Reply to RC2's comments

Dear Reviewer, thank you for the positive and constructive suggestions to improve our manuscript. Below are my responses to your comments.

The present manuscript focuses on the experimental and modelling aspects of the hydrologic behavior of a shrinking soil under repeated wetting-drying cycles. In particular, the role of cracks and their dynamic behavior during the cycles are emphasized. The overall content of the paper is very interesting, relevant and fits within the aim and scope of the journal. Regarding the novelty aspects. Experimental: I am not an expert in the subject, but I am assuming (as it also transpires from the paper) that this type of experiments (e.g., setting, soil type, involved processes, scale of observation) are well-established; the experimental results are of quality. Modelling: the authors emphasize the novelty aspect of the proposed dynamic (i.e., varying with the saturation degree of the soil matrix) crack permeability, yet, going through the paper, it appears to me that the proposed model strongly leverages on previous formulations introducing then some assumptions. The reference to the literature seems appropriate and reach; Figures could be of a better quality; Writing: I am not a native English speaker, but there are several unclear parts in the text and several errors, I highly recommend a careful revision of the text.

I have a set of comments which I hope would help to improve the quality of the paper.

Response: Thanks for your insightful summary of this study and we are very happy with your appreciation of our work. We agree that some of the figures and English text need further improvement. We will make revision in light of your suggestions in the new version. For the model novelty, please see reply to comment 1.

Comment 1: the authors define the novel dynamic dual permeability model DPMDy mainly by setting the relative permeability of the crack always equals to 1 (Eq. (28) and line287) while they leverage on Eq. (27) proposed by Steward et al., 2016b to determine the absolute value of the permeability of the crack. ① ***In this context, the DPMDy does not seem that novel, since it is mainly based on an assumption rather than a novel formulation/expression!*** ② ***Moreover, how reasonable it is to set the relative permeability of the crack always to 1? The less water there is in***

the crack the smaller the crack permeability should be.

In section 6.2.1 the authors compare the values of crack permeability for the DPMDy and dual permeability (DPM) models (see Eq. (25)), see Figure 17: The striking feature being that the crack permeability for DPM decreases over the drying cycle, while that for the DPMDy increases. ③ ***I would expect a decreasing trend for the crack permeability as the soil gets dry: we are speaking of the crack permeability associated with water, thus as less water is present in the crack the harder it gets to let it flow under a given head gradient; this is the meaning of including the relative permeability in Eq. (25).*** ④ ***At the same time, I do agree on the explanation provided by the author for the increasing trend of the DPMDy crack permeability: the drier the soil, the wider the crack, the easier it is to have water flowing … if we are talking of a completely saturated crack (as they assume), while I imagine that the saturation of the crack decreases during the drying cycle. I am seeing a bit of confusion on the meaning of absolute permeability, relative permeability and the permeability for a flowing phase.*** ⑤ ***Moreover, I am wondering what would be the results (e.g., crack permeability to water) if Eq. (25) is combined with Eq. (27) (that provides the dynamic aspect of the absolute crack permeability to water)? DPMDy is Eq. (25) + Eq. (27) under the assumption of relative permeability of the crack to water fixed at one.***

Response: Thanks for these insightful comments!

For comment ①, we agree with you that fixing the relative permeability of the crack always to be 1 (abbreviated as "$K_{c,r}$ = 1" hereafter) does not come from a novel formulation. Indeed, as one of the essential novelties in our model, we prefer to regard "$K_{c,r}$ = 1" as a new strategy (or a trick). This strategy ensures the crack permeability varies with the crack aperture (or ultimately the matrix water content) instead of the crack saturation degree. Such a trick avoids the unreasonably decreasing trend of the crack permeability during the dying and enlarging process of desiccation cracks. This new strategy is useful and never been reported in other studies, thus we still hold it is an important novelty in our model.

For comment ②, you're correct that in microporous media (e.g., soil matrix), for which, in dry conditions, capillary potential is the dominant term to water potential energy, the less water, the smaller the soil conductivity. However, as we mentioned in our model (Line 262), the crack domain is mainly composed of large voids, through which water is assumed to flow according to Poiseuille law (laminar flow at atmospheric pressure). This assumption implies that crack conductivity depends only on crack aperture, as the water content in that domain affects only the hydraulic radius of the flowing water cross section. The independence of crack conductivity from soil matrix water potential should not surprise, as it is a consequence of the non-equilibrium flow condition, which is typical of dual porosity media (e.g., Šimůnek et al., 2003), and which is responsible of the water exchange terms between the two pore domains (i.e., equation (3)). This exchange term would not exist if the potential energy of the water in the two pore domains was at equilibrium.

For comment ③, we are aware that in the usual unsaturated conductivity models, the relative permeability in Eq. (25) plays the role in linking the conductivity with the water content, and thus drying crack domain would always lead to decreasing crack conductivity. However, as mentioned above, such a trend would be physically unreasonable for the enlarging desiccation cracks, in which the assumption of Poiseuille laminar flow implies that the conductivity, in turn related to the hydraulic radius of the cross section of the water flowing through the crack, should grow with crack aperture, regardless the degree of saturation of the crack domain.

For comment ④, as already mentioned in the reply to comment ②, the assumption of laminar flow through the cracks, obeying Poiseuille's law, implies that the conductivity only slightly depends on the degree of saturation of the cracks, while it is directly related to crack aperture. This is the reason why, for the sake of simplicity, it is assumed to neglect the slight dependence of crack domain hydraulic conductivity on crack saturation degree, and consider only the dependence on crack aperture. Besides, the SWRC only controls crack domain water storage capacity, but it has no influence on the conductivity.

