Geophysical Research Abstracts
Vol. 16, EGU2014-10258, 2014
EGU General Assembly 2014

Determining Groundwater-Surface Water Exchange Fluxes and Their Spatial Variability Using the Local Polynomial Method LPML

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Understanding groundwater-surface water interaction has become an important aspect in many studies of coupled groundwater-surface water systems. The quantification and delineation of groundwater-surface water exchange fluxes is of special interest as fluxes are a key parameter in flow and transport processes at the groundwater-surface water interface (GSI). One way to quantify exchange fluxes across the GSI is by making use of heat as a natural tracer and measuring streambed temperatures over certain periods of time. Temperature time series data are commonly analyzed by (1) relatively simple and easy-to-use analytical solutions to the vertical 1D heat transport equation or (2) by numerical models, where they are sometimes used together with additional hydraulic field data for a more complex analysis of the underlying flow processes.

In this study, we estimate vertical exchange fluxes based on a new solution to the 1D heat transport equation, called LPML. It determines the frequency response function of the subsurface to a known input temperature at its top. This frequency response and its uncertainty are acquired by using the Local Polynomial (LP) Method. Afterwards, a maximum-likelihood (ML) estimator is applied to estimate fluxes and determine their uncertainty.

Temperature time series collected with multi-level temperature probes at several locations and various depths of the riverbed of the Slootbeek (Belgium) were analyzed with the LPML in several scenarios. For the Slootbeek, strongly heterogeneous upwelling conditions were found with flux estimates ranging from -19 to -650 mmd-1. Disparities in fluxes can be attributed to variations in riverbed morphology and organic matter content at the riverbed top. Results were compared to those obtained with VFLUX and STRIVE, two other 1D models often used to quantify fluxes, and showed a good agreement (within one standard deviation to same order of magnitude depending on the scenario). A comparison with direct flux measurements by means of seepage meters showed same order of magnitude results at three locations in the river.