Karlsruhe Institute of Technology

Institute of Applied Geosciences
Division of Geothermal Research

MOOSE/TIGER: New High Performance Simulator for Nonlinear Coupled THMC Processes

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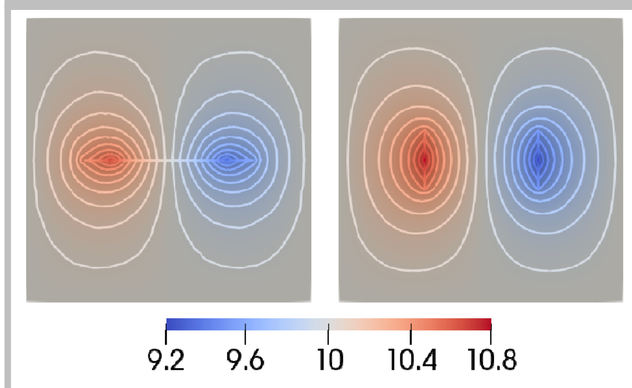
MOOSE

- The **M**ultiphysics **O**bject-**O**riented **S**imulation **E**nvironment (MOOSE) is a finite-element solver developed by *Idaho National Laboratory*
- Fully-coupled, fully-implicit solver
- Dimension independent physics
- Automatically parallel (largest runs >100,000 CPU cores!)
- Simplified modular development
- Built-in mesh adaptivity
- Intuitive parallel multiscale solves
- Continuous and Discontinuous Galerkin FE

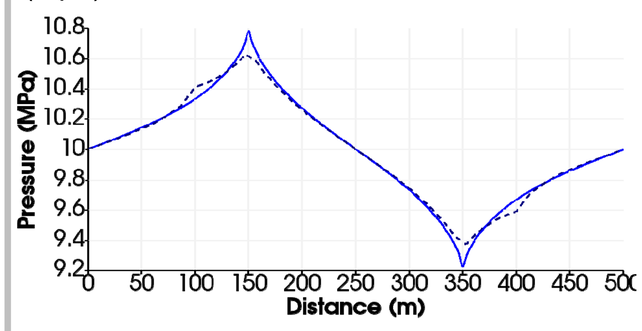
TIGER and Prospective

- The **T**HMC s**I**mulator for **GE**oscience **R**esearch (TIGER) is a MOOSE-based application developed by *Institute of Applied Geosciences*
- Capbale of modeling fractures and well paths as (lower dimensional) discrete features
- Able to simulate thermal and solute transports by considering anisotropic flow in porous media
- Hydro-Thermal (TH) simulator part is ready to use and intensively validated; three examples are illustrated here
- Navier-Stokes for flow modeling in wellbores is examined now and will be added in near future
- Coupling of mechanics and reactive chemistry is under progress

2D representation of a fractured reservoir

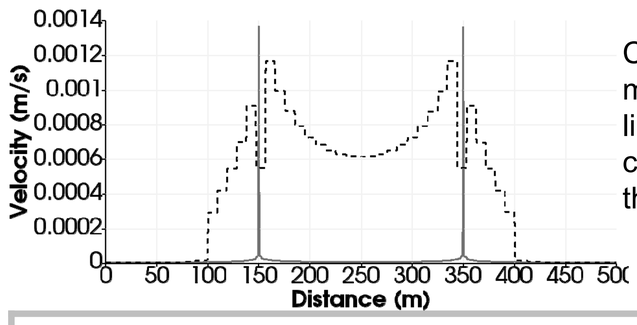


Side-by-side comparison of pressure contours (Mpa) for the both fracture orientations

