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PREFACE

Special issue on multiscale methods for flow and transport in heterogeneous porous media

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The properties of natural porous media display high variability levels and complex multiscale heterogeneity. The dynamic flow and transport processes in these large geologic formations are, in turn, multiscale in nature and are a natural target for multiscale formulations. The development of multiscale numerical methods for the solution of partial differential equations with heterogeneous coefficients across scales has received increasing attention during the past few years. This special issue is a collection of articles that, in the opinion of the guest editors, is a representative "cross section" of current research in the area. Some of the contributions, which we outline below, are based on work presented at the Eighth Society for Industrial and Applied Mathematics Conference on Mathematical and Computational Issues in the Geosciences held in Avignon in June of 2005, where the guest editors organized a minisymposium on "Multiscale Methods for Flow and Transport in Heterogeneous Porous Media."

Efendiev et al. [3] propose a multiscale framework that employs a flow-based coordinate system (streamlines) to include information from various scales. The key idea is that the scale interaction in the upscaled flow equations can be simplified in a flow-based coordinate system.

Juanes and Dub [4] present a variational multiscale mixed finite element method for problems with source terms with multiscale character (wells). They develop an enhanced localization assumption for the subgrid problems and incorporate multiscale source terms by a decomposition into coarse and deviatoric components.

Aarnes et al. [1] present a multiscale framework for flow simulation on corner-point grids (the industry standard for gridding complex reservoir geology). The multiscale mixed finite element method is used for the coarse problem, and a mimetic discretization for the subgrid problems. The authors also discuss how the choice of the coarse grid impacts the effectiveness of the method, and they offer guidelines that yield efficient overall schemes.

Chen et al. [2] present a framework for modeling full-tensor effects in subsurface flow simulations using nonlinear two-point flux approximation (TPFA), instead of multipoint flux approximation (MPFA) schemes. The paper presents algorithms for both single-scale and two-scale TPFA methods. The two-scale methods, which may be regarded as multiscale methods, are put into a general framework and identified as nonlinear TPFA methods.

Lunati and Jenny [8] present an extension of the multiscale finite-volume method to porous media flows dominated by gravity effects. The essence of the proposed method is to include an additional basis function that captures gravity redistribution and is independent of the coarse-scale pressure.

Lee et al. [7] extend the multiscale finite volume (MSFV) method to the black-oil model: the industry-standard representation of phase behavior for non-

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linear three-phase flow in oil and gas reservoirs. The extension includes compressibility, capillarity, solubility, and gravity. The black oil pressure equation is decomposed into three parts, and the MSFV method is used with appropriate definitions of the multiscale basis functions for each problem.

Nordbotten and Bjorstad [9] present a class of mass conservative domain decomposition (MCDD) preconditioners. The authors show how the multiscale finite volume method may be interpreted as a special case of the MCDD preconditioner. The paper offers increased insight into the underlying structure of the MSFV and a methodology for devising new multiscale methods of similar type.

Kippe et al. [5] review and compare three recent multiscale methods for solving elliptic problems in porous media flow: the multiscale mixed finite element method, the numerical subgrid upscaling method, and the MSFV method. They also include, in their comparisons, a recent adaptive local–global upscaling method. Their numerical simulations reveal properties of the various methods, which they discuss along with possible improvements.

Lambers et al. [6] present a scale-up approach where a stencil based on a local MPFA is used. The MPFA scheme is designed to be as close as possible to a TPFA. Their MPFA stencil varies spatially, and the specific stencil at a given location is determined using an optimization procedure.

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