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Comment on hess-2021-426

Anonymous Referee #3

Referee comment on "It rains and then? Numerical challenges with the 1D Richards equation in kilometer-resolution land surface modelling" by Daniel Regenass et al., Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2021-426-RC3, 2021

The authors presented in the manuscript a study dealing on 'improvements' in temporal and (vertical) spatial resolution in LSM. From the title alone I was attracted as the title suggest novelty and analysis, whereas the manuscript itself does not show any novelty at all. For me it seems y that some basic soil physical principles are not totally clear to the authors. Additionally, recently, Vereecken et al. (2019) published an overview article (Infiltration from the Pedon to Global Grid Scales: An Overview and Outlook for Land Surface Modeling), where from page 8 onwards exactly the problems raised here are shortly discussed. Additionally, there is a link provided (https://www.pc-progress.com/Downloads/Public_Lib_H1D/Using_HYDRUS-1D_to_Simulate_Infiltration.pdf) to a full set of simulations using a physical based model showing the effects of different spatial and temporal discretization on infiltration.

Additionally, there are many flaws and sometimes easy problems are made complicated. I worked over the manuscript in detail to about half and made many suggestions and provide comments either in the attached scan or below. After, I decided to have only a quick look at the results as I already made my opinion that the manuscript in its current form is not appropriate for publication.

ABSTRACT

Line 5: If you want to represent run-off and infiltration correctly, even sub-hourly data are needed, as short but intensive rainfall (e.g., thunderstorms) often cause high run-off as they often reach dry soils.

Last sentence in the abstract: I do not agree, as this is fact irrespectively of the scale models run at (as I also believe that the models commonly used will not change in their algorithms if smaller horizontal resolution will be used). To my understanding the scale (horizontal resolution) only changes the driving forces, especially precipitation.

INTRODUCTION

Line 63: This is exactly the problem in LSM. Here, it was suggested to use a depth-dependent profile of saturated hydraulic conductivities. Maybe by this more water can infiltrate but still we will have a wrong model setup generating good results. For sure, hydraulic conductivity will change over the depth profile (which has been shown in many publications and often Ks is high in ploughed layers) but why not first take care that the infiltration process is described correctly?

Line 75-80: To disentangle the effect of how Ks will be defined at different scales and what the effects of different forcing are (here precipitation) a simple scaling exercise could have been performed, such as those done for crop models and water balances by Constantin et al. (2019, doi.org/10.1016/j.agrformet.2019.05.013)

Line 82: by some form of the Richards equation. Exactly, this is the problem, as the Richards equation will be solved in the diffusivity form in most LSM and not in the mixed form as most (small) scale soil hydrological models. And this exactly generated the problems as an 'external' infiltration concept has to be implemented to solve the infiltration/runoff partitioning (such as Green-Ampt for example). An overview that this holds for most LSM is provided in Tab. 2 of the Vereecken et al. (2019) already mentioned above.

Line 86-87. Indeed, different PTF will allow higher or lower infiltration but with respect to the problem analysed here this is not a solution. Would be the same 'wrong change' as already done for the vertical dependent Ks.

Line 88-92. Indeed, if high resolution maps are used it does not make sense to use class PTFs for e.g. the 12 (or in some LSM only 11) USDA soil classes, as the same output will be generated as we would have for coarser resolution of the soil maps.

Line 92-93: Indeed, as from a soil hydrological perspective this has been already analysed over the last 20-30 years but seems not to be percolated to the LSM community (or at least part of this community).

Line 100: Adaptive time-stepping. At least in the soil hydrological model I use, adaptive time stepping has been implemented since the early 1990s.

Overall, it would be good just to benchmark the LSMs against analytical solutions of infiltration or against soil hydrological models and one would see if they can capture infiltration-runoff partitioning, infiltration front propagation etc.

THE SYSTEM UNDER CONSIDERATION

This section is somehow textbook knowledge and remind me of what I show in my lectures!

Line 121-123: The features you encountered in the experiment are not necessarily connected to soil heterogeneities. It is known that even homogeneous sandy soils will show so called finger flow, which are caused by the hydrophobicity of the sand grains. One a grain will be wetted, the sand turns to be hydrophilic and water can enter the profile, while other regions will stay dry. Additionally, this section is a bit out of scope here and mixes up different processes and problems with those you are working on.

SOIL HYDRAULIC MODEL

Line 159: Here, you state that the two soil hydraulic models need parameterization, which depend on soil texture. This is not fully correct. They depend on the soil pore (distribution), which depend on one hand on soil texture, but also on soil structure. For the conductivity function it is even more complicated as it also depends on pore connectivity.

Line 159. Where did you get the parameters from for the loamy soil? Which PTF or better class PTF was used? Looking at the parameters presented in Tab. 1 I wonder why you showed m for MvG and not n as m is classicaly bound to n by M = 1-1/n. I also wonder about the alpha value which is 3.6 and therefore too large for classical loamy soils. Finally, why is the saturated hydraulic conductivity Ks different between the two models used as Ks is a material constant of the soil itself?

GROUND RUNOFF

Maybe I got something totally wrong here but isn't this Dunne overland flow if the soil profile is saturated (often also denoted as saturation excess overland flow)? If yes, this is totally different (in its physical principles) as runoff generated by Hortonion overland flow, which is the precipitation excess with respect to the infiltration capacity?

Finally, why assuming a zero-flux boundary condition at the lower end. To my understanding and neglecting lateral water flow in the saturated zone this will later or earlier always generate Dunne overland flow if the ET is smaller as precipitation.

BOUNDRAY CONDITION

Here we are. In your case, Imax is set to Ks. In reality, this is only the case if infiltration will be only driven by gravity and not by capillary forces. This might happen if the soil is close to saturation but if the soil is much dryer infiltration at its onset can be larger as Ks. This is simple infiltration theory.

NUMERICAL IMPLEMENTATION FOR EQUIDISTANT GRIDS

Line 196: Are you sure that most LSM solve the Richards equation on equidistant discretization. I do not believe so, as to my knowledge most have finer discretization at the top end and increase the spacing with depth. This is also stated in line 216, where it is mentioned that LSM commonly choose grids with finer spacing close to the surface.

Finally, I do not understand why you have to stress on implementing non-equidistant gridding in your model as this is state-of-the-art in all other models.

Line 199: There are two points mixed up. The special and temporal resolution.

EXPERIMENT A…

Line 273: …reproduce the analytical solution. What is the analytical solution? Physically, maximum infiltration at saturated conditions without ponding water at the surface equals Ks.

To not understand what you mean by convergence. Numerical convergence does not necessarily mean that the process is represented physically (e.g. shape and wetting front speed)

EXPERIMENT B

Actually, it is not really of interest here how the forcing was calculated by COSMO as any forcing could have been used to show what you want to show. I would either delete or shift to the Annex (if any Annex is allowed in HESS)

FIGURES

Figure 5: Sorry if you define Theta_f as volumetric water content as done in Tab. 1 how

can you reach Theta_f of 1 here. This would mean only water and no soil in the systems! I would denote this as lake or ocean!

TABLES

In general, headers for tables should be above the table and not below (see Tab 1 and 2).

Please also note the supplement to this comment:
https://hess.copernicus.org/preprints/hess-2021-426/hess-2021-426-RC3-supplement.pdf