A very simple data-driven model based on flow diagnostics for reservoir management

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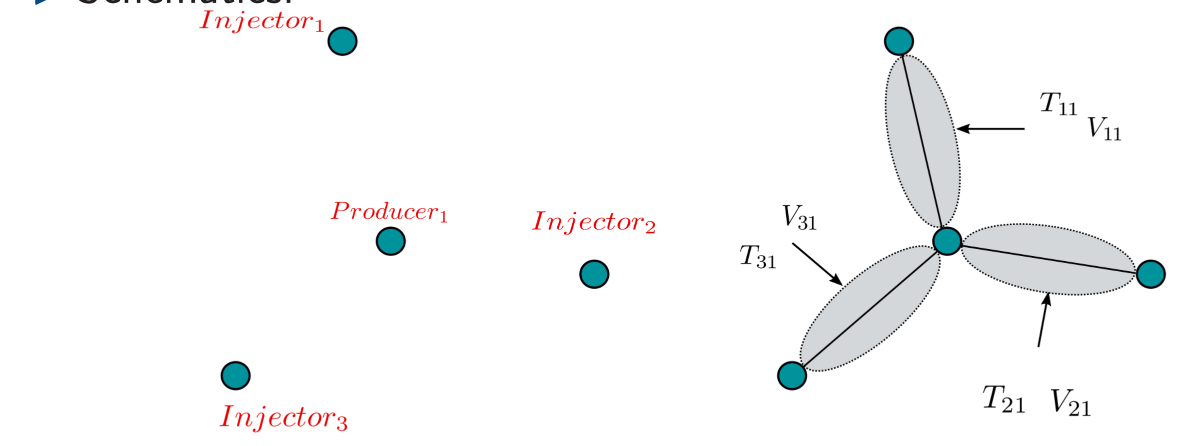
(1) – Introduction

- Full-physics reservoir models can be computationally prohibitive as a large number of simulation runs are required for history matching and optimization [1]
- Data-driven models may provide an attractive alternative to accelerate reservoir management [5]
- A large number of parameters and high complexity of the model can make a calibration procedure more difficult
- We proposed a methodology that used flow diagnostics to create a very simple model that requires an easy calibration procedure

(2) – Data-driven model

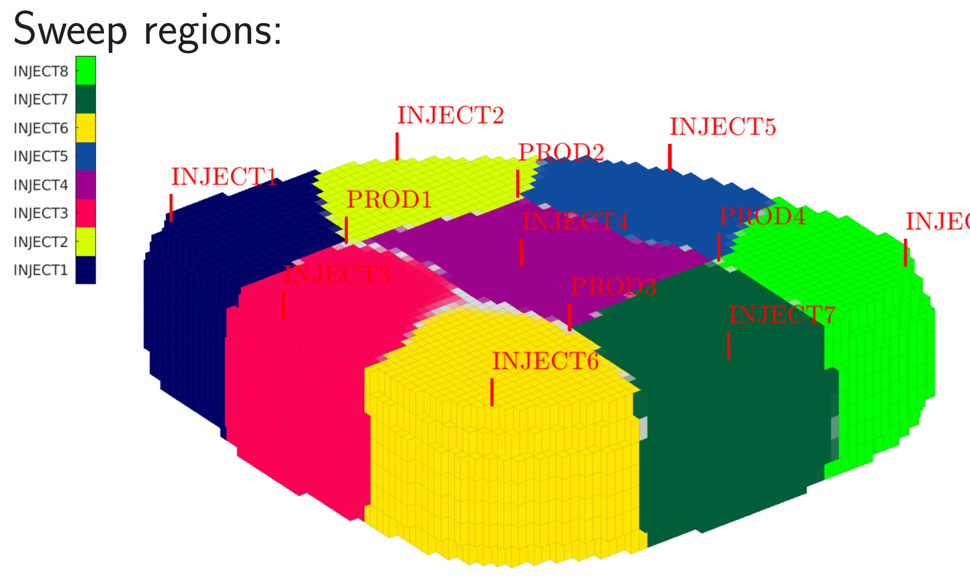
- We consider an INSIM type model [5] to represent each well-pair connection (injector and producer) with a 1D model
- Schematics:



