

# ***Interactive comment on “Is inversion based high resolution characterization of spatially heterogeneous river bed hydraulic conductivity needed and possible?” by W. Kurtz et al.***

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## General comments

The paper reports on the opportunity to account for full heterogeneity of riverbed leakage parameters in situations where significant interactions between watercourses and aquifers occur, and investigates the suitability of EnKF as inversion tool for estimating such parameters, based on the assimilation of hydraulic head data. The manuscript is concise, generally well written, and addresses a problem that is both relevant for the scopes of the journal and potentially very interesting for a wide portion of the hydrolog-

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ical modeling community.

Having said this, I have only one main concern, which regards the lack of details on the numerical experiments. In particular, I am referring to the fact that the aquifer properties (distribution of hydraulic conductivity– if spatially variable –, specific storage coefficient, retention curve parameters, etc.) are not reported in the manuscript. This has two consequences for the potential reader: i) who wants to reproduce the same experiments is not able to do that and ii) one is left wondering whether the conclusions of the study are due only to the variability of the leakage parameters or the interplay between aquifer properties and riverbed properties play a significant role. The latter point is especially relevant, as much importance is given by the authors to the spatial variability of the fluxes between river and aquifer and thus it is crucial that the missing details be included and the discussion of results integrated in view of the new information. This can (and should) be done at the beginning of Section 4 and in Section 6.

#### Specific comments

Page 5831: the title is too long, in my opinion. Suggest a shorter version, e.g., “Inversion-based high resolution characterization of spatially heterogeneous river bed hydraulic conductivity”.

Page 5834, line 5: suggest rephrasing the sentence. The reader might think other inversion methods are compared in this study, while only different zonation methods are investigated.

Page 5836, line 27: the reference to Camporese et al. (2009) is not relevant for “the characterization of heterogeneous subsurface properties in groundwater modeling”. A more appropriate reference is Camporese et al. (WRR, 2011), who used EnKF to assimilate concentration data derived from ERT in order to assess the distribution of heterogeneous hydraulic conductivity.

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Page 5844, line 1: two weirs and the confluence of rivers identify only four river reaches. How were the fourth point/fifth reach chosen?

Page 5844, lines 9-15: choosing the correct mean for the generation of the initial ensemble implies that the EnKF can work in an optimal situation, as it naturally reduces the uncertainty around a parameter space that already contains the true solution. I realize that this probably does not change the main conclusions of the paper, i.e., high-resolution inversion is better than limited zonation, but I suggest highlighting this point later in the discussion (page 5852, lines 21-29).

Page 5845, eq. (10): I suggest assessing the root mean square error through a double summation over the ensemble of realizations and the nodes. This would give a more robust estimate and would implicitly include information about the uncertainty of the ensemble.

From page 5850, line 23, to page 5851, line 2: this is intuitive, but would be even better to see it. I suggest adding a figure showing the comparison between the correlation structure  $\log(L)$ - $h$  in a region of high flux and in a region of low flux. Also, adding the information about the aquifer properties would allow giving more insight on why the performance is spatially variable.

#### Technical corrections

Page 5833, line 25: use “that” or “which” instead of “what”. The same mistake occurs several times in the manuscript.

Page 5833, line 26: better to use “conductivities” instead of “permeabilities”. In the classic hydrogeology literature, the latter are measured in  $[L^2]$ .

Page 5834, line 13: to avoid confusion, please state at the beginning of the paper that “log” denotes always the logarithm to base 10.

Page 5840, lines 4-5: English here seems a bit awkward, suggest rephrasing the sentence.

Page 5842, line 22 and elsewhere in the text: the units of leakage coefficients should be ( $s^{-1}$ ), not (m/s).

Figs. 3, 5, 9, 10, 11, and 14: to avoid overlapping in the eastern part of the model domain, I suggest plotting the data using a 1D coordinate system that follows the river reaches.

Fig.6: to better show the benefits of joint update of states and parameters, I suggest adding to this figure the behavior of RMSE for an open loop simulation (no updates at all) and a simulation with update of system state only. Also, consider re-calculating the RMSE as previously suggested (Page 5845, eq. (10)).

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