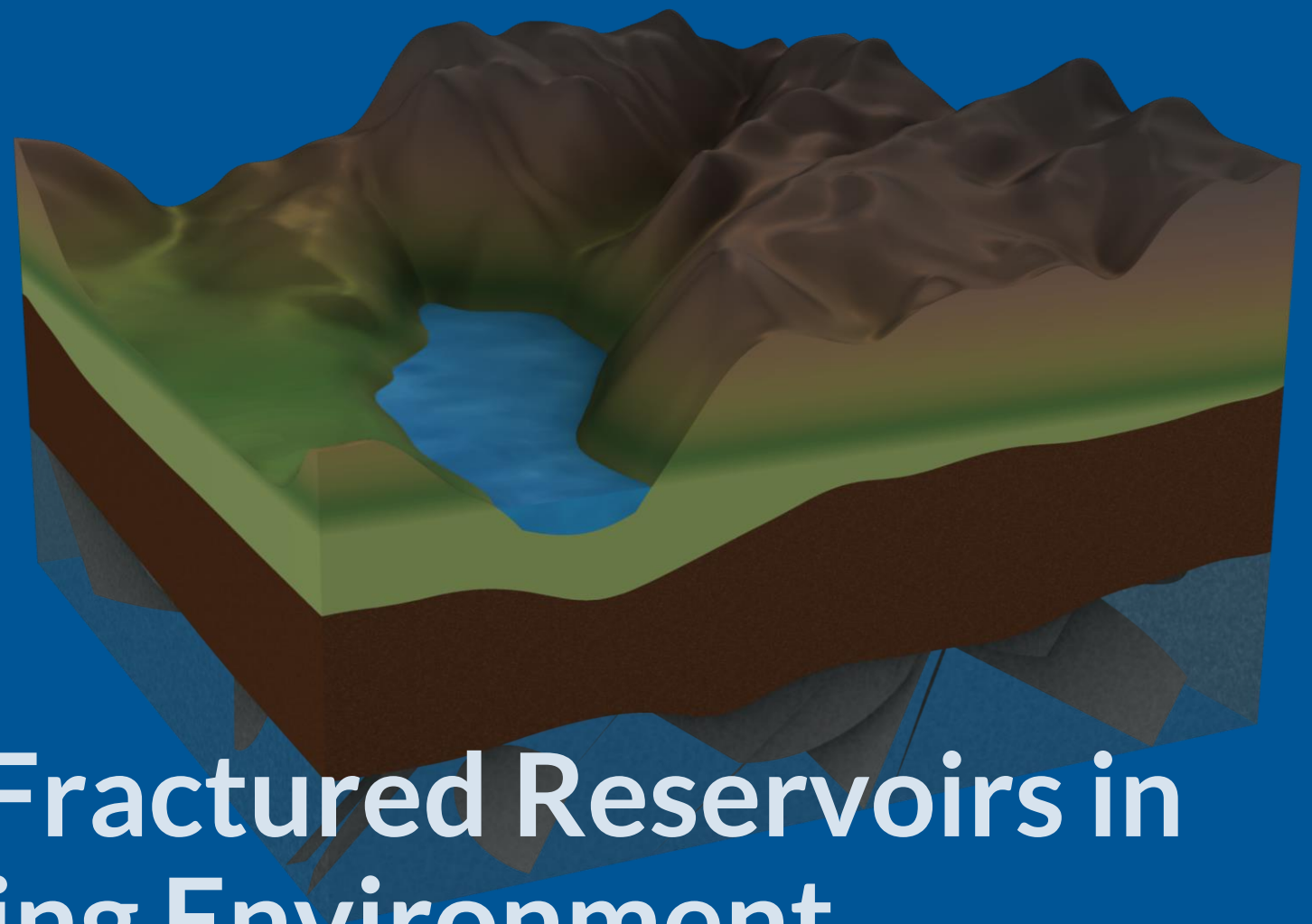

Multiphysics of Fractured Reservoirs in a Unified Modeling Environment

Nancy Bannach
Comsol Multiphysics GmbH

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COMSOL Compiler™
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  - Composite Materials Module
  - Geomechanics Module
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- Multibody Dynamics Module
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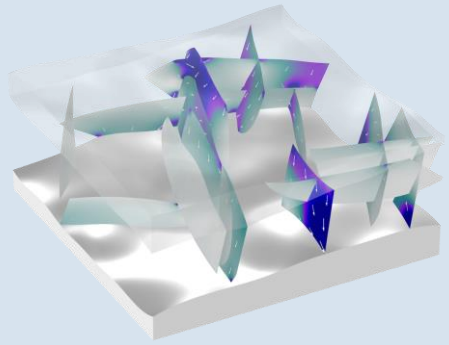
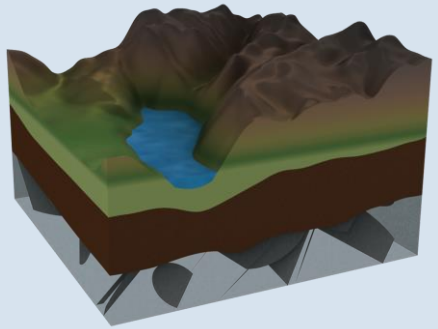
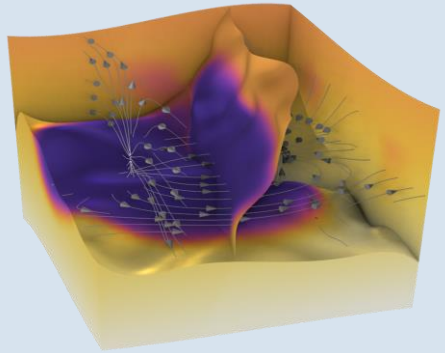
Content