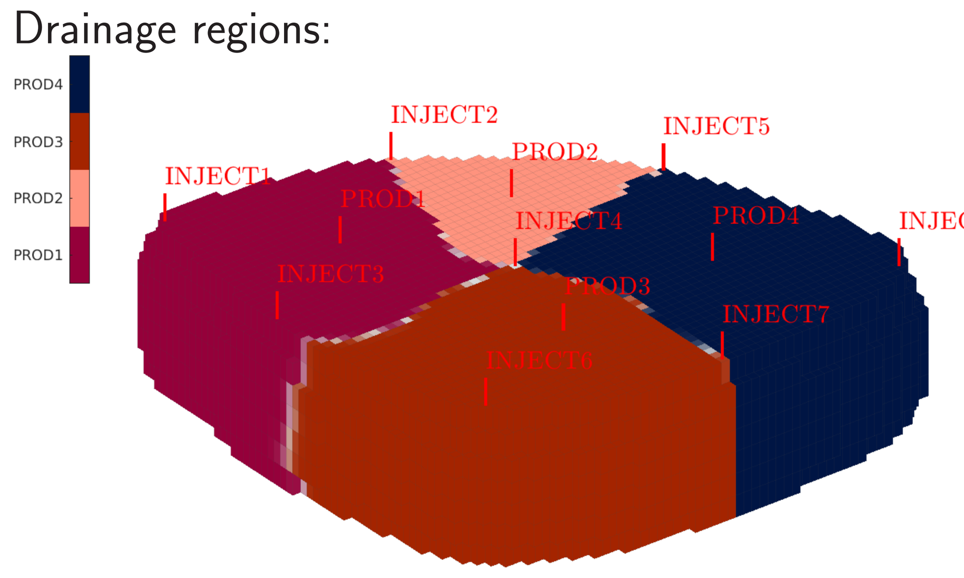
Tij – Transmissibility between injector i and producer 1
Vij – Volume between injector i and producer 1

(3) – Flow diagnostic

- Flow diagnostic refers to a set of simple and controlled numerical flow experiments that are run to probe a reservoir model [4]
- It establishes connections and basic volume estimates between injectors and producers
- It quickly provides a qualitative picture of the flow patterns in the reservoir
- Sweep regions:



- Drainage regions:



(4) – INSIM type data-driven model [5]

- Estimate T_{ij}, V_{ij} using flow diagnostic
- Build λ_{ij} and f_{ij} from history data
- For each time step n

For each well pair ij

Calculate well pair flux q_{ij}^n:

$$q_{ij}^n = T_{ij}\lambda_{ij}(S_{avg}^{n-1})(p_i^n - p_j^n)$$

Calculate well pair water flux qw_{ij}^n:

$$qw_{ij}^n = f_{i,j}(S_{avg}^{n-1})q_{ij}^n$$

Calculate the new average water saturation $S_{avg,ij}^n$
Solve for water saturation S_k^n (Buckley-Leverett equation) at well pair ij

$$S_k^n - S_k^{n-1} + v\left(f_{ij}\left(S_k^n\right) - f_{ij}\left(S_{k-1}^n\right)\right) = 0,$$

where $v = \left(\frac{\Delta t}{\Delta x}\right)\left(\frac{q_{ij}^n L_{ij}}{V_{ij}\phi_{ij}}\right)$.

$$S_{avg,ij}^n = mean(S_k^n)$$

p_i – Pressure at well i
L_{ij} – Distance between injector i and producer j
ϕ_{ij} – Porosity between injector i and producer j
Δt – Time discretization
Δx – Length discretization
k – Index for length discretization
n – Index for time discretization
v – Characteristic velocity

The Egg model [2]

