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Nonlinear Model Reduction with Localized Basis for Two-Phase Miscible Flow in Porous Media

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Abstract

This work presents an application of a model reduction approach to substantially decrease the simulation time for two-phase nonlinear miscible flow in porous media. Since this type of flow often contains detailed features in fingering displacement, the approach considered here employs the localized basis sets from Proper Orthogonal Decomposition (POD) in the Galerkin projection procedure to accurately capture the important dynamics of the system. Discrete Empirical Interpolation Method (DEIM) with corresponding localized basis is then applied to efficiently compute the projected nonlinear terms in the POD reduced system. The related theoretical aspect of this approach is discussed. This work also proposes an adaptive scheme based on an error estimate indicator to choose a subdivision of the localized basis, together with an efficient procedure for updating each localized basis during the online simulation. This localized model reduction approach is shown to construct a system that can accurately capture the characteristics of the original miscible flow in the 2D finite-difference discretized setting, with the dimension reduced by a factor of $\mathcal{O}(10^2)$ and the CPU time decreased by a factor of $\mathcal{O}(10^3)$.

Key words: Nonlinear Model Reduction, Proper Orthogonal Decomposition, Empirical Interpolation Methods, Nonlinear Partial Differential Equations, Miscible Viscous Fingering in Porous Media.