Hydraulic conductivity assessment via tracer test data assimilation: comparison between Ensemble Smoother and Ensemble Kalman Filter

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Abstract. The impact of the heterogeneous structure of natural aquifers on solute transport is well recognized and it is commonly accepted that the Fickian and non-Fickian evolution of contaminant plumes is mainly controlled by the spatial variability of the hydraulic conductivity *K*. However, this property is hard to estimate in natural porous media, since its knowledge is typically based on a spatially limited numbers of point sampling and/or in-situ tests.
Tracer test analyses have been widely adopted to identify the complex distribution of local hydraulic properties and, thanks to the recent development of geophysical methods like the borehole Electrical Resistivity Tomography (ERT), it is now possible to describe with a relatively low effort the spatio-temporal evolution of the injected solute. Still, it has to be considered that these techniques do not give direct information about the relevant hydraulic properties and thus a link between geophysics and hydraulics has to be identified. Previous studies (Camporese et al., *WRR 2011*, Crestani et al., *Under Review*) show that it is possible to infer the spatial distribution of *K* at the local scale, by combining the Lagrangian formulation of solute transport in groundwater with data assimilation techniques derived from the Kalman filter theory. Following this approach, and with the use of an augmented state technique, the hydraulic conductivity can be estimated with a reasonable accuracy through the assimilation of a sequence of time-lapse concentration images. The objective of this study is to compare the performances of the Ensemble Kalman Filter (EnKF) and the Ensemble Smoother (ES) as inverse modeling tools. By using the EnKF, the *K* spatial distribution is sequentially corrected as measurements become available. With the ES, measurement data at all collection times are assimilated at once, thus providing a direct correction of the prior estimation of the *K* field. As such, the ES is applied "off-line" of the model simulation. In this work, we compare the effectiveness of the two methods in reducing the uncertainty on the *K* spatial distribution and the computational cost of the two approaches. In addition, we investigate the effects on the estimation brought about by the lack of Gaussianity in the involved state variables.

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