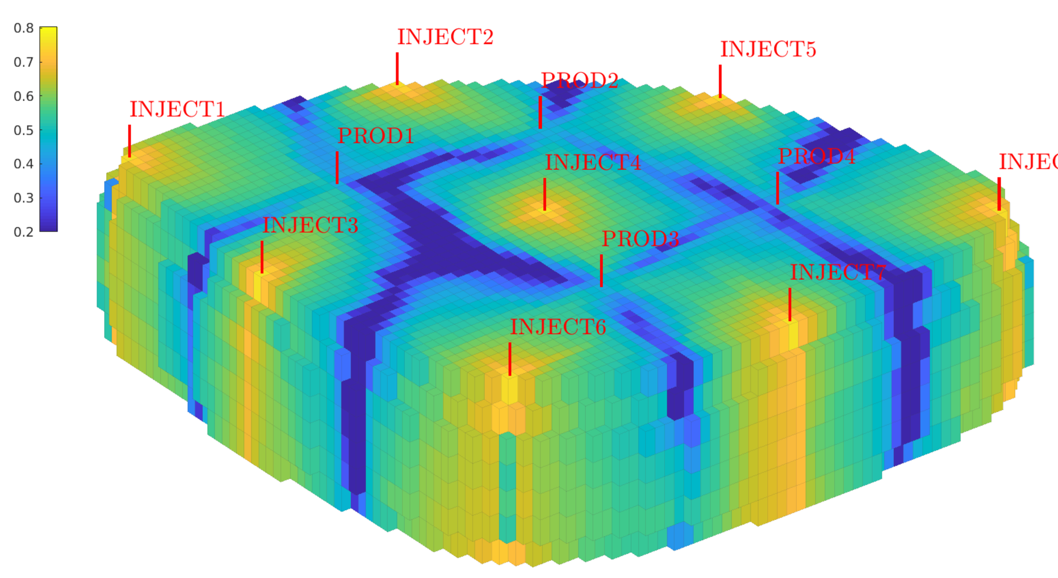


Figure: Water saturation S

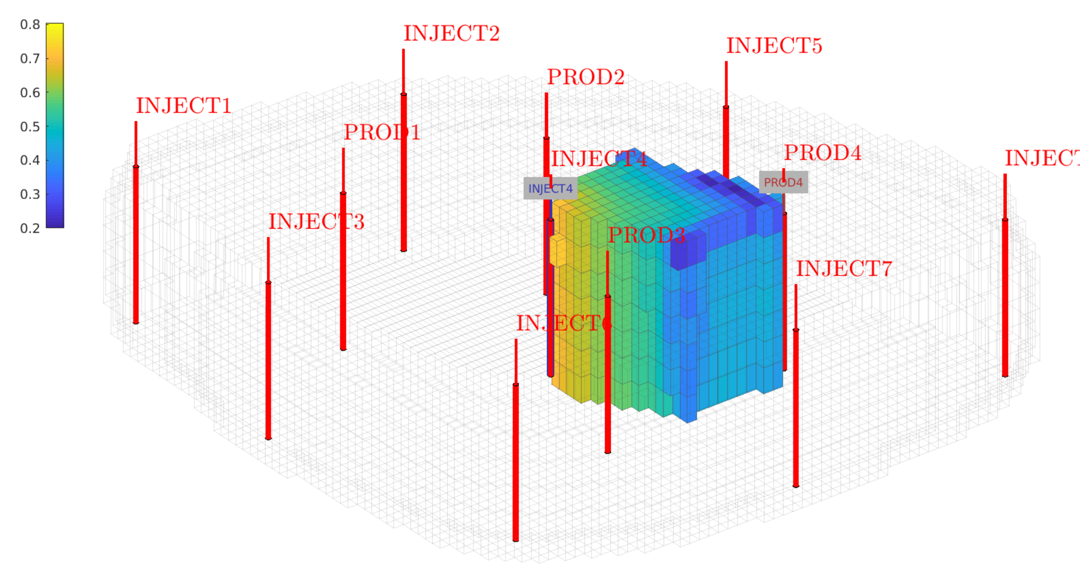
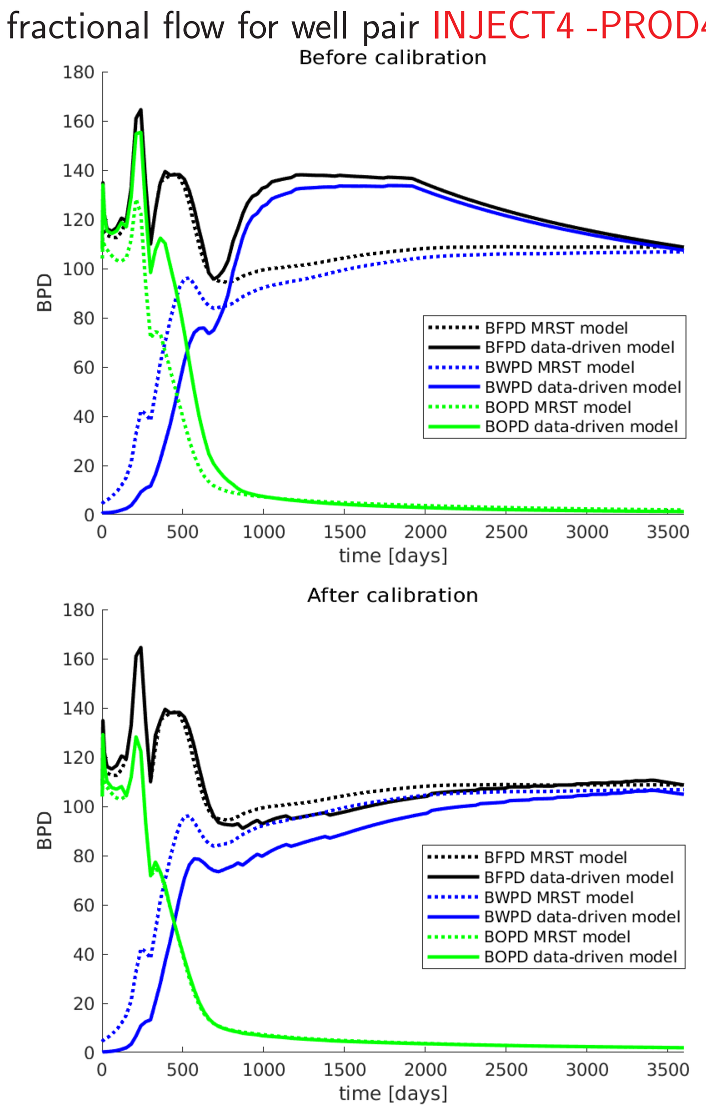


