Using MeshGraphNets to Predict Geologic Behaviors of the Illinois Basin – Decatur Project (IBDP)

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SMART

Science-informed Machine Learning to Accelerate Real Time (SMART) Decisions in Subsurface Applications

ABSTRACT

Reservoir simulation plays a critical role in the design, permitting, and long-term management of geological carbon storage, providing decision support needed for the monitoring, verification, and accounting processes. However, solving the multiphase, multicomponent flow and transport equations governing CO_2 plume migration is computationally demanding, even on high-performance computing clusters. The wafer-scale engine (WSE), packing nearly a million compute cores onto a single processor, represents a revolutionary technology for scientific computing for real-time support. In this work, we developed a two-phase CO_2-brine solver for running on WSE and demonstrated it on both synthetic and real-case studies. This poster presents preliminary results from validation and field data testing.

OBJECTIVES

- **Develop a two-phase compressible CO_2-brine solver for running on WSE**
- **Demonstrate numerical accuracy and scalability of the WSE-based solver on synthetic problems**
- **Demonstrate the WSE-based solver on well data from the Illinois Basin - Decatur Project (IBDP)**

TWO-PHASE MODEL

- The PDEs (partial differential equations) for fluid flow are developed by combining three equations: continuity equation, Darcy's flow equation and the fluid equation of state. The brine phase flow equation is given by

$$\frac{\partial (\varphi\, \rho_w\, S_w)}{\partial t} = \nabla.\left(\frac{\rho_w}{\mu_w}\, k\, k_{rw}\, (\nabla p_w + \gamma_w \nabla z)\right) + q_w$$

- The CO2 (gas) phase flow equation is given by

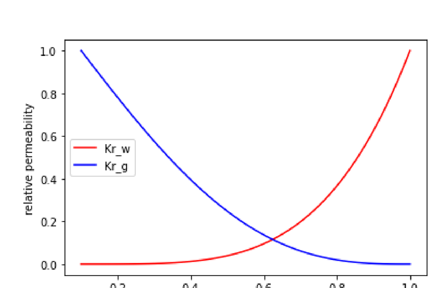
$$\frac{\partial (\varphi\,(\rho_g\, S_g + \rho_w\, S_w R_{sw}))}{\partial t} = -\nabla.\left(\left(\frac{\rho_g}{\mu_g} k\, k_{rg} + \frac{\rho_w}{\mu_w} k\, k_{rw} R_{sw}\right)(\nabla p_g + \gamma_g \nabla z)\right) + q_g$$

- The overall flow equation is obtained by multiplying the brine flow equation by (R_sw B_w/B_g) and adding the results to the CO_2 flow equation

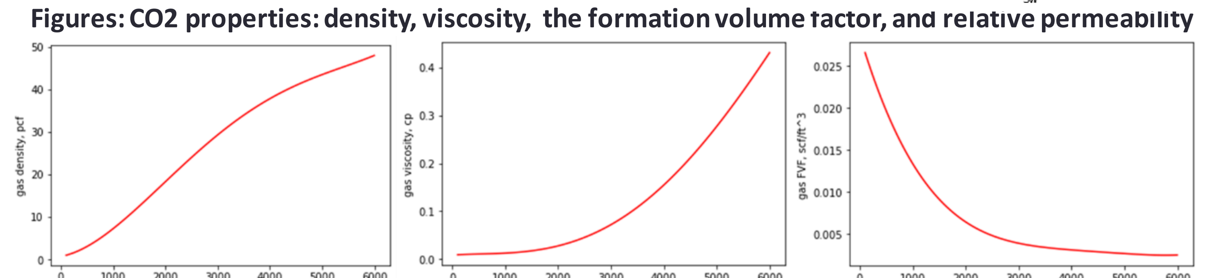
$$D_n \frac{dx_n}{dt} = T_n\, x^{n+1} + G_n + Q_n$$

PVT – BRINE & CO_2

- The PVT (Pressure – Volume – Temperature) properties of CO_2 are estimated using the Peng-Robinson (PR) Equation of State (EOS).
- The relative permeability calculations are performed using Corey's model.



