

# Stochastic Porous Media Modeling and High-Resolution Schemes for Numerical Simulation of Subsurface Immiscible Fluid Flow Transport

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## Abstract

This paper proposes stochastic petroleum porous media modeling for immiscible fluid flow simulation using Dykstra–Parson coefficient ( $V_{DP}$ ) and autocorrelation lengths to generate 2D stochastic permeability values which were also used to generate porosity fields through a linear interpolation technique based on Carman–Kozeny equation. The proposed method of permeability field generation in this study was compared to turning bands method (TBM) and uniform sampling randomization method (USRM). On the other hand, many studies have also reported that, upstream mobility weighting schemes, commonly used in conventional numerical reservoir simulators do not accurately capture immiscible displacement shocks and discontinuities through stochastically generated porous media. This can be attributed to high level of numerical smearing in first-order schemes, oftentimes misinterpreted as subsurface geological features. Therefore, this work employs high-

resolution schemes of SUPERBEE flux limiter, weighted essentially non-oscillatory scheme (WENO), and monotone upstream-centered schemes for conservation laws (MUSCL) to accurately capture immiscible fluid flow transport in stochastic porous media. The high-order schemes results match well with Buckley Leverett (BL) analytical solution without any non-oscillatory solutions. The governing fluid flow equations were solved numerically using simultaneous solution (SS) technique, sequential solution (SEQ) technique and iterative implicit pressure and explicit saturation (IMPES) technique which produce acceptable numerical stability and convergence rate. A comparative and numerical examples study of flow transport through the proposed method, TBM and USRM permeability fields revealed detailed subsurface instabilities with their corresponding ultimate recovery factors. Also, the impact of autocorrelation lengths on immiscible fluid flow transport were analyzed and quantified. A finite number of lines used in the TBM resulted into visual artifact banding phenomenon unlike the proposed method and USRM. In all, the proposed permeability and porosity fields generation coupled with the numerical simulator developed will aid in developing efficient mobility control schemes to improve on poor volumetric sweep efficiency in porous media.

**Key words:** permeability and porosity fields, turning bands method, Carman-Kozeny equation, SUPERBEE flux limiter, monotone upstream-centered schemes for conservation laws, weighted essentially non-oscillatory schemes.

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