High-fidelity simulation of CO_2-induced carbonate dissolution: From core to reservoir scale

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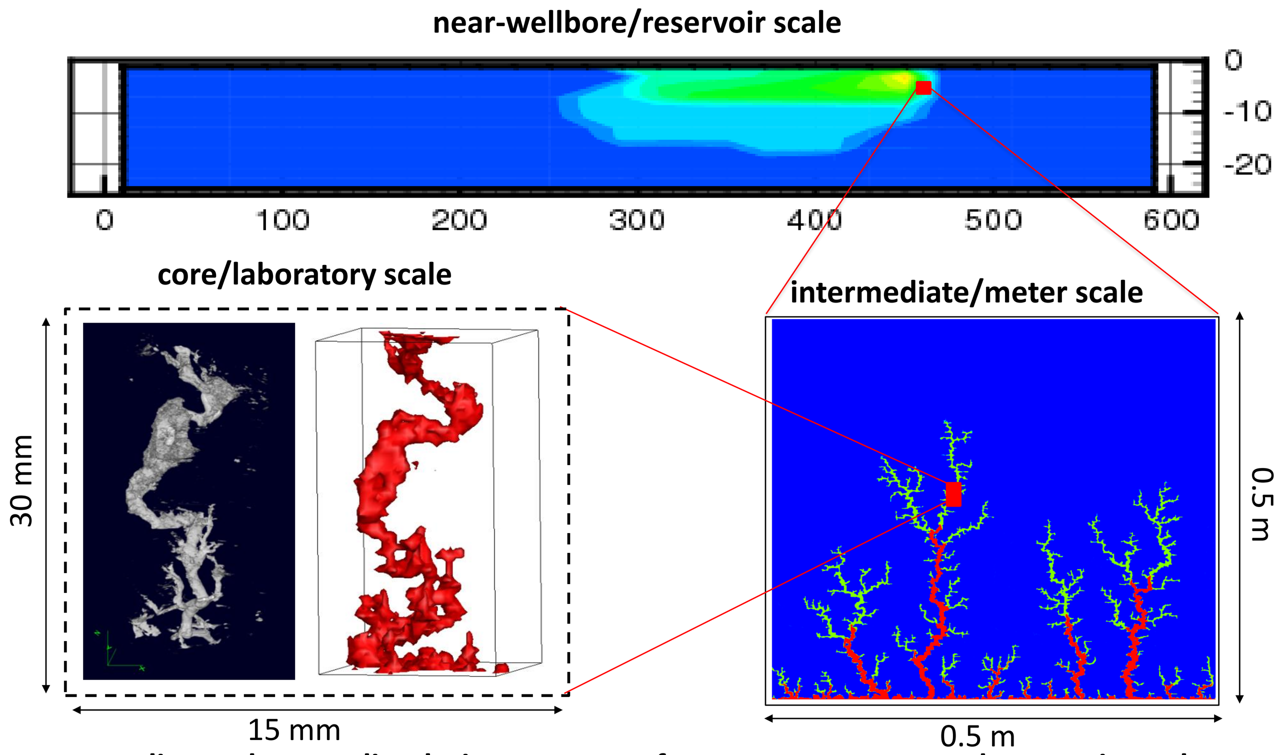
Introduction

- Developing a reliable reactive transport model that can accurately describe CO_2-fluid-rock interactions and their effects on rock porosity and permeability evolution is important for predicting the long-term CO_2 storage capacity in carbonate formations.
- Reactive transport models are often calibrated or validated by laboratory core-flooding experiment measurements.
- However, the upscaling of laboratory results to the field scale remains as a challenging research topic.