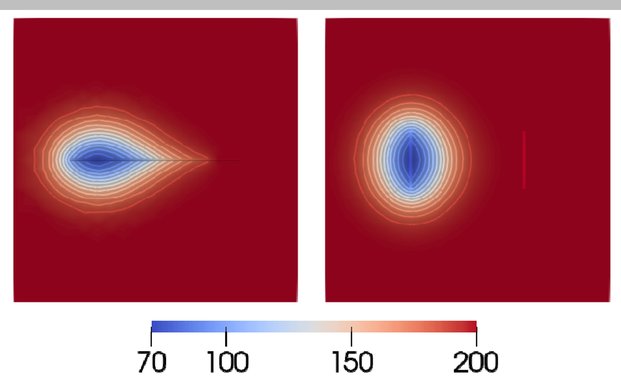


Comparison of pressure along the line which connects centers of fractures in the both orientations

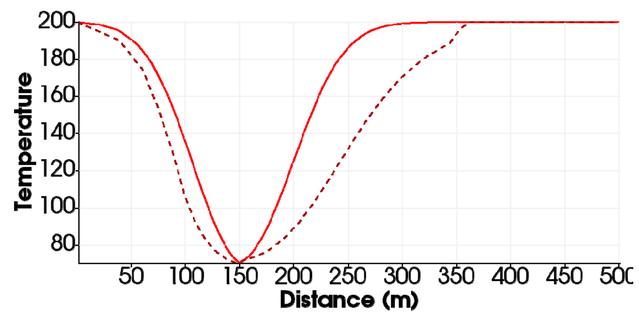
- A doublet system with two wellbores separated by a distance of 200 m and located directly within fractures
- Water circulated at a rate of 3 L/s and the injection temperature of 70°C for 30 years
- Two fractures orientations:
  - Two interconnected alongside fractures (dashed lines)
  - Two parallel fractures (continuous lines)



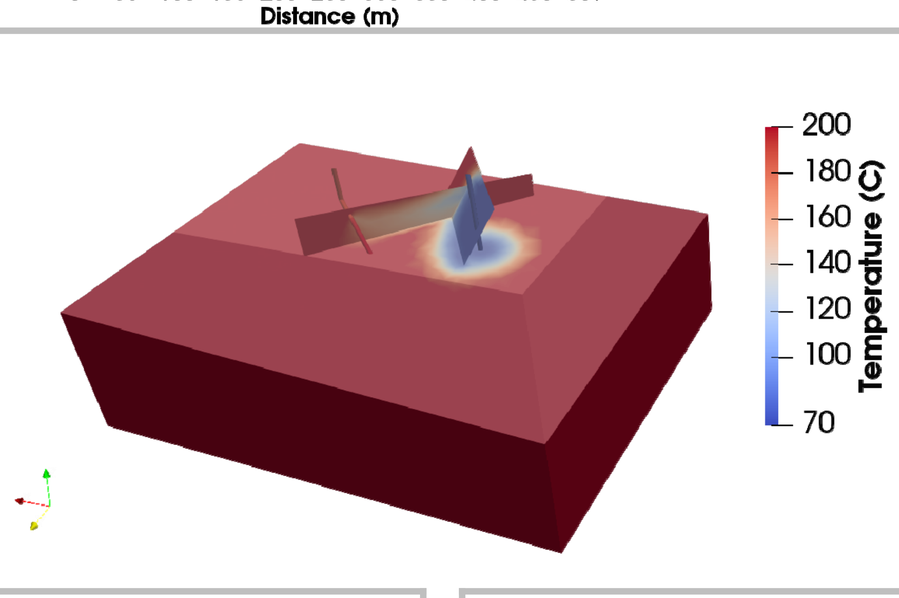
Comparison of velocity magnitude along the line which connects centers of fractures in the both orientations



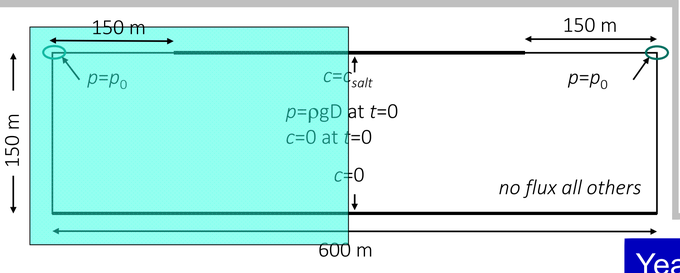
Side-by-side comparison of temperature contours (C) for the both fracture orientations



