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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Stochastic inversion of sequential hydraulic tests for transient and highly permeable unconfined aquifer systems" *by* C.-F. Ni et al.

Anonymous Referee #2

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This is a paper on hydraulic tomography analysis in an unconfined aquifer. The authors present both a synthetic and a field study to investigate the depth averaged variation of hydraulic parameters (K and Sy). I think the study could be a useful contribution to the hydrogeology literature, but I have some comments below that need to be addressed. In particular, there is a similar study on hydraulic tomography analysis of unconfined aquifer by Mao et al (2013), although Mao et al (2013) relied on the variably saturated flow equation (i.e., Richards' equation). Cardiff and Barrash (2011) also published a similar study and so the introduction should discuss the novel contribution of this paper in relation to the other published studies.

Comments 1. Introduction Paragraphs 1-2 Line 18: I am not sure whether Hernandez et al. (2006) developed a hydraulic tomography approach. Please check and conduct a thorough literature survey. Line 28: No, Neuman (1987) proposed the concept of hydraulic tomography first. However, the synthetic simulation by Yeh and Liu (2000) popularized the concept of hydraulic tomography. There are also other studies noted in Illman (2013) which reviewed the early to recent hydraulic tomography studies and perhaps you should look into this paper. I do not expect you to cite all the papers on hydraulic tomography listed in Illman (2013)'s paper but I think the key ones should be listed and reviewed in the introduction of your paper.

Paragraph 3 L14: I think that there are key laboratory and field hydraulic tomography studies that are missing here. L14: I am not sure whether Straface et al. (2011) conducted a hydraulic tomography survey. Please check carefully. Also, please note the studies of Berg and Illman (2011, 2013, 2014) in terms of field applications of the SSLE algorithm.

Paragraph 4: Line 17: You are examining the depth averaged case so why not talk about ln T instead of ln K?

3. Optimization algorithm Paragraph 3: Line 3: What do you mean by "ready"? Line 11: replace "head differences" with residual heads based on the previous sentence.

4. Sensitivity estimations for covariance matrices Paragraph 1 Line 15: Are all of these details necessary to be given in this paper when the details are provided in previous papers on this topic? Please think about putting this into an appendix or dropping it unless there is something new that should be presented.

5.1 Model description Paragraph 2 Line 14: Not sure that Figure 2 is a conceptual model. It simply shows the model domain and the different boundary conditions. It also shows the pumping and observation well locations. Can you combine this figure with Figure 1?

5.2 Results and discussion of the numerical example Paragraph 2: Line 21: I am not sure whether I understand what you are trying to do here. Are you doing a steady state simulation and comparing the resulting ln K estimation to the transient case? Line 23: Perhaps you should include a scatterplot to compare the two K estimates (one from steady state and one from transient).

Paragraph 3: Line 3: (Figure 5) Can you please explain this plot a little better? Are these calibration plots or are they validation plots? Also I would recommend Plotting these in terms of drawdowns. In addition, I was not clear whether these are plots for each pumping test or results from tomography (calibration) by adding 1 to 5 pumping tests to the analysis?

Line 11: So you had to include 14 or so conditioning points in the inverse modeling effort. I think the previous studies by Yeh and his colleagues have not had to do this. Is there a reason why this is the case?

Line 18: This is a new finding. Reading Yeh and his colleagues' past papers, it looks like the variances are higher away from where there are data points regardless of whether the boundary is close or not. Can you provide an explanation of why you see these results with lower variance along the top and bottom boundaries?

6.1 Site description Paragraph 1: Line 18: What is the K of the Cholan formation and how does this compare to the K of the alluvium? Please be more specific so that you can better justify treating the bottom boundary as no flow.

Paragraph 2: Line 25: Please be more precise about how long the screened intervals are for both the injection and observation wells. Please consider including a table of the well locations and screen lengths including the elevation of the well.

Paragraph 3: Line 9: How did you monitor the head in the injection well? Line 14: Why did you not include the heads at the injection well? For example, Illman et al. (2008) did not include head data from the pumped location because of skin effects and other

potential nonlinear effects (e.g., well losses due to inertial flow, etc.).

6.3 Parameter estimations Paragraph 1 Line 30: You mention that the model did not include any K and Sy observations. My understanding is that SSLE requires at least one observation to begin the estimation process. Please clarify.

Paragraph 2: Line 18: How do these estimates compare to what you know about the geology? Are the estimated K values consistent with K estimated from grain size analysis or other local estimates such as from slug tests?

Line 19: I would think that these Sy values are on the low end given that Sy = saturated water content - residual water content. Can you comment on this further?

Line 25: Do you expect a similar cokriging error variance distribution for K and Sy? And why is the error larger for Sy on the right side of Figure 11b while there is a bull's eye on the left side. Can you please provide the reader with some insights on this distribution?

6.4 Boundary effect on parameter estimations Paragraph 1 Line 9: I do not think the first part of this sentence is necessary given that you say the same in the previous paragraph. It is repetitive.

Paragraph 2: Line 21: This analysis is interesting and kind of important. It shows that hydraulic tomography may provide information on K and Sy heterogeneity beyond the vicinity of the well field. This contradicts with the findings of Bohling and Butler (2010) and I think you should state this here. Also I recommend you plotting the error variance distributions for each case. Finally, you should refer to Sun et al (2013) and discuss the implications of how tomography may be able to map regions beyond the immediate vicinity of the wells.

7. Conclusions Paragraph 1 Line 20: I suppose this is a form of sequential cokriging interpolation but I believe SSLE is more than cokriging. To avoid confusion in the literature, I suggest referring this approach as SSLE.

Paragraph 2: Line 9: The boundary condition effect on the estimated K. I am a little

puzzled here because other applications of SSLE did not result in lower variances of K at the constant head boundaries. What you are fixing is the boundary heads and not K so I do not see any reason why the variance should approach zero. I would think quite the contrary that away from available data points, the variance estimates would be larger even near boundaries. This issue needs further clarification and investigation.

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