Geophysical Research Abstracts
Vol. 19, EGU2017-6783, 2017
EGU General Assembly 2017

Investigating temporal and spatial patterns of groundwater-surface water interaction on a river reach by applying transient thermal modelling

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The quantification of groundwater-surface water interaction is an important challenge for hydrologists and ecologists. Within the last decade, many new analytical and numerical estimation methods have been developed, including heat tracer techniques. In a number of publications, their sources of errors were investigated, and future directions for the research in groundwater-surface water exchange were discussed. To improve our respective knowledge of the Belgian lowland Aa River we reinvestigate temperature data which was gathered in the river bed and used for the quantification of the 1D vertical groundwater-surface water exchange. By assuming a thermal steady state of the river bed temperature distribution, Anibas et al. (2011) were unable to use the full potential of the entire large data set. The analysis tool STRIVE is modified to use the river water temperature time series as the upper model boundary. This transient thermal set up overcomes many of the limitations of the steady state assumption and allows for the analysis of vertical 1D exchange fluxes in space and time. Results of about 380 transient simulations covering a period of more than 1.5 years show high absolute changes in exchange fluxes in the upstream part of the river. However, in the downstream part, the relative changes in fluxes are larger. The 26 spatially distributed thermal profiles along the river reach are interpolated using kriging based on variograms calculated from the temperature dataset. Results indicate gaining conditions for most locations and most of the time. Few places in the downstream part show losing conditions in late winter and early spring. While in autumn and winter the mean exchange fluxes can be -90 mmd^{-1}, in spring to early summer fluxes are only -42 mmd^{-1}. The river bed near the banks shows elevated fluxes compared to the center of the river. Probably driven by regional groundwater flow, the river bed near the left and right bank shows fluxes respectively a factor 3 and 2 higher than at the center of the river. The transient model allows for the calculation of model quality (like the RMSE) and can be used for data sets collected at any time during the year. The flux results represent integrations over the simulated period (i.e. weeks or month); short time changes in groundwater-surface water interaction cannot be estimated. With the adapted STRIVE model, future research can focus on the role of heterogeneity of the riverbed and better integration of riverbed parameters like hydraulic and thermal conductivities.