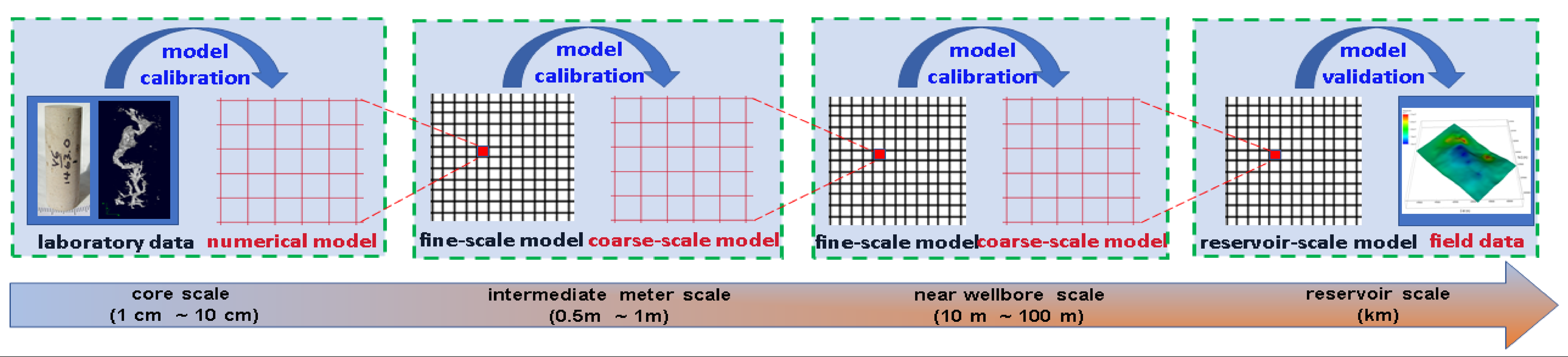


upscaling carbonate dissolution processes from core- to meter and reservoir- scales

- The objectives of this study are to
  - Develop a high fidelity intermediate scale (meter-scale) model that honors CO_2-induced carbonate dissolution from laboratory experiments.
  - Develop an effective upscaling approach to establish a direct relationship between core- and large-scale models.

