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Experimental and numerical study of evaporation from heterogeneous porous media

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Evaporation is a key process for water exchange between soil and atmosphere. In addition to the atmospheric demand, evaporation rate is controlled by the material properties of the subsurface and the interplay between capillary, viscous and gravitational forces. In case of heterogeneous systems consisting of materials with different hydraulic functions, the evaporation process may be dominated by the hydraulic coupling of the materials. To analyze the effect of hydrologic coupling on drying rate, the water distribution during evaporation from a heterogeneous Hele-Shaw cell (500 x 280 x 20 mm) was monitored using neutron transmission technology.
The structure consisted of a tortuous fine textured inclusion of 20 mm thickness and 1100 mm in length connecting top and bottom of the cell. The background material was coarse quartz sand with particles ranging from 0.7 to 0.9 mm in diameter.
Initially, air enters the large pores of coarse sand while the fine medium remains saturated. A capillary pressure difference between the drying front in coarse sand and the surface of the fine drives horizontal water flow from the coarse material to the fine textured inclusion. Due to the high conductivity of the coarse sand the water supply was not limited by the horizontal flow in the background material. In the fine material, however, water flow is affected by viscous dissipation and the evaporation rate decreased with the length of the flow path within the fine. The experiment was simulated with a two-phase flow model that reproduced the experimental findings.
With the experimental and numerical study we conclude that the drying rate was controlled by the hydraulic coupling in the subsurface and could not be deduced from the surface structure. This result limits the modeling of water balance between soil and surface based on surface information alone.