

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



Hyoungkeun Kim^{1,2}; Mina Rezkalla^{1,2}; Alex Sun^{1,2}; Dirk T. VanEssendelft³; Chung Yan Shih⁴; Guoxiang Liu⁴; Hema Siriwardane³

¹National Energy Technology Laboratory, 1450 SW Queen Ave, Albany, OR 97321, USA; ²NETL Support Contractor, 1450 SW Queen Ave, Albany, OR 97321, USA; ³National Energy Technology Laboratory 3610 Collins Ferry Road, Morgantown, WV 26505, USA; ⁴National Energy Technology Laboratory, 626 Cochran Mill Road, Pittsburgh, PA 15236, USA

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 CO₂ 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 CO₂-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 CO₂-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

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

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

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

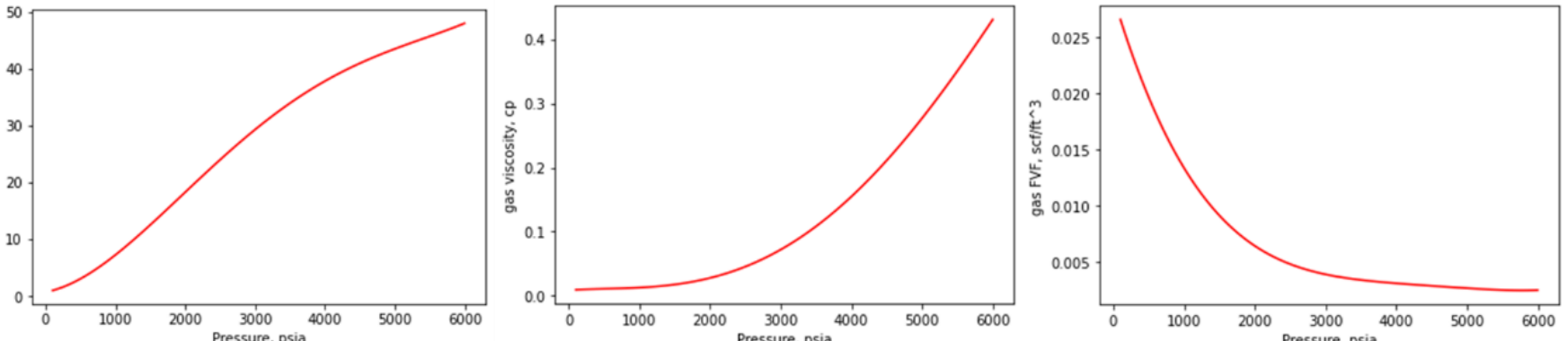
- The overall flow equation is obtained by multiplying the brine flow equation by (R_{sw} B_w/B_g) and adding the results to the CO₂ flow equation

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

PVT – BRINE & CO₂

- The Pressure – Volume – Temperature (PVT) properties of CO₂ 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

