We’d like to thank the reviewer for its careful reading and its useful comments.

The manuscript focuses on the use of a Richards-based solver to reproduce hydrological observations from multiple lysimeters in France. The case study is also used to compare three soil hydraulic models (i.e., Brooks-Corey, van Genuchten-Mualem, a combination of both). The aim is relevant for HESS and somehow interesting, however the manuscript possesses multiple methodological weaknesses:

1. The choice to use the ISBA LSM model, which was conceived to operate on larger scales, to investigate a process at the lysimeter level (and prove a soil physics point: Brooks vs van Genuchten) is questionable. The model solves the Richards equation using a Crank-Nicolson scheme but there are no details about the spatial discretization, boundary conditions, etc. By reading this (https://doi.org/10.1029/2018MS001545), the model seems to use a multi-layer approach based on the finite difference. Widely used vadose zone hydrological model such as HYDRUS or SWAP use schemes that comply with the mass conservative approach proposed by Celia et al. (1990). These models have been widely tested, and would be a more rational choice to investigate processes at the lysimeter level and compare multiple soil hydraulic models.

The ISBA LSM model is applied at global, regional and local scales. Several studies showed the good performance of ISBA at local scale : Boone et al., 2000, Calvet et al., 1999, Decharme et al., 2011. Moreover, studying lysimeters with LSM allows us to verify and to propose improvement directions for simulations at larger scale, such as the integration of a heterogeneous profile with depth.
Moreover, compared to SWAP or HYDRUS models, ISBA solves both the water and energy budgets at a fine temporal scale so as to provide atmospheric models with surface flux (latent and heat fluxes) and boundary conditions (surface temperature and albedo for instance).

The Richards equation is solved numerically using a Crank-Nicholson implicit time scheme where the flux term is linearized via a one-order Taylor series expansion and as Hydrus or SWAP, uses a mass conservative method (Decharme et al., 2011, Decharme et al., 2013, Masson et al., 2013). The mixed form of the Richards equation is solved, as it has more robustness with respect to mass balance.

Thank you for noticing that spatial discretization and boundary conditions were missing.
In this study, the soil discretization was adapted to the lysimeter depth and to the measurement depths: 13 soil layers are used, with nodes at 0.01, 0.04, 0.1, 0.2, 0.4, 0.6, 1.0, 1.2, 1.4, 1.6,1.8 and 2 m. A free drainage condition is used at the

bottom of the soil column. Additionally, a one-year simulation is performed and the output of the simulation are used

We'll add all these informations in the revised version of the article

2. The whole methodology on the comparison between model predictions and observations is cumbersome to read, not novel, and weak.

   Sorry that you didn't enjoy the reading, although reviewer 3 stated that ", the paper is well written and a pleasure to read" . The simulations of the lysimeter data are made using a SVAT model used in regional hydrology, weather and climate models, which is not that common, and include even an interactive vegetation scheme. The comparison of the simulation with the observation is made using classical statistical scores, but also, focussing on specific events, which again is not that common. Hovmoller diagrams (figures 9, 10, 12) and Taylor diagram (figure 11) are used. But it seems that the comment focuses mainly on the estimation of the soil parameter, according to the following points:

- No error metric is reported to compare multiple soil hydraulic models. Besides fitting (which should be quantified), other metrics should be used to compare also the complexity of the models (e.g., at least Akaike Information Criterion)
- The calibration procedure should compare time series of modeled and observed soil water quantities (e.g., water contents). An objective function or a likelihood (e.g., NSE, Gaussian, etc) should be selected, and a numerical algorithm should be used to perform the model calibration. Further, parameters uncertainty should be assessed to see how informative are data, and whether the choice of a more complex model is justified. Only after having performed a statistically robust analysis, it is possible to try to explain why BC+VG is better and when. As they are, methods don't support enough the conclusions, and neither represent a novel contribution to the field.

