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Hydrology and Earth System Sciences Discussions

Interactive comment on "Identifying a soil hydraulic parameterisation from on-ground GPR time lapse measurements of a pumping experiment" *by* A. Dagenbach et al.

Anonymous Referee #3

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In the manuscript "Identifying a soil hydraulic parameterization from on-ground GPR time lapse measurements of a pumping experiment" concern authors' efforts in estimating the soil hydraulic parameters using time lapse GPR data in a controlled setup. In general, I found the paper to be well written. However, I feel that many of the real-word complications associated with a field case have not been addressed in this paper, and a major revision is needed before it is accepted for publication. These issues are addressed below:

1. Two big assumptions were made in this research.

   (a) Subsurface water flow in the unsaturated zone and in groundwater is governed by the Richards equation, which is a function of soil water content and hydraulic conductivity. In this manuscript numerical simulations for modeled GPR signal were performed for an unsaturated zone (50 cm above water table) without considering the effect of unsaturated hydraulic conductivity.

   (b) Simulations were performed for one sand layer and the soil hydraulic parameters were estimated for a single layer, whereas experimental setup has three layers, top layer and bottom layer (uncompacted and compacted). Furthermore, the dimensions used in numerical simulation are not the same as in experimental setup.

2. In this study, time-lapse GPR measurements showed qualitatively that enough information is contained in the radargram during injection and pumping of water. In the quantitative analysis (numerical simulation), time-independent 1-D permittivity profile was used to generate the radar signal. Modeled time-lapse GPR data was not generated and compared to the measured time-lapse GPR signal. Therefore, title of the manuscript should be changed as time-lapse GPR data was not used to estimate soil hydraulic parameters.

3. The exact location of a pumping tube and a stationary GPR antenna installation is not mentioned in the text and also in Fig 1. It is important as the experimental setup has big dimensions (19m x 4m x1.9m) and if GPR antenna is close to pumping tube will have different signal response as compared to far away from pumping tube. What are the dimensions of a pumping tube (radius of pipe, open area per meter of slotted pipe)? Is a single pumping tube used to saturate such a big setup? If pipe of small radius and small area of opening are used than the water level may risein the pipe above the water table and create a gradient of soil moisture in the top layer, which is not considered and discussed in this manuscript.

4. In the section 2, it is mentioned that after injecting water of 3800 L within 2 hrs, the system equilibrated for 2 hr. What was the criterion of equilibrium?It may take more time to stabilize as the water is injected through pipe, which may forms a gradient of water level above the water table. It would be great if the water level fluctuation data can be providedduring the system equilibrated for 2 hrs.

5. What was the logic to compact part of the second layer and leave 20 cm uncompacted at depth 80-110 cm? It increases complexity and the two layer problem become three layer.

6. P-9098 L-14: "uniform infiltration" should be replaced with "uniform saturation".

7. Change the title 3.1 "Infiltration" to saturation. Infiltration is the process by which water on the surface of ground enters the soil. However, in this section GPR signal is discussed when water is injected through the pipe and the sand layer get more saturated (water level increases). Kindly replace infiltration with saturation.

8. In section 3.1 and 3.2, Fig 2 (a) and (b) are discussed in detail and the radargram is show from 16 ns to 26 ns. The radargram 0-16 ns should be provided and discussed as it would be great to see which type of reflections are recorded in the top layer as there may be a gradient of soil moisture in the top layerformed because injection and drainage has been done using a pipe.

9. Page 9098, L 23: "The pumping event was conducted by infiltrating a total amount of 3800 L within 2 h". In hydrology, pumping is used to take out water from well. Whereas, here water is injected into the system. Rephrase the sentence.

10. For Figure 4 please provide values for the extreme ends of the x-axis.

11. Page 9102, L 23: "full van Genuchten". Such an expression is never used in literature. I think it can be replaced with classical van Genuchten.

12. Page 9103, L 10: How θ_s and $\theta_r$were calculated?

13. (a) Page 9103, L11: For numerical simulation the sand profile is considered as a single layer and having 2 m depth. Whereas experimental setup has three layers (top sand layer, compacted and uncompacted sand layer) of 1.9 m tick. Furthermore, the simulation domain for FDTD isconsidered to be 2m x 2m x 2.7m whereas the experimental setup dimensions are 19m x4m x 1.9m. It is not possible to reproduce the measured GPR signal by using different dimensions and layer setting for numerical simulation. Repeat the numerical simulation with exact dimensions and layer thicknesses.

14. Page 9106, L 2: On which basis h_0 is fixed to 0.25 m?

15. Page 9106, L 20: "This shows that a reflection from sands parameterized by the Brooks-Corey paramerisation are suitable to reproduce the given experimental data." Why such data is not reproduced? This is the main objective of the manuscript that soil hydraulic parameters were estimated using time-lapse GPR data. Without generating a modeled time-lapse GPR data and comparing it with the measured GPR data the estimated soil hydraulic parameters are always questionable.

16. Depth mentioned in experimental setup (1.9 m) does not match with figure 1 (180cm). Correct it and use same units "m" or "cm" throughout the manuscript.

17. There is no discussion in the paper regarding potential sources of error in the hydraulic property estimates obtained from the GPR data. I think that it needs to be more clear in the results and conclusions that there were a number of assumptions made that, in reality, could result in model errors that significantly bias hydraulic property estimates.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 9, 9095, 2012.