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Identification of time-variant river bed properties with the Ensemble Kalman Filter

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An adequate characterization of river bed hydraulic conductivity (L) is crucial for the assessment of river-aquifer interactions. However, river bed characteristics may change over time e.g. due to flooding events that erode the river bed. Using static leakage parameters for the simulation of river-aquifer interactions can thus lead to erroneous simulations of river-aquifer exchange fluxes when river bed properties change over time. Sequential data assimilation with the Ensemble Kalman Filter (EnKF) allows for an update of model parameters in real-time and may thus be capable of assessing the transient behaviour of L.
The updating of time-variant L was tested in a synthetic experiment, but based on real-world data from the Limmat aquifer in Zurich (Switzerland). Forcing data for the simulations were taken from real-world measurements. A 3D finite element model of the Limmat aquifer in Zurich was used to assess the performance of EnKF in capturing time-variant L. A reference run (total simulation period: 609 days) was generated that should mimic the erosion of the river bed through a flooding event. For this purpose, L was artificially increased by one log unit at a major flooding event after 155 days. Hydraulic head data from this reference run were assimilated by EnKF jointly updating hydraulic heads and L.
Different simulation experiments were carried out. In a first set of experiments hydraulic head data were assimilated during the complete simulation period. Results show that L is only partly corrected and that the adaptation time is rather high. The low adaptation is related to the decrease of variance in the time period before the flooding event where L is constant. As a consequence the ensemble spread at the flooding event is rather low which results in too low weights for the measurement data and too high weights for the model predictions in EnKF after the flooding event. In a second set of experiments data assimilation started immediately after the flooding event. The updated L were in this case much closer to the true values with a lower adaptation time. However, as it is a priori unknown when river bed properties change and because it is desirable to assimilate data continuously, an improved procedure was developed. It is shown that the adaptation of the ensemble spread of L on the basis of innovation statistics (where the expected distribution function of deviations between model predictions and data is compared with the found deviations) allows for continuous data assimilation and correctly adapting L at the same time.