Experimental and numerical studies on role of air flow in transient water retention behavior in one-dimensional layered system subjected to drainage and wetting

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Abstract. Transient water retention in the unsaturated zone of the shallow subsurface near the land surface is strongly affected by the climate conditions such as precipitation, wind, and heat flux at the land/atmospheric interface. Understanding of water retention behavior in this critical sub-zone of the subsurface is important in many engineering applications, e.g., detection of buried objects such as landmines, development of preferential air pathways that carry toxic vapor to subsurface structures and basements. In traditional vadose zone studies, it is typically assumed that air phase is free to move and hence the air pressure within all soil pores is at atmospheric. However, under certain conditions of subsurface heterogeneity, our preliminary experiments revealed that air flow plays a critical role in the transient soil water saturation distribution when the formation is subjected to mass flux boundary conditions. This suggests, when, modeling transient soil water distribution, the application of Richard's equation that assumes the air phase is free to move may not be valid. Hence to capture this behavior accurately, it may be necessary to model the flow as a two-phase problem. In this study, we will present results from a set of one-dimensional column experiments to show that neglecting air flow leads to inaccurate representation of the water drainage and wetting behavior. An initially saturated layered system in which a coarse sand layer is overlaid by a fine sand layer was subjected to drainage and then wetting. Soil moisture, water and air pressures were continuously monitored. To measure the air pressure, a new probe using hydrophobic cups was developed and tested. During the drainage cycle, immediately after air penetrated into the coarse sand layer, air pressure dropped significantly below atmospheric pressure; indicating that air flowed into the coarse sand layer. On the other hand, in the wetting cycle, air pressure became positive showing that the air was compressed. The results show that, without incorporating air flow, the experimentally observed drainage/wetting behaviors could not be reproduced accurately in models. Incorporation of air flow leaded to significant improvement when model results were compared to experiments.

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