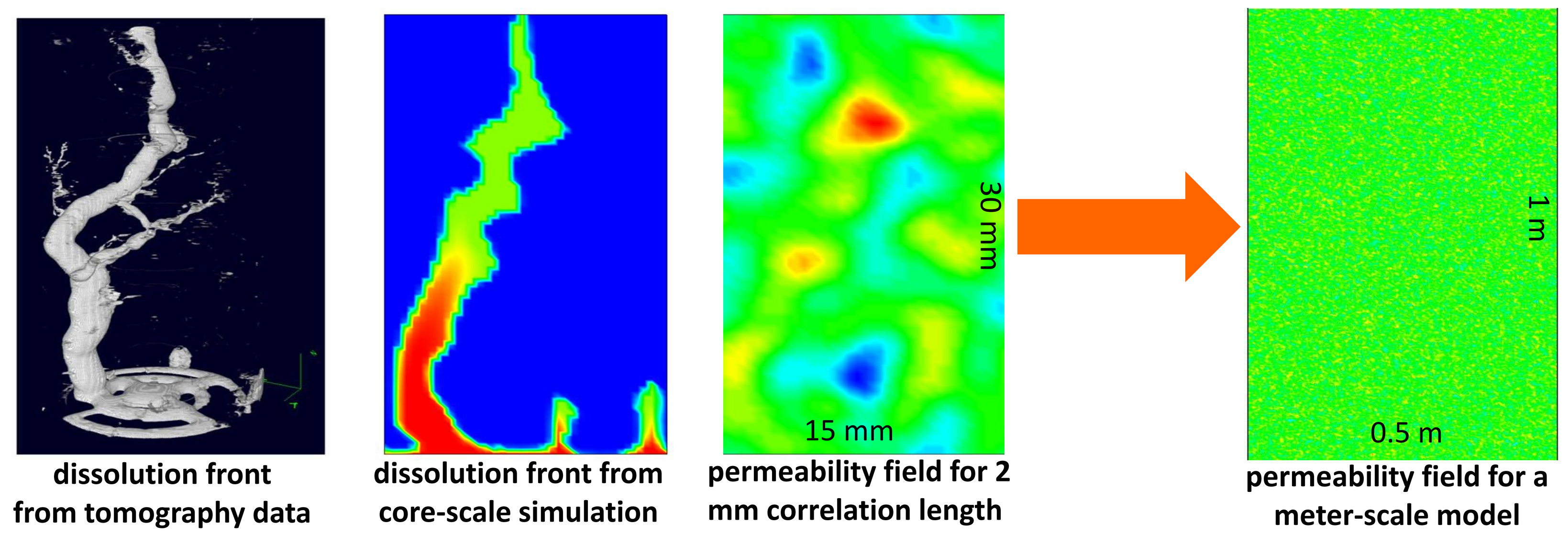
Technical approach

- Leverage advanced simulation and high-performance computing capabilities to extend an experimentally-calibrated core-scale model to directly simulate CO_2-induced dissolution of low-permeability carbonate rocks at a meter scale.
- Develop a strategy to upscale reactive transport processes from fundamental physical scale to reservoir scale. At each scale,
  - Perform high-resolution simulation at a fine scale;
  - Use fine-scale simulation results to calibrate coarse-scale models;
  - Apply calibrated models to next large scale level



High-resolution simulation of carbonate dissolution at a meter scale

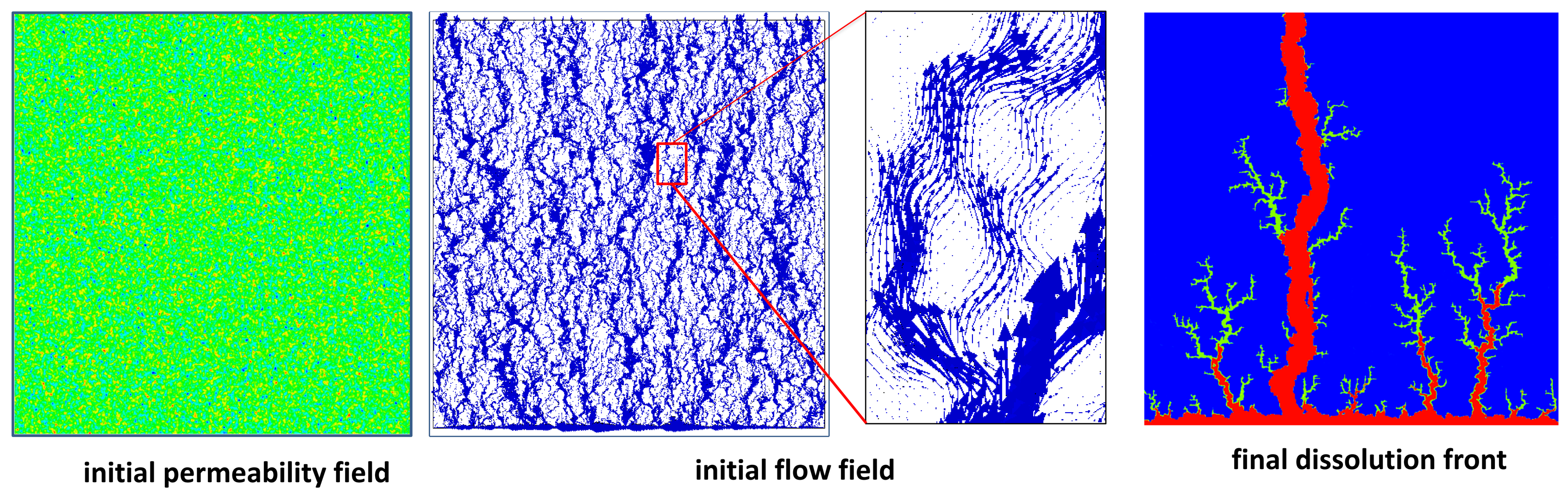
- Construct a permeability field that honors rock characteristics and dissolution patterns as observed from core-food experiments, and extend it for meter-scale simulation



- Leverage massively parallel computing for high-fidelity simulation of carbonate dissolution