Figures: CO2 properties: density, viscosity, the formation volume factor, and relative permeability

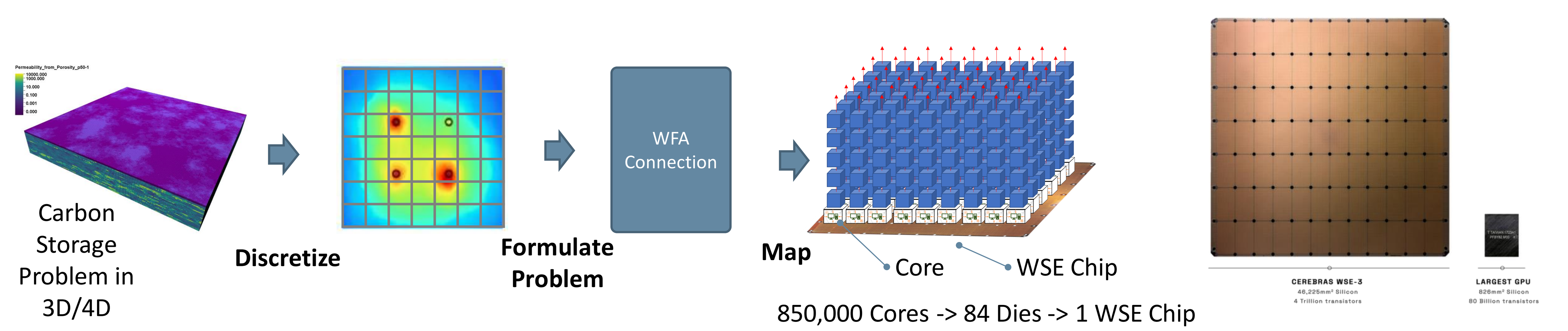


METHODS AND RESULTS

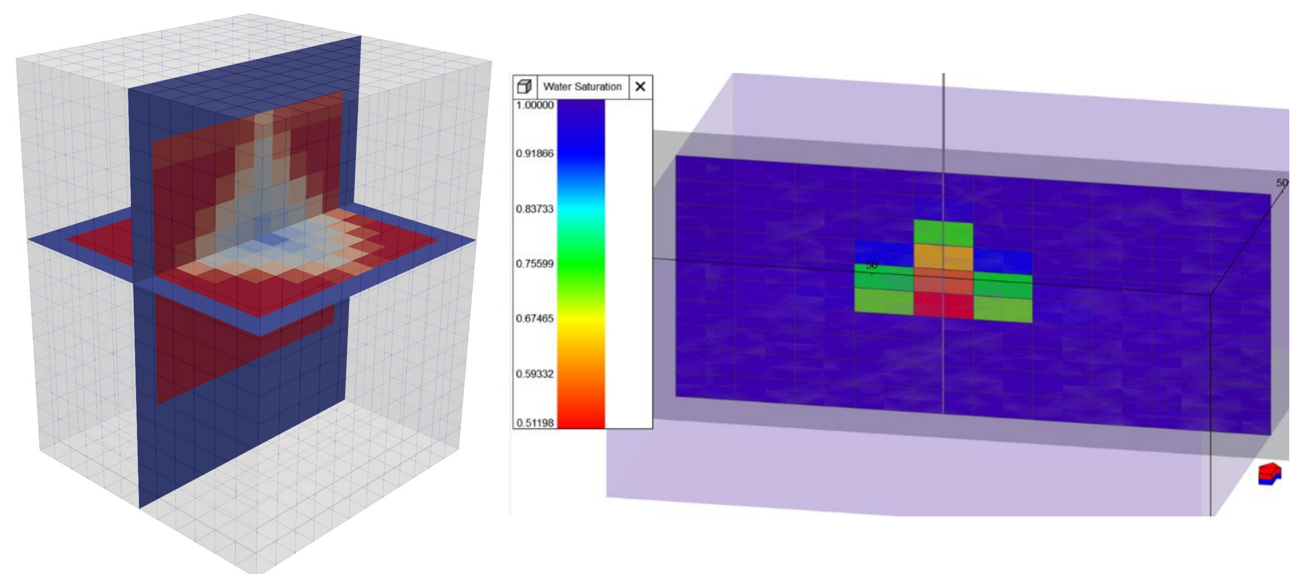
EXECUTIVE SUMMARY

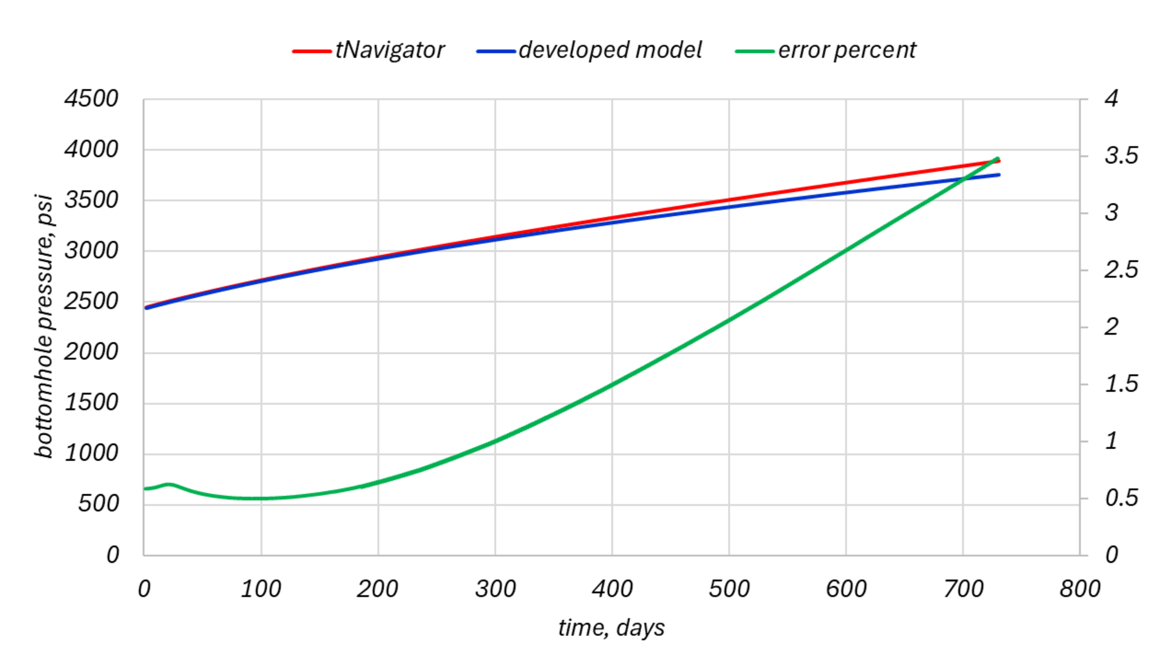
As the first step in developing the WFA (Wafer Field Application) code of two-phase model toward the simulation of CO_2-injection, the team developed