribution (T, CVT) was modelled numerically. This analysis was done for the static head as well as the dynamic head.
Comparison of the exchange velocity and residence time obtained from the two methods indicates that hyporheic exchange is explained a) a relatively wide range of hydraulic head anomalies, a fractal scaling behaviour and c) a domination of static head driven exchange over dynamic head driven exchange.