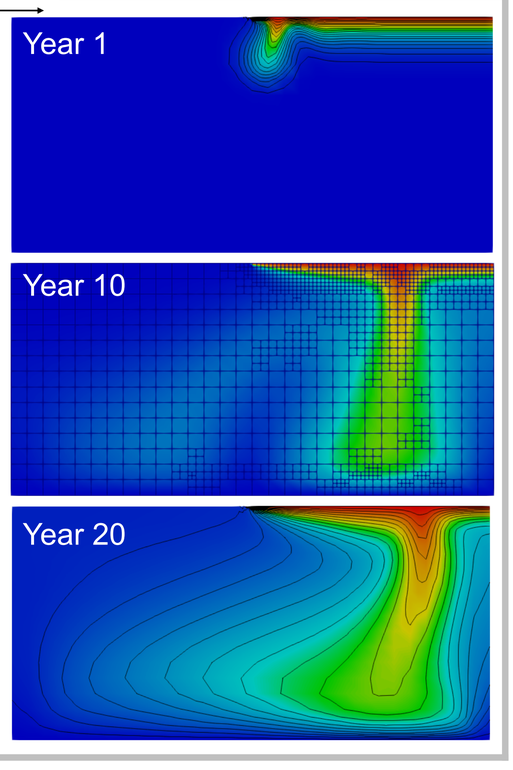
Comparison of temperature along the line which connects centers of fractures in the both orientations



Natural Convection

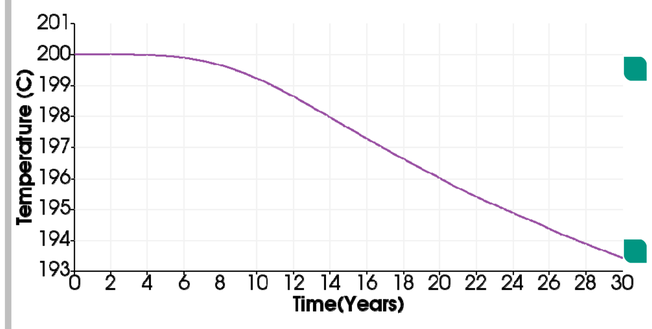


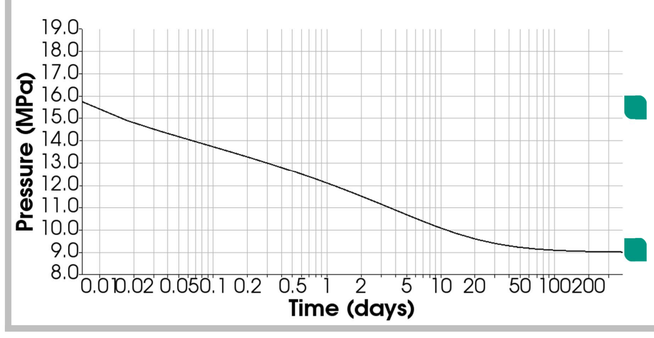
- Fluid density can vary with the contaminant concentrations producing buoyancy flow
- Geometry and initial conditions are explained as the above figure and the green area is simulated due to the symetry of the problem
- Snapshots of concentrations and its contours during the 20-year simulation period are provided (0=dark blue and 1=dark red)
- The concentration snapshot at year 10 shows mesh adaptivity capability to better capture the concentarion propagation front



3D EGS reservoir

- A 3D reservoir comprising of two discrete crossed fractures (a vertical and a tilted) and a doublet wellbores (a non-vertical production well) is simulated
- The reservoir dimensions is 2x1.5x1 km at the depth of 1.8 km with the ambient temperature of 200°C
- Water circulated at a rate of 50 L/s and the injection temperature of 70°C for 30 years.
- The temperature and pressure variations by time at the production well are illustrated
- The temperature distribution is shown in the middle figure





HELMHOLTZ
RESEARCH FOR GRAND CHALLENGES