EnKF Workshop 2023

Inferring Relative Permeability Curves with Ensemble Kalman Method

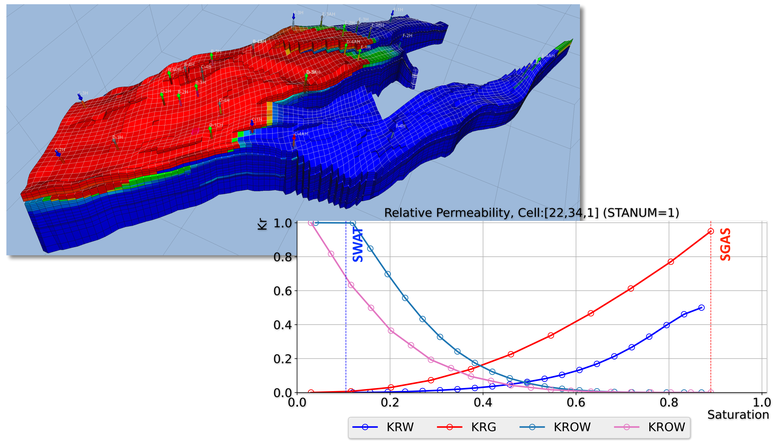
Xu-Hui Zhou[1], Haochen Wang, James McClure[1], Cheng Chen[3], Heng Xiao[2]

[1]Virginia Tech, USA [2]University of Stuttgart, Germany [3]Stevens Institute of Technology, USA

University of Stuttgart

VIRGINIA TECH

Motivation

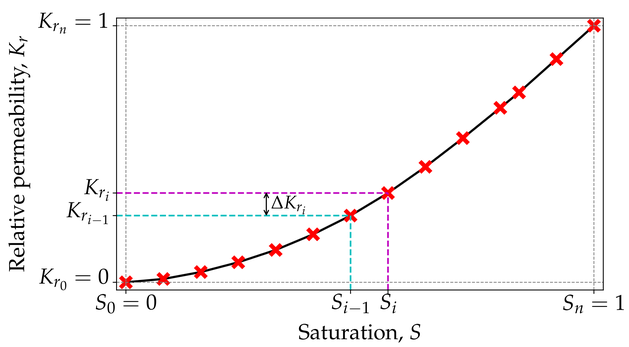


- Accurately estimating relative permeability is important for determining the feasibility of oil and gas production.
- Laboratory measurements of relative permeability may not accurately describe multiphase flows in field-scale reservoirs.
- Advances in reservoir monitoring technology opened opportunities for data collection.
- Such data can aid inference of relative permeability curves.

Relative Permeability Curve Representation

We represent relative permeability curves through

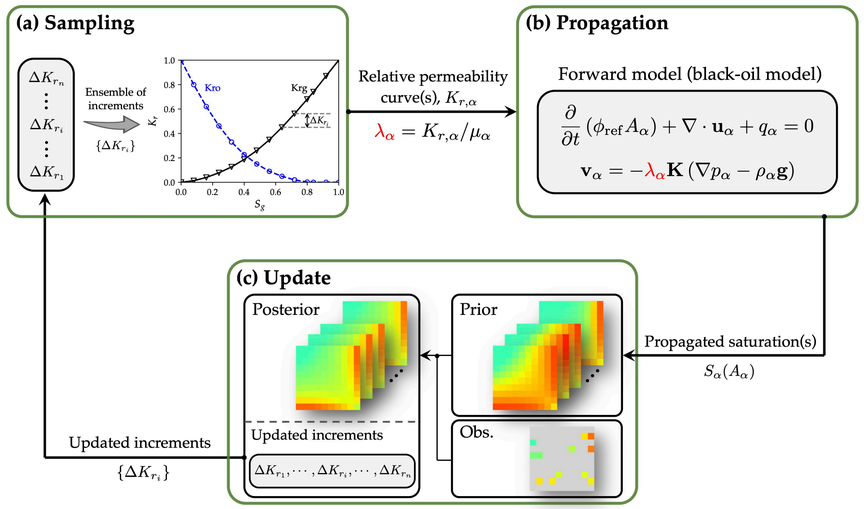
- by adding positive increments of relative permeability ΔK_r.
- Such a scheme guarantees **monotonicity** and **boundness** in [0, 1].