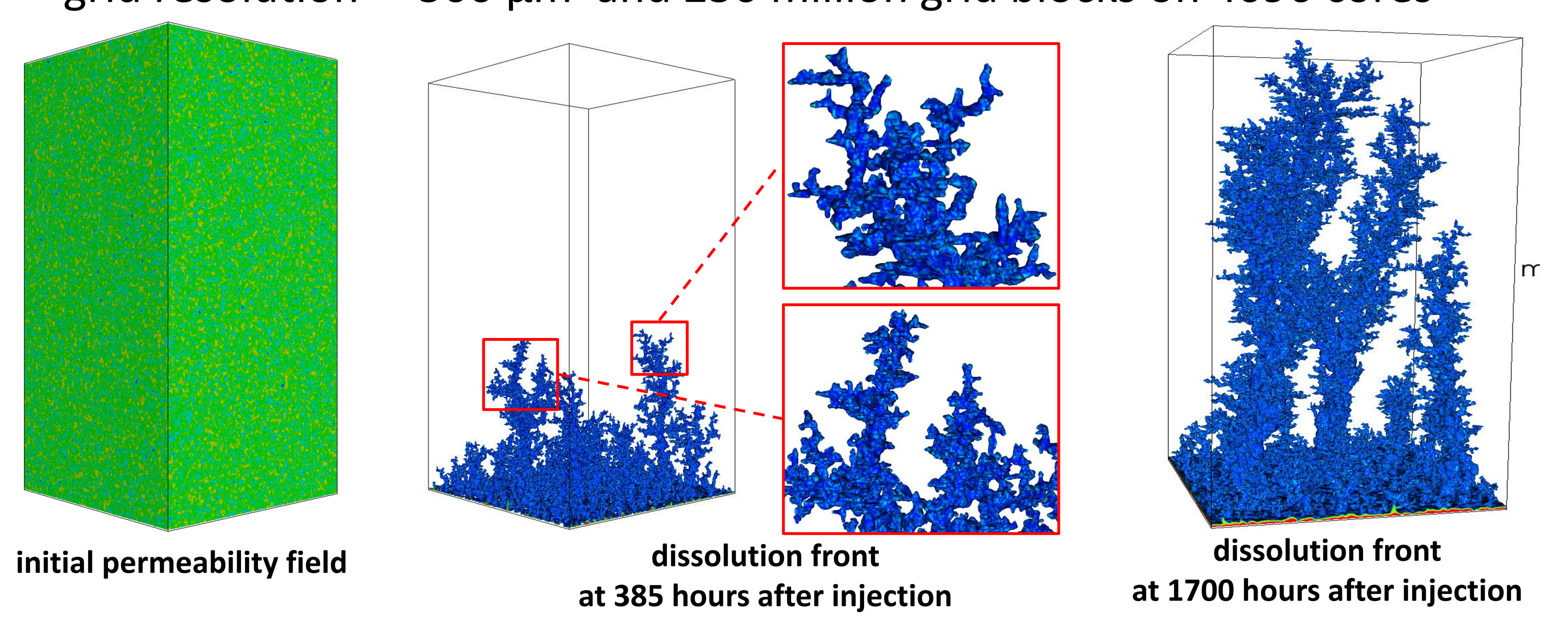
CO_2 saturated brine is injected into 2D 0.5 m X 0.5m rock domain

