Interactive comment on "Efficient estimation of effective hydraulic properties of stratal undulating surface layer using time-lapse multi-channel GPR" *by* X. Pan et al.

Anonymous Referee #1

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In this paper, Pan et al. evaluated the performance of time-lapse multi-channel GPR in estimating stratal soil hydraulic parameters at plot scale. Some key factors in the inversion were discussed based on a series of synthetic and field studies. In my opinion, this paper is interesting, generally well written and easy to follow, I recommend its publication after a moderate revision. The following comments may be helpful in improving this manuscript.

1. "structural errors" are mentioned many times in the manuscript. However, an explicit definition is absent. What are included in the structure errors? Are they only related to the geometric error in the underlying interface between the two layers?

2. Page 6 Line 4. The Latin-hypercube was used to generate the initial ensemble. Please provide and justify the initial (prior) statistics for the hydraulic parameters. Also, do you consider the correlation between soil hydraulic parameters? This might have impacts on your inversion results, e.g., Scharnagl 2011 and Man 2016.

3. Please provide some information regarding the computational cost in the inversion since "efficient estimation" is highlighted in the title. For example, how many CPU-hours were needed in 40 iterations in your field case. What about the computational cost in a single model evaluation if a 3D model is considered to cope with the lateral flow?

4. Page 6. The early stopping may cause the overestimation of uncertainties. How do you choose an appropriate iteration number in practical applications? Please clarify.

5. Please shorten the caption of figure 4 since it is rather long.

6. Figure 5 shows significant unresolved biased errors. If I understand correctly, is it possible to alleviate this problem by incorporating geometric stratal errors in the architectures? To be more specific, it seems that all the inversions are based on the same interface (shown in Figure 2). Can you use an interface ensemble instead? This is similar to the treatment of using initial parameter ensemble in your inversion.

References: B Scharnagl, JA Vrugt, H Vereecken, M Herbst. Inverse modelling of in situ soil water dynamics: Investigating the effect of different prior distributions of the soil hydraulic parameters. Hydrology and Earth System Sciences, (2011). 15 (10), 3043-3059. J Man, W Li, L Zeng, L Wu. Data assimilation for unsaturated flow models with restart adaptive probabilistic collocation based Kalman filter. Advances in water resources (2016) 92, 258-270