Abstract Submitted
for the DFD17 Meeting of
The American Physical Society

Energy-based upscaling of immiscible two-phase flow in porous media: flow regimes and applicability conditions DAVIDE PICCHI, ILENIA BATTIATO, Stanford Univ — Empirical or theoretical extensions of Darcys law for immiscible two-phase flow have shown significant limitations in properly modelling the flow at the continuum-scale. We tackle this problem by proposing a set of upscaled equations based on pore-scale flow regimes, i.e., the topology of flowing phases. The incompressible Navier-Stokes equation is upscaled by means of multi-scale expansions and its closures derived from the mechanical energy balance for different flow regimes at the pore-scale. We also derive the applicability conditions of the upscaled equations based on the order of magnitude of relevant dimensionless numbers, i.e., Eotvos, Reynolds, Capillary, Froude numbers, and the viscosity and density ratio of the system. We demonstrate that the classical two-phase Darcy law is recovered for a limited range of operative conditions and it is compatible only with the connected-pathway flow regime, while additional terms accounting for interfacial and wall interactions should be incorporated to model accurately ganglia or drop traffic flow.

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Date submitted: 01 Jul 2017 Electronic form version 1.4