grid resolution = 375 µm and 1.96 million grid blocks on 256 cores

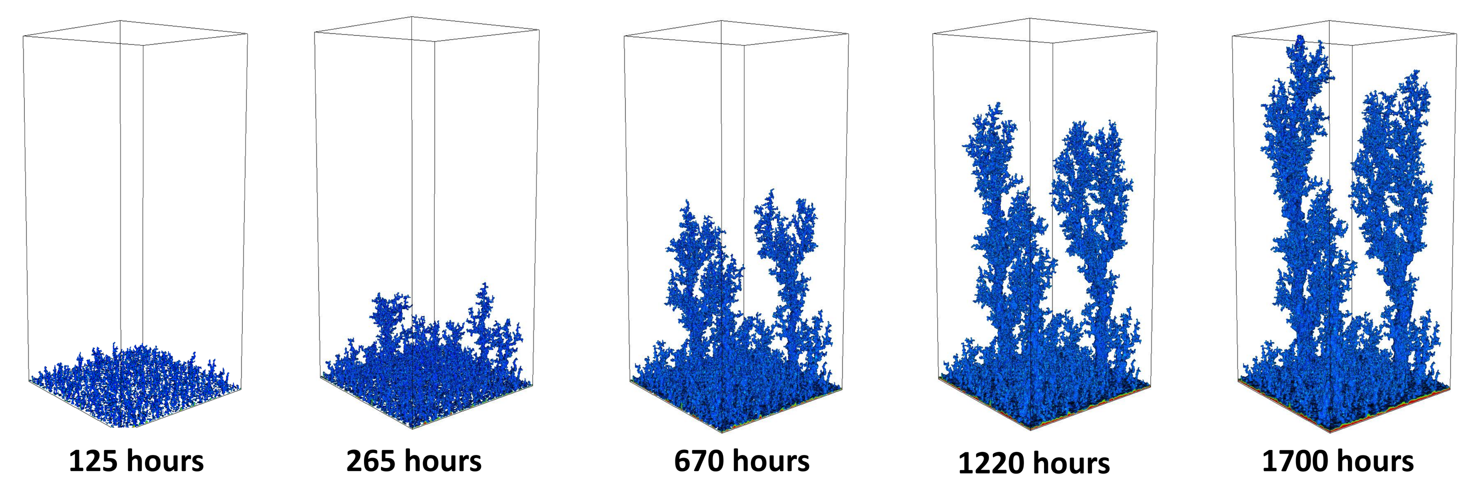


CO_2 saturated brine is injected into 3D 0.25 m X 0.25m x 0.5m rock domain

grid resolution = 500 µm and 250 million grid blocks on 4096 cores



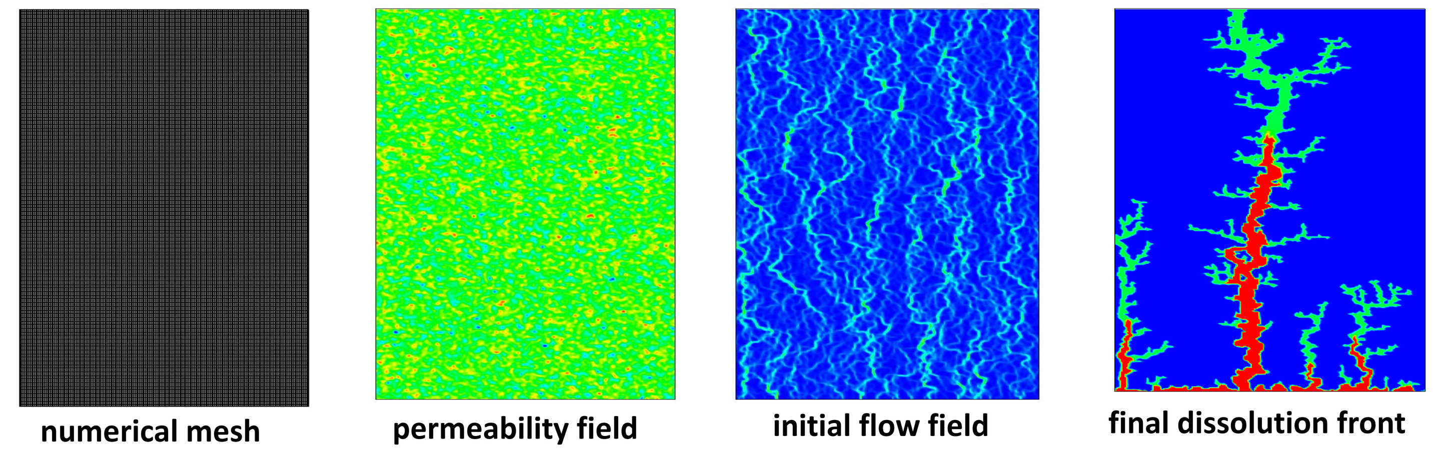
temporal and spatial development of dissolution front



