

Fast inference of microporosity phases properties of carbonate rocks with machine learning for characterizing CO₂ flow behaviors

Zhenkai (Josh) Bo, Hannah P. Menke, Julien Maes, Ahmed H. Elsheikh, Kamaljit Singh

Institute of GeoEnergy Engineering, Heriot-Watt University, Edinburgh, U.K.

DigiPorFlow
Research Group

EPSRC

Engineering and Physical Sciences
Research Council

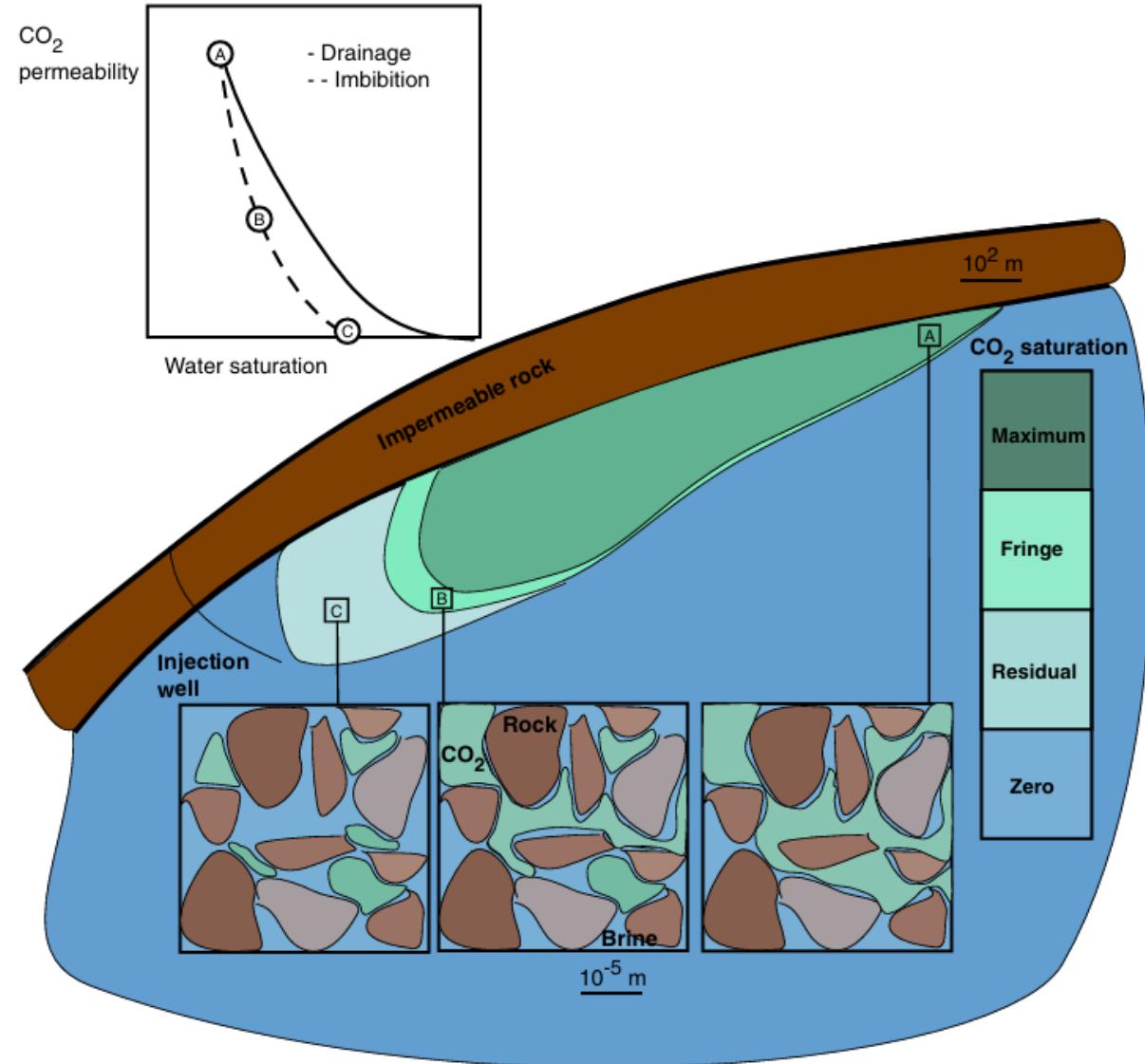


ECO-AI project



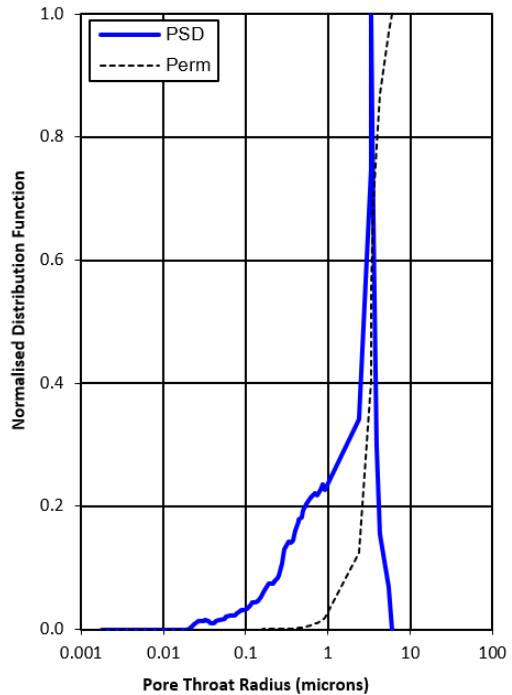
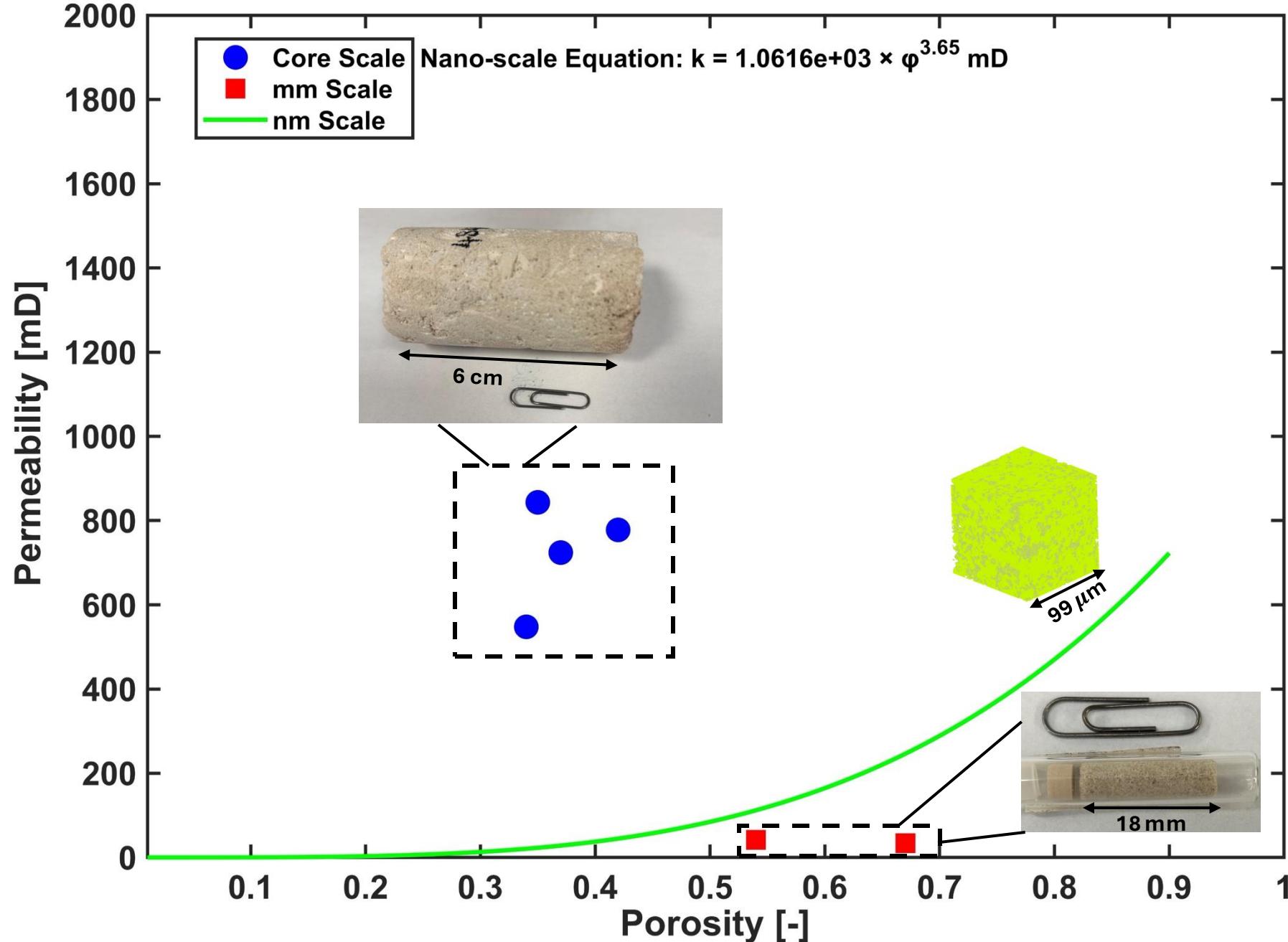
Content