the preliminary WFA code of two-phase flow model with CO_2 Brine PVT approximation. The WFA code is compared to t-Navigator for benchmark test and tested on the Neocortex Sdf WSE toward the simulation of IBDP experiment

WFA on WSE



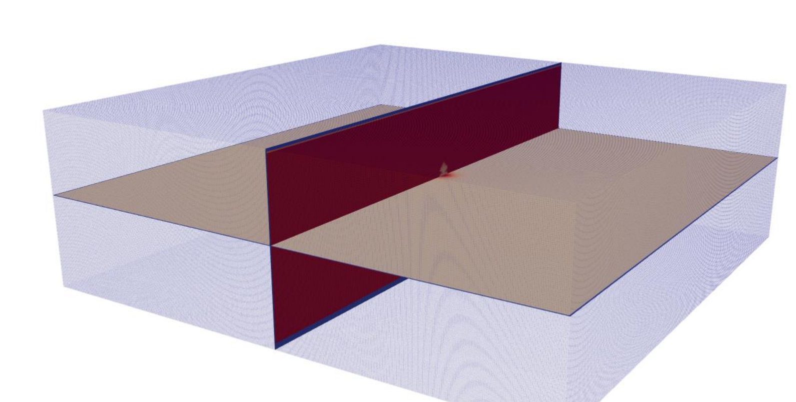
Comparison study with tNavigator





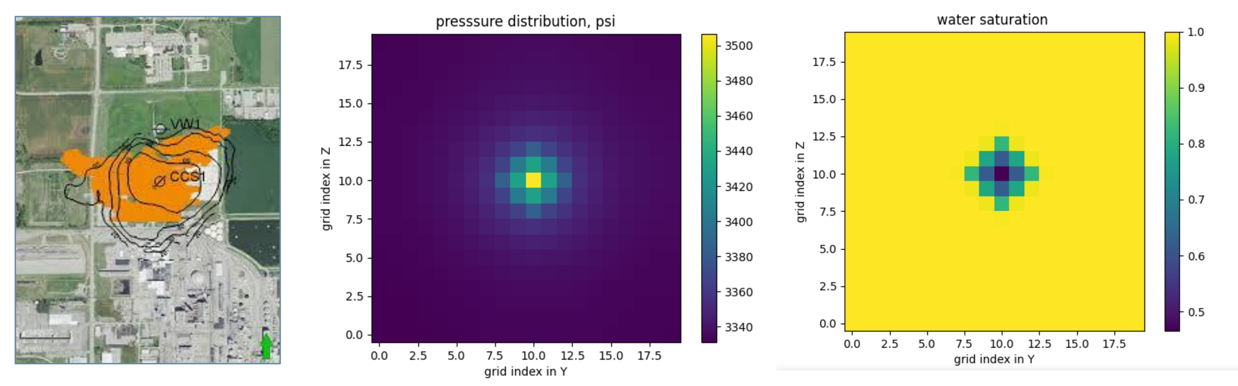
Scalability study on Neocortex Sdf WSE 1000 days injection