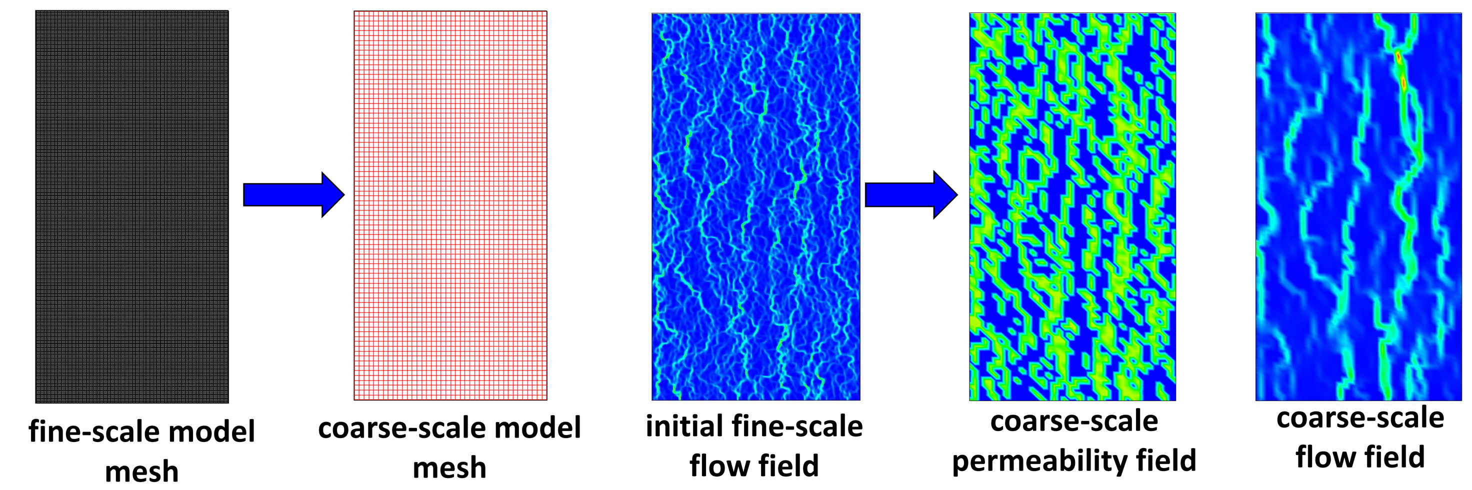
Upscaling fine-scale to coarse-scale simulation

CO_2 saturated brine is injected into 2D 0.2 m X 0.4 m rock domain

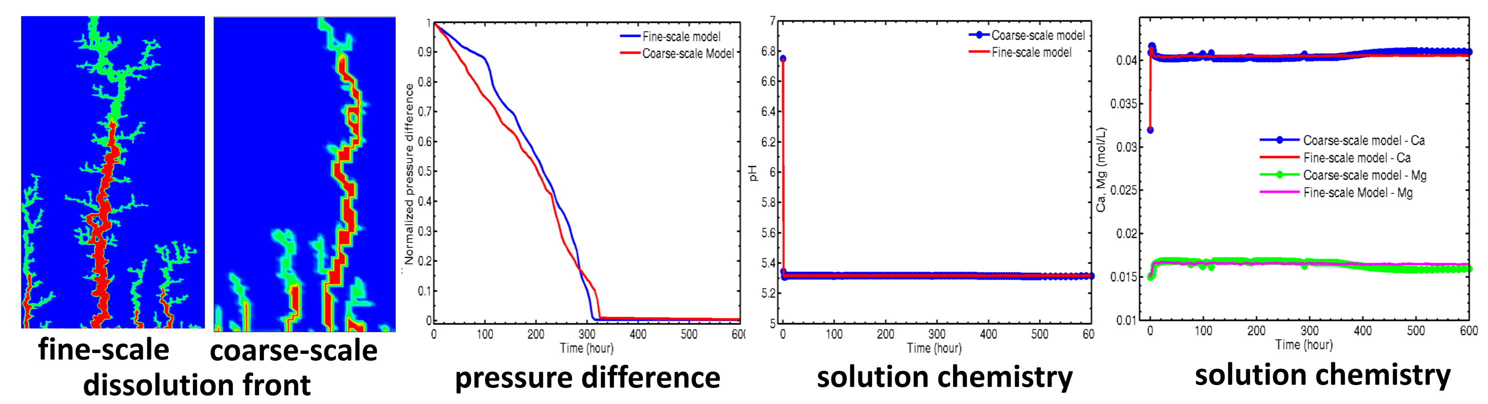
fine-scale model with grid resolution = 1 mm

