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# NMR as a method to determine water content changes in the upper soil layer during evaporation

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Water exchange between bare soil and atmosphere is controlled by evaporation. In the topmost soil layer moisture content and hydraulic conductivity may change strongly and capillary film flow (stage I) from saturated regions to the surface discontinues. Evaporation is now mainly driven by vapor diffusion through a dry layer (stage II). Water vaporizes in the unsaturated zone inside the soil what strongly reduces the evaporation rate and also soil surface temperature to a considerable amount. The dynamics of the transition from stage I to stage II as well as film flow and vapor diffusion at low water contents have received little attention.
In this study we investigated water content changes in the uppermost soil layer with high spatial resolution using nuclear magnetic resonance (NMR). NMR is a feasible noninvasive method where the received signal of hydrogen protons allows conclusions on moisture and pore size distribution. The overall aim is to apply a mobile nuclear magnetic resonance surface sensor (NMR-MOUSE) directly for field measurements. This sensor has a max. measurement depth of 25 mm and operates at a Larmor frequency of 13.4 MHz. The general challenges of NMR in soils are the inherent fast transversal relaxation times of the soil matrix especially next to the residual moisture content. Therefore, as a first step of validation we applied and compared NMR-MOUSE measurements with magnetic resonance imaging (MRI) using an initially saturated sand column. The column was evaporated over 67 days and water content profiles were recorded by 1D-T2 relaxation measurements using the NMR-MOUSE as well as different 3D-MRI sequences during drying.
Firstly, we report on the sensitivities and limits of the different devices and measurement sequences. Considering these data, we could monitor that over a period of 58 days the moisture decreased rather uniform until the onset of stage II. Thereafter, a dry surface layer developed and a retreating drying front was observed.