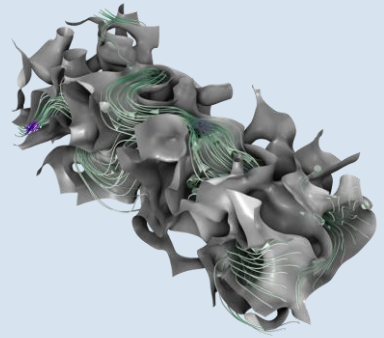
Motivation



Fractured Reservoirs



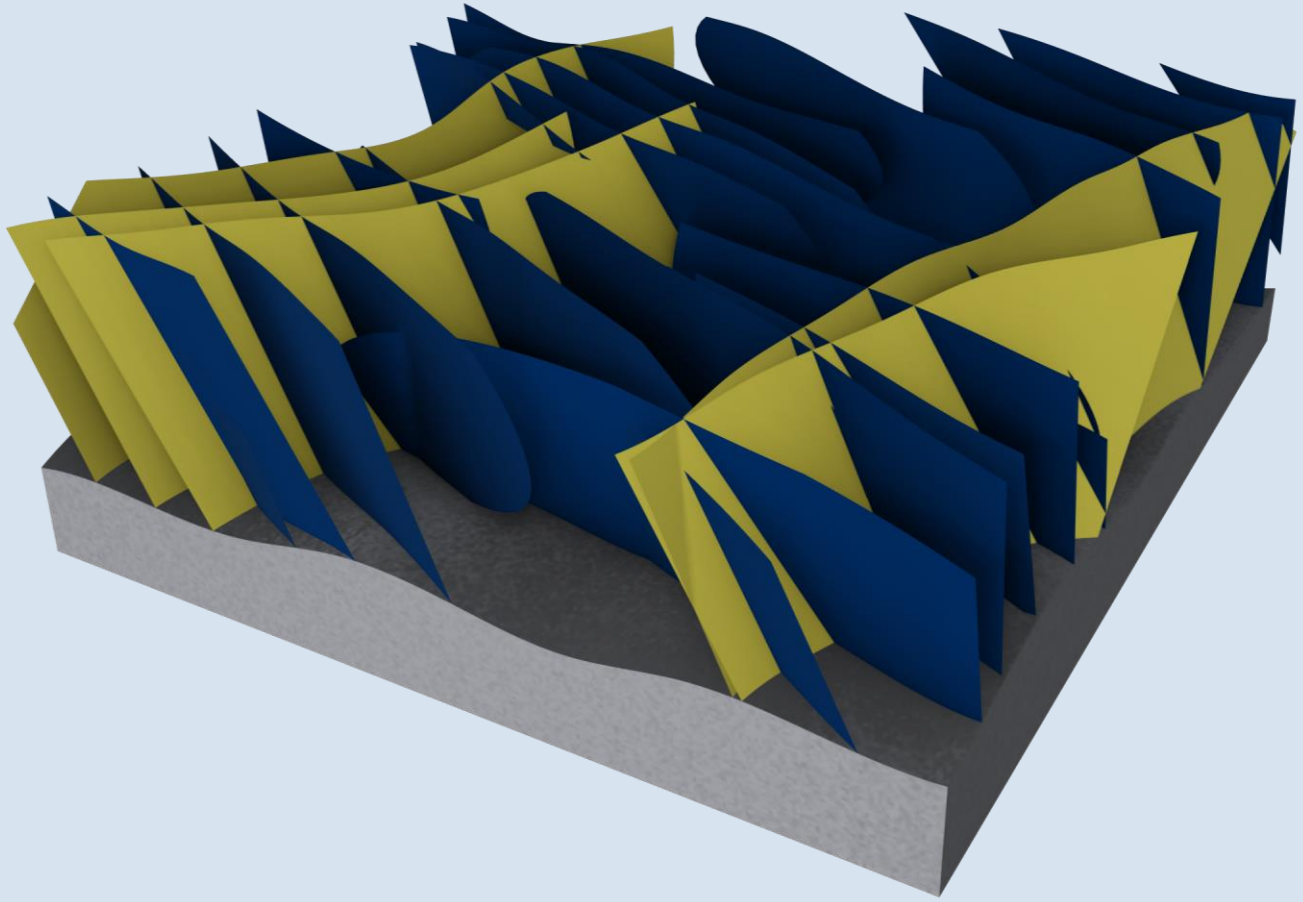
Multiphysics Modeling



Summary and Outlook

WHY ARE WE HERE?

Motivation



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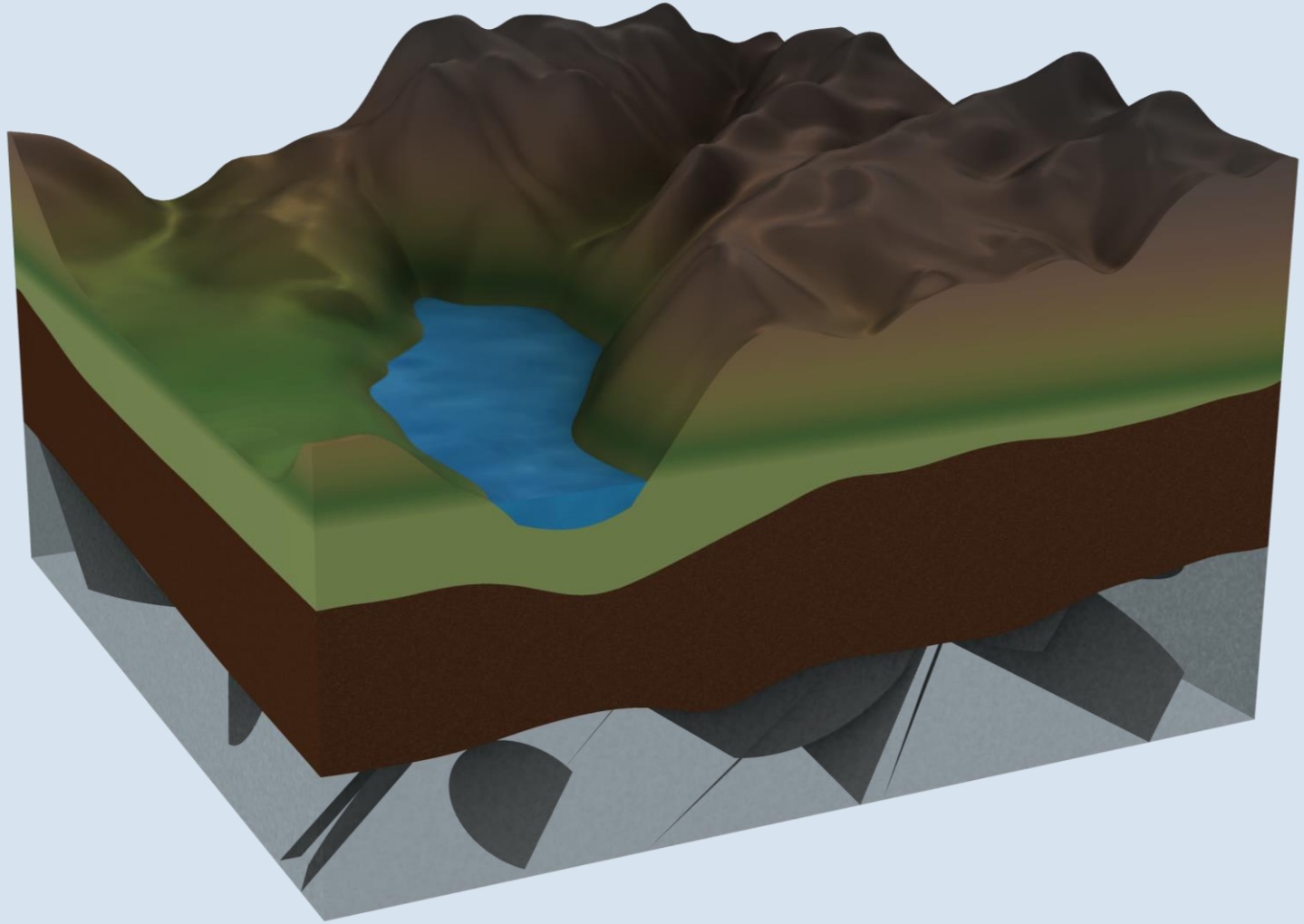
WHAT ARE WE TALKING ABOUT?

Fractured Reservoirs

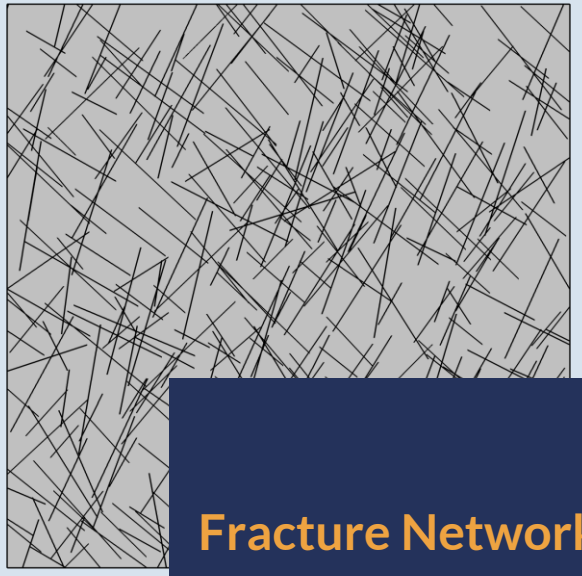


Fracture Reservoirs

Faults & Large Structures

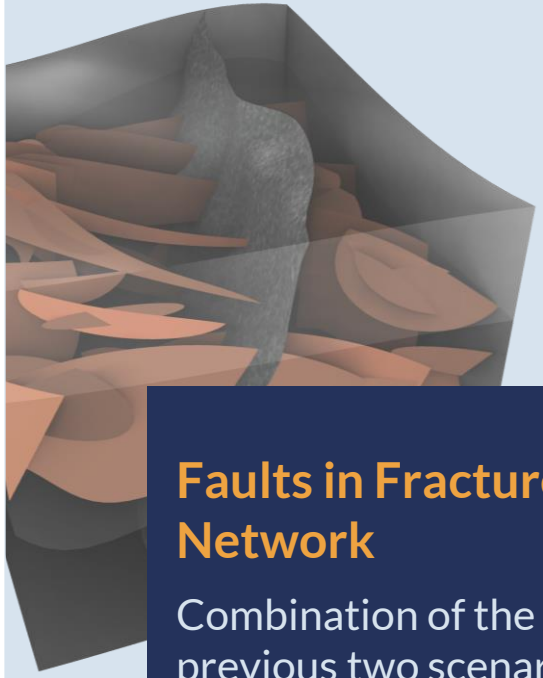
Very few large structures with significant impact for overall properties.

