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Hydrology and Earth System Sciences Discussions

Interactive comment on "Estimating field-scale soil water dynamics at a heterogeneous site using multi-channel GPR" *by* X. Pan et al.

Anonymous Referee #2

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1.) This submission maybe a potentially valuable scientific contribution in the field of hydrogeophysics. Recent work (e.g., Lunt et al. 2005, Wollschlager & Roth, 2005) has clearly demonstrated that traveltime information from GPR reflection profiling can provide very useful water content information. The major issue in this approach is obtaining accurate estimates of reflecting interface so that the traveltime data can be converted into electromagnetic (EM) wave velocity.

The use of multi-channel ground penetrating radar (GPR) systems is an effective means of acquiring this information. There are several papers (i.e., Gerhard et al. 2008, Pan et al. 2012) that employ the methodology used in this paper to the estimate of soil moisture content. Gerhard et al. (2008) considered a single date and Pan et

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al. (2012) looked at seasonal variations. Since the methodology is not novel, the potential contribution needs to be related to its application to monitoring a short-duration infiltration event.

To establish the significance of their contribution, the authors need to more explicitly place their work in the context of the existing papers using GPR methods to monitor short-duration infiltration events, both natural (i.e., precipitation events) and artificial. With regards to GPR reflection profiling, the authors should consider the following papers: Schmalz et al. (2002); Truss et al. (2007); Moysey (2010); Haarder et al. (2011) and Steelman & Endres (2011). How does the current submission advance the state of the science?

2.) The authors need to give details regarding the processing of the GPR data. What software package was used? What processing steps (e.g., dewow, gains, filters) were used? What were the values of processing parameters selected? Were the same processing steps, processing sequence and parameter values used for all the data sets? If not, why and what potential impact could this have on the results?

3.) Figure #1: Indicate approximate location of top of saturated zone? Is there a significant capillary fringe (zone of tension saturation)? It should be remembered that the water table is a piezometric surface and may be well below the top of the capillary fringe (the boundary of interest for GPR). This information is important give the authors' statement that water salinity probably restricts depth of investigation.

4.) The comparison between the TDR and GPR needs to be done in terms of dielectric permittivity or EM wave velocity; these are the basic properties that are being tested. The conversion of both measurements into water content and volume significantly obscures this comparison.

Given the nature of the TDR sampling, a more appropriate approach would seem to be to obtain an average permittivity for each lithologic unit and determine the overall permittivity for the section using ray theory. This quantity would be directly comparable

HESSD

9, C3407–C3410, 2012

to the permittivity value obtained from the multi-channel analysis.

5.) The multi-channel analysis method in Gerhard et al. (2008) and Pan et al. (2012) implicitly assume straight ray paths. Large vertical velocity gradients are quite probable during transient hydrologic events due to variations in moisture profile. These gradients can cause significant ray bending, impacting the validity of permittivity value obtained from the multi-channel analysis.

6.) In the absence of independent observations (e.g., gravimetric soil moisture sampling) or supporting hydrological modeling, I have very serious reservations about much of the details about soil moisture dynamics inferred from the GPR data presented in this paper. The most that can reliable inferred from the data is that there are temporal changes in the average dielectric properties between the surface and the stratigraphic reflector after the rainfall event that is consistent with a general decrease in water content over time; this is not a new contribution to the science. Statements about moisture redistribution due to dune ridge-valley structure and downward fluxes lack support. Given that the scientific significant of this contribution needs to be related to its application to GPR monitoring a short-duration infiltration event, this is significant shortcoming of this submission.

In view of the serious shortcomings of this paper, I strongly recommend that the authors completely revise this paper and concentrate on only those points that can be strongly supported by their data.

References cited in this review that are not listed in the submitted paper:

Haarder, E. B., M. C. Looms, K. H. Jensen and L. Nielsen (2011). Visualing Unsaturated Flow Phenomena Using High-Resolution Ground Penetrating Radar, Vadose Zone Journal, 10, 84-97.

Moyesy, S. M. J. (2010). Hydrologic Trajectories in Transient Ground-Penetrating-Radar Reflection Data, Geophysics, 75, WA211-WA219.

HESSD

9, C3407–C3410, 2012

Schmalz, B., B. Lennartz and D. Wachsmuth (2002) Analyses of Soil Moisture Content Variations and GPR Attribute Distribution, Journal of Hydrology, 267, 217-226.

Steelman, C. M., and A. L. Endres (2011). Vertical Soil Moisture Dynamics in the Vadose Zone: A High-Resolution GPR Reflection Study, Proceedings of the 6th International Workshop on Advanced Ground Penetrating Radar, Aachen.

Truss, S., M. Grasmueck, S. Vega and D. A. Viggiano (2007). Imaging Rainfall Drainage withing the Miami Oolitic Limestone using High-Resolution Time-Lapse Ground-Penetrating Radar, Water Resources Research, 43, W03405.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 9, 8027, 2012.