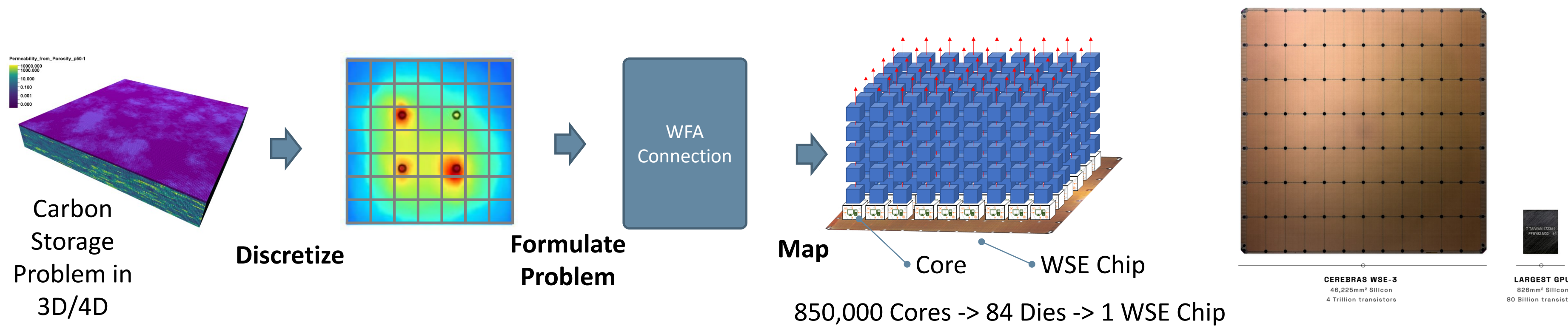


METHODS AND RESULTS

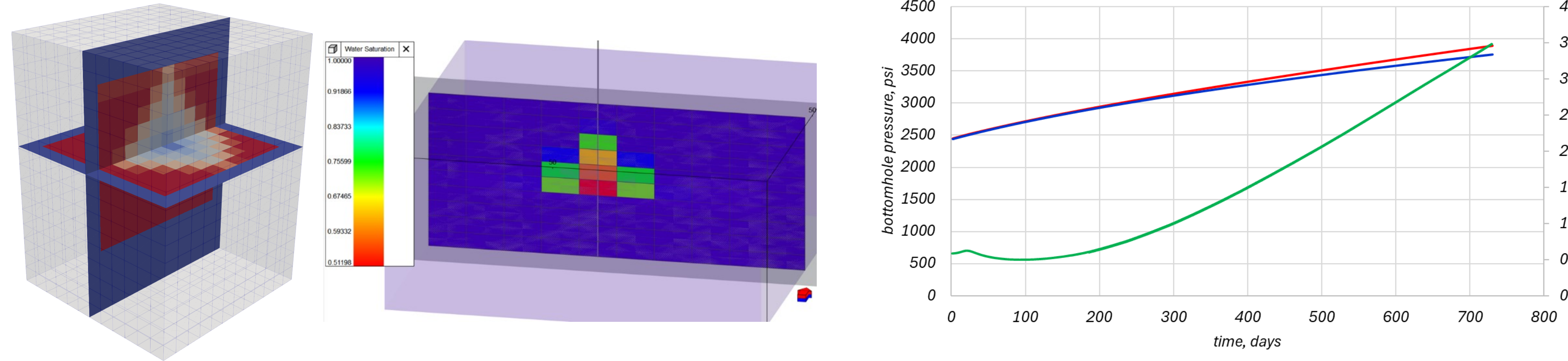
EXECUTIVE SUMMARY

As the first step in developing the Wafer Field Application (WFA) code of a two-phase model toward the simulation of CO₂-injection, the team developed the preliminary WFA code of a two-phase flow model with CO₂-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