- Carbonate rock sample heterogeneity
- Multi-scale pore network modeling
- Inversion model-ESMDA
- DNN and DNN-ESMDA workflow
- Results
- Validation
- Conclusion

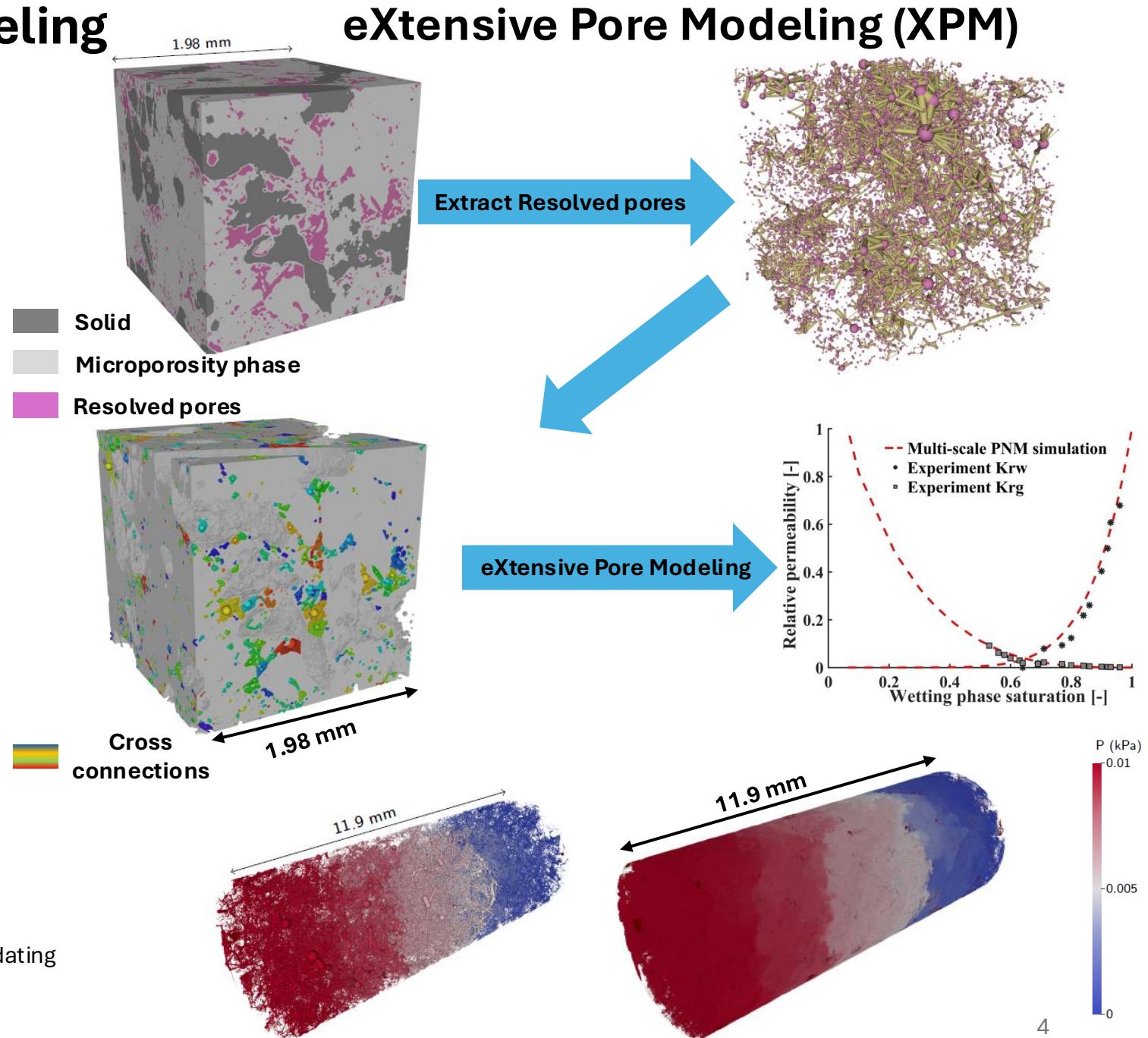
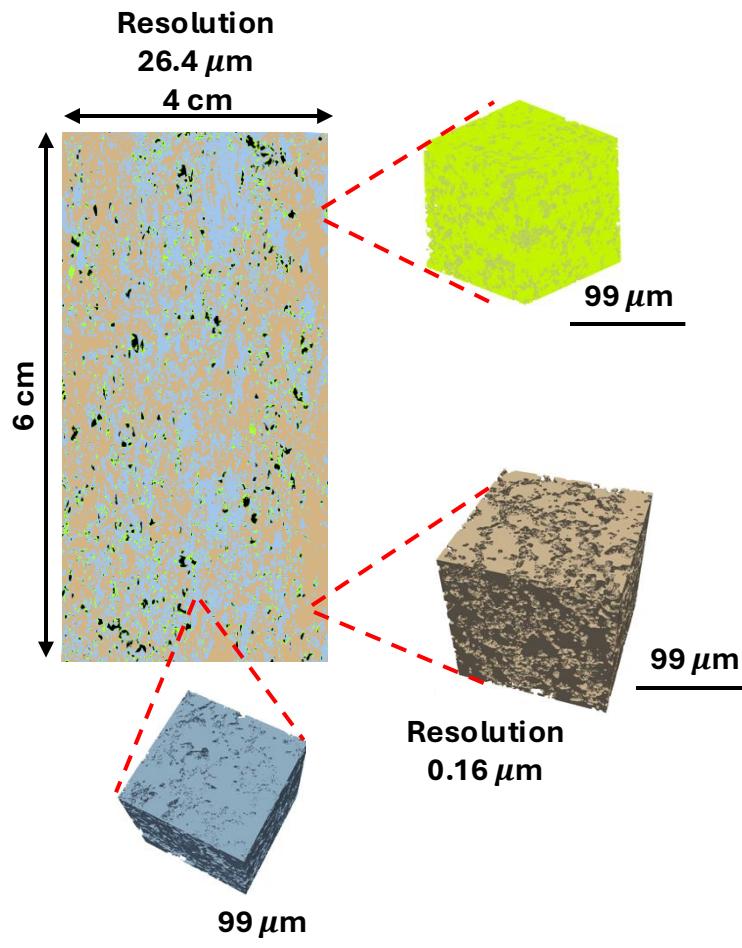


Krevor, S., Blunt, M.J., Benson, S.M., Pentland, C.H., Reynolds, C., Al-Menhali, A. and Niu, B., 2015. Capillary trapping for geologic carbon dioxide storage—From pore scale physics to field scale implications. International Journal of Greenhouse Gas Control, 40, pp.221-237.

