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

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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 the 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 partial differential equations (PDEs) 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

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

- The CO_2 (gas) phase flow equation is given by

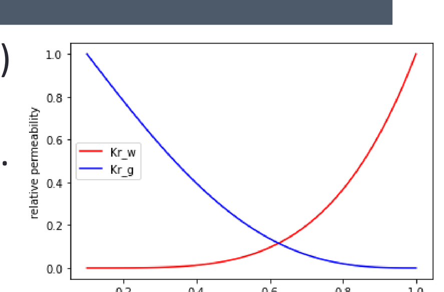
$$\frac{\partial(\varphi(\rho_g S_g + \rho_w S_w R_{sw}))}{\partial t} = -\nabla.((\frac{\rho_g}{\mu_g}k\,k_{rg} + \frac{\rho_w}{\mu_w}k\,k_{rw}R_{sw})(\nabla p_g + \gamma_g \nabla z)) + q_g$$

- 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

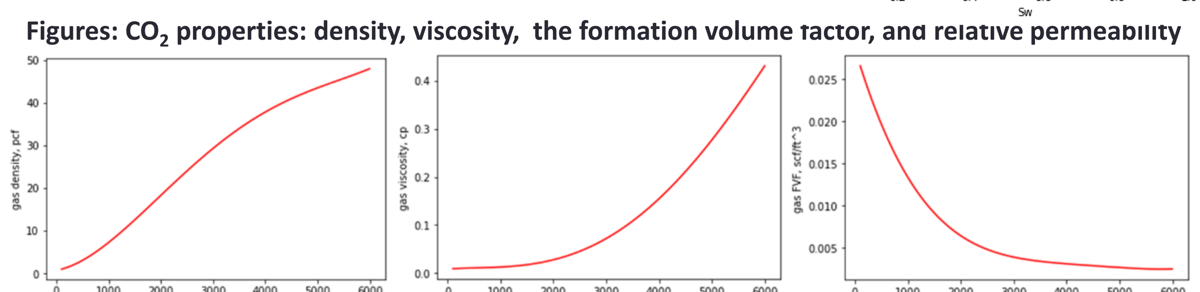
$$D_n\frac{dx_n}{dt} = T_n x^{n+1} + G_n + Q_n$$

PVT – BRINE & CO_2

- The Pressure – Volume – Temperature (PVT) 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: CO_2 properties: density, viscosity, the formation volume factor, and relative permeability

