General comments

The authors analyze, through a numerical experiment, the retrieval of the unsaturated soil hydraulic properties from ground-penetrating radar (GPR) travel times corresponding to the wetting front as well as to fixed reflectors during an infiltration event. The hydrodynamic simulation involves a 1D solution of Richard’s equation and the top and bottom boundary conditions are a 10 cm pressure head (Dirichlet) and a 1 m deep water table, respectively. Only one soil type, sand-like, is analyzed. The radar system reduces to a point at the soil surface, under water, and propagation times are calculated from propagation velocities derived from water content. The radar-antenna system and interactions with the medium are not accounted for. Sensitivity analyses as well as parameter estimation using the Markov Chain Monte Carlo Bayesian approach show that travel time information indeed provides valuable information to estimate the soil hydraulic properties. Different parameter sensitivities and corresponding uncertainties are observed and discussed.

The paper is well written and presented. It is technically sound and of interest to the scientific community. Nevertheless, compared to the state of the art, its novelty is quite limited. It is a case study and the interest mainly lies in the specific boundary conditions that are used for the hydrodynamic event as well as to the corresponding analyses. The fact that the radar and radar-medium interactions are not modeled limits the scope of the conclusions for real applications. The physical interpretation of the results could be deepened. The state of the art close to the topic of interest should be reviewed and links should be made with the observations of the authors.

Specific comments
Title and state of the art: The title should be more informative regarding the content of the paper. Indeed, the interest of ground penetrating radar to identify the soil hydraulic properties has already been demonstrated by many studies during these last two last decades. In that respect, a deeper literature review should be made to demonstrate the interest of the present study. Several studies relatively close to the topic of this paper are not referred to.

Abstract: The scientific outcomes/novelties of the study should be highlighted. The presentation of the results could be more quantitative or precise.

Line 24: Add a comma after « namely ».

Line 29: Replace « A typical and prevalent approach” by “The reference method in soil physics”.

Line 105: Please justify the choice of that case study with respect to the objectives of the study (and eventually the state of the art).

Line 106, “The infiltration is driven by a constant pressure head of 10 cm applied at the surface of the soil”: Please justify the use of such boundary condition. Why not using a Neumann-type boundary condition (flux), as prevalent in environmental and agricultural applications? This would also be better suited to the use of GPR. It is worth noting that the antenna-medium coupling, which is permittivity dependent, will strongly affect the recorded radar waveforms for such experiment. This will inherently distort the estimation of the travel times if not modeled using a full solution of Maxwell’s equations. This should be discussed in the presentation of the limitations of the present study.
Figure 1: Which discretization was used to calculate the depth-dependent reflection coefficient? Please explain/justify.

Line 124, “The initial condition is a hydrostatic pressure distribution corresponding to a water table at 100 cm depth”: You can indicate that in that case the soil moisture profile corresponds to the water retention curve.

Line 133: Add a comma before “respectively”.

Line 138: Add a bracket before “Fig. 1”.

Line 146: Use either “relative dielectric permittivity” or “dielectric constant”, not “relative dielectric constant”.

Line 157: Use italic for mathematical variable “N”.
Equation (7): Please note that this assumes the medium electrical conductivity to be 0 (not true in practice but good approximation above about 300 MHz and below 1 GHz, as above 1 GHz dielectric losses do occur with water) and the relative magnetic permeability to be 1 (good approximation in most cases).

Line 169, “whatever the hydraulic parameters”: Is it really true? The transition sharpness depends on the soil hydraulic properties and boundary conditions, as well as on soil type.

Figure 2 caption: The value of the residual water content seems relatively large for a soil with such alpha and n values (sand-like). The choice of the soil hydraulic parameters should be justified in the text.

Equation (3): You may explain the choice of the exponent “1/2” in the hydraulic conductivity function. In principle, this exponent could take other values, depending on the soil type.

Line 205: Surround “respectively” with commas.

Table 1: Why choosing a relatively high value for the lower bound of n (1.5)? You may use 1.1 in order to include much more soils.
Line 265: Add a comma after “i.e.”.

Line 289: “The parameter n has therefore a negligible effect on the TWT_f”: Please explain the physical reason. Would the results be the same for different boundary conditions?

Line 316: Would that sensitivity be explained by the fact that at early times, the soil moisture profile does correspond to the soil water retention curve (hydrostatic equilibrium), which is significantly influenced by n? See also my previous comment.

Line 338: Please justify the use of a standard deviation of 0.5 ns.

The conclusions drawn in this paper are very specific to the theoretical case study that was analyzed. It would provide more value to the paper to include additional soil types, and/or, additional boundary conditions, and/or a real case study. At least discussions on the scope and limitations of the conclusions should be provided.