

Interactive comment on “Joint inference of groundwater-recharge and hydraulic-conductivity fields from head data using the Ensemble-Kalman filter” by D. Erdal and O. A. Cirpka

Anonymous Referee #2

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General comments

Ensemble Kalman filter is used here to jointly infer hydraulic conductivities and recharge by assimilating head data. The authors evaluated effect of the prior model on success of the method and concluded that a correct prior model is critical, which is consistent with previous research. My main concern includes two items in the “specific comments”: item 4 and 8, in which the former is related to the mathematical model of EnKF and the latter the example to illustrate the compensation between hydraulic conductivity and recharge. Please revise the manuscript accordingly.

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Specific comments

1. Page 5568 line 20-25: The authors cited work by Hendricks Franssen et al. (2004) who jointly estimated hydraulic conductivity and groundwater recharge. What is the difference between this work and the one in the submission? What is the improvement here? Can the authors comment it?
2. Page 5572 line 1-5: Recharge rate, as a boundary condition, is determined based on such as precipitation, infiltration and geographic conditions (rivers and pumping wells). However the recharge here seems more likely the specific flux at the interface of blocks (discretized for numerical simulation) according to the authors “recharge depends on the gradient of the original transmissivity field”. Please clarify the meaning of “recharge” that is inferred from head data in this study.
3. Page 5572 on Fig.1: What are the initial and boundary conditions (except the recharge at the center) of this example?
4. Section 3.1 Kalman filter on page 5573 through 5574: Vector X_t consists of two elements, heads h_t and parameters (recharge and log-conductivity) while the head h_t can be simulated as $f_t(h_{t-1}, X_t)$, that is $h_t = f_t(h_{t-1}, X_t)$. If this is correct there would be mistake in the objective function $W(x)$ (equation 6) since the X_t contains head vector h_t that is considered again separately in the second term $(f_t(h_{t-1}, X_t) - Y_t)^T R^{-1} (f_t(h_{t-1}, X_t) - Y_t)$. Either the head vectors can be excluded from the vector X_t or the second term of the objective function should be removed. The corresponding comments and following equations should be revised accordingly, i.e., equations 7-13.
5. Page 5575 equation 11-13: The series of equations are used to calculate the covariance between parameters and/or simulations. The denominator should be $n-1$ rather than n , that is, $1/(n-1)$ instead of $1/n$ in these equations.
6. Page 5577 line 6-7: What do the authors mean by “combined patterns of hydraulic conductivity and recharge”?

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7. Page 5577 line 20: Here it says “the conductivity and recharge fields are uncorrelated”. On the contrary the authors stated earlier that “the apparent recharge depends on the gradient of the original transmissivity field” (page 5572 line 1-2), which indicates a close correlation. Please clarify this.

8. Page 5581 line 16-20: “it is always possible to compensate a missing or wrong conductivity with a recharge, and this is also clearly seen in the last column of Fig.5: the estimated recharge shows remarkable similarity with the reference conductivity field.” In Fig.5 the estimated recharge does show similarity with the reference conductivity field because the wrong recharge prior is sampled using the true conductivity field model NOT because they can compensate each other. They are two different things in my opinion. The authors need find another example to illustrate the compensation effect between conductivity and recharge derived in Section 2.

9. Page 5595 Fig.2: The last plot in Fig.2 shows the spatial distribution of recharge over the domain. The recharge is time-varying with a seasonal trend (page 5577 line 13 as well as shown in the “river stage” plot of Fig.2). So the question is which time does this recharge plot show? Also please add title for the X axis in the plot of “river stage” (it should be time I guess).

Technical corrections

1. Page 5570 line 3: “. . . was worse then. . .” should be “. . . was worse than. . .”
2. Page 5570 line 5-10, page 5578 line4, page 5581 line 2 and 16: The authors mentioned “Section 2”, “Sect.2”, “Section 3”, “Sect.4” and “Sect.5”. It would be better to keep consistent.
3. Page 5576 line 9-10: “. . . parameter that it is primarily required. . .” remove “it”
4. Page 5577 line 19: “. it should be. . .” use capital letter in “it”
5. Page 5579 line 7-8: “We have also conducted successful assimilations also estimating the trend parameter.” Too many “also”

6. Page 5580 line 20: “smaller errors in predicting heads than the...”. Correct “then” to “than”

7. Page 5581 line 28: “. . . it would to be difficult to. . .” modify this sentence.

8. Page 5582 line 4-6: revise this sentence.

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