Explicit resolution is required.



Fracture Network

Large number of fractures where individual characteristics is not relevant but the impact of the whole system needs to be taken into account



Faults in Fracture Network

Combination of the previous two scenarios: A large structure where details are important but also a network model is required.

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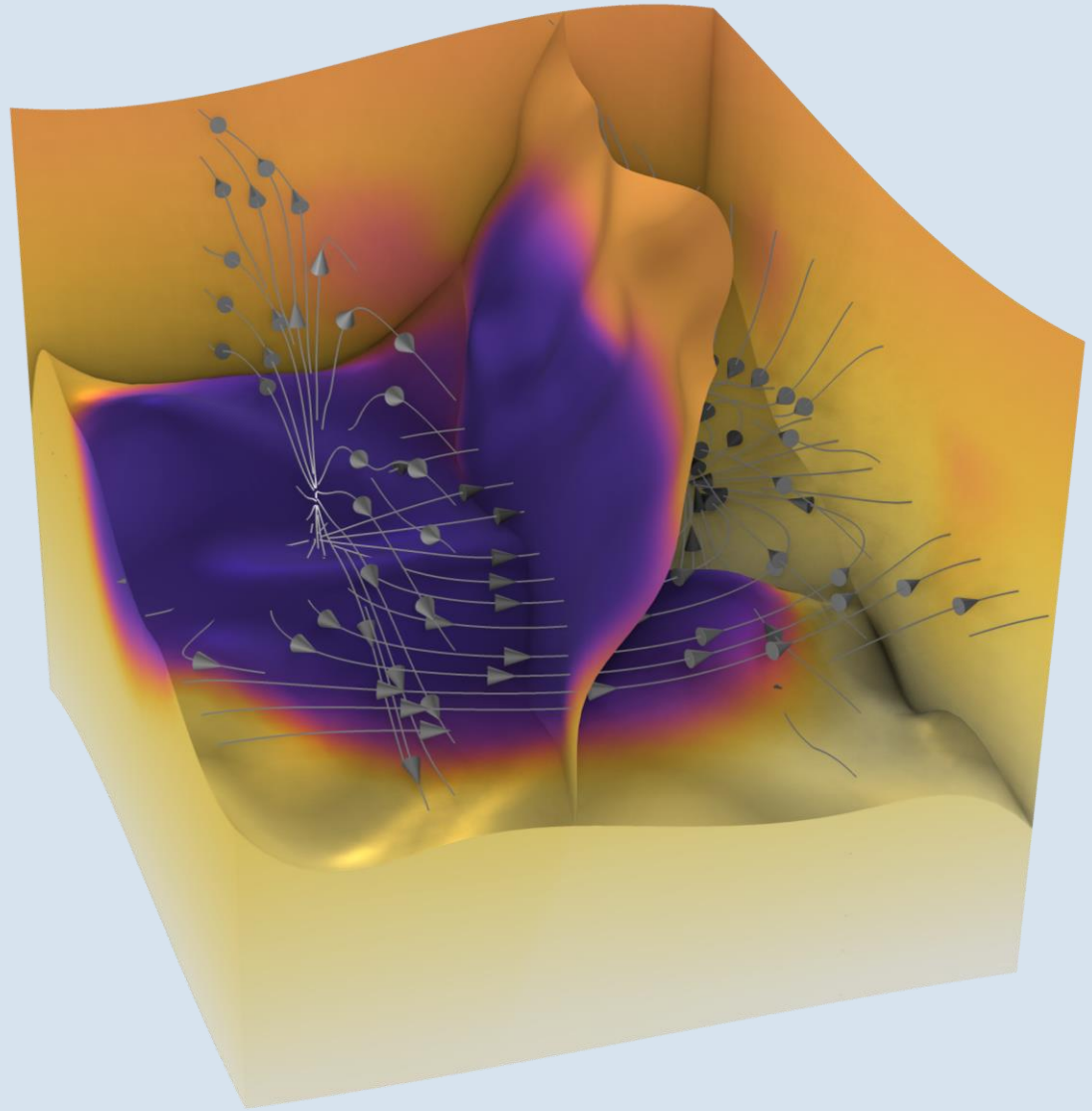
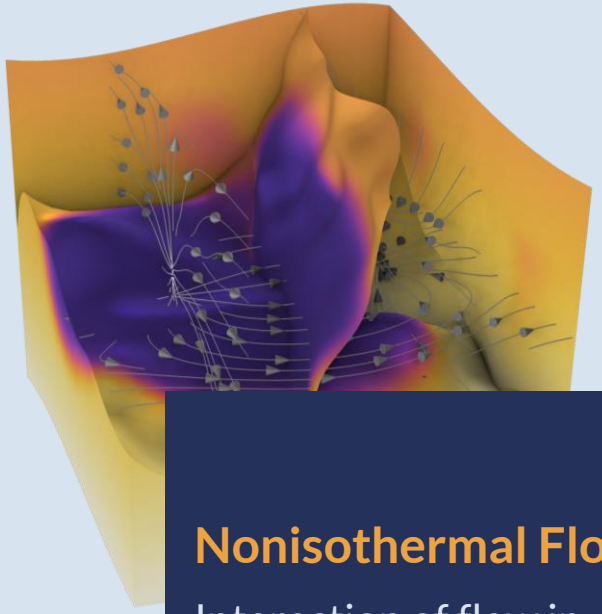
WHAT CAN WE DO

Multiphysics Modeling

Combination of multiple physical effects for simulations of real-world phenomena



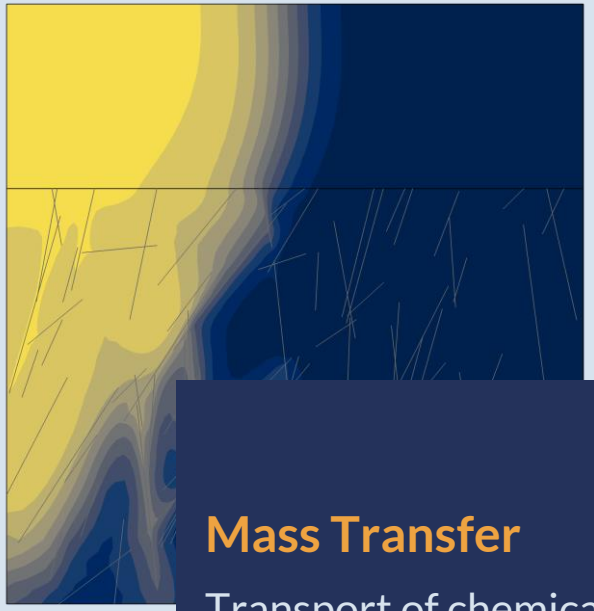
Multiphysics



Nonisothermal Flow

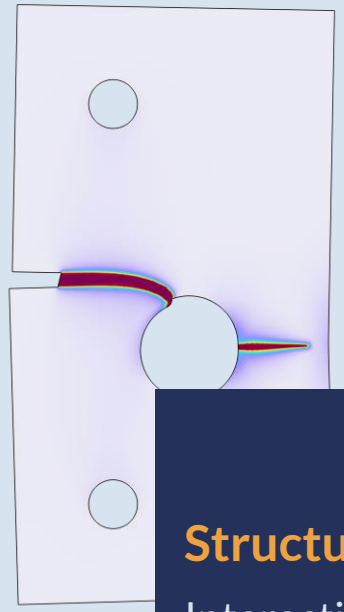
Interaction of flow in porous media with heat transport.