Carbonate rock sample heterogeneity

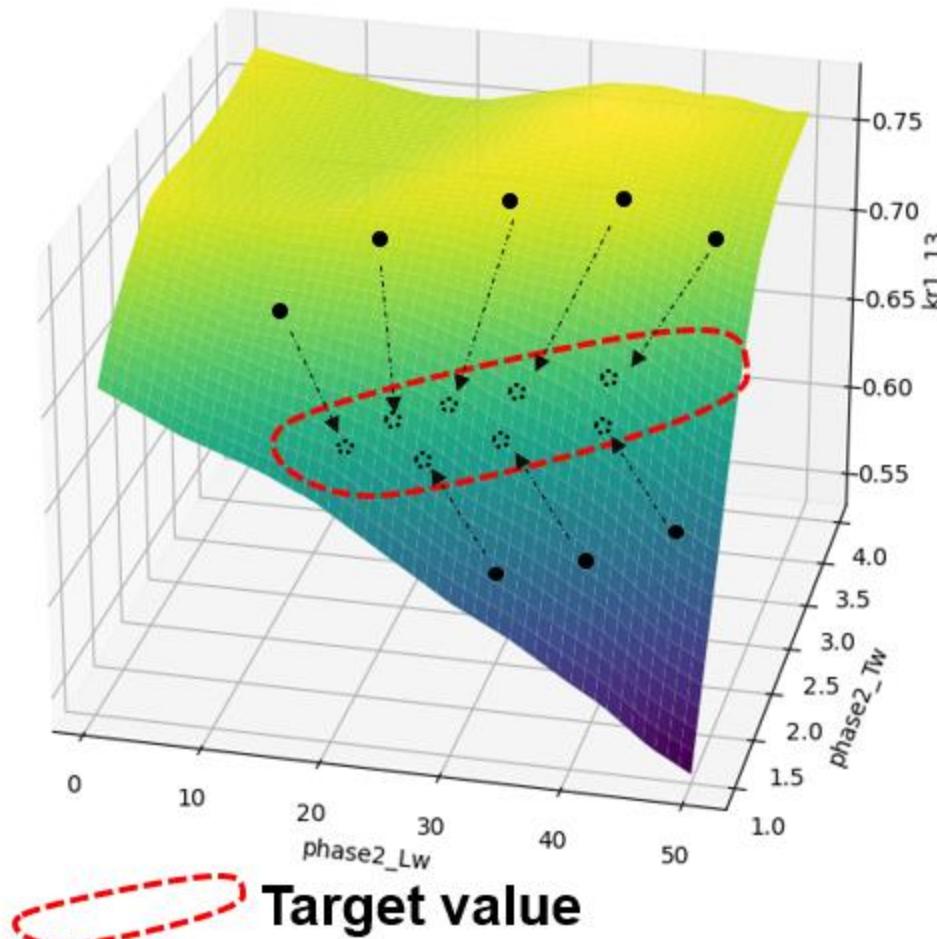


Multi-scale pore network modeling

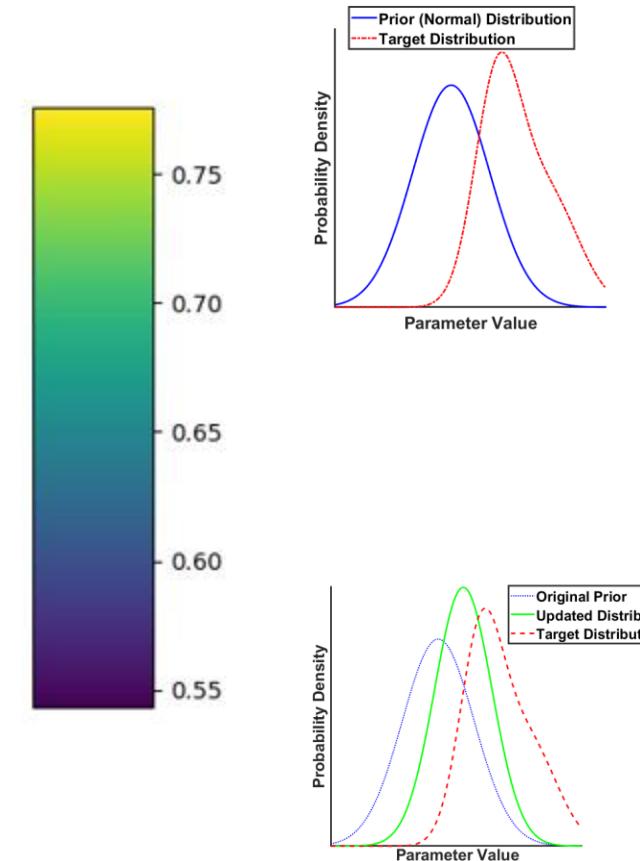


Petrovskyy, D., Maes, J., Menke, H.P., Ali, M., Singh, K., 2025. Validating hybrid macropore-Darcy networks for permeability calculation in gigascale images of microporous rocks. In preparation.

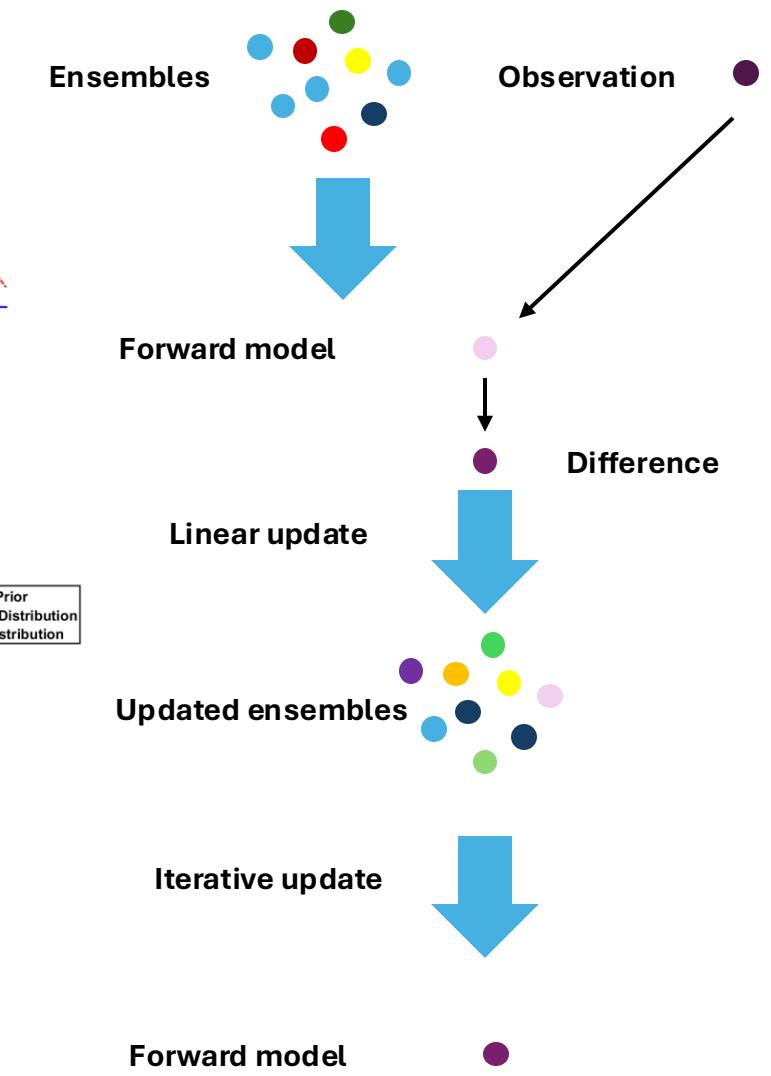
Inverse model - ESMDA



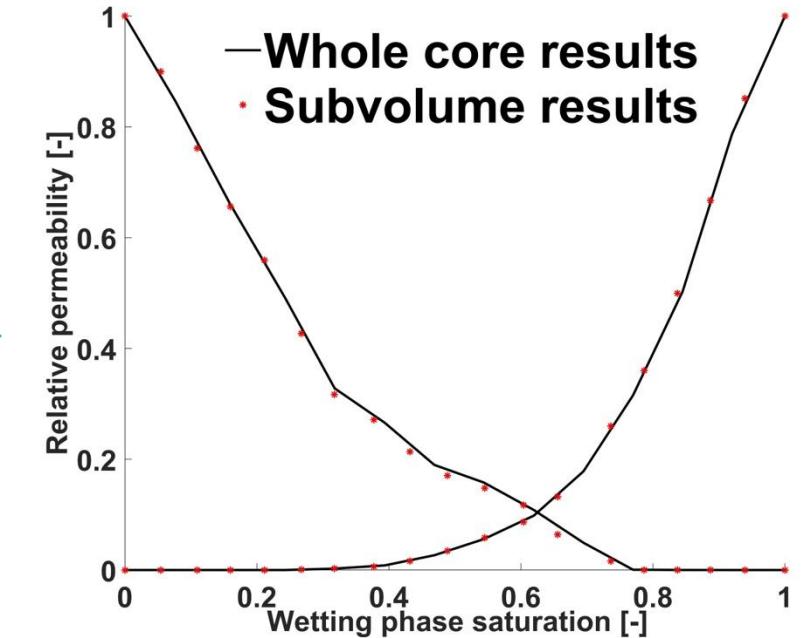
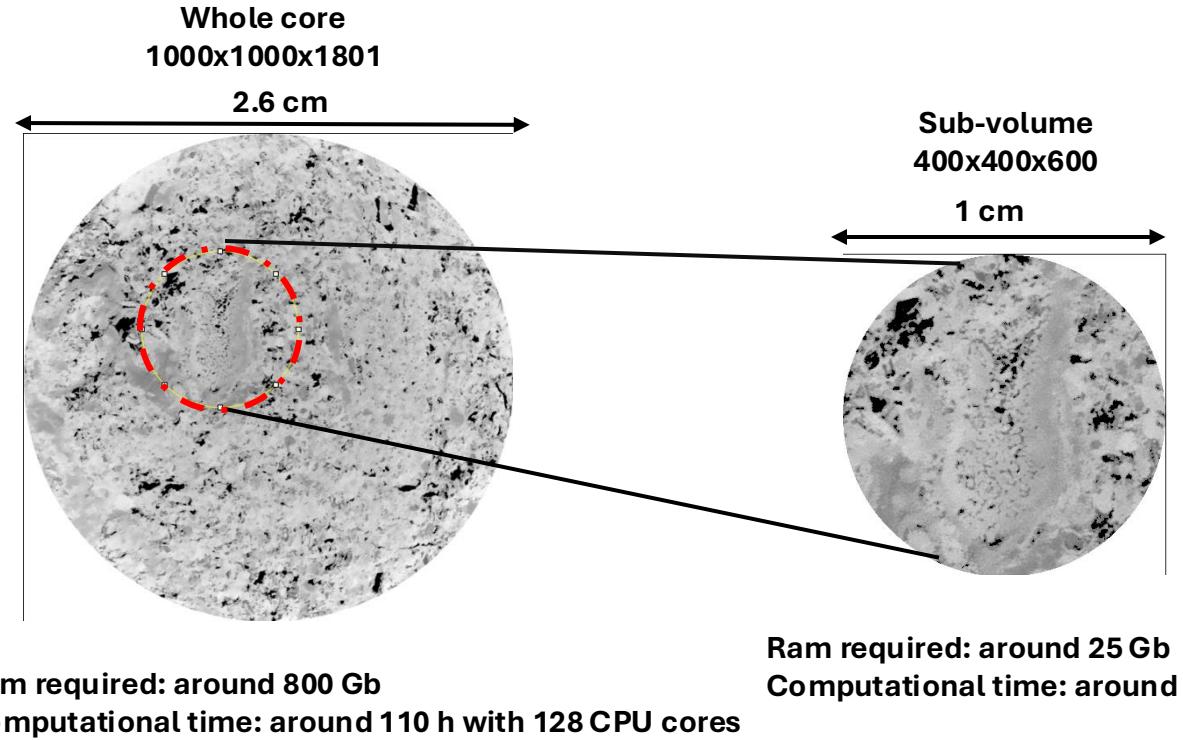
- **Prior distribution**
- **Posterior distribution**