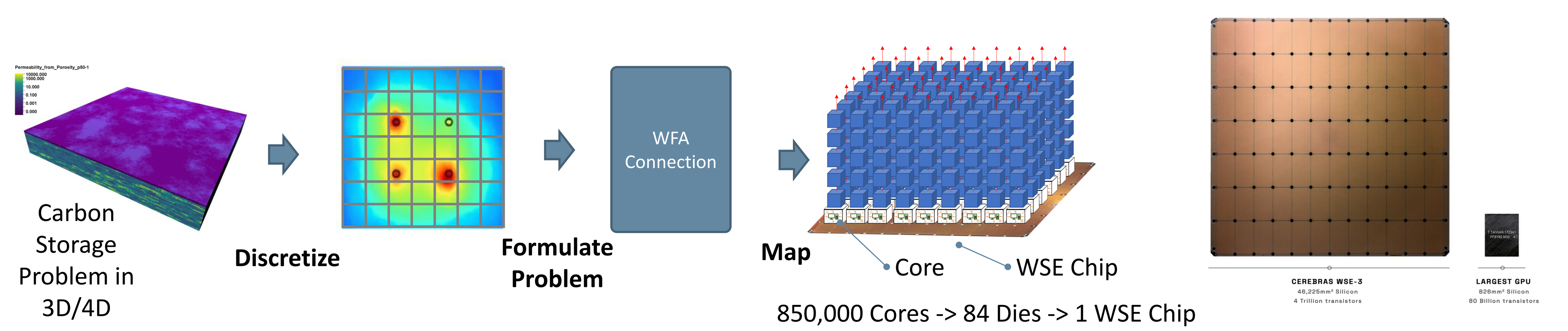


METHODS AND RESULTS

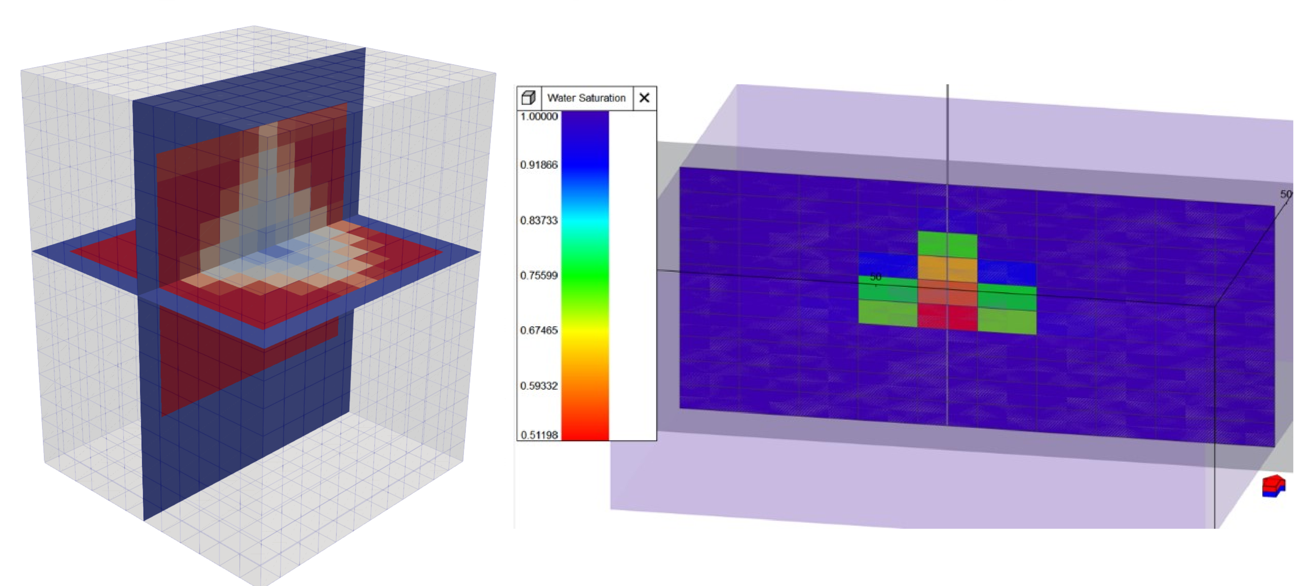
EXECUTIVE SUMMARY

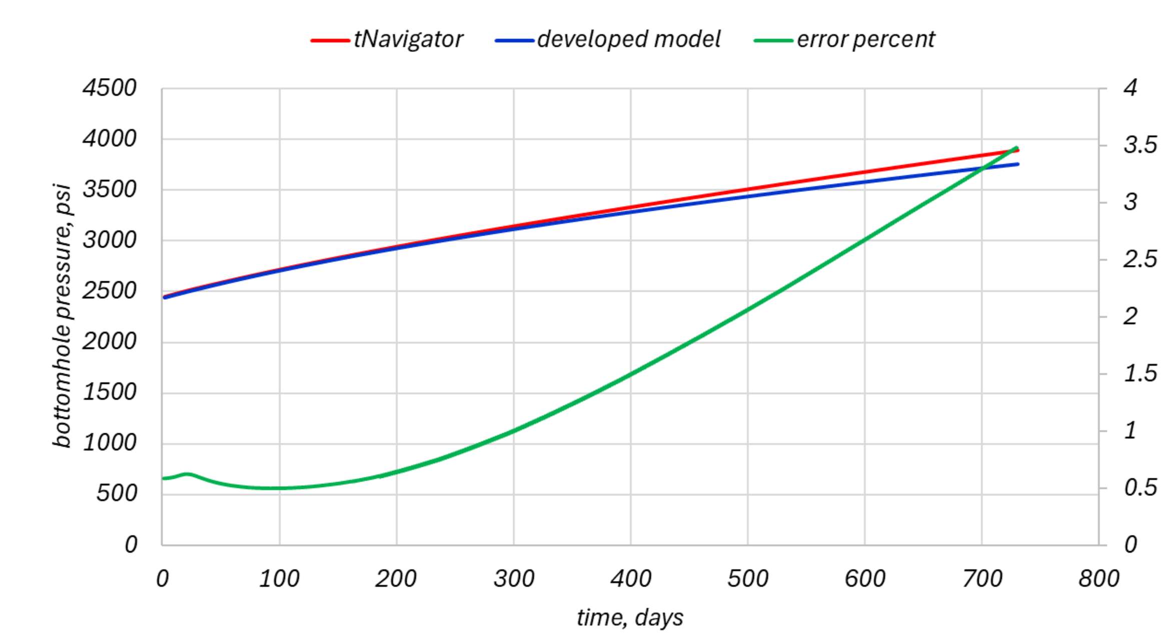
As the first step in developing the Wafer Field Application (WFA) code of a two-phase model toward the simulation of CO_2-injection, the team developed the preliminary WFA code of a two-phase flow model with CO_2-brine PVT approximation. The WFA code was compared to t-Navigator for benchmark testing,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