Geothermal Applications.



Mass Transfer

Transport of chemical species including adsorption, reactions and dispersion.



Structural Mechanics

Interaction of fluid flow with mechanics in poroelastic materials.

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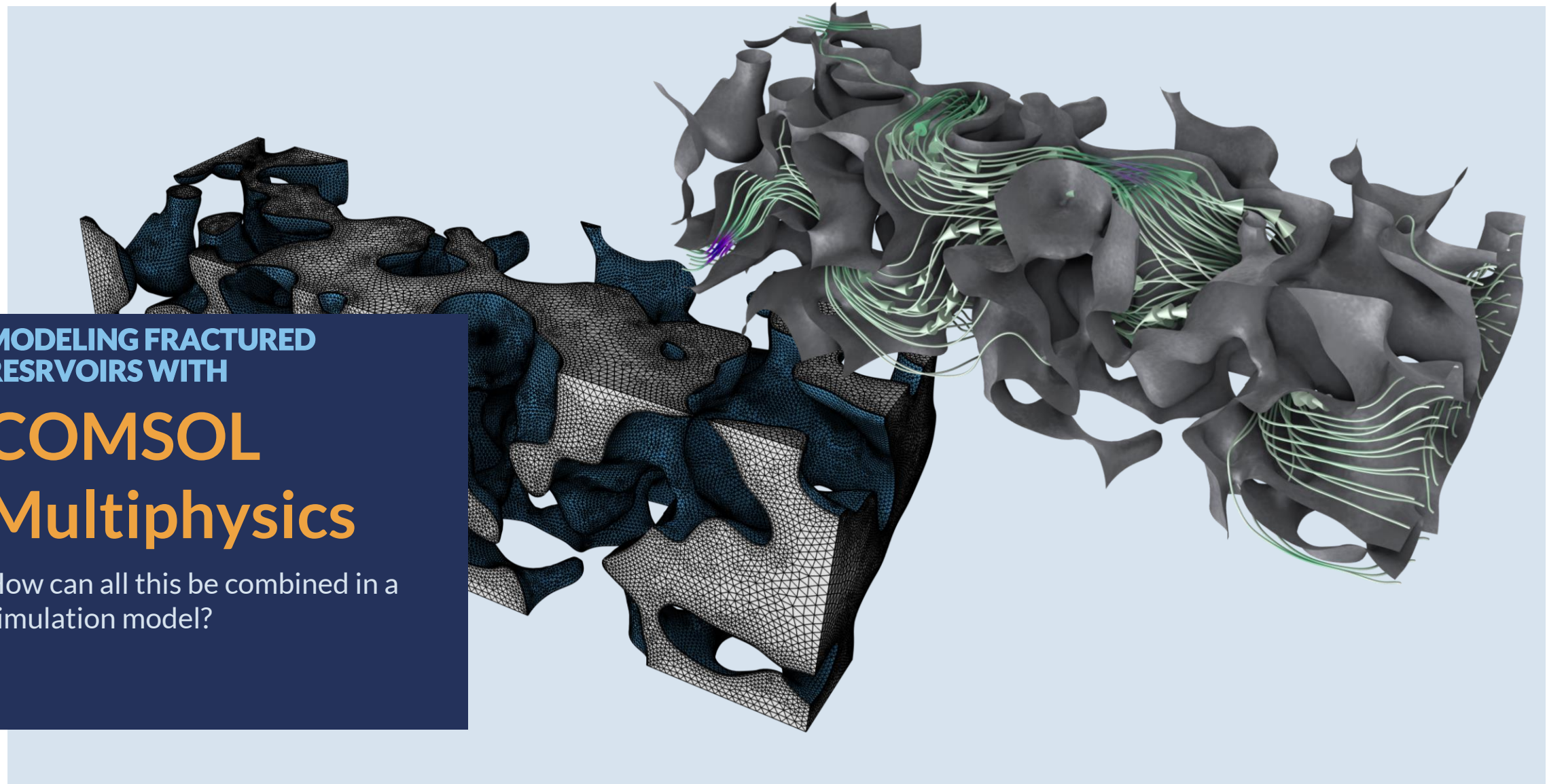
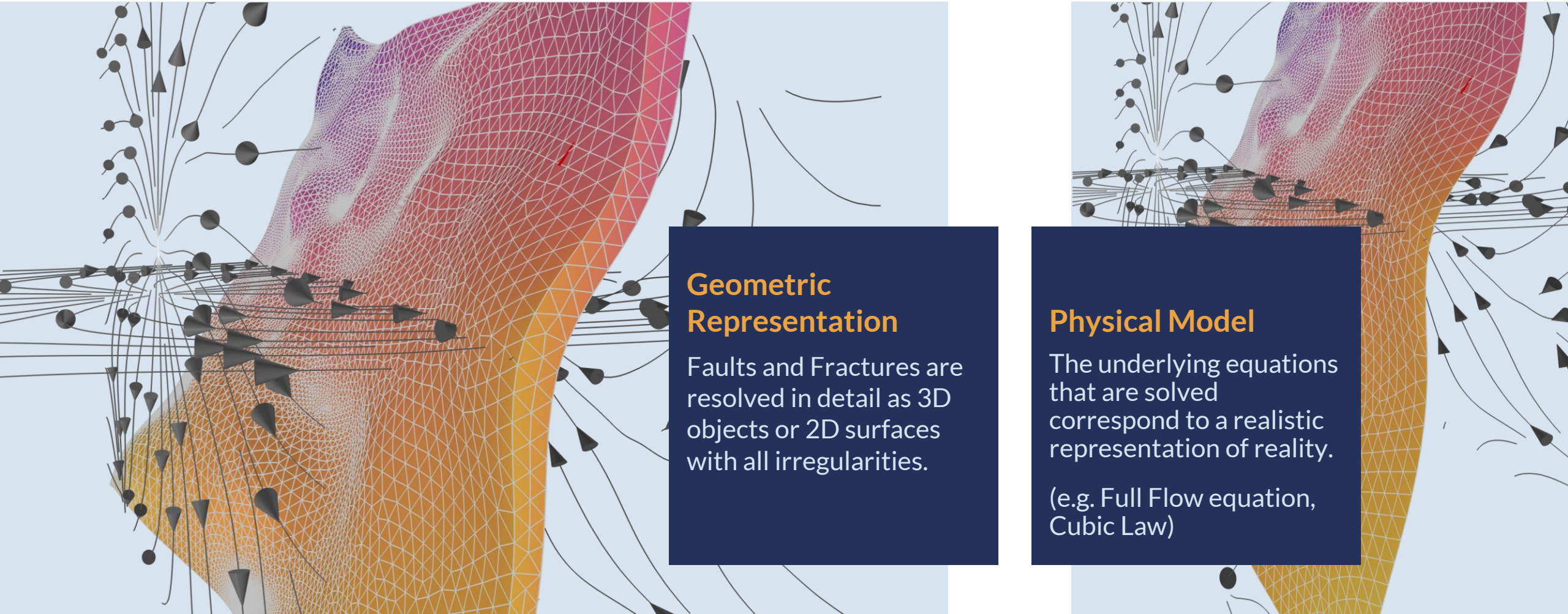


MODELING FRACTURED RESRVOIRS WITH

COMSOL Multiphysics

How can all this be combined in a simulation model?

Explicit Modeling



Geometric Representation

Faults and Fractures are resolved in detail as 3D objects or 2D surfaces with all irregularities.