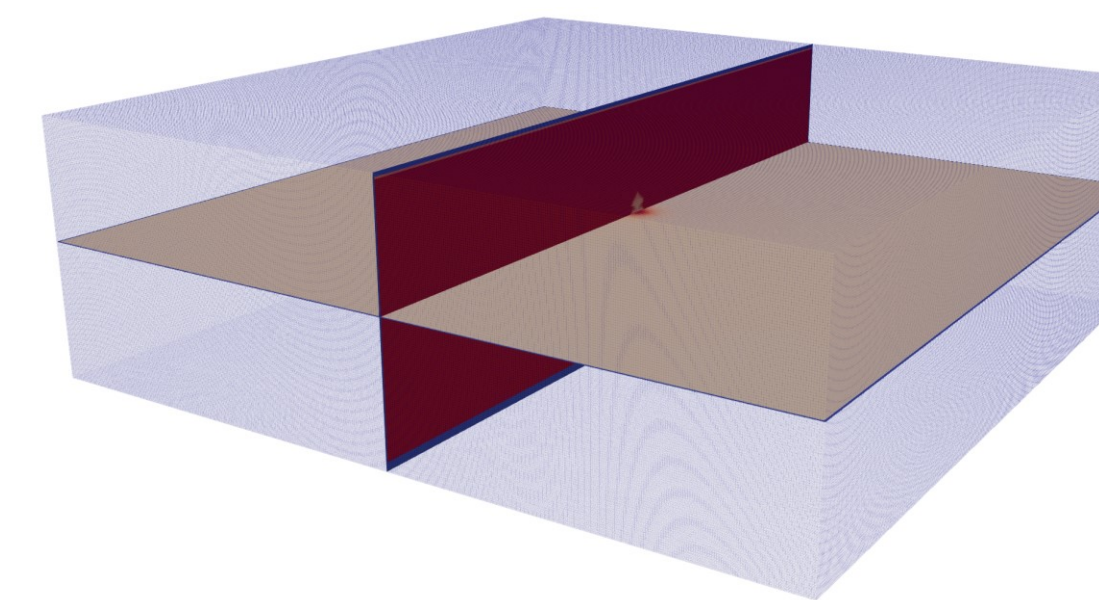


Comparison study with t-Navigator



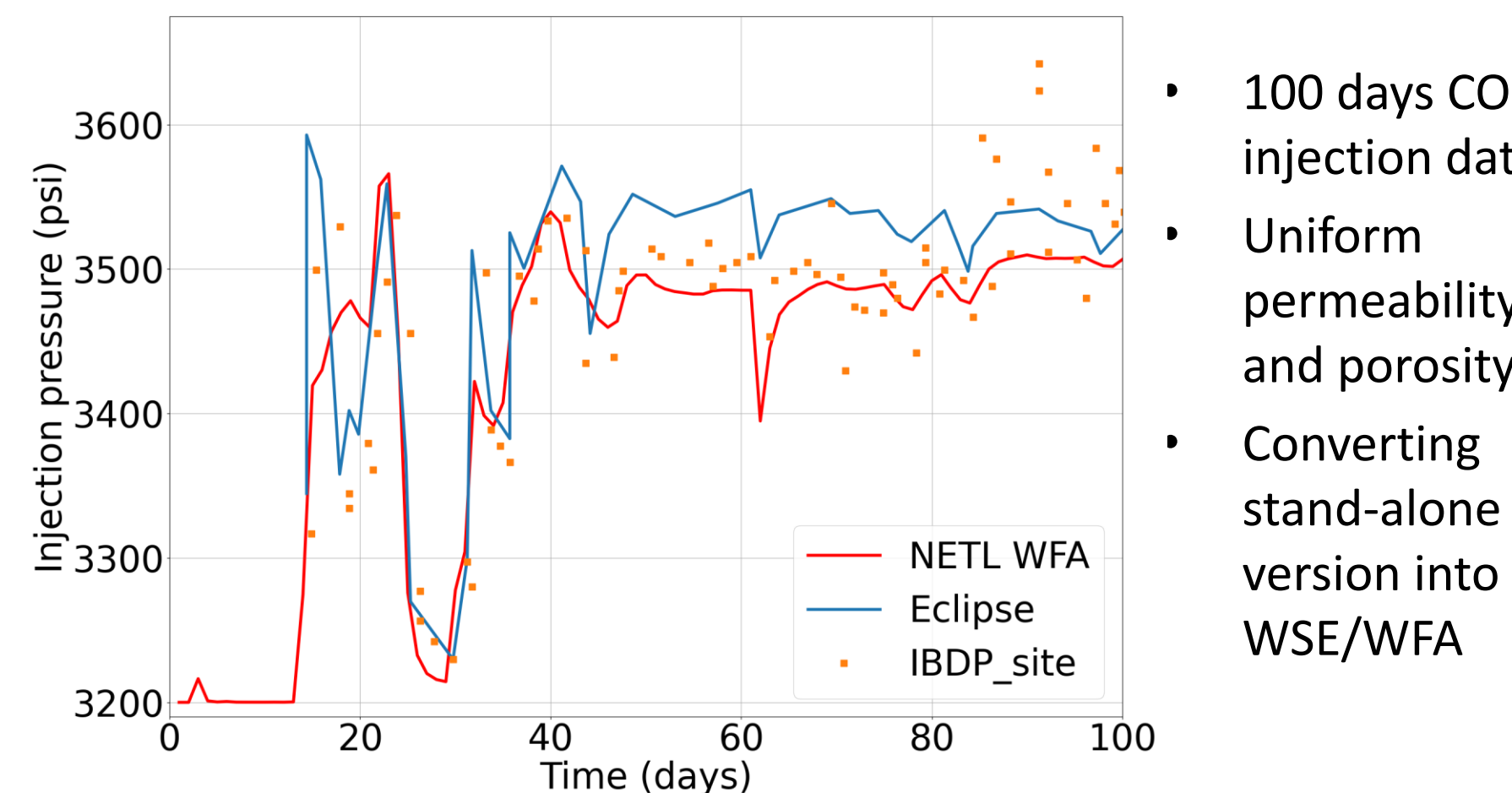
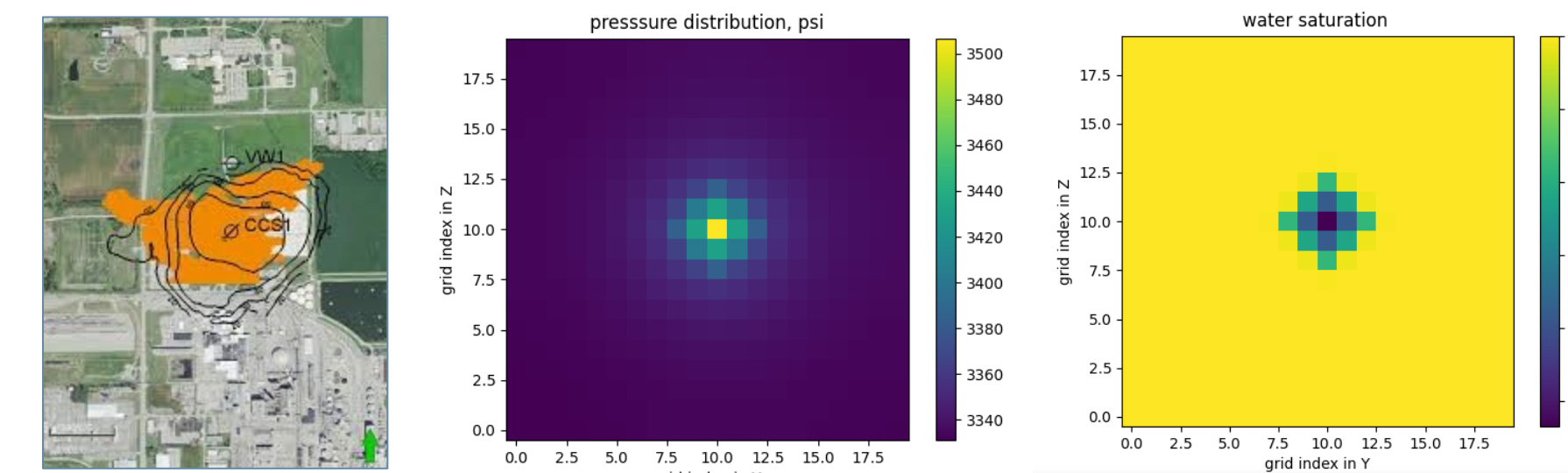
Scalability study on Neocortex Sdf WSE 1,000 days injection

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 CO₂ 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 CO₂ and brine.
- Benchmarked results against t-Navigator outcomes.
- Tested scalability on Neocortex Sdf WSE.
- Tested preliminary case based on IBDP CO₂ 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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- Area of Review and Corrective Action Plan for ADM CCS #2 Oct2016, IL-115-6A-0001, Attachment B

DISCLAIMER

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