Dear John Nimmo,

thank you very much for reviewing our manuscript. We have considered all of your statements carefully. Please find below our detailed answers to all comments. We are convinced that your comments will lead to considerable improvement of our work and thank for this constructive input. For convenience, we numbered the comments.

Kind regards,
Andre Peters, Sascha C. Iden, and Wolfgang Durner

Major comments

1. This paper evaluates the relative merits of four different capillary bundle models, applied within the framework established in the earlier paper P23 (Peters and others, 2023), for predicting unsaturated hydraulic conductivity from retention data. The tests are rigorous and conducted for data from twenty-three widely different soils, and using four different commonly used formulas for representing the soil water retention. The results are satisfyingly definitive in showing that the Mualem model gives the best results. Another contribution of this paper is in exploring and elucidating the function of the saturated tortuosity coefficient introduced in P23.
   An important insight revealed in lines 230-241, and noted in line 179 and elsewhere, is that the value of the saturated tortuosity coefficient τ_s depends on the particular conductivity model it is used with. This is not surprising, though it brings out the fact that unless τ_s can be computed independent of a K model, it is not universal and not a property of the medium. This feature seems at odds with the hypothesis of a universal value as described by P23. It should be explained and perhaps elaborated in the discussion.

   We are thankful for this comment and will discuss that its general value depends on the capillary bundle model in the revised manuscript and replace the word “universal”. Actually, this is in accordance to our previous interpretation of τ_s:

   > *“In real soils, however, the deviation from flow in straight capillary bundles is not only affected by tortuosity in the strict sense but also by other soil-related factors such as the surface roughness of pore walls, non-circular capillaries, and dead-end pores. Additionally, not only the geometry of the pore space may differ from the ideal case but also such fluid properties as surface tension and viscosity likely will be different from those of pure free water. Finally, capillary bundle models will not represent the pore distribution and connectivity in an ideal way. Therefore, we seek in this contribution an empirical value of τ_s that lumps all these effects.”* (Peters et al., 2023, section 2.3).

   Nevertheless, we take this remark as a welcome addition to the current manuscript. We will extend the first sentence, which introduces this fact (lines 230ff of the current version):

   > “Figure 3 shows that the different conductivity prediction models give different optimal values for the saturated tortuosity coefficient, τ_s. This is in accordance with the discussion of the nature of τ_s in Peters et al. (2023) who acknowledge that the notion of a universally applicable saturated pore tortuosity is untenable. Rather, it must be seen as a porous medium property in the context of the specific conceptualization of a capillary bundle model."

2. This paper needs added material in the introduction or a separate section that reviews previous tests and comparisons of capillary bundle models (e.g. van Genuchten and Nielsen, 1985; Hoffmann-Riem and others, 1999; Kosugi, 1999). That will help make clear the context of this work and the contribution it adds to the existing literature. Although I hesitate to mention my own work in a manuscript review, a paper of mine (Nimmo and Akstin, 1988) is directly relevant and has some parallels with the present work. In it, we tested four capillary bundle models, three of which are among the four tested in this new manuscript. Our test was done on different samplings of identical soil material, with variations in packing and preparation to produce samples that varied modestly in porosity and hydraulic properties. As in the present work, the model of Mualem (1976) was found to be preferable. The test made a convincing demonstration of the basic utility of capillary bundle models in showing that measured retention curves for different samples, plugged into the capillary bundle models, gave rise to predicted conductivity curves that differed from each other, in direction and in approximate magnitude, in the same way the four sets of measured conductivity data differed. At the time of that study, this result raised my previously dubious regard for the usefulness of capillary bundle models.

   We appreciate this suggestion and intend to incorporate an expanded paragraph into the introduction. This addition will encompass prior comparisons of capillary bundle models, including the four papers you recommended, along with the works of Jackson et al. (1965) and Jackson (1972), in conjunction with the research by Madi et al. (2018).

3. Though the work in this manuscript shows little real innovation, it has value in its thorough testing of widely used models and in providing helpful information for anyone considering the hydraulic conductivity-predicting model put forth in P23. It should be published after moderate revision.

   We agree that this study is less innovative than the previous study (P23). Yet we believe that it contributes to science and practical applications by helping to select the most appropriate models.

