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Magnetic resonance imaging of slow water flow during infiltration and evaporation by tracer motion

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Water fluxes in soils control many processes in the environment like plant nutrition, solute and pollutant transport. In the last two decades non-invasive visualization methods have been adapted to monitor flux processes on the small scale. Magnetic resonance imaging (MRI), also well known from medical diagnostics, is one of the most versatile ones. It mostly probes directly the substance of interest: water, and it offers many opportunities to manipulate the observed signals for creating different contrasts and thus probing different properties of the porous medium and the embedded fluids. For example, one can make the signal sensitive to the total proton density, i. e. water content, to spatial distributions of relaxation times which reflect pore sizes, to spatial distributions of transport coefficients, and to concentration of contrast agents by using strongly T1 weighted MRI pulse sequences. In this presentation we use GdDTPA2- for monitoring flux processes in soil columns in an ultra-wide bore MRI scanner. It offers the opportunity for monitoring slow water fluxes mainly occurring in soil systems which are not monitorable with direct MRI flow imaging. This contrast agent is most convenient since it behaves conservatively, i.e. it does not sorb at different soil materials and it is chemically stable. Firstly, we show that its mode of action in natural porous media is identical to that known from medical applications as proved by the identical relaxivity parameters [1]. Secondly, the tracer is applied for the visualization of flux processes during evaporation-driven flow. Theoretical considerations by forward simulation predicted a lateral redistribution of solutes during evaporative upward fluxes from highly conductive fine material to neighbouring domains with low water content and conductivity. Here we could prove that such near-surface redistribution really takes place [2]. Thirdly, this tracer is applied for the investigation of water uptake by root systems. Depending on the transpiration conditions slow uptake in the dark is present, where the tracer moves directly into the xylem. When fully illuminated, the tracer uptake is limited by the Caspari band, and it is enriched strongly in the roots cortex. The results so far show that this tracer offers a new window for monitoring slow water fluxes in bare and grown soil columns.

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