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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Data assimilation with multiple types of observation boreholes via ensemble Kalman filter embedded within stochastic moment equations" *by* Chuan-An Xia et al.

Anonymous Referee #1

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General Comments The paper refers to a numerical analysis, aimed at estimating the permeability field of a confined three-dimensional aquifer, based on head observations collected in piezometers that give different information. The aquifer conditions mimic the effects of a fully penetrating well pumping test that works for a certain time interval and the head recovery process following the ending of pumping. The monitoring piezometers considered are of three types: point detectors obtained with a multi packer device (type A), piezometers with multi-level sampling (type B) and fully penetrating wells for the entire thickness of the aquifer layers (type C). The reference aquifer is

heterogeneous with stationary second order pdf function (lognormal distribution) and exponential covariance. The variance of the field was assumed equal to 0.2 but some numerical tests were performed on a field with similar characteristics but with variance 1.70. The method used to solve the inverse problem is an Ensemble Kalman filter with stochastic moment equations (MEs-EnKF), already presented by the same authors in two-dimensional applications. A large number of numerical experiments were performed: a) varying the type of piezometers arranged in three areas of increasing distance from the well; b) differentiating the method of solving the stochastic equations to represent or not the flow exchange between the piezometers of type B and C and the surrounding aquifer; c) varying the variance of the field; d) evaluating the effect of an inflation coefficient. Finally, a comparison was made with the performance of a common Monte Carlo Ensemble Kalman Filter (MC-EnKF). The work aims to provide field operational indications such as the greater or lesser reliability of the types of piezometers investigated and on the methods of analysis through the evaluation of the results of the numerical tests performed.

Specific comments The work is strongly founded and explores topics of undoubted interest using consolidated methodologies which, in the current applications, are extended to three-dimensional cases. Some points for discussion can be the following. The proposed method MEs-EnKF is particularly convenient compared to the MC-EnKF with respect to the calculation times. However, being a perturbative method, albeit approximated to the second order, it presents the need for a limitation of the values of the variance. The tests carried out, aimed at evaluating the effect of high variances, explore the 0.2 - 1.7 range without going further. A point of interest is also the simulation of the flow between piezometers and the surrounding aquifer. It requires to set the dimensions of the effective radius and the radius of the well; it is not evident if the adopted dimensions should correspond to the real size of the borehole. Given that the piezometers with packers are more expensive and more complicated to install, one may wonder if the tests carried out suggest that it can be enough to install them only in zone 1 (closest to the pumping well) to obtain accetable reliability degree.

Technical correction It is necessary that the authors extend Table 1 by detailing the characteristics of the numerical experiment carried out for each test. This would be of great help to better interpret the graphs in figures 6-11 as well as the descriptive text in chapters 4 and 5. It is essential that Figures 6-11 are provided in color to better distinguish the different trends in the different tests. A detailed check of the correspondence between citations in the text and bibliographic references is necessary. The list of bibliographic references also needs accurate revision.

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