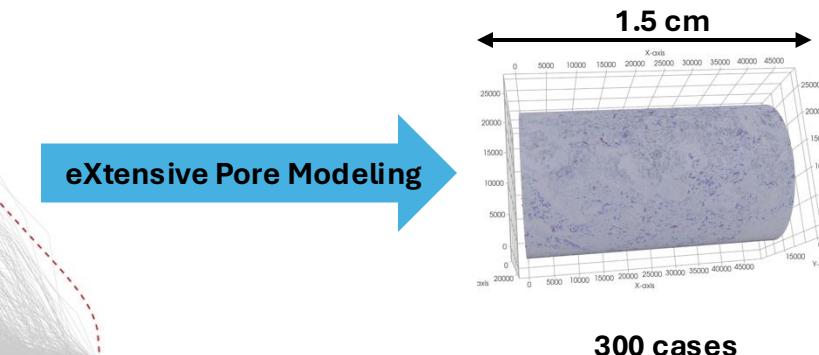
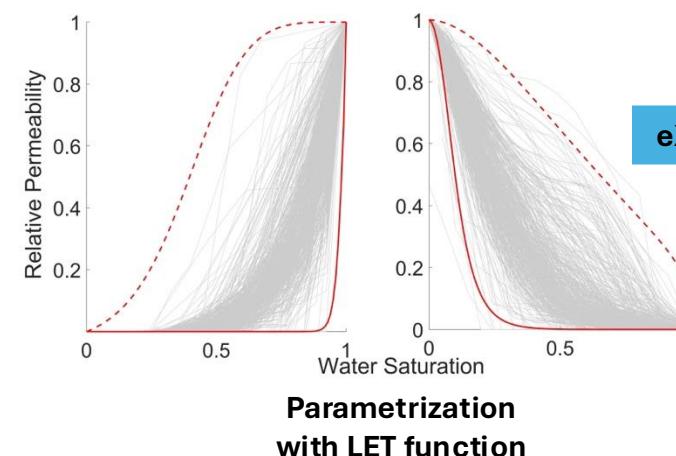
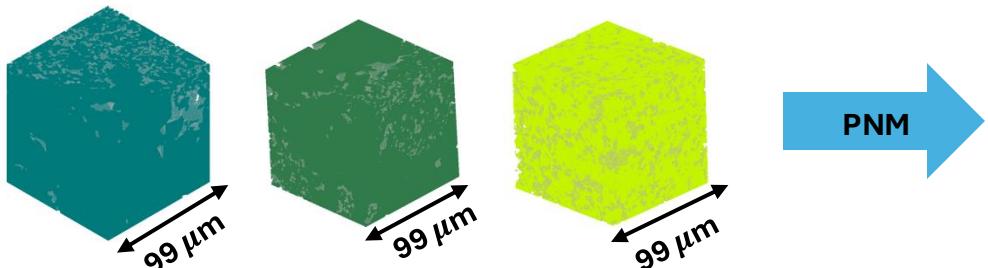
ESMDA workflow



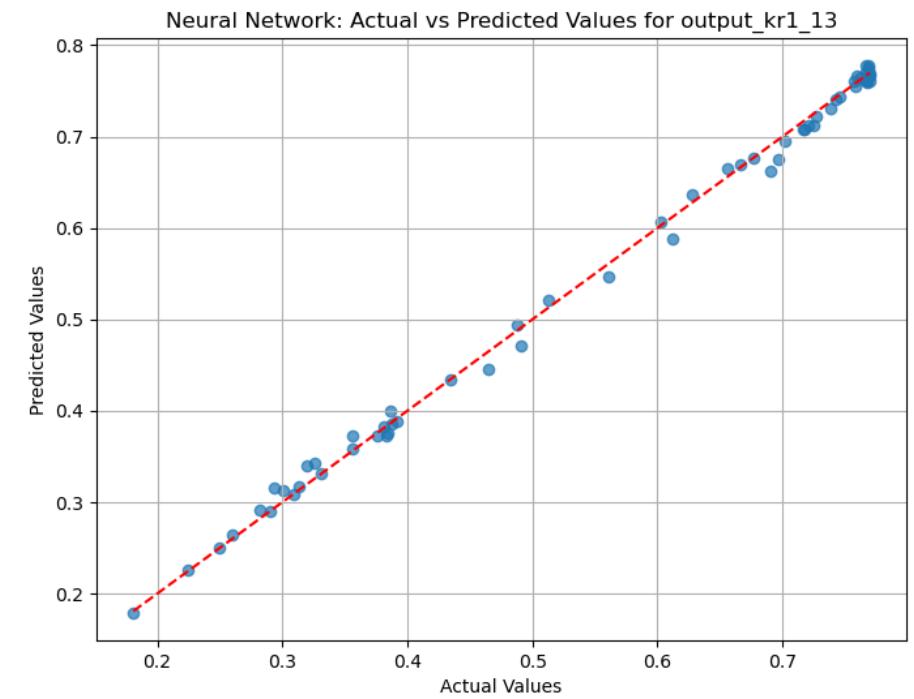
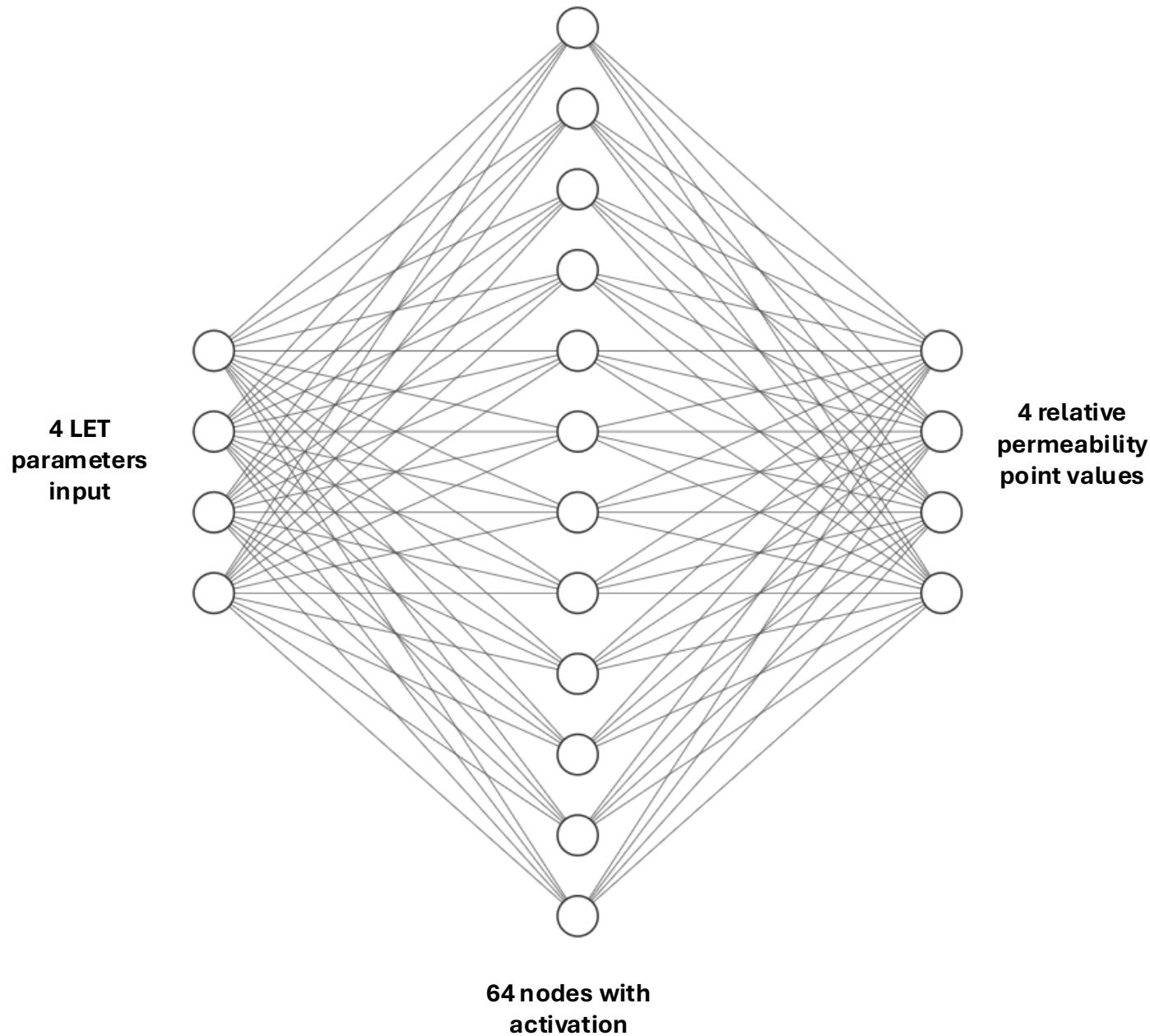
Simplify simulation