Physical Model

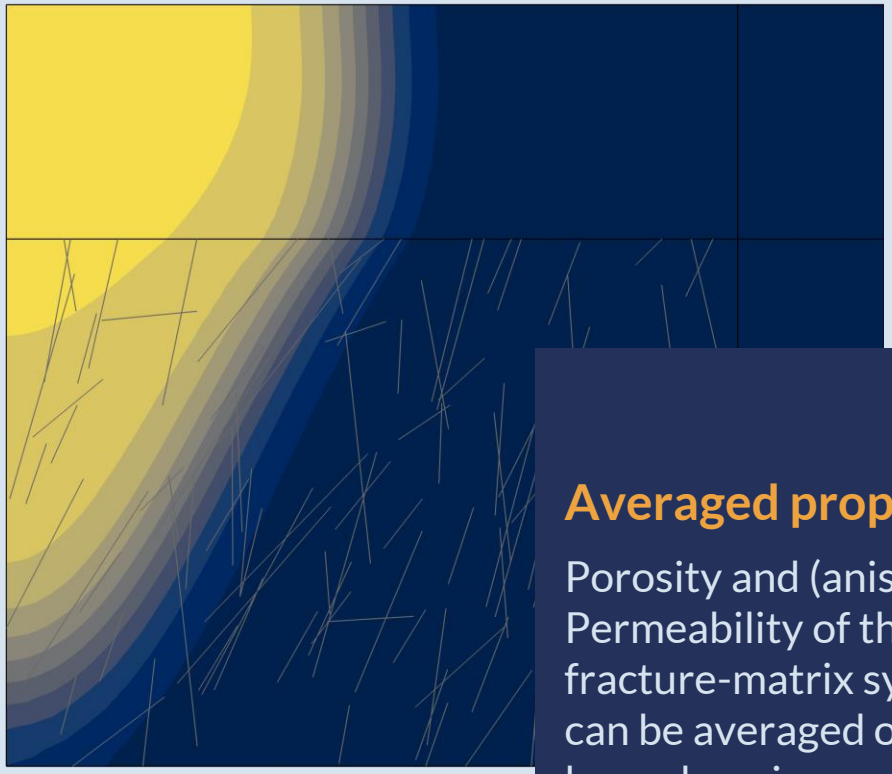
The underlying equations that are solved correspond to a realistic representation of reality.

(e.g. Full Flow equation, Cubic Law)

Homogenized Properties

Fractured System

Almost uniformly distributed fractures



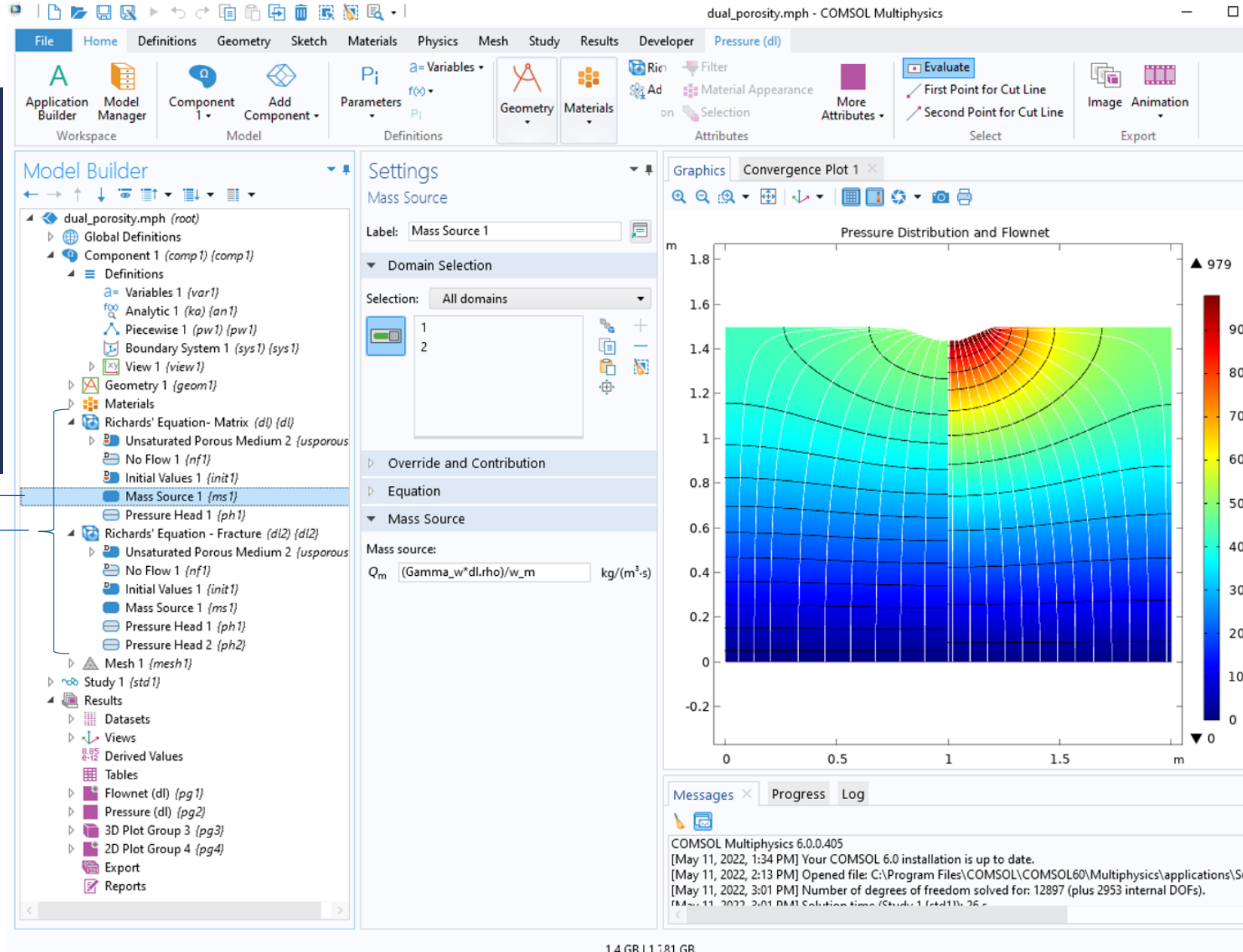
Averaged properties

Porosity and (anisotropic) Permeability of the fracture-matrix system can be averaged over large domains.

Dual Porosity & Dual Permeability

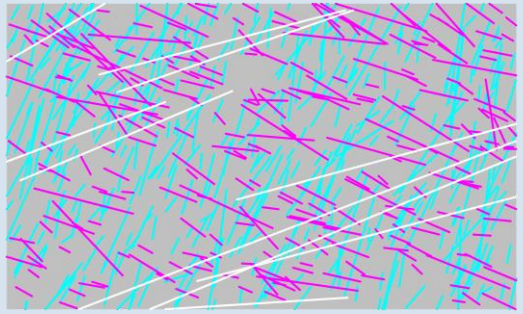
Two flow equations – one describing the flow properties in the porous matrix and one in the freacture system

Interaction of both systems via a mass source term.

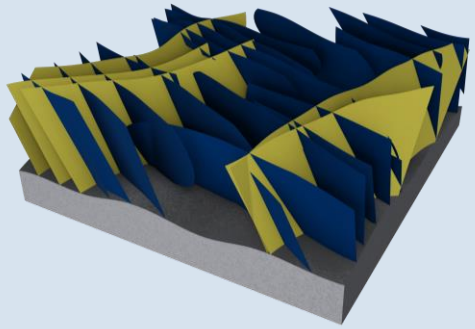


Discrete Fracture Networks

2D DfFN with random fracture distribution



2D DFN with 3 different fracture sets and power law distribution



3D DFN with 2 different fracture sets.