For comment ⑤, we have compared the curve of Eq. (25) + Eq. (27) to that of only Eq. (25). As shown in the figure below, the crack conductivity calculated by Eq. (25) + Eq. (27) would result much lower with respect to that only using Eq. (25), and it would also show a strange non-monotonic trend with the saturation degree.

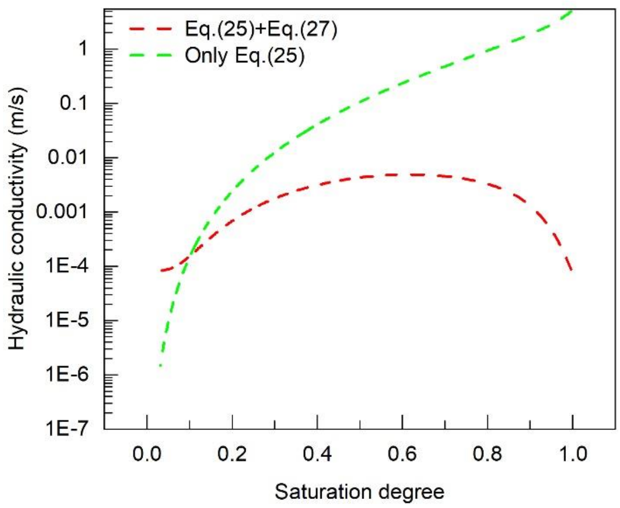

Fig. reply-1 Crack permeability calculated by only using Eq. (25) and combing Eq. (25) + Eq. (27)

Comment 2: Lines 596-597 "With regard to the water flux, while the three models all have acceptable errors to the measured data, the DPM overpredicted the water flux of PF-DC but underestimate the water exchange from cracks to soil matrix." It is my understanding that the DPM underestimates the water exchange from cracks to soil matrix w.r.t. to other models (e.g., see Figure 18 and Sec. 6.2.2), but not respect to the actual behavior which is not recorded in the experiment (it is a difficult task), please clarify.

Response: Thanks for the comments! You're correct here. We will change this sentence in light of your suggestions as follow:

Line 596-597: With regard to the water flux, while the three models all have acceptable errors to the measured data, the DPM overpredicted the water flux of PF-DC but underestimated the water exchange from cracks to soil matrix compared to other models.

Comment 3: What is depicted in Figure 16? The caption does not say it, a reader must search in the main text for it.

Use the same color legend for the two panels in Figure 8 (see measurements at 25 cm) and specify what are the additional data (red and blue curves), please. Figure 6: the legend is very small. General: I would avoid dashed (or dotted) curves when is not necessary (e.g., Fig. 6a; Fig. 12; Fig. 14; Fig. 15), the quality of the images is not very high and it gets quite hard to see dashed curves, please consider change them.

Response: Thanks for pointing out these issues, we will revise these figures in our new version.

Comment 4: Unclear text parts. Line 48 "the effects of crack dynamics on the PF-DC through experiment studies" should not be experimental? Line 51 "However, other studies found that the PF-DC also leads water to rapidly infiltrate into deep soil even desiccation cracks" even WHEN dessication? Line 59 "An improve understanding of the PF-DC combined with theory methods is also needed" THEORETICAL methods? Lines 66-67 "The DPoM and DPM concepts belong to the dual-domain framework that assumes the soil pore system can be represented" that assumes THAT the soil? Line 84 "volume and hydrological properties keep constant" remain constant. Lines 89-90 "Later modification of SWAP incorporated the aforementioned process, but with a cost of neglecting shrink-swell behavior of soil." A later modification .... but AT THE cost; Line 92: "Coppola et al. (2012); (2015) took another step forward to allowed crack volume…" to ALLOW. And many more throughout the whole text, e.g., Line 516 "In addition, another interesting phenomenon is the transient decrease of ð¤c,exp and increase of 5cm ðexp …" are you referring to ðexp at 5 cm depth? It is not clear; Line 582 "It corresponds to some experimental results that the PF-DC also exists and leads water rapidly infiltrate into soils even desiccation cracks are nearly closed during … " leads water TO rapidly infiltrate .... even IF dessication cracks are nearly. Please revise it very carefully!!

Response: Thanks for pointing out the grammar issues. We will check through the manuscript to carefully revise these and other issues.

Comment 5: SWRC at line 31 is not clear what it is. AOI in figure 3, what does it stand for? Se,c in Eq. (25) is not defined.

Response: Thanks for pointing out. SWRC refers to the soil water retention curve and AOI indicates area of interest. Se,c is the saturated degree of the crack domain. We are sorry for presenting their abbreviation without any explanation at the first time when they appear in the manuscript. We will add detailed explanation of these abbreviations in the revised manuscript.

Comment 6: After Eq. (1)-(4) the list of symbols is detailed by giving one line to each, this changes for Eq. (5)-(13), then again for Eq. (14) one line to each symbol. Be consistent!

Response: Sorry for the mistakes. We will unify them as one line in the new version.

Comment 7: Table 1 says statistical results, what statistics are involved here?

Response: This indeed is misleading. We will revise "statistical results" as "manual readings".

Comment 8: many parameters of the model(s) have been calibrated (see Table 3), but it is not clear how? Which calibration strategy has been used?

Response: For Table 3, only SWRC parameters for the crack domain and mass transfer coefficient a_w have been empirically assigned. All the other parameters come from fitting procedure to measured data. We will add more information about parameter estimation in the revised manuscript.

References:

Šimůnek, J., Jarvis, N. J., van Genuchten, M. T., and Gärdenäs, A.: Review and comparison of models for describing non-equilibrium and preferential flow and transport in the vadose zone, J. Hydrol., 272, 14-35, 10.1016/s0022-1694(02)00252-4, 2003.