Training data for machine learning

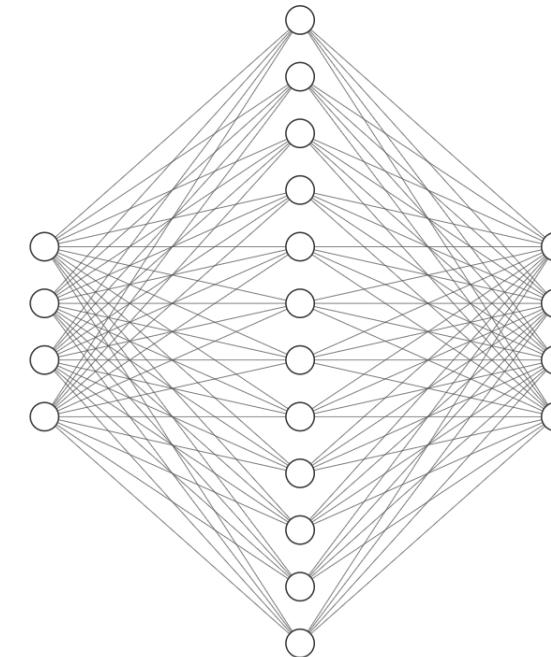
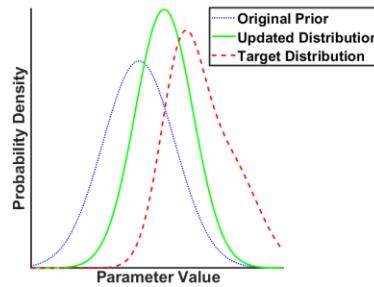
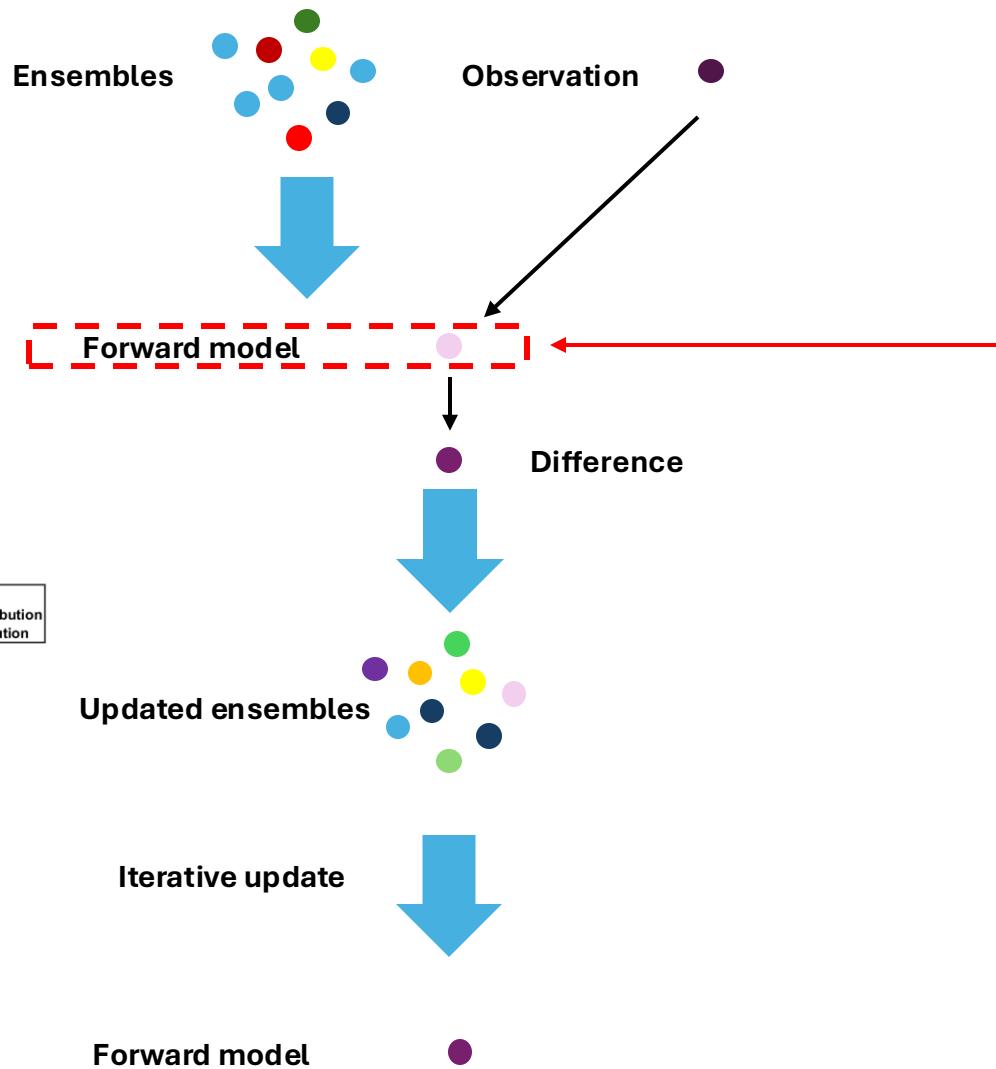
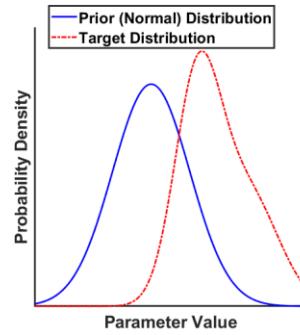


