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Do effective properties for unsaturated weakly heterogenous media exist? An experimental study.

A. Bayer (1) and H. -J. Vogel (1) and K. Roth (1)

Institute of Environmental Physics, University of Heidelberg, Im Neuenheimer Feld 229, D-69120 Heidelberg (andreas.bayer@iup.uni-heidelberg.de)

The hydraulic properties of a vertical sand column were measured in a multistep outflow experiment. A weak heterogeneity of the material was generated due to the filling process of the column. During the experiment the vertical distribution of water was measured with a high spatial resolution using X-ray attenuation.
As in typical experiments, the estimation of hydraulic parameters through inverse modeling was based on the measured outflow dynamics without considering the detailed information on the vertical profile of water contents. Assuming a van-Genuchten/Mualem parameterization of the hydraulic properties, the outflow dynamics could be reproduced reasonably well. Based on the resulting effective hydraulic functions the dynamics of water inside the sand column was calculated, and we compared the results to the direct measurements. Due to the heterogeneous structure of the sand column, we found a considerable disagreement.
Using the measured water content profiles at different pressure steps, it was possible to roughly reconstruct the vertical hydraulic structure of the column. Another simulation of the multistep outflow experiment based on this heterogeneous description reproduced both, the water content profile and the cumulative outflow. Evidently, a realistic representation of the hydraulic structure leads to reliable predictions of the water dynamics for arbitrary initial and boundary conditions while effective hydraulic properties fail. This is demonstrated by numerical simulations.
Hence, effective properties for unsaturated weakly heterogenous media do exist, but they are only valid for the specific situation of the experiment which was used for inverse parameter estimation. This conclusion sounds trivial but it may be one key to explain the failure of flow and transport models in many applications.