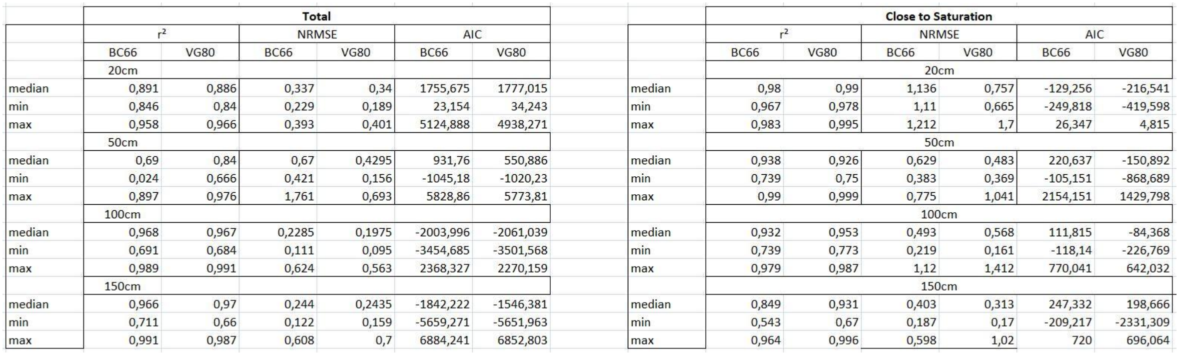
Thank you for these useful comments. Indeed, we did not provide details on the soil parameters calibration procedure, as we mainly focused on the difference between the soil parameters derived from in-situ data to those derived from pedotransfer functions. We will add the details in the revised version of the article.

The calibration of the soil parameters was performed using two methods: i) an objective least squares function which minimizes the sum of the squares of the deviations and corresponds to maximizing the likelihood with a normal distribution (function nls of rstudio). ii) the package SoilHyP (Dettmann et al., 2022) which uses the Shuffled Complex Evolution (SCE) optimization.

The two methods converge on very closed estimated parameters ($\delta b: 1.6;\ \delta n: 0.01; \delta wsat: 0.0085\ (m^3 m^{-3}); \delta\alpha: 2\ (m^{-1});\ \delta\Psi sat: 0.019\ (m)$).

Statistical scores and errors metrics on the estimation of the soil water retention curves (WRC) are presented in Table R1.1 for the BC66 and VG80 relationships at each depth. On the entire fit and close to saturation ($> \omega_{sat} * 0.9$), values median, minimal and maximal are presented. The fitted are generally better in depth, and a better r² for VG80 than for BC66 near to saturation. Near saturation, the NRMSE is also better for VG80 than BC66.

Table R1.1 : Statistical scores (regression, r²) and errors metrics (Normalized Root Mean Square Error, NRMSE, and Akaike information criterion, AIC) for the BC66 and VG80 relationships at each depth (20-50-100 and 150 cm) on the total entire fit (Total) and close to saturation ($> \omega_{sat} * 0.9$) for all lysimeters for soil water retention curves (WRC).

