Geophysical Research Abstracts
Vol. 15, EGU2013-7894, 2013
EGU General Assembly 2013

Joint assimilation of piezometric heads and groundwater temperatures for improved modelling of river-aquifer interactions

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Measured groundwater temperatures close to streams contain valuable information for the assessment of mass transfer rates between river and aquifer and the hydraulic properties around a streambed. For groundwater management close to rivers, the characterization of these hydraulic properties is of special interest because exchange fluxes between river and aquifer influence the sustainability of groundwater abstraction and the quality of pumped drinking water. Additionally, it can be important for groundwater management to gain reliable predictions of groundwater temperatures, e.g. in order to regulate the temperature of extracted drinking water.
Data assimilation techniques, like the ensemble Kalman filter (EnKF), provide a flexible stochastic framework to merge model simulations with different types of measurement data in order to enhance the (real-time) prediction of groundwater states and to improve the estimation of uncertain hydraulic subsurface parameters. EnKF has already been used for managed river-aquifer systems to improve the prediction of groundwater levels and the estimation of hydraulic parameters by the assimilation of measured piezometric head data. As temperature data can provide additional information on stream-aquifer exchange it is investigated whether this information further constrains states, fluxes and parameters of the river-groundwater system.
For this purpose, we performed data assimilation experiments with two different model setups: (i) a simple synthetic model of a river-aquifer system where the parameters and simulation conditions were perfectly known (ii) a more complex model of the Limmat aquifer in Zurich where real-world data were assimilated. Results for the synthetic case suggest that a joint assimilation of piezometric heads and groundwater temperatures together with updating of uncertain hydraulic conductivities and leakage coefficients gives the best estimation of states, fluxes and hydraulic properties (i.e. hydraulic conductivities and leakage coefficients). Focusing on the river streambed, we found that the assimilated piezometric head data mainly gave information on the magnitude of river-aquifer exchange fluxes and assimilated temperature data led to a better characterization of the spatial distribution of leakage coefficients. It also became obvious, that localization techniques have a positive influence on the estimation of hydraulic conductivities because they are able to restrict non-physical parameter updates. Results for the real-world case also indicate that a good prediction of groundwater temperatures can be achieved through data assimilation with EnKF where the best results were obtained with a simultaneous update of model parameters.