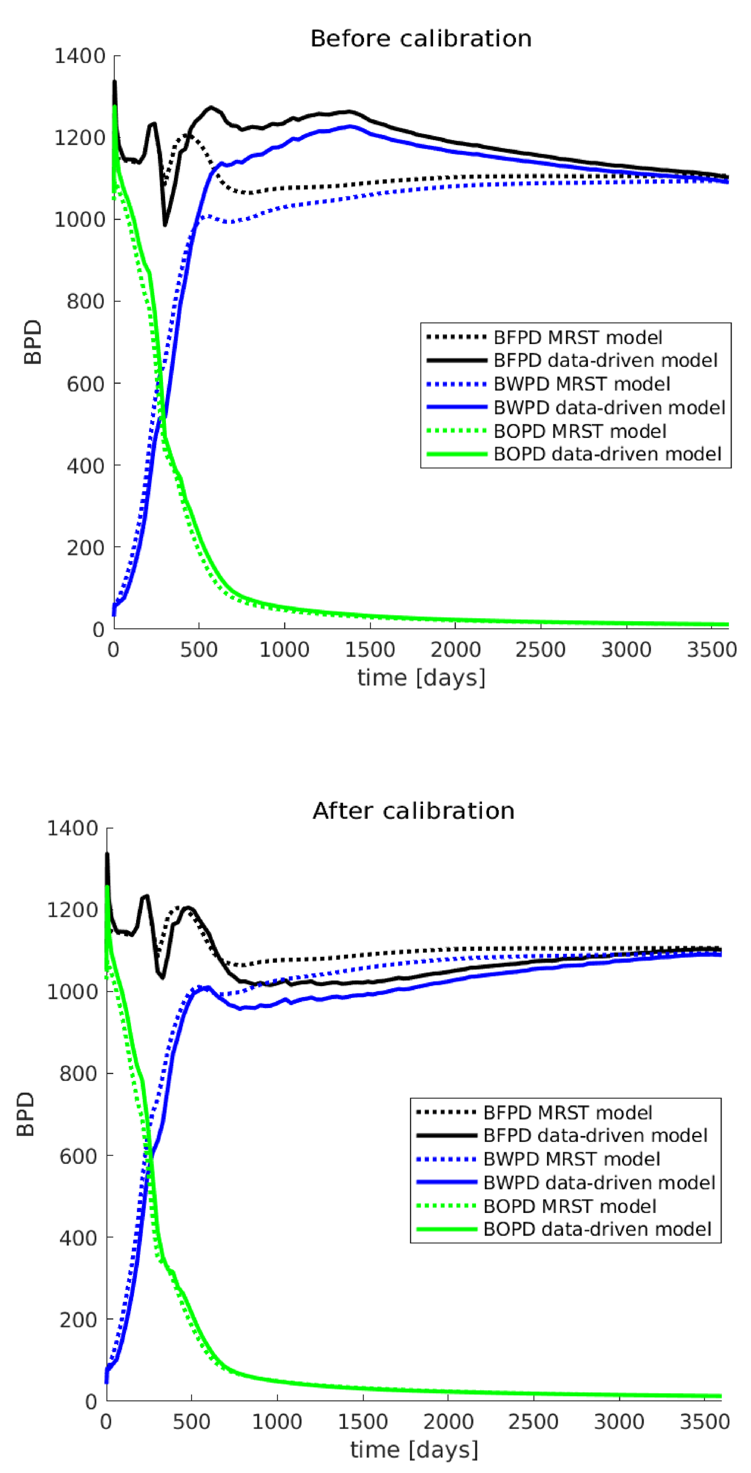
Figure: Well pair volume INJECT4 -PROD4 obtained from flow diagnostics