- Simple shaped fractures (lines, ellipses, polygons)
- Position, size, orientation and aperture follow different distribution functions
- Create DFN models to analyze reservoirs with different characteristics

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Settings

Discrete Fracture Network — 3D

Reset | Add | Update | Delete All

Data

Component:	Component 1 (comp1) {comp1}
Interface:	New Darcy's Law interface

General

Number of fractures:	25
Bounding box:	From geometry
Selection:	All domains

Size

Distribution:	Power law	
Minimum axis length:	1	m
Maximum axis length:	5	m
Power law exponent:	2	
Use random seed:	19820309	

Orientation

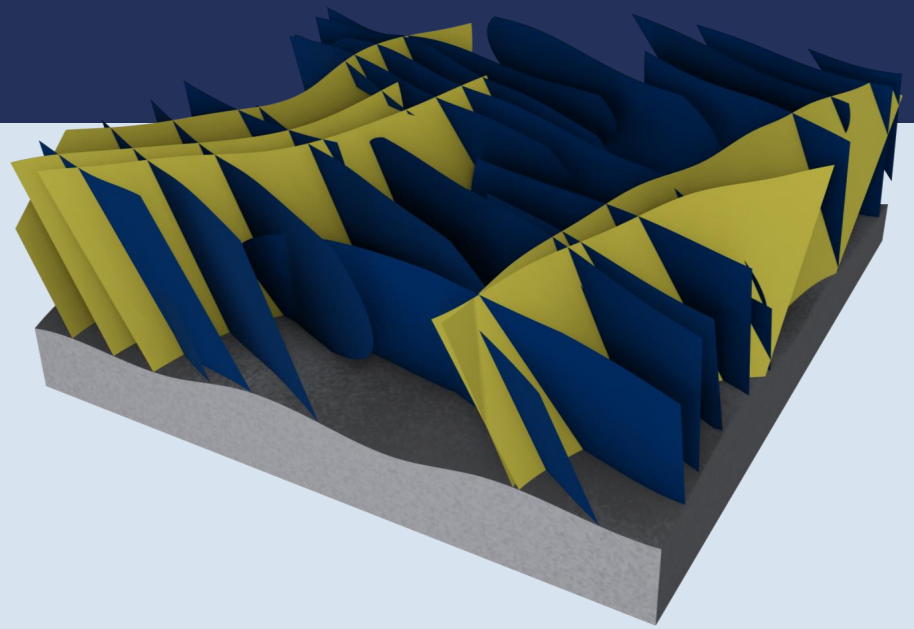
Distribution:	Fisher	
Strike:	60	°
Dip:	45	°
Dispersion coefficient:	0.1	
Use random seed:	19820309	

Properties

Porosity:	0.7	
Roughness factor:	1	
Aperture distribution:	Size proportional	
Proportionality factor:	0.001	

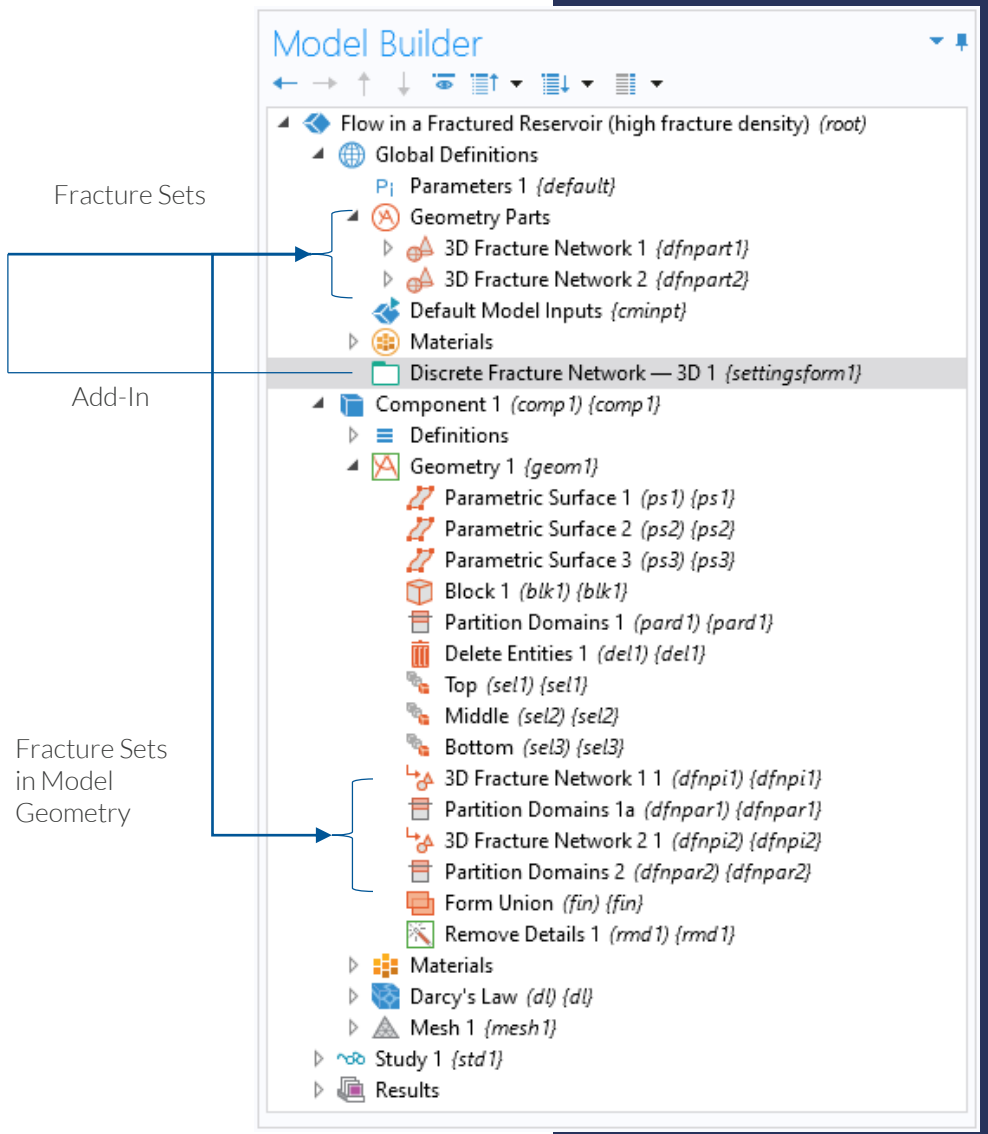
Discrete Fracture Network Add-In

Use a ready-to-use Add-in to add a discrete fracture network following different distribution functions for fracture size, orientation and aperture.



