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Discussions

Interactive comment on "Simulating preferential soil water flow and tracer transport using the Lagrangian Soil Water and Solute Transport Model" *by* Alexander Sternagel et al.

Anonymous Referee #1

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Modelling infiltration processes and the associated tracer transport in a porous media is a challenging task for the possible presence of strong spatial heterogeneities in the hydraulic parameters that characterize the soil. In particular, the presence of macropores can lead to preferential flows that are difficult to retrieve with traditional Richard-based models. The authors propose a new approach to improve the simulation results of a Lagrangian 1-D model introduced by Zehe and Jackisch 2016. The new LAST-model partitions the precipitation into two domains, a 'slow' domain describing the infiltration in the soil matrix, and a 'fast' domain constituted by a collection of marcopores. There are several parameters that describe these macropores, and the more relevant are the three possible depths of the macropores, the diameter, the saturated hydraulic con-

ductivity and the number of macropores at the different depths. The solute masses are converted into a large number of particles (in this case two milions) for the Lagrangian simulation of the infiltration problem.

To prove the efficacy of the model, the Authors show that the LAST model outperforms the previous Lagrangian model in a real infiltration example. Finally a sensitivity analysis shows the stability of the model and the possible changes when varying different parameters.

Although the problem is of relevance for many HESS readers, I think that more results are required to support and validate the proposed method. In fact, the pfd adds several degrees of freedom for the description of a 1-D infiltration problem, and only one infiltration test is not sufficient to prove its efficacy and the limitations with respect other methods. Details regarding the calibration of the model parameters are missing. Moreover there are many points that need to be better explained in the description of the method, as detailed in the minor comments. For these reasons I recommend major revision.

MAJOR COMMENTS

1. The proposed model is introducing a large number of additional parameters that cannot be directly related to physical properties of the soil and that require adequate calibration. I think that using 16 parameters to retrieve 10 data points (Figure 3c) might introduce a strong over-parametrization of of the model. Thus, additional examples of application of the model to real data are needed, including calibration procedures and measures of goodness of fit. In particular, a fair validation would be to compare LAST with a 1-D Richards-based model that considers a simple soil heterogeneity (e.g., hydraulic parameters changing in two or three layers of the domain).
2. Beside calibration, I find very difficult to apply LAST to different infiltration set-

tings. For example, if deeper domains or longer durations of the experiment are considered, would it be always sufficient to have three classes for the length of the macropores? Why not having the classes of macropores evenly spaced along the domain? Moreover, the sensitivity of model results to the number of macropores is very low. Is it possible to consider just one macropore, and consequently adapting its diameter and the diffusion fluxes with the soil matrix?

3. The authors present three real infiltration tests, but compare the new LAST model with respect to the previous infiltration model in only the third example. Why not applying the LAST model also to the other two infiltration tests? Can you please show that proper calibration of the LAST model is suggesting to not consider the pfd component in those tests?

MINOR COMMENTS

1. Page 2, line 20: please insert a reference for the 'Double domain model'.
2. Page 5, line 10: the caption of Figure 2 is not sufficient to understand the figure. The figure should be better explained in the text. In particular, which is the relation between the grid element and the macropores?
3. Page 5, line 15: also the concept of cubic storage is really vague from the text and the figure and it is not in agreement with the cylindrical shape of the macropores.
4. Page 5, line 33: in Case 3 the accumulated water should create a ponding volume for both the soil matrix and the macropores. Why this is not taken into account in equations (3) and (4)?
5. Page 5, line 36: m_{matrix} and m_{pfd} described in equations (3) and (4) should be the infiltration capacities, not the mass of water that infiltrates as stated in line 36.

6. Page 6, eq. 3: at my understanding, this equation is approximating the infiltration capacity for the first grid element. Why does it involve the potential gradient in the second grid element?
7. Page 6, eq. 4: the power 2 should be outside the parenthesis.
8. Page 6, lines 20-23: does this mean that the time step changes at each temporal iteration? In fact the deepest unsaturated grid element changes in time. Do the macropores fill at the same speed? From what I understand at lines 10 and 11, the water reaches different depths during the same time step, depending on the depth of the pdf. I think this should be clarified.
9. Page 6, line 25: what is the boundary condition at the bottom of the macropores? From this description, the model can handle only no-flow condition, which is a big limitation.
10. Page 6, line 14: what does the term 'coupled' means here? Does this mean that the water in these grid elements entered the system at the same time (and thus have the same tracer concentration)?
11. Page 7, line 10: why three depths? This seems a very arbitrary choice without a real physical meaning.
12. Page 7, line 15: how can the diffusive water flow be simultaneous? The water in the small macropores reaches the deepest unsaturated level much faster than the water in the big macropores, thus it should start the diffusive flow before.
13. Page 7, line 20: Why are the Authors using a harmonic mean in (6) and an arithmetic mean in (3)?
14. Page 7, line 24: it is still not clear what are C and D_M and their meaning is the opposite of what is defined in the caption of Figure 2.

15. Page 8, Lines 4, 7: what is the depth of the soil samples? Please specify also the initial soil saturation used in the model.
16. Page 9:, eq 7: how was this coefficient computed?
17. Page 9, section2.4.3: the proposed macropore structure has many degrees of freedom. Is it possible to calibrate / validate such a model with infiltration measurements?
18. Page 9, line 20: Which kind of sensitivity analyses is performed? Sensitivity of which output of the model? From table 2 I understand that the parameters used in the sensitivity analysis are evenly spaced in the parameter space. Usually in MC-approaches the parameters are randomly selected from the parameter space.
19. Page 9, lines 31 – 33: this part should go in the discussion.
20. Page 10, line 1: This sentence is not clear here. I suggest to describe the observations (and the possible difference with the mode outputs) in the methods section. Please provide more information about how these observations are obtained. The real process is three-dimensional. How are these concentrations obtained? Are they an average of the concentrations in different layers?
21. Page 10, line12: change ‘suggest’ with ‘suggests’
22. Page 11 , line 3: please specify which are the three values of k_s considered
23. Page 11, Section 3.3.2: please discuss why in figures 7a and 8d the concentration increases between depths -0.15 and -0.4 for all the macropores diameters considered.
24. Page 12, line 30: This sentence in not correct: to prove this sentence, the sensitivity analysis should be performed by perturbing the parameters of the real-case

experiment. However the parameters of the real-case experiment are not among the ranges considered in the sensitivity analysis.

25. Page 12, lines 31-33: this modelling detail should be specified in the model setup. Which is the computational cost of the model when using 2 million particles?
26. Page 13, line 18: From figure 5, the sensitivity of the results with respect the considered variation of k_s is quite small. What are the differences when changing k_{pfd}?
27. Figure 2, caption: the saturated hydraulic conductivity of a macropore here is indicated with k_s, while in the main text (page 5, line 8) it is indicated with k_{pfd}. I think the same notation should be used for these two variables. From the figure I am not sure to understand the difference between the diameter of macropore (D_M) and the circumference of a grid element (C). Why the length of a grid element is expressed as $dz(\Delta z)$?
28. Figure 2b: this figure is really not clear and not well explained in the caption. Do the three cylinders correspond to three different time-steps? The times should be better indicated in the figure and the caption should describe what is happening in the three steps.
29. Table 2: please consider using a parameter range that covers the parameters used in the Spechtacker test. Not only it is important to see the sensitivity of the model in this test, but I think the results obtained for the Spechtacker are quite interesting, having a very deep infiltration.
30. References: please check the references: Zehe and Bloshl in not in the correct place. Sometimes there is an ‘and’ before the last author, sometimes not.

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