

PATTERN FORMATION IN MULTIPHASE FLOW THROUGH POROUS MEDIA: CONTINUUM MODELS AND PHASE DIAGRAMS

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Summary. Carbon capture and geologic storage, dissociation of methane hydrates in permafrost, infiltration of water in soil, and enhanced oil recovery, are some relevant examples of multiphase flow in porous media. While flow instabilities and pattern formation play a central role in these processes, our ability to describe them using mathematical models has been hampered by the lack of a macroscopic theory that explain the patterns observed in experimental and field conditions. We propose a new approach (phase-field modeling) to advance our fundamental understanding of multiphase porous media flow. The basic tenet, with origins in the mathematical description of solidification processes, is that the free energy of the system should reflect the inhomogeneous distribution of fluid phases in the pore space, in the spirit of the Cahn-Hilliard description of nonuniform systems.

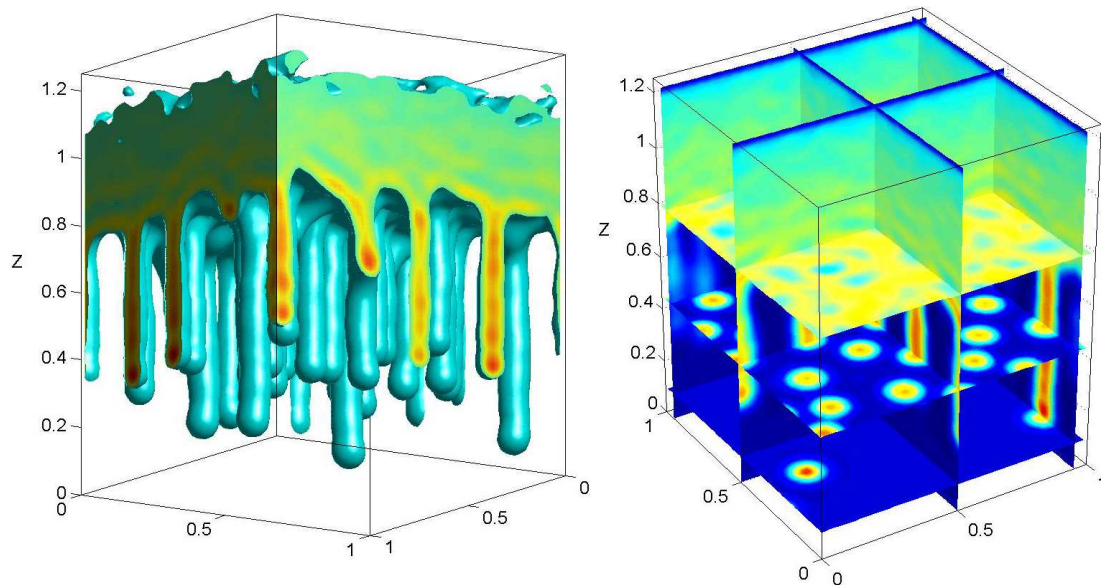


Figure caption: Three-dimensional simulation of redistribution of water in the vadose zone. Classical models of unsaturated flow are unable to explain the wetting front instability during gravity-driven infiltration into dry soil, which gives rise to preferential (fingering) flow. The proposed model reproduces the observed flow patterns, and quantitatively describes the properties of the fingers in terms of the model parameters.