Neural network training

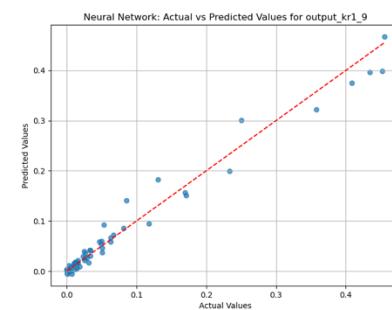
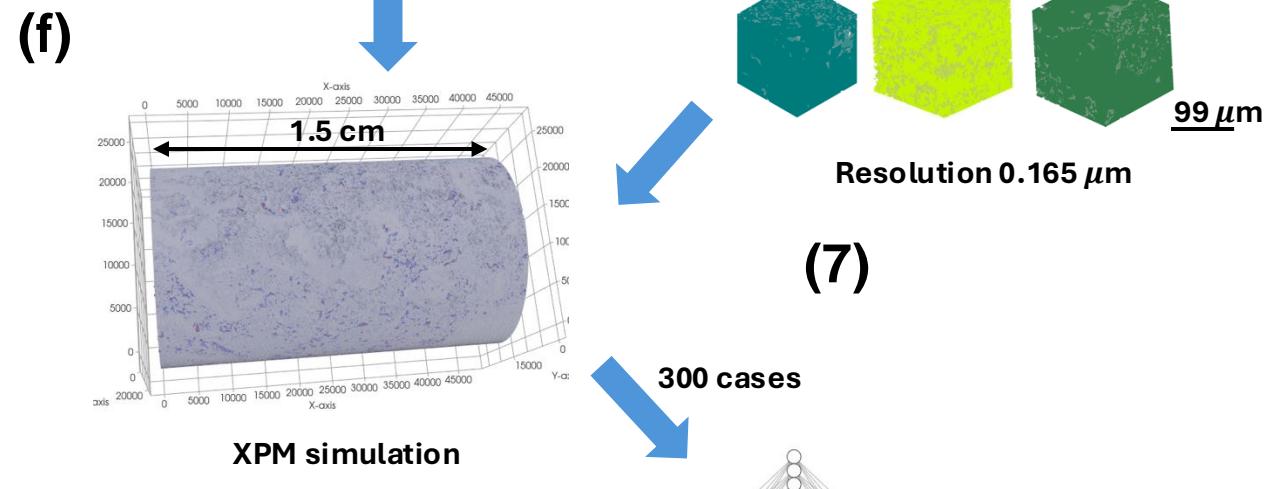
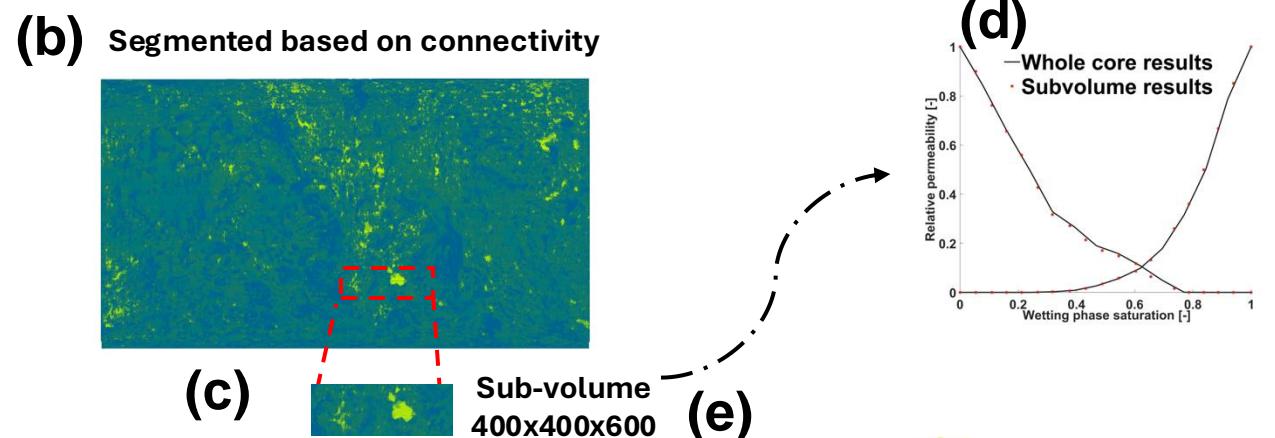
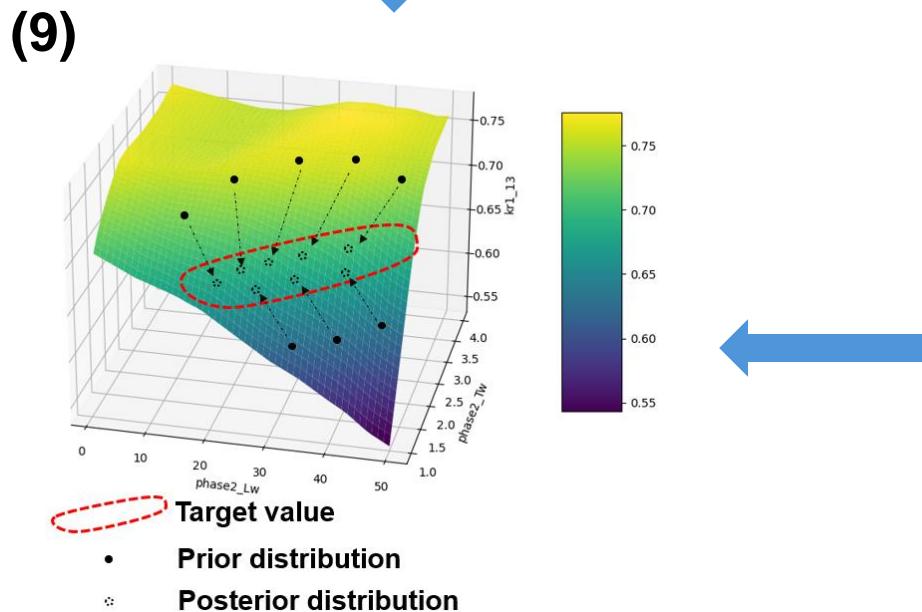
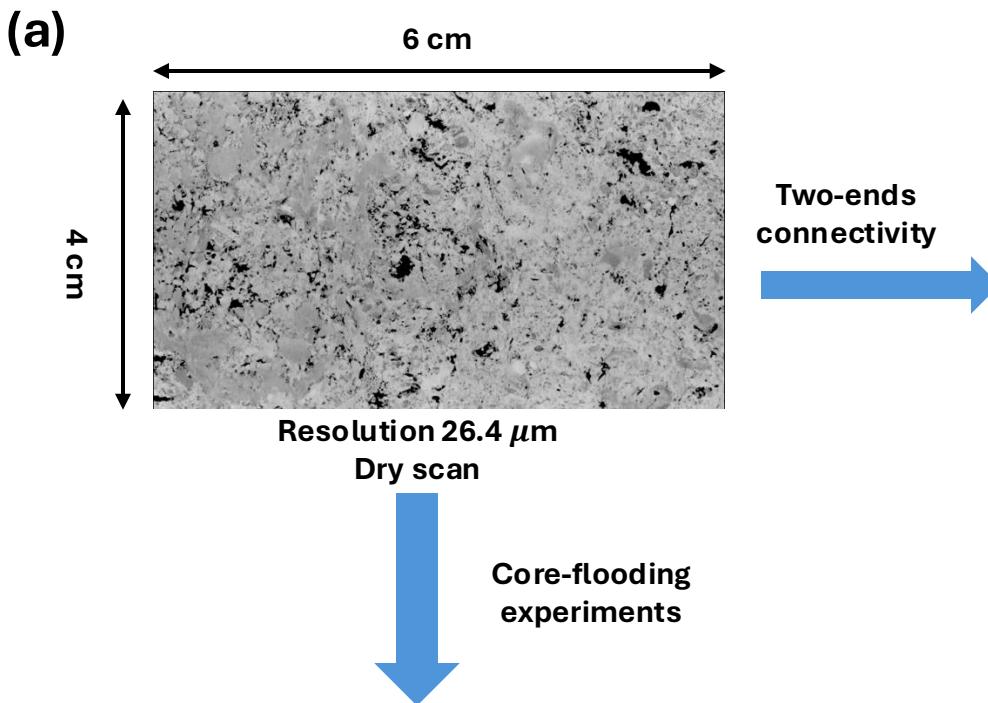