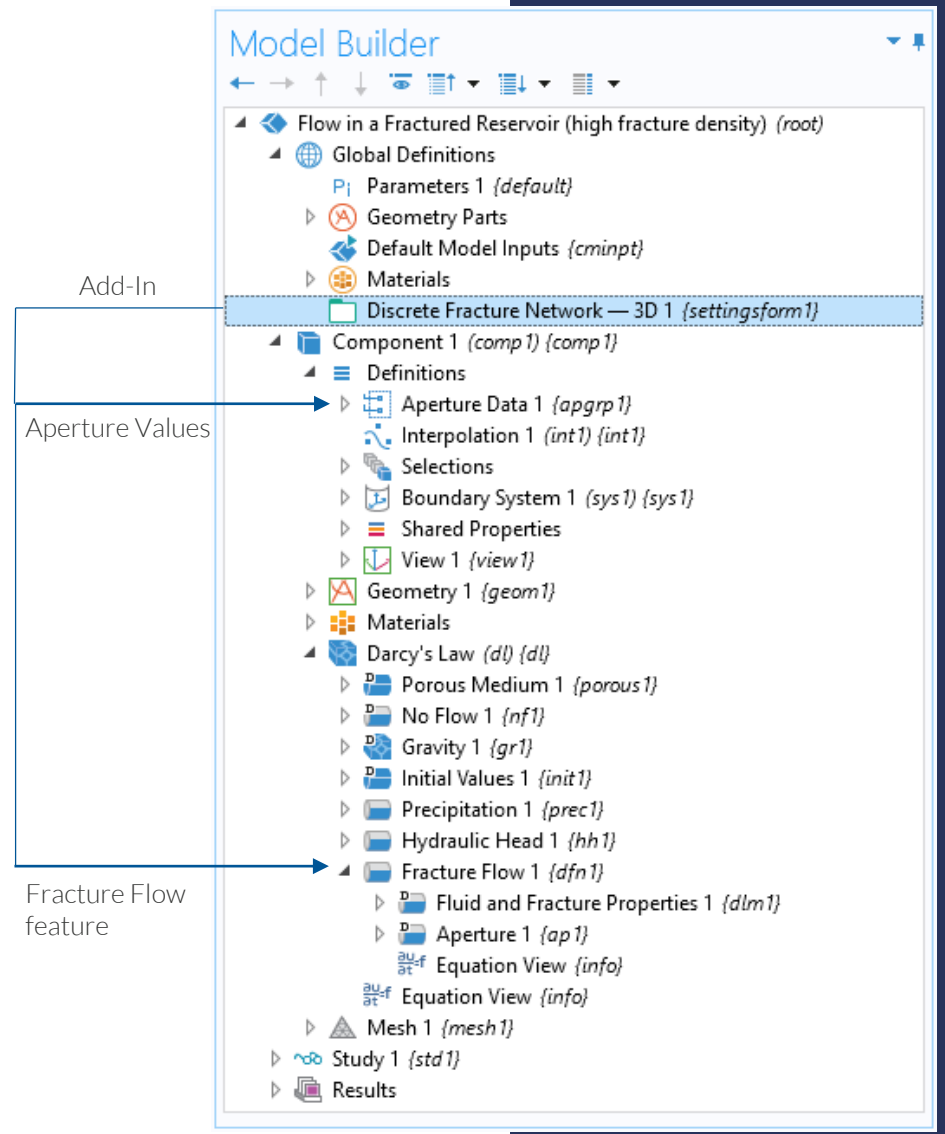
Discrete Fracture Network Add-In

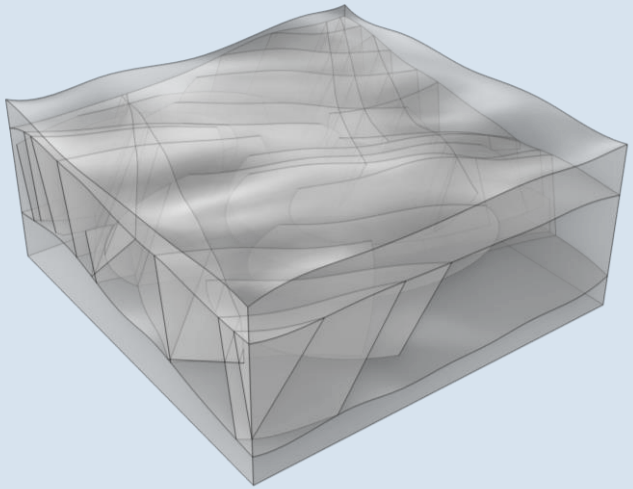
- Create on or multiple fracture sets with different distribution functions
- Imports the fracture sets into an existing or new geometry

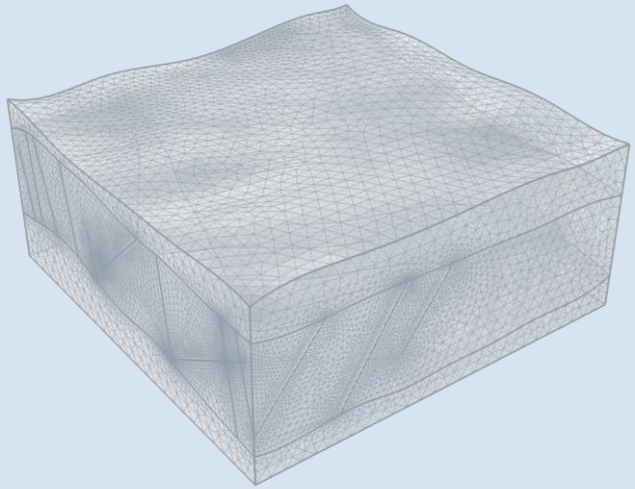


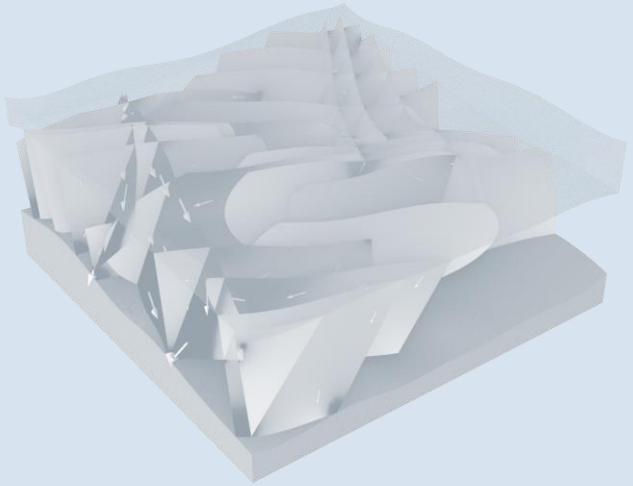
Discrete Fracture Network Add-In

- Create on or multiple fracture sets with different distribution functions
- Imports the fracture sets into an existing or new geometry
- Assigns aperture value to each fracture
- Sets up a Fracture Flow feature using Cubic's law



