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Hydrology and Earth System Sciences Discussions

Interactive comment on "Improving soil moisture profile prediction from ground-penetrating radar data: a maximum likelihood ensemble filter approach" *by* A. P. Tran et al.

Anonymous Referee #2

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General Comments:

In the manuscript "Improving soil moisture profile prediction from ground-penetrating radar data: a maximum likelihood ensemble filter approach" concern authors' efforts to use sequential assimilation procedure to determine the accuracy of the soil moisture profile prediction using time-lapse ground-penetrating radar (GPR). In general, I found the paper to be well written and the subject of the research is both timely and important. However, I feel that many of the real world 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. Three big assumptions were made in this research, which

should be addressed:

a. In the proposed synthetic study four models were combined (HYDRUS-1D, two petrophysical relationships and radar model) in a sequential assimilation procedure to improve soil moisture profiles and no error was considered in these four models which is a very big assumption. For instance, flow is not 1-D in nature due to heterogeneity, petrophysical relationships can vary from one place to other, and always there are measurement errors in any geophysical data. Some percentage of error should be included in all four models to get a better picture how much the GPR signal is sensitive to these errors.

b. The frequency used to generate GPR signal was in the range of 1-3 GHz. In such a high frequency range the subsurface permittivity and electrical conductivity profiles are frequency dependent, whereas in the proposed method frequency independent conductivity and permittivity models were used. Furthermore, no discussion in the paper about the phase center used for the antenna as in such a wide range of frequency the phase center of the antenna is frequency dependent. Please justify why electrical material properties can be considered to be frequency independent, since the Green's function used for wave propagation in 3-D multilayered media is frequency dependent.

c. In real field conditions the initial condition, lower boundary condition and the hydraulic parameters are mostly unknown, especially in terms of spatial soil heterogeneity. In this study the soil hydraulic parameters were fixed and lower boundary condition was assumed to be known, which is a big assumption. The idea in the proposed method is to use GPR as a remote sensing tool to improve the soil moisture profile prediction. How will the GPR signal respond if these assumptions are not considered? All these limitations should be discussed in the paper.

Specific Comments:

1. In the first paragraph of the introduction and the first sentence of the abstract main focus is on the root zone soil moisture, whereas in this paper synthetic analysis were

performed considering a bare soil. I think root zone can be replaced with shallow unsaturated zone.

2. Page 1584 L 6: Remove "Recently". As it's almost decay that Lambot et al. (2004b) developed this method.

3. Page 1588 L 3: Please explain in more detail why the distance between the antenna and medium was fixed to 37 cm? No explanation is provided at which distance the antenna phase center was considered as the antenna phase center is frequency dependent.

4. Page 1589 Eq 6, 7: Please justify why these specific frequency independent models were used? Why frequency dependent models for permittivity and electrical conductivity are not used?

5. Page 1590 Equation 8 & 9: The superscript "f" and "a" can be in italic format as other variables are mentioned in italic format. Similar in description on line 17.

6. Page 1590 L 18: In the proposed approach four models (HYDRUS-1D, two petrophysical relationships and radar model) are used in a close loop and the model error vector (ωt) was considered zero, which is a very big assumption. Include some errors in all the four models as the real world is more complex.

7. Page 1592 L 20: In a synthetic homogenous soil column with a depth of 80 cm was discretized into 32 equidistance elements. To have a good resolution of subsurface the layer thicknesses in the electromagnetic model should be less than one tenth of minimal wavelength. Have you considered this while considering your discretization? The existing 32 equidistance elements (2.5 cm) is a big discretization if we consider maximum frequency of 3 GHz used in this study.

8. Page 1594 L 15: Clearly mention that the signal shown in the figure is the amplitude of the frequency-domain. Why phase of the frequency-domain is not shown? Please mention if the phase does not show these variations.

9. Page 1594 L 18-19: It is discussed that the frequency range of 1-3 GHz was used whereas the frequency domain plots in the figure 3b, d, f shows the range of 0-350 MHz, which is not consistent with the text. The lowest frequency in which Vivaldi antenna can operate with a high signal to noise ratio is 500 MHz for a small size of antenna. At 3 GHz the day and night effect in the top 0-2.5 cm soil should be clearly visible, which cannot be seen in any figure. The reason may be the big discretization (2.5 cm) for such a wide range of frequencies.

10. Page 1595 L 13: The sub figure 4a represents that the synthetic soil moisture profile at initial time (0 h). It is sure that the initial profile was considered as a constant with depth equal to 0.2 cm3cm-3 (already discussed on page 1593 Line 17-18). How the synthetic profiles at initial time (0 h) was constructed for clay, loam sand and silt? Please provide more explanation.

11. Page 1599 Paragraph 3.2: Please mention in the text somewhere that how much time it takes to complete one simulation with 5, 30 and 50 h.

12. If possible please include more recent references from HESS and cite the following two recent articles, related to the use of GPR for the estimation of soil hydraulic parameters to construct soil moisture profiles.

Dagenbach, A., J. S. Buchner, P. Klenk & K. Roth, 2013. Identifying a parameterisation of the soil water retention curve from on-ground GPR measurements. Hydrol Earth Syst Sci 17(2):611-618 doi:10.5194/hess-17-611-2013.

Jadoon, K. Z., L. Weihermüller, B. Scharnagl, M. B. Kowalsky, M. Bechtold, S. S. Hubbard, H. Vereecken & S. Lambot, 2012. Estimation of Soil Hydraulic Parameters in the Field by Integrated Hydrogeophysical Inversion of Time-Lapse Ground-Penetrating Radar Data. Vadose Zone Journal 11(4) doi:10.2136/vzj2011.0177.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 10, 1581, 2013.