Geophysical Research Abstracts
Vol. 14, EGU2012-11603, 2012
EGU General Assembly 2012

Coupled water and heat transport modelling to evaluate reach scale hyporheic exchange fluxes

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Surface waters and groundwater are the interconnected hydrological main parts of stream catchments. They are coupled by variable water, solute and heat exchange processes through streambed sediments. The spatial and temporal variability of these exchange processes depend on the heterogeneity of hydraulic and thermal streambed properties and the interplay between stream and groundwater hydraulic conditions. Better understanding these processes facilitates the research on biogeochemical and ecological processes at the direct interface between river and aquifer (hyporheic zone) and their effects on ecosystem functioning in natural and human impacted water resources. Besides intense experimental investigations, simulation models are used to advance the process understanding and to develop predictive capability of such coupled hydrological systems.
The aim of this study is the development of a 3-D, coupled water flux and heat transport model of an exemplary lowland river using the control-volume finite element model HydroGeoSphere to quantify heat exchange fluxes. HydroGeoSphere is a fully-integrated surface-subsurface flow and transport model including fully-integrated thermal energy transport. We will use river head and hyporheic temperature measurements to calibrate the numerical, process based model. Subsequent transient simulations based on an experimental data set will highlight the advantages of using HydroGeoSphere for identifying the complex water and heat flux patterns in natural systems.
Field data were collected at an experimental river reach of about 100 m at the Selke River, which is a lowland gravel bed river in Germany, characterized by distinctive pool riffle sequences. Time series of hydraulic heads and temperatures were measured at different depth in the river bank and within the river. For the hyporheic zone temperature survey multi-level temperature lances, measuring surface water temperature and streambed temperatures at 7 different depths, up to 0.6 m deep, were permanently installed along the pool riffle sequences and within flat parts of the river channel. River exchange was furthermore investigated by active heat tracer experiments using heat pulse injection. The spatial variability of hydraulic conductivity of the streambed sediments will be estimated by Sequential Gaussian Simulation based on the evaluation of scattered slug tests.
The results of the 3-D numerical model will clarify the spatial and temporal behavior of the surface water groundwater exchange flux and distinctive temperature patterns at the experimental site. The evaluation will highlight the benefit of coupled water and heat transport modelling to evaluate the spatial and temporal variability of reach scale hyporheic water and heat exchange fluxes.