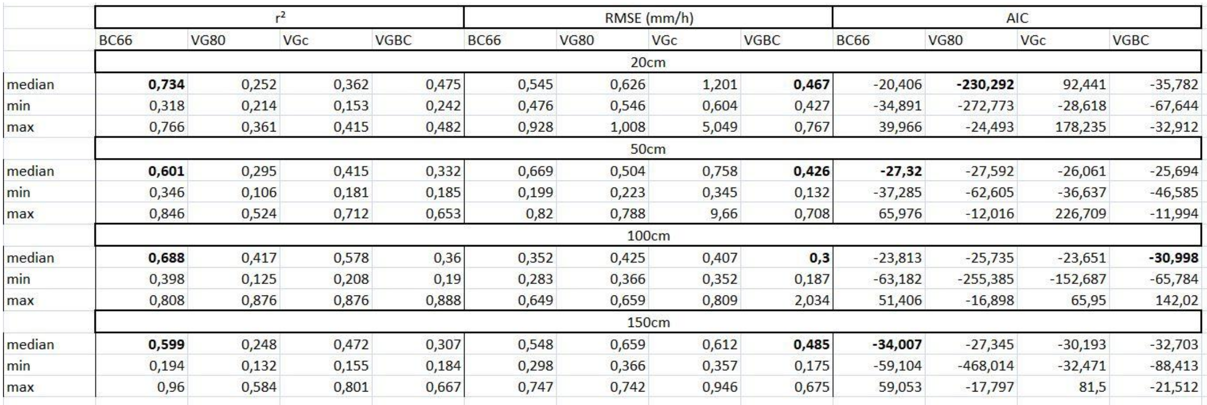


	Total					
	r²		NRMSE		AIC	
	BC66	VG80	BC66	VG80	BC66	VG80
	20cm					
median	0,891	0,886	0,337	0,34	1755,675	1777,015
min	0,846	0,84	0,229	0,189	23,154	34,243
max	0,958	0,966	0,393	0,401	5124,888	4938,271
	50cm					
median	0,69	0,84	0,67	0,4295	931,76	550,886
min	0,024	0,666	0,421	0,156	-1045,18	-1020,23
max	0,897	0,976	1,761	0,693	5828,86	5773,81
	100cm					
median	0,968	0,967	0,2285	0,1975	-2003,996	-2061,039
min	0,691	0,684	0,111	0,095	-3454,685	-3501,568
max	0,989	0,991	0,624	0,563	2368,327	2270,159
	150cm					
median	0,966	0,97	0,244	0,2435	-1842,222	-1546,381
min	0,711	0,66	0,122	0,159	-5659,271	-5651,963
max	0,991	0,987	0,608	0,7	6884,241	6852,803

	Close to Saturation					
	r²		NRMSE		AIC	
	BC66	VG80	BC66	VG80	BC66	VG80
	20cm					
median	0,98	0,99	1,136	0,757	-129,256	-216,541
min	0,967	0,978	1,11	0,665	-249,818	-419,598
max	0,983	0,995	1,212	1,7	26,347	4,815
	50cm					
median	0,938	0,926	0,629	0,483	220,637	-150,892
min	0,739	0,75	0,383	0,369	-105,151	-868,689
max	0,99	0,999	0,775	1,041	2154,151	1429,798
	100cm					
median	0,932	0,953	0,493	0,568	111,815	-84,368
min	0,739	0,773	0,219	0,161	-118,14	-226,769
max	0,979	0,987	1,12	1,412	770,041	642,032
	150cm					
median	0,849	0,931	0,403	0,313	247,332	198,666
min	0,543	0,67	0,187	0,17	-209,217	-2331,309
max	0,964	0,996	0,598	1,02	720	696,064

The calibration of the hydraulic conductivity curves (HCC) was also realized. For each depth, we estimated the hydraulic conductivity at saturation with the water volumetric content and the drainage at 2m for at least 3 years by averaging the drainage values for each water volumetric content value. Statistical scores are shown in Table R1.2 for the four relations. RMSE are better at depth with closer differences than at surface, and always better for VGBC (<0.5 mm/h). AIC are relatively closed between the four relations.

Table R1.2 : Statistical scores (regression, r²) and errors metrics (Root Mean Square Error, RMSE, and Akaike information criterion,AIC) for the BC66 and VG80 relationships at each depth (20-50-100 and 150 cm) for calibration for hydraulic conductivity curve (HCC).



	r^2				RMSE (mm/h)				AIC			
	BC66	VG80	VGc	VGBC	BC66	VG80	VGc	VGBC	BC66	VG80	VGc	VGBC
	20cm											
median	**0,734**	0,252	0,362	0,475	0,545	0,626	1,201	**0,467**	-20,406	**-230,292**	92,441	-35,782
min	0,318	0,214	0,153	0,242	0,476	0,546	0,604	0,427	-34,891	-272,773	-28,618	-67,644
max	0,766	0,361	0,415	0,482	0,928	1,008	5,049	0,767	39,966	-24,493	178,235	-32,912
	50cm											
median	**0,601**	0,295	0,415	0,332	0,669	0,504	0,758	**0,426**	**-27,32**	-27,592	-26,061	-25,694
min	0,346	0,106	0,181	0,185	0,199	0,223	0,345	0,132	-37,285	-62,605	-36,637	-46,585
max	0,846	0,524	0,712	0,653	0,82	0,788	9,66	0,708	65,976	-12,016	226,709	-11,994
	100cm											
median	**0,688**	0,417	0,578	0,36	0,352	0,425	0,407	**0,3**	-23,813	-25,735	-23,651	**-30,998**
min	0,398	0,125	0,208	0,19	0,283	0,366	0,352	0,187	-63,182	-255,385	-152,687	-65,784
max	0,808	0,876	0,876	0,888	0,649	0,659	0,809	2,034	51,406	-16,898	65,95	142,02
	150cm											
median	**0,599**	0,248	0,472	0,307	0,548	0,659	0,612	**0,485**	**-34,007**	-27,345	-30,193	-32,703
min	0,194	0,132	0,155	0,184	0,298	0,366	0,357	0,175	-59,104	-468,014	-32,471	-88,413
max	0,96	0,584	0,801	0,667	0,747	0,742	0,946	0,675	59,053	-17,797	81,5	-21,512

