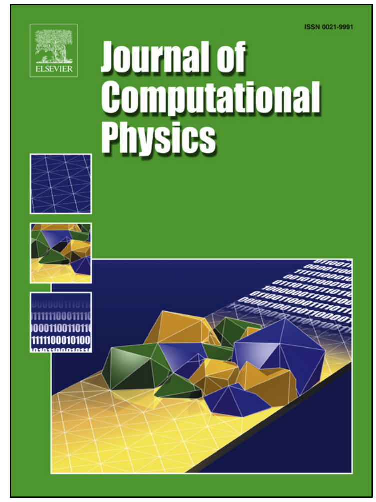

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A Multi-Scale Network Method for Two-Phase Flow in Porous Media

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Abstract

Pore-network models of porous media are useful in the study of pore-scale flow in porous media. In order to extract macroscopic properties from flow simulations in pore-networks, it is crucial that the simulation domains are large enough to be considered representative elementary volumes. However, existing two-phase network flow solvers are limited to relatively small domains. For this purpose, a multi-scale pore-network (MSPN) method, which takes into account flow-rate effects and can simulate larger domains compared to existing methods, was developed. In our solution algorithm, a large pore network is divided into several smaller sub-networks. The algorithm to advance the fluid interfaces within each subnetwork consists of three steps: (1) A meso-scale pressure is computed using upscaled transmissibilities on a coarse-grid with coarse-cells representing the sub-networks; (2) the obtained meso-scale pressure field is interpolated (prolonged) onto the sub-networks and the fluid-fluid interfaces within each subnetwork are independently advanced in time using a dynamic network flow solver; and (3) the upscaled meso-scale transmissibilities are updated based on the updated fluid configurations in each subnetwork. For prolongation and upscaling, the methodology of the existing multi-scale finite volume (MSFV) method is employed. Validation studies are presented and results obtained with the MSPN method are compared to results obtained with an existing dynamic network flow solver.

Keywords: Multi-scale, Network models, Porous media, Two-phase flow

1. Introduction

Two-phase flow in porous media [1, 2, 3] is important for numerous applications including enhanced oil recovery [4], groundwater remediation [5], and carbon dioxide sequestration [6]. For these applications an understanding of the flow mechanisms at the pore scale is crucial in understanding the flow at the macroscopic (Darcy) scale. This is because upscaled macroscopic flow parameters are dependent on both pore-space heterogeneity and topology, as well as on the fluid phase distribution within the pore-space.

Darcy's law, which relates the volumetric flux of a fluid with its pressure gradient, is a commonly used phenomenological law for describing multiphase flow in porous media at a continuum scale. It requires the specification of several parameters, such as macroscopic capillary pressure and relative permeability, which can be extracted either in laboratory experiments or by pore-scale simulations. The advantage of pore-scale simulations is that, unlike laboratory experiments, the rate at which they can produce results only depends on the available computational power. Moreover, different flow scenarios can be studied simultaneously in the same flow domain.

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