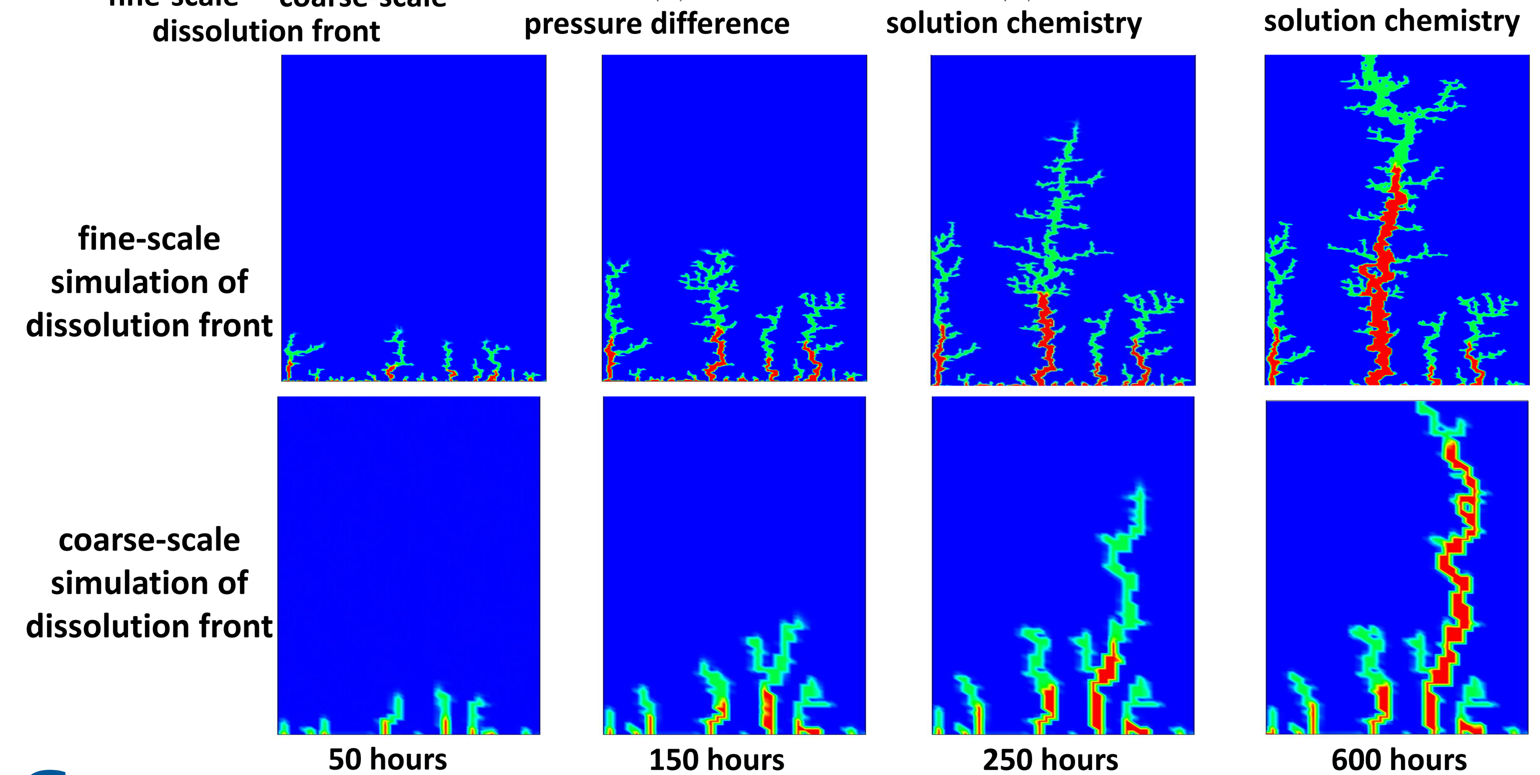


analyze fine-scale flow field and upscale initial permeability field to a coarse scale (grid resolution = 5 mm)



comparison between fine- and coarse-scale simulation





Summary

- We have developed an integrated multi-scale modeling framework for simulating CO_2 induced carbonate dissolution and its effects on rock porosity change.
- We will apply the developed model to upscale mineral dissolution and reactive transport processes from core- to reservoir scales.

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