

The role of low-field nuclear magnetic resonance in critical zone research

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Many pressing environmental issues, such as the dynamics of surface water and groundwater, the behaviour of the changing cryosphere, addressing soil and water pollution, and the dynamics of natural and intentional carbon storage, are strongly linked to critical zone processes. Understanding the linkage and interactions among geological, hydrological, chemical, biological, climatic, and anthropogenic processes within the critical zone requires innovative scientific approaches. Geophysical methods characterize the spatiotemporal distribution of subsurface properties in a minimally invasive way and have shown great promises in critical zone research. Among these methods, low-field nuclear magnetic resonance (NMR) is an emerging method that has been used in many geoscience and environmental science applications. Leveraging its direct sensitivity to the proton, the low-field NMR provides non-invasive and fast characterization of different natural and engineering systems. In critical zone research, NMR measurements have been performed at the bench scale, borehole scale, and surface and allow prediction of basic properties of rocks and porous media, including volumetric water contents, saturation degrees, porosity, pore-size distribution, the amount of irreducible and free water, permeability, and hydraulic conductivity. In this presentation, I will discuss how water content, water distribution and fluxes, and weathering processes in carbonate critical zones are quantified and predicted using NMR methods at various scales. I will show how to link laboratory NMR findings with field NMR observations in this context. The key hydrogeological parameters will be quantified, the conceptual model of groundwater flow paths will be updated, and the water distribution in unsaturated weathered bedrock in a karst system will be defined using a recent study as an illustration. Through laboratory studies, theoretical modeling, and field work, we develop new NMR methodologies to improve the understanding of critical zone architecture and the hydro-, bio-, and geochemical processes within it.