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Experimental and theoretical study of unsaturated flow in fractured media

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Unsaturated flow in fractured media is an important process with relevance to a large number of industrial and environmental application. In this work, we report recent experimental and theoretical investigations on unsaturated flow in single fractures, fracture intersections, and fracture networks. Wo focus on how small-scale flow physics influences the spatial and temporal characteristics of unsaturated flow in discrete fracture networks. We propose theoretical models for predicting water splitting at fracture intersections and for predicting water breakthrough time in an unsaturated fracture network. We validate these models by comparing with experimental observations. We show that the breakthrough time in a fracture network decreases with the increase of initial saturation. We also find that avalanche infiltration mode, i.e., sudden release of a large amount of water from the network, emerges spontaneously in the network, and is modulated by the local splitting behavior. We further show that the power spectral density of the water saturation time series in the network follows a power law with an exponent of −2 for all simulations with different structural parameters and local flow rules, suggesting a universal self-organized criticality behavior for unsaturated flow in fractured rocks.

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