Results from before and after calibrating the fractional flow for well pair INJECT4 -PROD4



(5) – Producer 4

- Results from before and after calibrating the fractional flow at producer 4

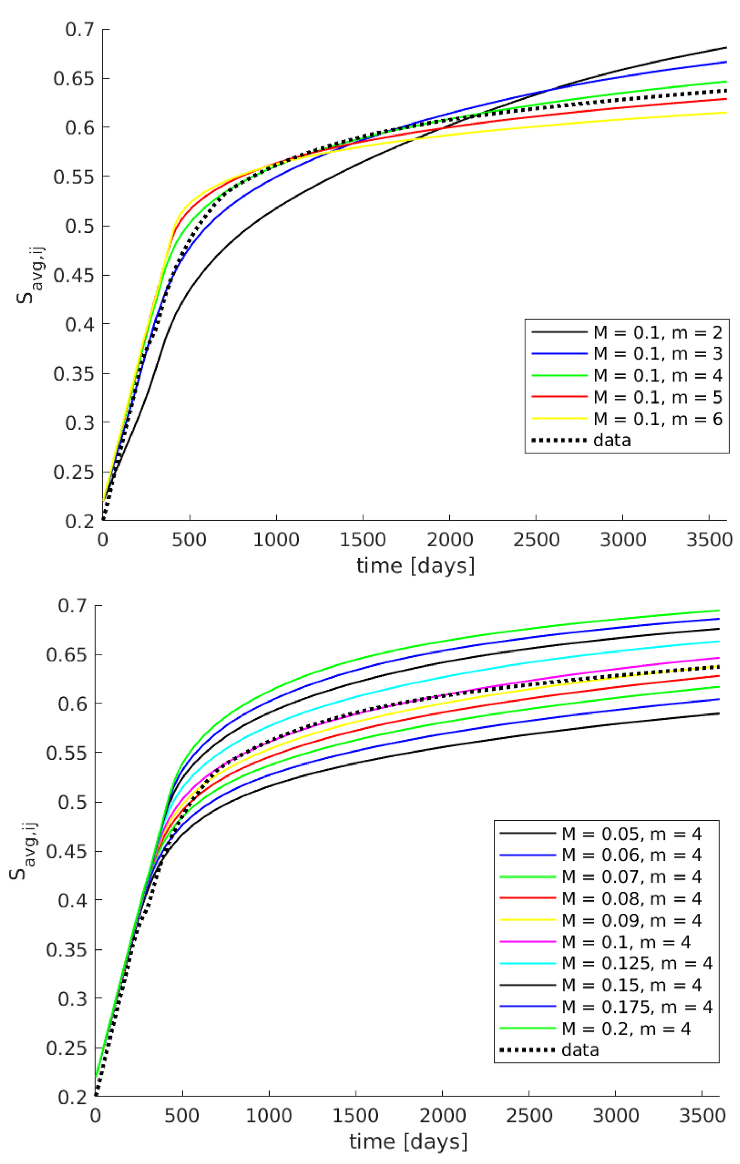


(6) – Calibration procedure for the fractional flow

- We define a general fractional flow function with parameters m and M

$$f_{ij}(S) = \frac{S^m}{S^m + M(1-S)^m}$$

- We try different values for parameters m and M and choose the ones that match the average water saturation obtained by MRST at each well pair volume



(7) – Example: The Egg model

About the setup

- Synthetic reservoir model with ∼ 25,000 cells [2]
- Fluid properties based on realistic oil cases
- Simulation of water injection schedule over a period of 3600 days
- Simulated using MRST [3]

Simulation results

- Very close match despite the fact that we use a simple calibration procedure
- Some discrepancies in production curves due to the simplicity of the model

(8) – References

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[3] K.-A. Lie. *An Introduction to Reservoir Simulation Using MATLAB/GNU Octave: User Guide for the MATLAB Reservoir Simulation Toolbox (MRST)*. Cambridge University Press, Jul 2019. ISBN 9781108492430.

[4] O. Møyner, S. Krogstad, and K.-A. Lie. The application of flow diagnostics for reservoir management. *SPE Journal*, 20(02), Apr. 2015.

[5] G. Ren, J. He, Z. Wang, R. M. Younis, and X.-H. Wen. Implementation of physics-based data-driven models with a commercial simulator. *SPE Reservoir Simulation Conference*, 2019. doi: 10.2118/193855-ms.

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