***Hard constraints*:**

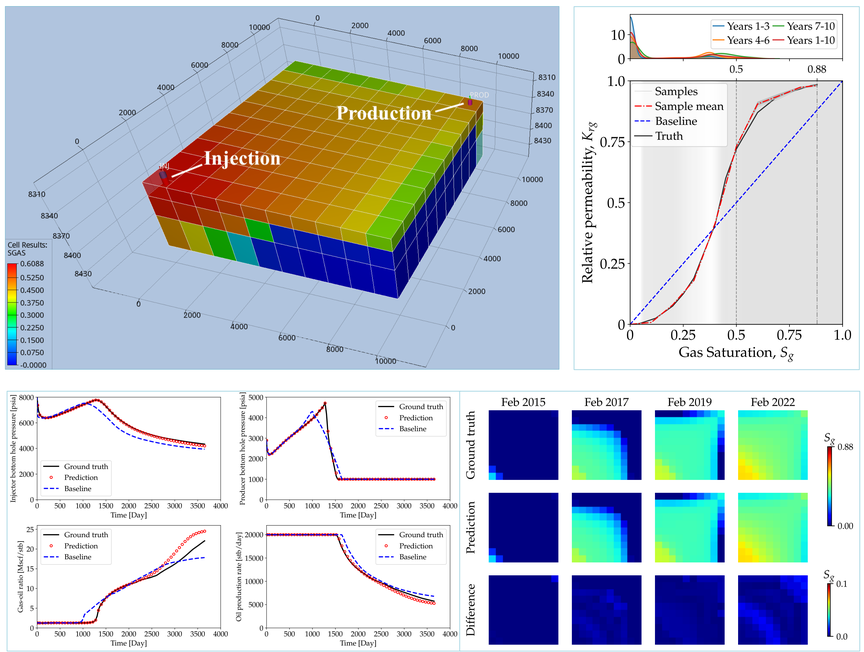
$$\left.\begin{array}{ll}(1) & \Delta K_{r_i} > 0 \\ (2) & \sum_{i=1}^{n} \Delta K_{r_i} = 1\end{array}\right\} \Rightarrow \Delta K_{r_i} = \frac{\exp(\omega_i)}{\sum_{j=1}^{n} \exp(\omega_j)}$$

Iterative Ensemble Kalman Method

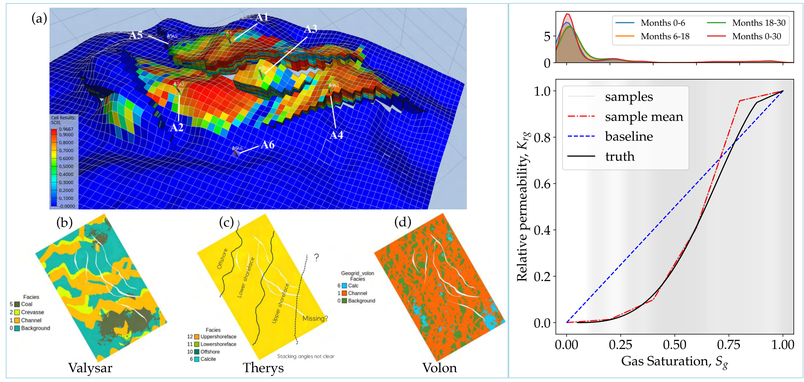


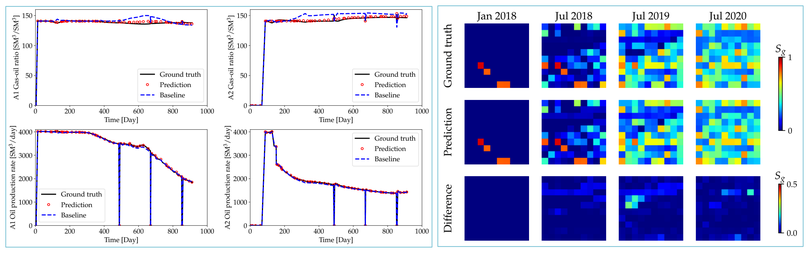
- **Step (a)**: Sample the parameters ω based on initial prior distribution and represent the relative permeability curve accordingly.
- **Step (b)**: Propagate each relative permeability curve in the ensemble to saturation field by solving the black-oil equations.
- **Step (c)**: Update the parameters ω based on the observation data.

Case 1: SPE-1 Benchmark



Case 2: Drogon





Conclusion

- Developed an ensemble-based framework for inferring relative permeability curves from sparse saturation data.
- Proposed a presentation of relative permeability curves with embedded monotonicity and boundedness.
- Demonstrated the inferring capability of the proposed method on synthetic benchmarks developed by SPE and a field-scale case developed by Equinor with real-field features.

Bibliography

- X.-H. Zhou, H. Wang, J. McClure, C. Chen, H. Xiao, Inference of relative permeability curves in reservoir rocks with ensemble Kalman method, *European Physical Journal E*. arXiv: 2305.01029

Acknowledgement

- We acknowledge Xin-Lei Zhang (Chinese Academy of Sciences), Hongsheng Wang (UT Austin), and Tor Harald Sandve (NORCE) for their discussions and suggestions.
- This work was financially supported by the U.S. Department of Energy's National Energy Technology Laboratory.
- Contact Heng Xiao (heng.xiao@simtech.uni-stuttgart.de).