Specific comments:

L15-20 Not really. Drainage is the amount of water that bypasses the root zone.

It is true that drainage can be associated with different fluxes, which is why we provided the definition. Indeed, if drainage is sometimes associated to the amount of water that bypasses the root zone (Silburn et al., 2013) it is also traditionally associated to the part of precipitation that flows through the first meters of soil down to the aquifer (Philip et al., 1969, Whisler et al., 1970). We will add these references to the revised version of the article.

L47-50 Nonlinearity cannot be a source of criticism, otherwise an endless number of equations used in environmental modeling should be “criticized”. I would remove this part. Richards equation is not perfect, but we are still far from finding a viable, widely used, and extensively validated alternative.

We agree with your comments, and we agree to remove this part.

L56 BC66 has that sharp singular point near the air-entry pressure that makes it not very stable. (https://doi.org/10.1029/93WR03238). Authors indeed discuss this point later. However, more specific references are needed to prove your point that BC66 is more numerically stable than VG80.

Thank you for highlighting this point. The non-linear form of the VG80 hydraulic conductivity has a high reduction at pressures near saturation in particular for n values close to 1, and has numerical convergence problems (Van Genuchten 1980, Vogel 2000), notably when parameters n and m are dependent (Dourado et al., 2011).

We proposed to modify the article like this : The non-linear form of the VG80 hydraulic conductivity has a high reduction at pressures near saturation in particular for n values close to 1, and has numerical convergence problems (Van Genuchten 1980, Vogel 2000), notably when parameters n and m are dependent (Dourado et al., 2011).

Data: Please add details about TDR sensors (e.g., type, accuracy, calibration type) and tipping bucket resolution

On the GISFI site, TDR probes are RIME-PICO32 sensors with internal TDR-electronics. They are set horizontally and record the water content in cm3 cm− 3 (± 0.01) on an hourly basis. The calibration was performed on two measurements, one in dry and one in water-saturated condition. In the OPE site, soil moisture sensors used (UMP-1Umwelt Geräte Technik GmbH) are based on frequency domain reflectometry (FDR) method and measure local change in dielectric permittivity.

Tipping bucket resolution is 0.1mm.h-1 on the two sites.

L124-125 Is the heat transport included in the numerical simulation of lysimeters? If yes, key equations should be provided. Otherwise, it should be removed from the text.

Yes, as stated, the heat transport is solved. Most Land Surface Models use multilayer soil diffusion schemes, which solves mass and heat diffusive equations. We chose not to provide the equations, since only a global statics is provided on the ability of ISBA, to solve soil temperature line 229.
We propose to add heat transport and temperature equations in the appendix. The surface soil temperature evolves to the surface heat flux rate G (W m²) for N soil layers by the use of the classical one-dimensional Fourier law (Boone et al., 2000, Decharme et al., 2013).

$$\frac{\delta Ts}{\delta t} = C_T [G - \frac{\overline{\lambda 1}}{\overline{\Delta z 1}} * (T_1 - T_2)]$$

$$\frac{\delta Ti}{\delta t} = \frac{1}{C_{gi}} \frac{1}{\Delta zi} [\frac{\overline{\lambda} i-1}{\Delta \overline{z} i-1} * (T_{i-1} - T_i) - \frac{\overline{\lambda i}}{\Delta \overline{zi}} * (T_i - T_{i+1})]$$

where Δzi (m) is the thickness of the layer i, $\Delta \overline{z} 1$ (m) is the thickness between two consecutive layer nodes, C_{gi} (J m−3 K−1) is the total soil heat capacity, and λi (W m−1 K−1) is the inverse-weighted arithmetic mean of the soil thermal conductivity at the interface between two consecutive nodes.