R² ranges from 0.94 to 0.97

ESMDA workflow



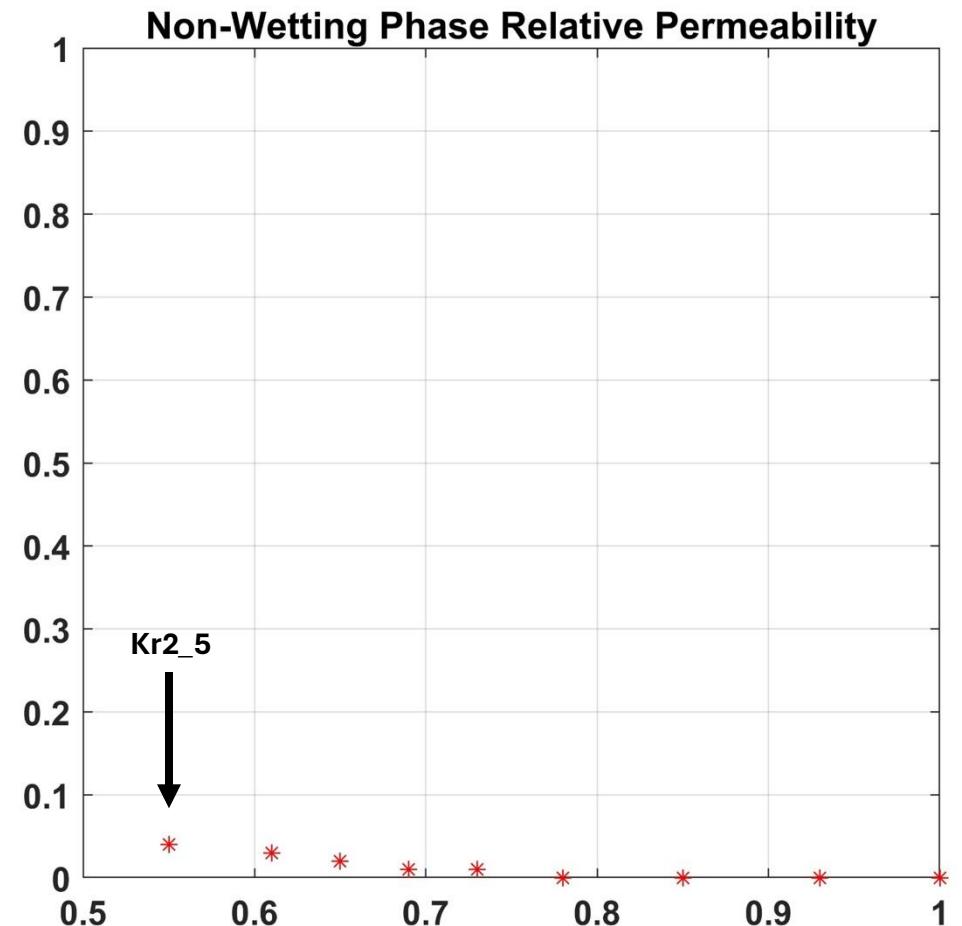
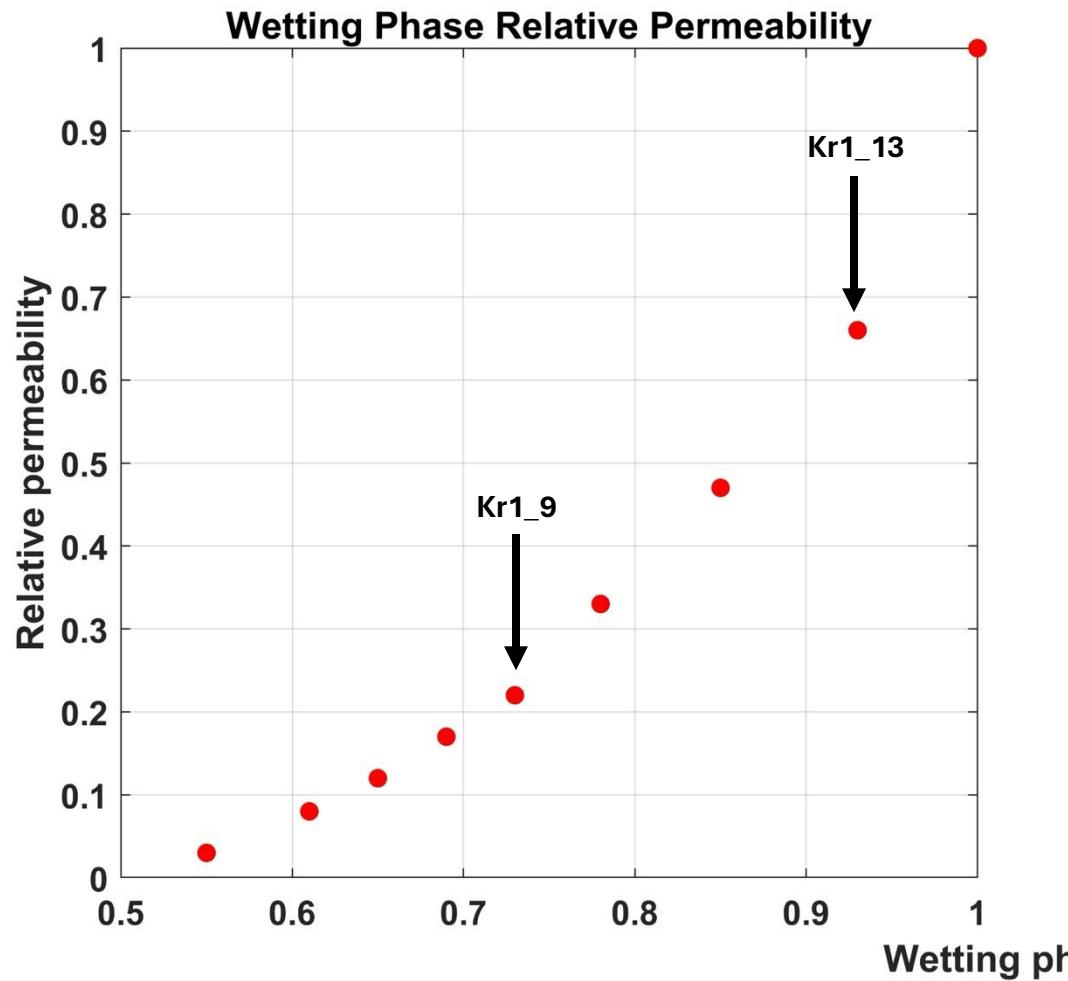
DNN-ESMDA framework



4 input, 64 hidden nodes, 4 outputs

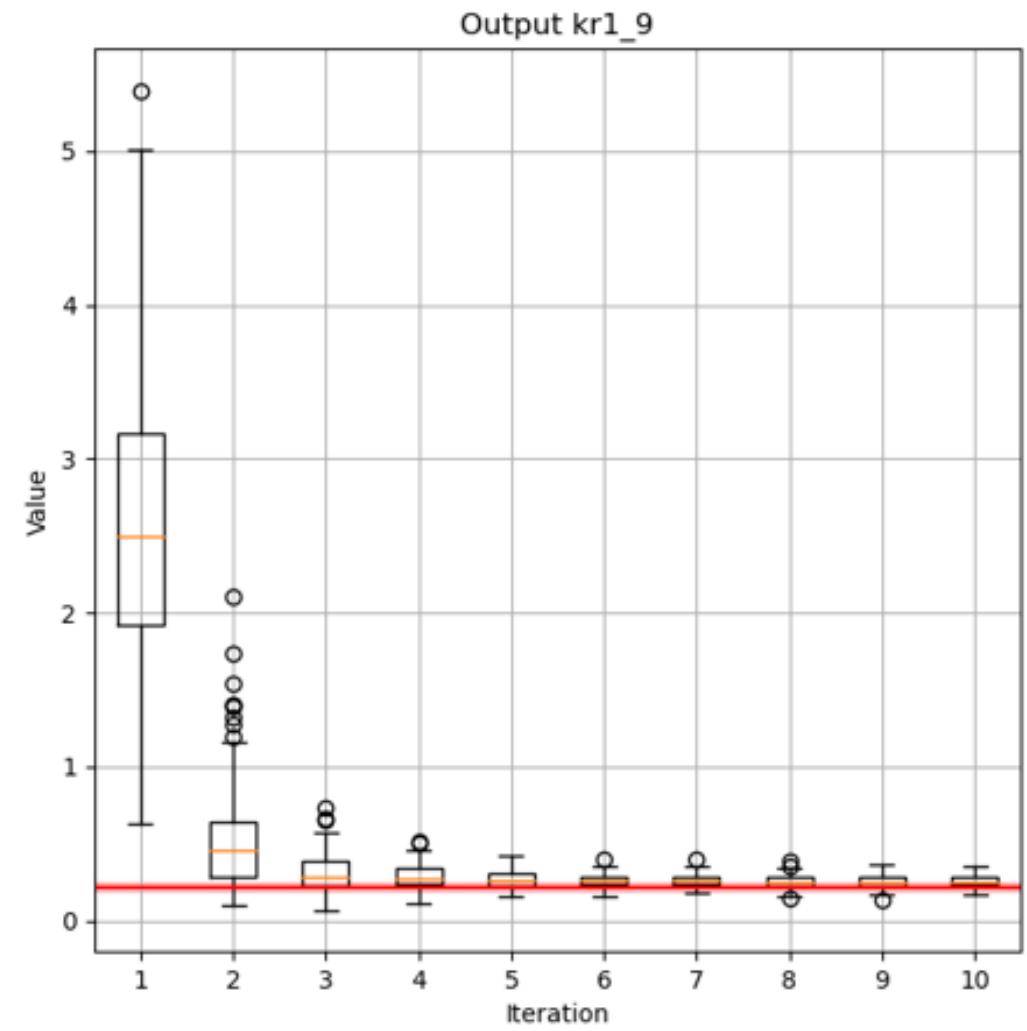
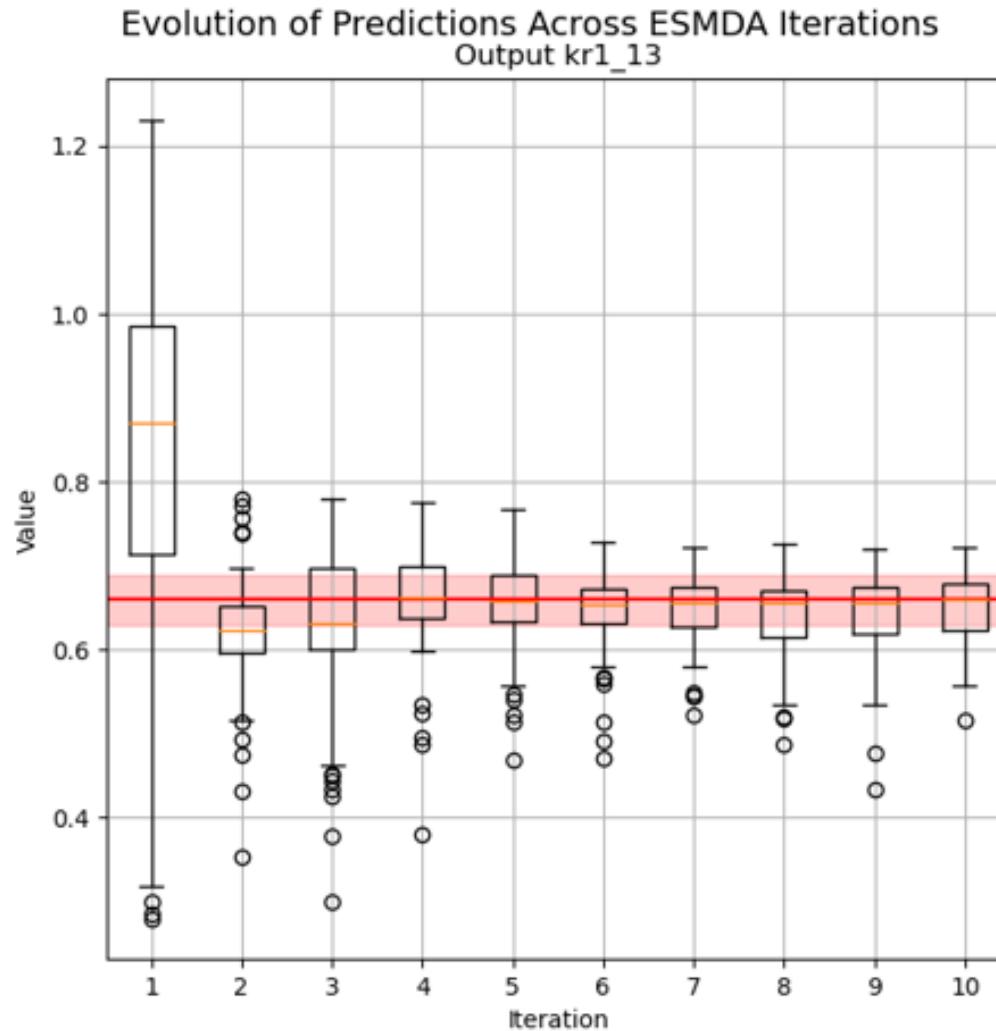
9

