

## ***Interactive comment on “A Bayesian Consistent Dual Ensemble Kalman Filter for State-Parameter Estimation in Subsurface Hydrology” by B. Ait-El-Fquih et al.***

### **Anonymous Referee #2**

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A one-step-ahead smoothing based dual EnKF is presented for state-parameter estimation of groundwater flow models. The performance of the algorithm is tested through a set of sensitivity analysis and comparison with standard joint and dual EnKF. The paper is well written and I have only a few questions.

#### Main concerns

1. A one-step-ahead smoothing based dual EnKF is presented in the manuscript. The authors compared results of the new method with standard joint and dual EnKF. As mentioned by the authors, Gharamti et al (2015) proposed a new EnKF method too by combining the one-step-ahead smoothing formulation (page 3). What will the result look like if these two one-step-ahead based EnKF methods are compared? Also the

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dual EnKF OSA needs to be better distinguished from the one by Gharamti et al (2015).

2. Page 8. The authors talked about one-step-ahead smoothing function but did not explain what is this function used for? What role does it play in the new algorithm dual EnKF OSA and how does it work?

3. Page 11. The observation data are used three time in dual EnKF OSA rather than twice as in the dual EnKF. The authors thus concluded that it is in a fully consistent Bayesian formulation. Please clarify the relationship between them. Also please relate this with the comment on standard dual EnKF that the ensemble does not represent the forecast pdf (page 8 lines 231-233).

4. Page 11 line 527-528 “The proposed dual EnKF OSA efficiently recovers the reference trajectory of MW2 and MW3”. I think this statement is not so proper since the trajectory or trend of the reference is not captured well by any method, including the dual EnKF OSA. The reference is barely covered by the ensemble and the peak values are late in the ensemble at MW3. But I agree that the dual EnKF OSA works better than the other two methods.

5. Page 17 line 534 “We further examine . . . .against the joint- and dual- EnKFs . . . .” But in Figure 7 only the results by dual-EnKF and dual- EnKF OSA are shown. The results by joint EnKF are not included.

6. Page 18 line 576 “ the dual- EnKF OSA tends to maintain a larger variance at the edges than the dual-EnKF, which in turn increases the impact of the observations”. I have two questions on this: first, it is difficult to tell (Figure 10) the “larger” variance by dual- EnKF OSA. Their results look pretty similar. Secondly, why will the variance of hydraulic conductivity at the edge increase the impact of the observations (at 9 wells) which is not so near from the edges? Furthermore, the boundary conditions are either no-flow or constant head which have limited influence on observations. One suggestions on the color bar of the figure: the white color does not appear in the bar but occupy a lot of area in the Figure and the contours make the figure complicated.

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## Minor corrections

1. Page 2 line 38, “Hendricks Franssen and Kinzelbach, 2009” instead of “Franssen and Kinzelbach, 2009”. At the same time, please correct the item in the reference list (page 22).
2. Page 5 line 150. “Let, for an ensemble . . . , r denotes” should be “denote” instead of “denotes”?
3. Page 10. The equation 25 looks exactly the same as equation 5. Is this correct?
4. Figure 1, the black crosses represent hard measurements according to the text on Line 425. But it can also be added here to avoid any confusion.
5. Title of the subsection 5.5 “further assessment of the dual- EnKF OSA scheme” does not reflect the content. From the title we expect the result by dual- EnKF OSA only. But in fact it still compares the results of three methods. It could be changed to “prediction capability assessment” or something like this.

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