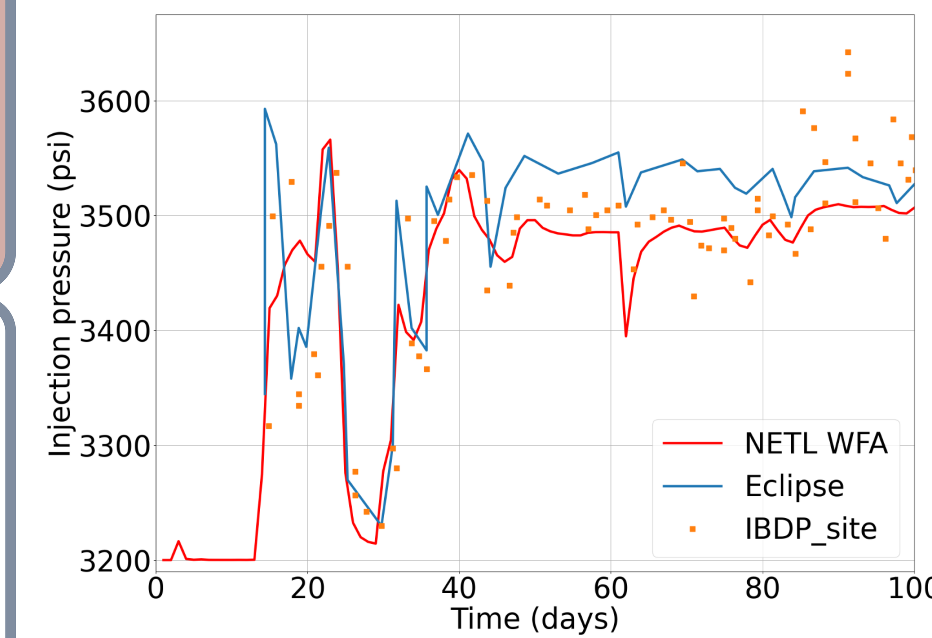
Nx	Ny	Nz	Total # cells	cs-2 time
100	100	124	1.24 M	~ 1.38 sec
200	200	124	4.96 M	~ 1.54 sec
300	300	124	~ 11.2 M	~ 1.65 sec
400	400	124	~ 19.8 M	~ 1.79 sec



- **Mesh size of (400x400x124)**

IBDP EXP COMPARISON





- 100 days CO_2 injection data
- Uniform permeability and porosity
- Converting stand-alone version into WSE/WFA

REMARKS

- **Developed proof-of-concept WFA code of two-phase model with PVT of CO_2 and brine**
- **Benchmarked results against t-Navigator outcomes**
- **Tested scalability on Neocortex Sdf WSE**
- **Tested preliminary case based on IBDP CO_2 storage dataset**

FUTURE WORK

- **Development of pre-conditioner for linear solver on WSE/WFA**
- **Benchmark study using t-Navigator on Joule3 CPUs/GPUs**
- **Validation study based on legacy IBDP experiment/simulation**

REFERENCE

- Petroleum reservoir simulation – basic concepts, Khalid Aziz, 2005
- Redlich, Otto; Kwong, J. N. S. (1949). "On The Thermodynamics of Solutions". Chem. Rev. 44 (1): 233–244. doi:10.1021/cr60137a013. PMID 18125401.
- Kamil Rocki, Dirk Van Essendelfty, Ilya Sharapov, Robert Schreiber, Michael Morrison, Vladimir Kibardin, Andrey Portnoy, Jean Francois Dietikeryz, Madhava Syamlaly and Michael James: Fast Stencil-Code Computation on a Wafer-Scale Processor. arXiv:2010.03660v1 [cs.DC] 7 Oct 2020
- Area of Review and Corrective Action Plan for ADM CCS #2 Oct2016, IL-115-6A-0001, Attachment B

DISCLAIMER

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