Revisions based on referee comments.

Line numbers in our replies refer to the version with the marked changes.

Referee 1

Referee 1 wanted more clarity about Eq. (4). We added Rossi and Nimmo's (1994) model as Eq. (4) to the Introduction and discussed it in detail there. Our new parameterization is therefore Eq. (5) in the revision. We added a line below that equation explaining how the different branches were taken from Eqs. (3) and (4). Referee 1 also asked us to list the advantages of Eq. (5), but we already did that in the original text (lines 155-157 of the revision).

We did not change the figures because referee 1 only had problems when the figures were printed in black and white, which is a minor issue.

Referee 2

We expanded the discussion of the unphysical behavior of retention curves that have non-converging integrals as reported by Fuentes et al. (1991) (lines 63-70).

In the Theory section the subsection on the hydraulic conductivity curve, lines have been added to indicate that the main focus on the paper is on the retention curve and the examination of the hydraulic conductivity curve limits itself to finding a closed-form expression. We also explained the limitations of using fixed parameters according to theoretical model when no conductivity data are available and the possibility to fit conductivity parameters independently from the retention curve if the data allow this. We added a line in the Results and Discussion section alluding to this added text (line 384-386).

A brief discussion of the limitations of the conductivity model was added below Eq. (14b). This paragraph concludes with the reference to a recent publication with more sophisticated conductivity models that was already included in the first version.

We decided against seeking additional data to test our parameterization because the hydraulic conductivity is not the main focus of the paper and the measurement technology required to produce the type of data that would be needed does not exist to our knowledge.

Comments not addressed in our earlier response to Referee 2:

Line 209, eq. (13): Is tau chosen as 0.5?

The text as written is correct: the expression is valid for any value of τ. See Madi et al. (2018) for limits to its range. When we used the retention parameters to estimate conductivity curves we set the parameter values in Eq. (14a) (Eq. (13a) in the first version) according to Mualem (1976). The text mentions this, and also gives these parameter values, including that of τ.

Lines 225 – 231: I propose to choose less but better data with (i) consistent lab measurements for both SWRC and K(theta) and (ii) some data with K(theta) values at very negative pressures

If we could have we would have done so, but to our knowledge there are no conductivity measurements at low matric potentials that do not rely on conversion from water contents to matric potential through the water retention curve. In a paper that introduces a new retention curve parameterization, the reliance of the conductivity data on that same parameterization would create complications in the logic of the line of argumentation.

Figure 1: Why RIA and VGA are different for the loamy sand?

This is why we argue for more data points near saturation. There is not enough information in the data to pinpoint the air-entry value, and VGA and RIA have enough flexibility to produce different curves that match the available data very well. The fitting code in one case settled on an air-entry value very close to zero, and in the other case on a value closer to the wettest unsaturated observation point. If the data provide more guidance in the range near-saturation, this will reduce the uncertainty about the shape of the retention curve that is evident from Fig. 1.

Table 2: You should add Ks and hd (and beta) values for RIA

The table only contains the fitting parameters, parameters that are expressed as functions of the fitting parameters should therefore not appear in the table. Table 2 is strictly concerned with the retention curve. K_s does not appear in the retention curve.

Figure 2: Choose different color for VGA for silt loam – it is too similar to clay

We changed the color to a lighter hue of blue in both Fig. 1 and Fig. 2 for consistency.

Lines 293 - 298: The reference to Bitelli and Flury is illustrative – maybe the authors could use some of those data as well to fit SWRC

We added fits to one of Bittelli and Flury's (2009) samples, because all samples were from the same location and the disturbed samples were of limited interest to us. The three sigmoidal parameterizations tested in this paper gave very similar results, except in the very dry range, where RIA's log-linear branch deviated from the asymptotic branches of the other two. The difference between the data sets resulted in distinctly different fitted SWRCs. The results corroborate the rest of the paper, as well as Bittelli and Flury's (2009) findings. Interestingly, the inclusion of data points in the dry range resulted in a value of the matric potential at oven dryness that is very close to the value reported in the literature as being representative for many ovens. We added a section (including a figure and a table) in the Results and Discussion starting at line 350.

Line 320: the only sample with K(theta) measured in the lab (soil 4450) is poorly described by RIA ...

We modified the text to explain that fitting the conductivity curve with retention data only is not a good idea.

Lines 331-335: There is no experimental evidence that the RIA trends are better – this is just a description of modeled behavior.

This is correct. The text reflects this and makes no claims about RIA being better.

Figure C5 & C9, Soil 1122 (and other examples): The authors obviously cut the curves at pF=6.8 for VGA and VGN. Probably this should be stated and explained in the captions.

The referee is correct. A sentence explaining this was added to the third paragraph of Appendix C.

Lines 363-365: The statement that 'small differences between SWRCs can have a significant influence through different hydraulic conductivity curves' should probably be revised; even for the very same SWRC curve the water flow will be different due to different conductivity functions

Valid point. We clarified the text.

Lines385-386: The statement that 'RIA was better able to produce a conductivity curve with a substantial drop ...' is misleading because we do not know if this 'substantial drop' is in agreement with measurements

We used 'produce', not 'reproduce'. The statement therefore is not misleading but an accurate description of the capability of RIA to produce conductivity curves with substantial drops just below saturation. For soils with well-connected pore networks and perhaps tunnel-like biopores (i.e., root holes), such drops can be expected. We therefore posit that this is a desirable property.

TECHNICAL CORRECTIONS/COMMENTS

Line 17: State that the infinite slope at saturation is considered to be physically impossible

Done.

Line 37: Write out SWRC at the beginning of the main text

Because we use many abbreviations we listed them all in Appendix A. Therefore we did not write them out in full on their first occurrence.

Line 96: the shape of the samples ('cylindrical') is not relevant; maybe 'equilibrating short soil samples'?

Because the samples are cylindrical, their cross-sectional area is independent of the sample height. When the fitting code calculates the water content of the sample, it therefore assigns the same weight to each depth interval. Therefore, the shape of the samples is relevant. So is their orientation. We therefore added 'vertically placed'.

Line 157: delete 'the' ('... the the logarithmic ...)

Thank you. Corrected.

Line 238: Is Tamale not in the tropical climate zone?

No, the climate is semi-arid there. Tamale is located between the tropics to the south and the Sahel to the north.

Line 315: delete 'goes'

Corrected.

Line 344-345: what do you mean with 'reduced Ks-value' and the 'high Ks-value' for clay soils?

As the text at the end of Material and Methods explains, UNSODA had two samples for the same location with markedly different values for K_S. In all probability, one of them had macropores, and the other did not. Because K_S scales the conductivity curve, using the macroporous K_S lifted the rest of the conductivity curve, and the values became unrealistically high for capillary flow in a clay soil. We therefore used the K_S -value of the other sample instead.

Line 352: for the loamy sand under temperate climate, the results ranged from 92 to 104 % (Table 3) – why is this difference more than 10%? Was the deviation in the silt loam (84-115%) not higher?

The referee is right. We corrected the mistake in the text.

Line 353: For loamy sand in 'semi-arid' climate, the 89% value for evaporation has higher deviation than 10%

We corrected the text.

Line 354: Temperate, not 'temperature'

Corrected.

Line 439: delete 'of'

Corrected.