4. other comments:
   - 28: Reword. Functional form is not mandatory. There are alternatives, like tabulated values, though little used.

     Will be done.

   - 33: “Any liquid flow ceases” is too definite a statement. Better to just say vapor flow becomes the dominant transport process.
     You are right. Will be changed accordingly.

   - 50: Seems like a misplaced comma.

     We guess you mean the comma at line 49, which will be deleted.

   - 92: Better to say “particles” than “molecules” because molecules are subject to Brownian motion and do not individually follow a streamline.

     Right. But we hesitate to name it “particles”, because in our understanding (we are non-native speakers), the term is referring to the solid phase. Hillel uses the term “(flickering) clusters” (Hillel D. 1988. Environmental Soil Physics, Academic Press, page 26). We will use “parcels of water” in the revised version.

- 99: Subscript sc is reversed in equation.

  Thanks, will be adjusted.

- 133: Define θs and θr.

  Will be done.

- 161: Insert “among”—they are among the most commonly used . . .

  Will be done.

- 220: In Fig. 1, curves for CCG and Bur are faint and hard to see—should be thicker. Also colors should be different to show more contrast than between the blue and green shown. Similar effects in Fig. 4.

  We tried to use a barrier free color scheme but agree that this can be improved. We will do so in the revised version.

- 311: To help the reader, for the left side of Fig. 6, note briefly what is different to give four slightly different retention curves when the same FX model is used for each.

  We fitted the model combinations (retention and conductivity model together) to the data. Since the retention parameters alpha, n and m influence the shape of both(!) functions, the retention fits differ slightly for the different model combinations although we used always the same retention model. We will make this clear in the revised manuscript.

- 345-387. Appendix A1 is highly duplicative of original publications and the appendix in P23. It should be omitted, except possibly for part A1.3. The material in part A1.3 might be better placed in the main text.

  You are absolutely correct. Our initial intention behind presenting the complete model in the Appendix was to enhance its availability to the community, eliminating the need for users to refer to external sources. However, considering that the model is already provided in P23 (which is readily accessible as an open-access resource), we will follow your suggestion.

- 411: There is no Figure 7. Must be Figure A4.

  Thanks for that hint. You are right, it must be Fig. A.4.

Cited literature

Hoffmann-Riem, H., van Genuchten, M.T., and Flühler, H., 1999, General model of the hydraulic conductivity of unsaturated soils, in van Genuchten, M.T., Leij, F.J., and Wu, L., eds., Proceedings of the international workshop on Characterization and measurement of the hydraulic properties of unsaturated porous media: Riverside, CA, University of California, p. 31-42.

Jackson, R. D. (1972). On the calculation of hydraulic conductivity. *Soil Science Society of America Journal*, *36*(2), 380-382.

Jackson, R. D., Reginato, R. J., & Van Bavel, C. H. M. (1965). Comparison of measured and calculated hydraulic conductivities of unsaturated soils. *Water Resources Research*, *1*(3), 375-380.

Kosugi, K., 1999, General model for unsaturated hydraulic conductivity for soils with lognormal pore-size distribution: Soil Science Society of America Journal, v. 63, 270-277 p.

Madi, R., de Rooij, G. H., Mielenz, H., and Mai, J. (2018): Parametric soil water retention models: a critical evaluation of expressions for the full moisture range, Hydrol. Earth Syst. Sci., 22, 1193–1219, https://doi.org/10.5194/hess-22-1193-2018.

Mualem, Y., 1976, A new model for predicting the hydraulic conductivity of unsaturated porous media: Water Resources Research, v. 12, no. 3, 513-522 p.

Nimmo, J.R., and Akstin, K.C., 1988, Hydraulic conductivity of a sandy soil at low water content after compaction by various methods: Soil Science Society of America Journal, v. 52, no. 2, 303-310 p.

Peters, A., Hohenbrink, T. L., Iden, S. C., van Genuchten, M. T., & Durner, W. (2023). Prediction of the absolute hydraulic conductivity function from soil water retention data. *Hydrology and Earth System Sciences*, *27*(7), 1565-1582.

van Genuchten, M.T., and Nielsen, D.R., 1985, On describing and predicting the hydraulic properties of unsaturated soils: Annales Geophysicae, v. 3, no. 5, 615-628 p.