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Lehmann, Peter; Hoogland, Frouke; Or, Dani

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On the air-entry value of porous media: New insights from measurements, imaging and pore scale modeling

Peter Lehmann, Frouke Hoogland, and Dani Or

Soil and Terrestrial Environmental Physics, ETH Zurich, Zurich, Switzerland (peter.lehmann@env.ethz.ch)

The air entry value is the capillary pressure associated with the formation of a continuous gas phase, hence marking the onset of unsaturated conditions in a porous medium. Near the air-entry value, transport properties change abruptly hence the importance of reliable determination of this value for modeling processes in the vadose zone. Typically, air entry value is inferred from the soil water characteristics of a porous sample subjected to step-wise increase in applied suction. This procedure is laborious and may require long equilibration times, and is difficult to apply for coarse media. We present an alternative and simpler method to deduce air entry-value from continuous evaporation from an initially saturated porous sample. As water evaporates and menisci form and penetrate the surface, the capillary pressure (measured with a tensiometer at any depth) abruptly changes and marks the macroscopic air entry value. This value remains remarkably constant during evaporation and receding drying front (after accounting for hydrostatic front position). We present experimental results from different porous media confirming that air-entry values deduced from soil water characteristics and evaporation experiments are similar. We employed pore scale imaging and network modeling to confirm that the air-entry value corresponds to the critical path that is needed to form a continuous air phase and its macroscopic value remains stable at a drying front that traverses a uniform porous medium. For layered media, corresponding adjustments in air entry values and air invasion patterns have been predicted and measured.