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A new approach for measuring unsaturated hydraulic conductivity including hysteresis – with suprising insight to non-equilibrium water dynamics

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The unsaturated hydraulic conductivity of soils is in general hard to measure directly and therefore it is normally determined by inverse modeling of (de)saturation experiments. We developed a new and rather simple direct measuring method using soil columns where gravity-flow conditions are established for different but fixed flow rates following a computer controlled protocol. This is done for wet towards drier conditions by decreasing the flow rate and vice versa to capture hysteretic effects.

During the measurements we observe a surprising characteristic behavior of the water potential inside the core which reflects a slow change of hydraulic conductivity with time: Coming from a high water potential and lowering the flow, the potential first drops, as expected, but then it gradually rises again with time indicating a decrease of hydraulic conductivity. This is true over a large range of water potential. When increasing the flow rate we observe the opposite behavior, i.e. the conductivity is slowly increasing with time with convergence towards a constant value.

This phenomenology can be explained if we assume that the water content/water potential relation (Θ_Ψ) is not a static property but that the system slowly tends towards an optimal relation expressed by the main drainage and wetting branches of the water retention characteristic. Then for a rather constant water content (that will give a constant conductivity) the water potential will change with time towards the optimal configuration.

This behavior has been described before. There are Θ_Ψ characterizations that take this phenomenon into account, but so far it was hard to measure the dynamics of the transition between non-equilibrium state versus equilibrium. We think that our approach has the potential to quantify the soil water non-equilibrium dynamics.