DNN-ESMDA implementation

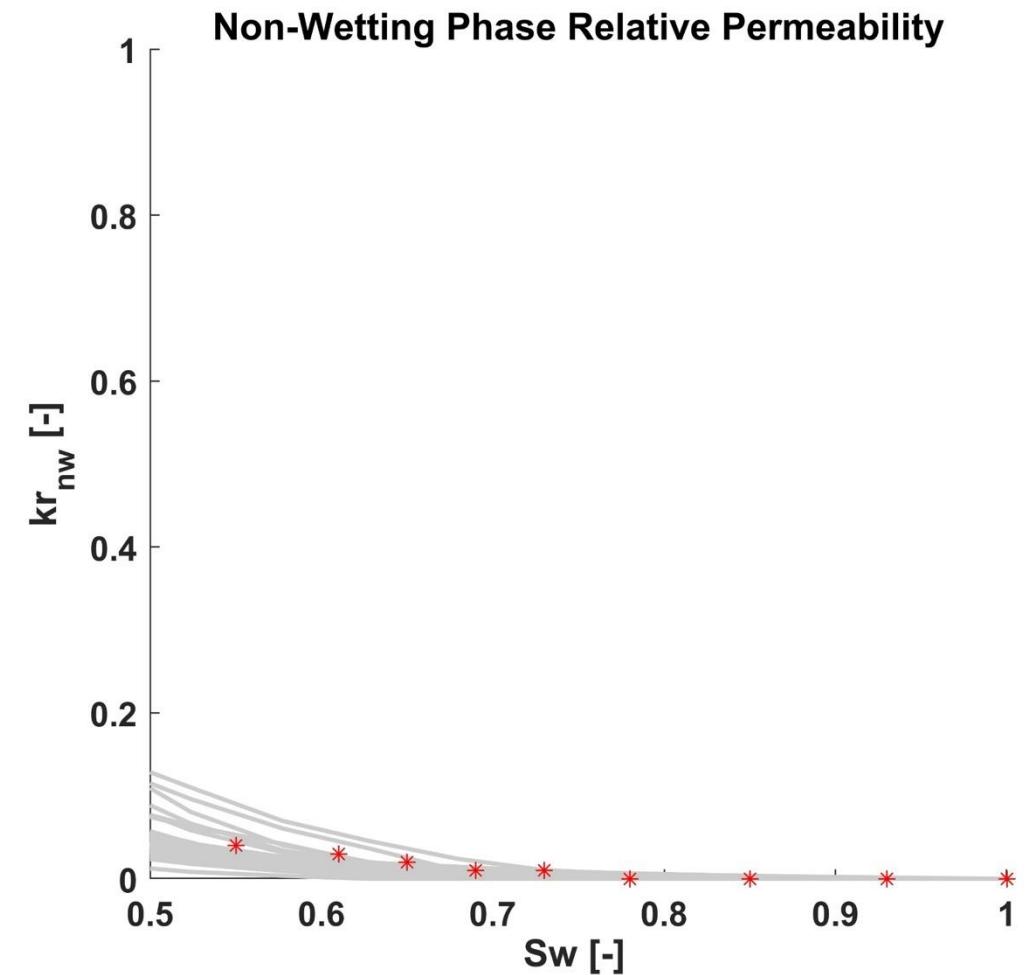
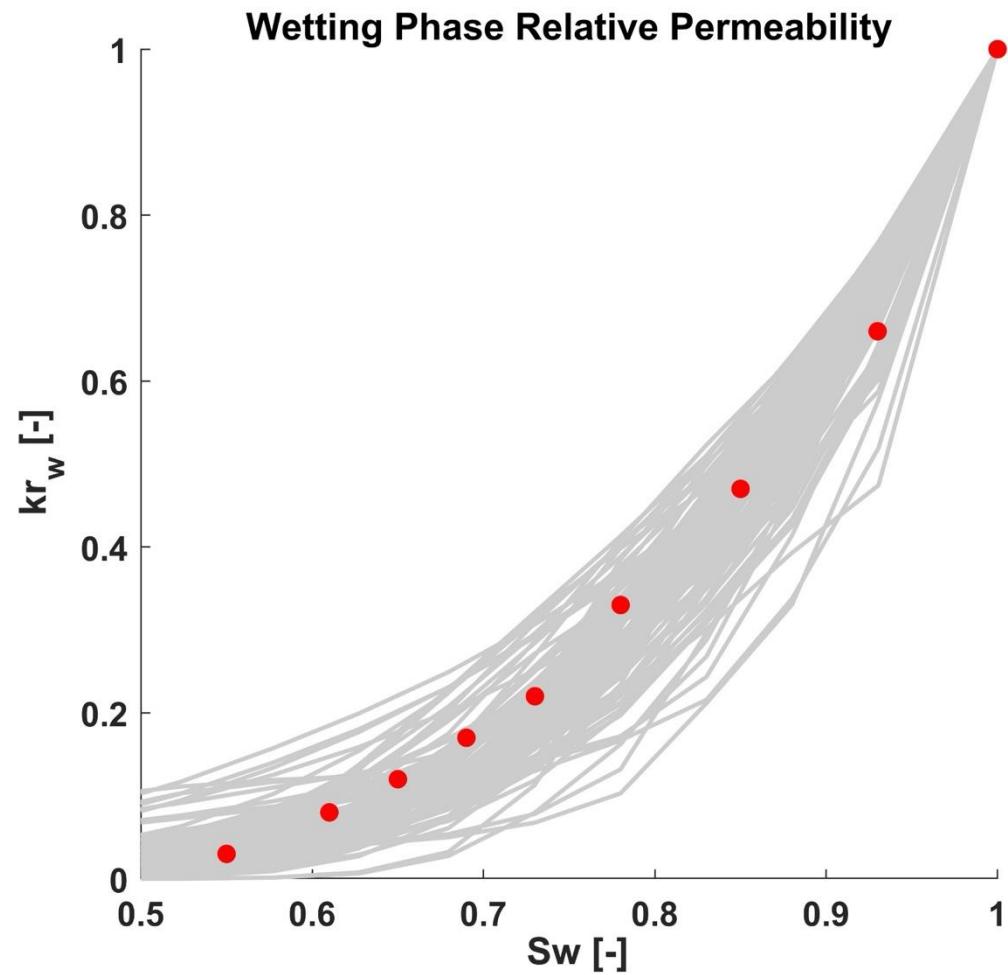


Input error for Kr1 is 0.03 and 0.01 for Kr2

DNN-ESMDA results



Validation



Conclusion and outlook

- We present a DNN-ESMDA framework for fast inference of microporosity phases properties.
- Compared to conventional method to implement inversion operations, trained DNN can shorten the length from thousands of hours to seconds.
- Future work can link the inference properties with AI-generated rock images.