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Lattice-Boltzmann simulations describing how a heterogeneous distribution of hydrophobicity created by dry mucilage affects water retention

Jonas Bentz (1), Ravi Ajitbhai Patel (2), and Eva Kroener (1)

(1) University of Koblenz-Landau, Institute of Environmental Sciences, Geophysics, Landau, Germany, (2) Paul Scherrer Institute, Villigen, Switzerland

The improvement of plant growth and health is of importance in practical soil science and is closely-linked with the knowledge about the rhizosphere. 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 turns hydrophilic respectively hydrophobic depending on its hydration status: when swollen, mucilage is hydrophobic but becomes hydrophilic 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, till 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 capillary rise in soil. We utilize a three-dimensional 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.
The simulations allow us to quantitatively evaluate how heterogeneous micro-scale distribution of interfacial tension affects the macro-scale water retention behavior. The main conclusions resulting from our simulations are: (i) the larger the standard deviation of interfacial tension the larger the hysteresis in water retention and the larger the water repellency during imbibition; (ii) the larger the characteristic length of patterns the larger the hysteresis in water retention; (iii) water repellency during rewetting is enhanced if the hydrophobic areas form a connected network compared to the case when they are present as isolated spots.
In future, simulations will be carried out using the geometry of real soil. The numerical model is planned to be validated by comparing to results derived from experiments on glass slides prepared with a heterogeneous distribution of hydrophobicity and later on real soil prepared with dry mucilage.