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How heterogenous distributions of hydrophobicity affects the capillary rise in soil

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A central component of the rhizosphere is root mucilage, a hydrogel exuded by plants that dramatically alters chemical and physical properties of the soil. It is characterized by its large water holding capacity and is hydrophilic or hydrophobic depending on its hydration status: when swollen, mucilage is hydrophilic but becomes hydrophobic when dry, forming local hydrophobic spots on the surface of soil particles. The morphology of these hydrophobic regions formed by dried mucilage is affected by the type of mucilage and microorganisms and can vary from isolated local spots, to networks spanning across larger areas of the soil particle surface. However, until now the understanding on how this heterogeneous distribution and its morphology affect water retention and water repellency in soil is limited.

Therefore, the goal of this study is to investigate the impact of the spatially heterogeneous interfacial tension distributions on the capillary rise in soil. We utilize a two phase flow model based on the Lattice-Boltzmann to numerically simulate capillary rise between glass slides having a heterogeneous distribution of interfacial tension during imbibition and drainage. Parallel we validate the numerical simulation with capillary rise experiments between slides prepared with simplified heterogeneous distributions of interfacial tension using the Wilhelmy plate method, which is a widely-used method to measure macroscopic interfacial tensions between liquid and solid.

The simulations and experiments allow us to quantitatively evaluate how heterogeneous micro-scale distribution of interfacial tension affects the macro-scale water retention behavior. This we could approximately explain with three hypotheses: The equilibrium capillary rise volume (i) is a measure for the hydrophilicity of a field, (ii) capillary rise is affected by the standard deviation of the interfacial tension field, (iii) hysteresis is induced by the heterogeneous field and depends on the correlation length of the patterns.

In future, simulation and experiments will be extended also to the geometry of real soil.