L130-140 This part should be moved after the Richards equation, and should describe how it is connected to the sink term S(z). Key equations should provided. Citing refs is good, but the manuscript should stand by itself.

Thank you for your judicious suggestion, we will move this part.

The sink term S(z) is the evapotranspiration from vegetation and evaporation from the bare soil.

L147-148 what is the discretization of the soil profile? What are the boundary conditions used?

Infiltration in ISBA is computed at a 5-minute time steps as the precipitation that drops through the canopy and reaches the first layer of soil. The Green-Ampt approach is used to determine the maximum amount of water that infiltrates the soil.

For the boundary conditions, please refers to the answer to your question #1 above

Figure1. Very confusing. It is difficult to appreciate differences. What are the dashed lines? Figure+Caption should be self-explanatory

We are sorry that the figure seems confusing and we will improve the caption. The figure has two main goals: i) to illustrate the variability of the soil properties between two soil columns and within the soil profile and ii) to illustrate the difference between BC66 and VG80.

We agree that the 1st point is easier to see than the 2nd one, and this is why the dashed lines were added. The dashed lines are the derived values of the water content at saturation and matric potential at saturation for BC66 which is also the alpha parameter for VG80. Therefore, the vertical lines help to show the differences between the expressions of BC66 and VG80, as the value of the matrix pressure cannot have lower values for BC66 (in absolute value), while it can with VG80.

This will be added in the caption, and added line 180.

L176 There is not a single error metric to support the conclusion that one formulation is better than the other. It is really puzzling to see that.

Thank you for raising this point. Indeed, it appears quite clearly from such a graph that the VG80 expression of matrix potential is closer to the observation

close to the saturation than BC66, and the article mainly focussed on how this impacts the simulation of the soil water content and soil water drainage, with numerous statistics on these comparisons.
But of course, we can add the statistics on the soil parameters calibration. . Please, refers to the answer to your question #2 above that provides the full statistics.

L192 VG80 not stable for n<1.3?! Never experienced something like this. Indeed, I agree with the Authors that n>1.1 is a good constraint.

Thank you for sharing your agreement. The relation m=1-1/n; applicated in this study for the VG80 relations, is not recommended for n <1.25 and n > 6 (Van Genuchten 1985). The non-linear form of the VG80 hydraulic conductivity has a high reduction at pressures near saturation in particular for n values close to 1, and has numerical convergence problems (Van Genuchten 1980, Vogel 2000).

L197 Having a highly negative tortuosity is not recommended. Actually Schaap suggests a value of -1 (https://doi.org/10.2136/sssaj2000.643843x)

Thank you for raising this point. The NRMSE score on the comparison between observed and simulated drainage of the sensitivity tests are presented in Table R1.3. Best results were obtained for a tortuosity fixed at 0.5 for OPE lysimeters (O1-O2 and O4); and -5 for GISFI lysimeters (G1-G2-G3-G4).

Table R1.3 : Normalized Root Mean Square Error (NRMSE) scores from simulations with VG80 for each lysimeters, with variation of the parameter l.

	NRMSE						
l	**G1**	**G2**	**G3**	**G4**	**O1**	**O2**	**O4**
-5	0,738	0,851	0,861	0,81	0,867	0,929	0,777
-2	0,741	0,875	0,989	0,813	0,861	0,946	0,753
-1	0,763	0,93	0,968	0,81	0,873	0,931	0,763
-0,5	0,738	0,898	0,969	0,855	0,873	0,926	0,763
0,5	0,774	1,038	0,876	0,817	0,694	0,817	0,708
1	0,929	1,185	0,899	0,826	0,812	0,826	0,715
2	0,878	1,144	0,861	0,849	0,694	0,824	0,708
5	0,966	1,031	0,948	0,869	0,77	0,83	0,736

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