Statistical prediction of waterflooding performance by K-means clustering and empirical modeling

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Objective:

Statistical prediction is often required in reservoir simulation to quantify production uncertainty or assess potential risks. Most existing uncertainty quantification procedures aim to decompose the input random field to independent random variables, and may suffer from the curse of dimensionality if the correlation scale is small compare to the domain size.

Method:

Developed a new K-means clustering assisted empirical modeling approach, for efficiently estimating waterflooding performance for multiple geological realizations:

(1) Firstly perform single-phase flow simulations in a large number of realizations, and uses K-means clustering to select only a few representatives, on which the two-phase flow simulations are implemented.

(2) The empirical models are then adopted to describe the relation between the single-phase solutions and the two-phase solutions using these representatives.

(3) Finally, the two-phase solutions in all realizations can be predicted using the empirical models readily.

Results:

(1) Applied to both 2D and 3D synthetic models and is shown to perform well in the P10, P50 and P90 of production rates, as well as the probability distributions as illustrated by cumulative density functions.

(2) Be able to capture the ensemble statistics of the MC results with a large number of realizations, and the computational cost is significantly reduced.

Algorithm. K-means clustering and empirical modeling

1: Randomly generate a large number of realizations.
2: Perform single-phase flow simulations on all realizations.
3: Use K-means clustering and choose one representative in each group.
4: Perform two-phase flow simulations on the representatives.
5: Fit the empirical models for pressure/total rate and fractional flow.
6: Use the empirical models and single-phase solutions to predict the two-phase solutions.

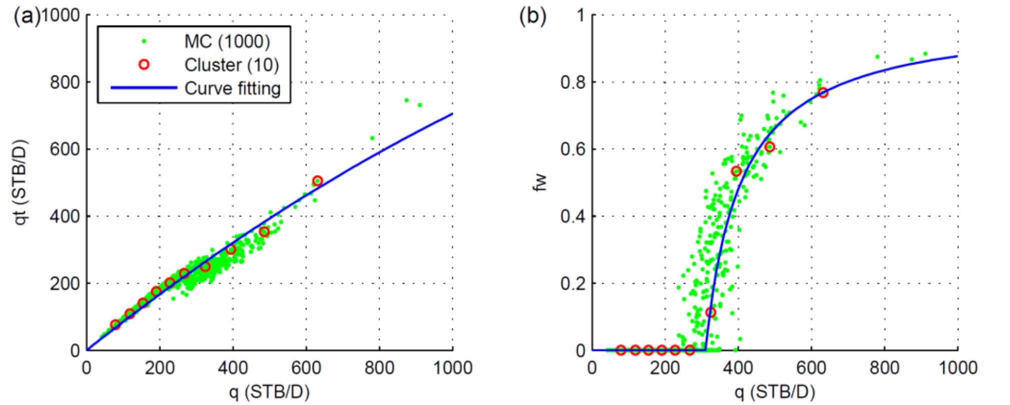

Fig. 1 Empirical models and curve fitting: (a) total production rate as a function of single-phase production rate, fitted by a quadratic function; and (b) fractional flow as a function of single-phase production rate, fitted by an exponential function with truncation.

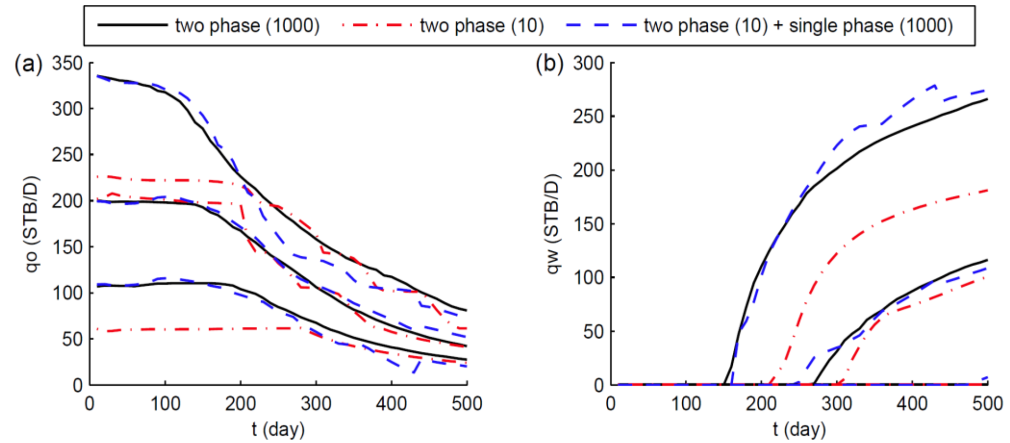

Fig. 2 Exact and estimated P10, P50 and P90: (a) oil production rate; (b) water production rate.

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