Investigating pore coupling effects in near-surface environments using nuclear magnetic resonance

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Assessing and monitoring underground water resources is of increasing importance to ensure the continuous supply of fresh water for human activity and endangered ecosystems. These underground water resources include fully saturated aquifers and soil moisture and rock moisture. Nuclear magnetic resonance (NMR) is a non-invasive geophysical method with unique sensitivity to water. It is based on the magnetization and relaxation process of the spin magnetic moment of hydrogen atoms forming water molecules. NMR technique has been applied for hydrocarbon exploration and hydrogeologic investigation where it helps to characterize underground water distribution and water transport in different geologic materials. However, the interpretation of NMR data from samples with complex and heterogeneous geometries requires the consideration of pore coupling effects, which is often neglected in routine NMR data analysis. A pore-coupled system presents a significant magnetization exchange between macro and micropores within the measurement time, which makes the independent characterization of each pore environment difficult. Previous studies have explored different factors controlling pore coupling, such as network geometry and surface geochemistry, using a wide range of methodologies including laboratory experiments and numerical modelling strategies. In this presentation, we search to review, assess, and expand on previous findings on pore-coupling effects using NMR and aim to propose a unifying model to describe the pore coupling effect in unsaturated condition. We applied a random walk simulation on a simplified two-connected-pores system to evaluate and compare the main controlling factors identified in literature. In particular, we tested the influence of surface relaxivity on the pore coupling effect, as well as the influence of the degree of physical connectivity between the pores (understood as the pore-throat length) and of the effects of pore sizes (both absolute and in relation to each other). Developing a better understanding of pore coupling effects and its mechanisms is of great importance for the accurate estimation of hydrogeological parameters from NMR data. Improving the interpretation of NMR data in complex geometries prone to pore coupling and in unsaturated conditions is essential for this approach to reach its full potential.