WFA on WSE



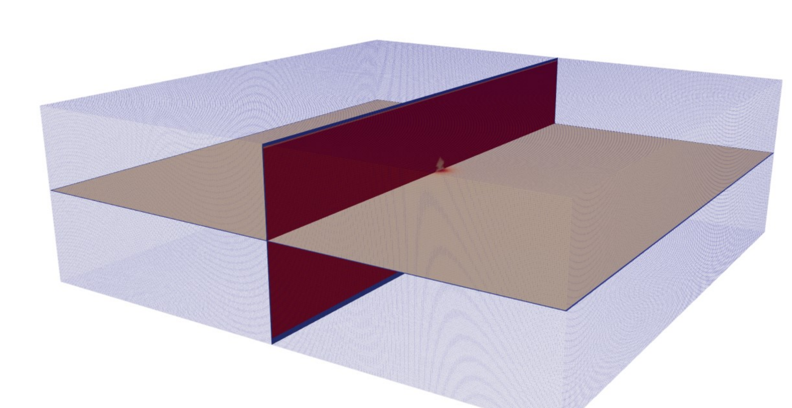
Comparison study with t-Navigator





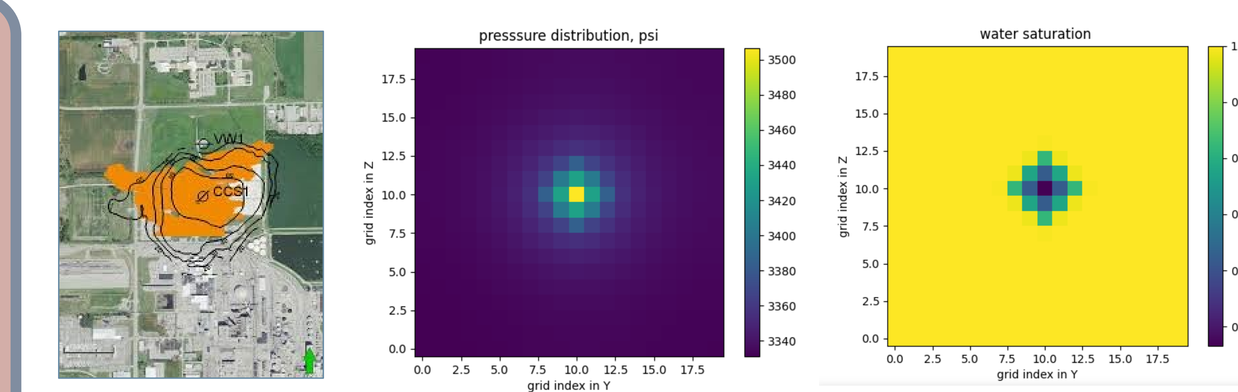
Scalability study on Neocortex Sdf WSE 1,000 days injection

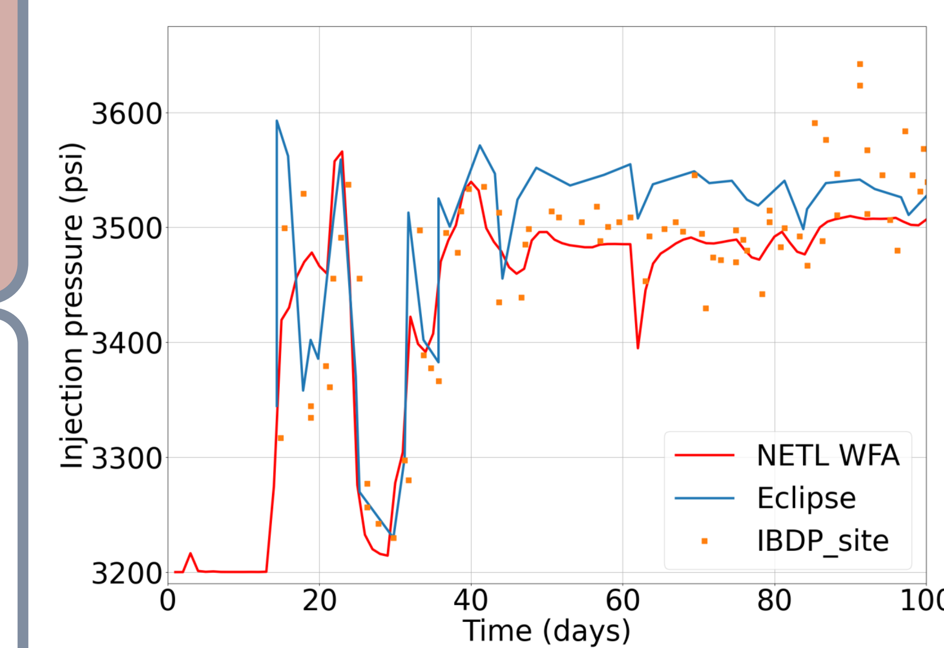
Nx	Ny	Nz	Total # cells	cs-2 time
100	100	124	1.24 M	~ 1.38 sec
200	200	124	4.96 M	~ 1.54 sec
300	300	124	~ 11.2 M	~ 1.65 sec
400	400	124	~ 19.8 M	~ 1.79 sec



- **Mesh size of (400 x 400 x 124)**

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 the 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

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- 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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