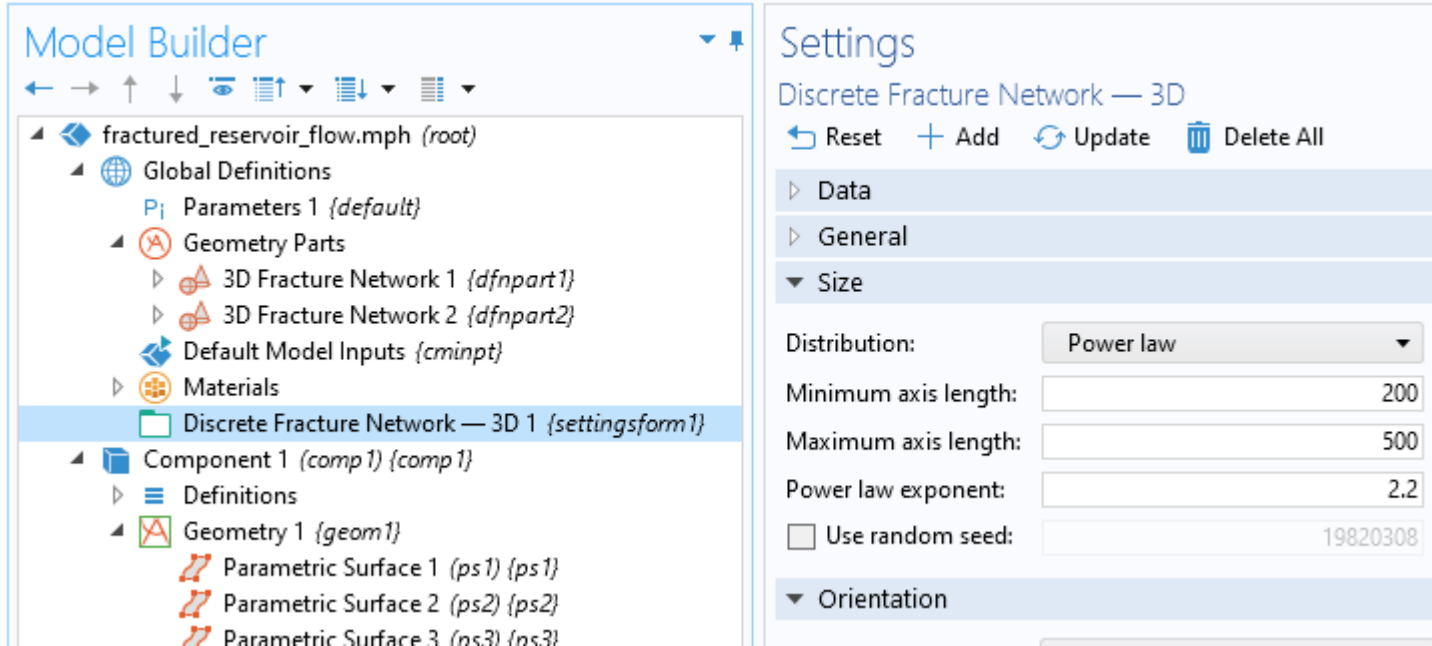


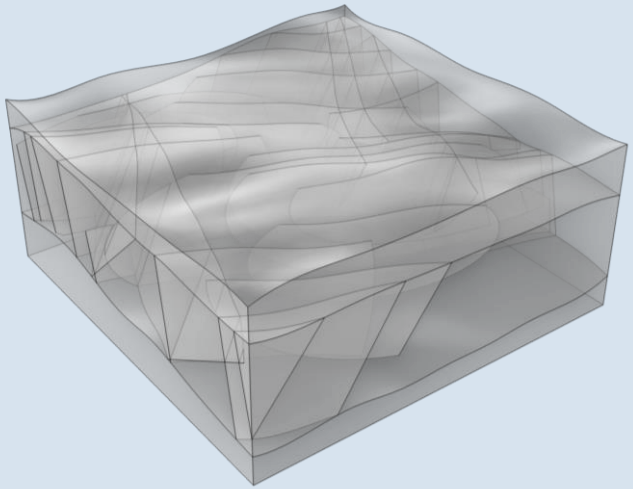


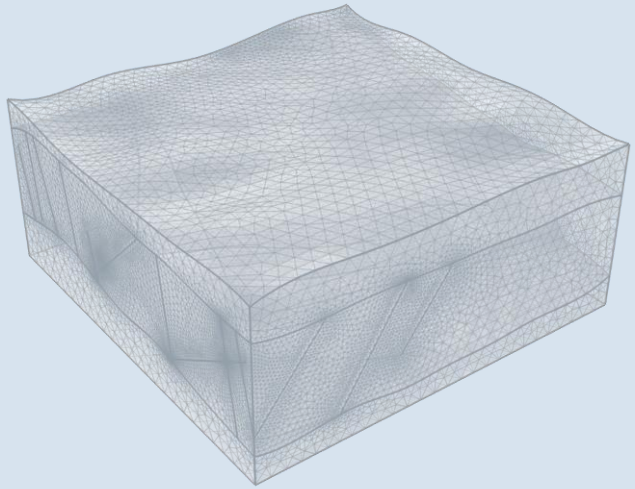


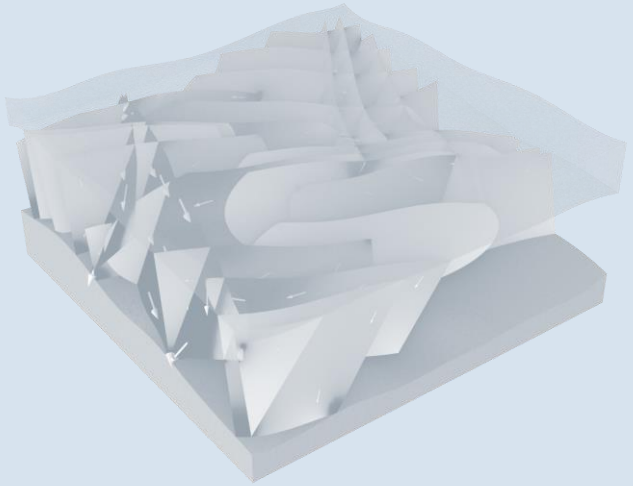
Modeling Workflow

- Create the geometry and DFN



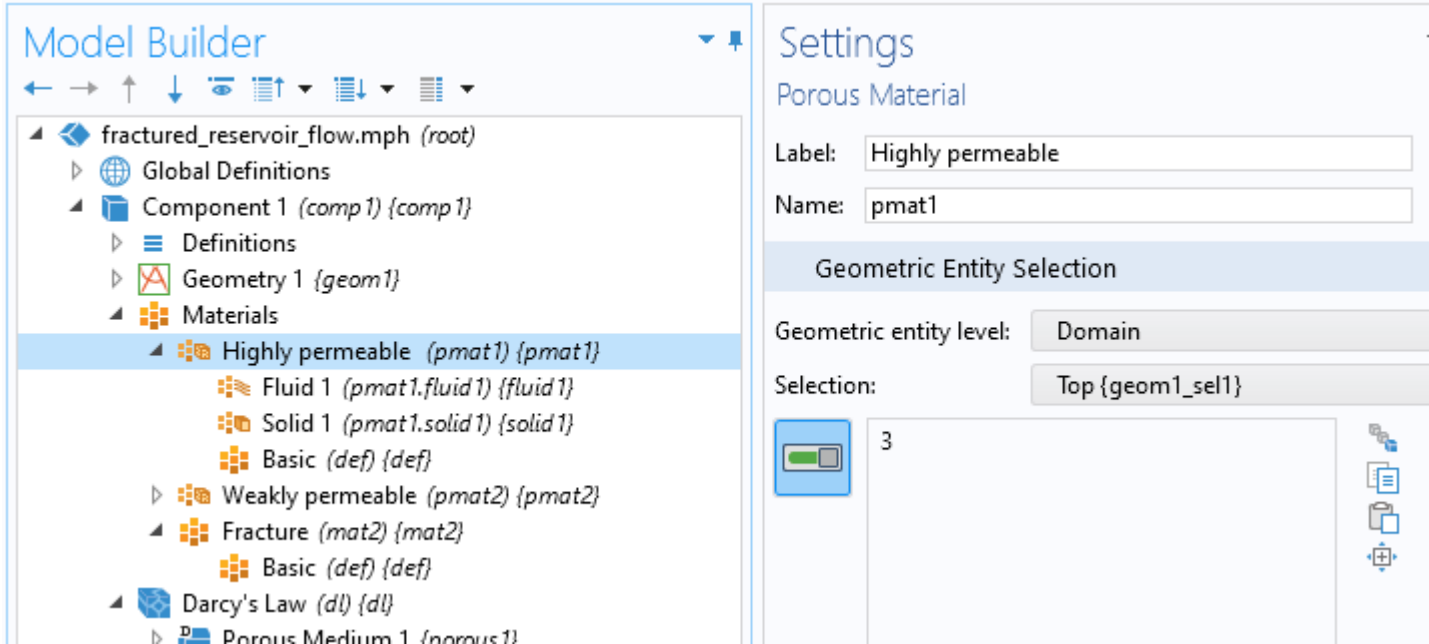


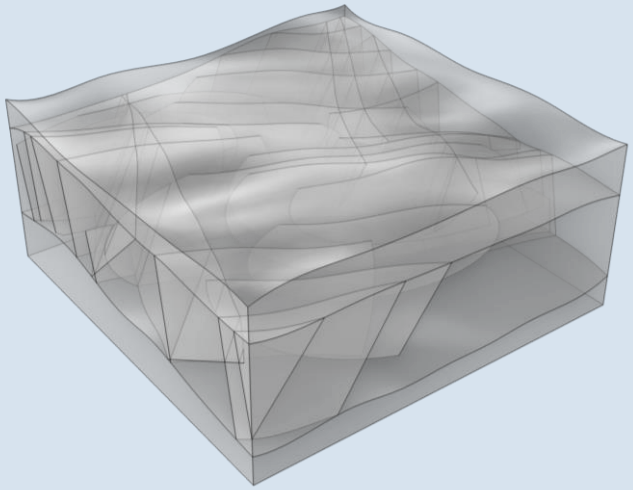


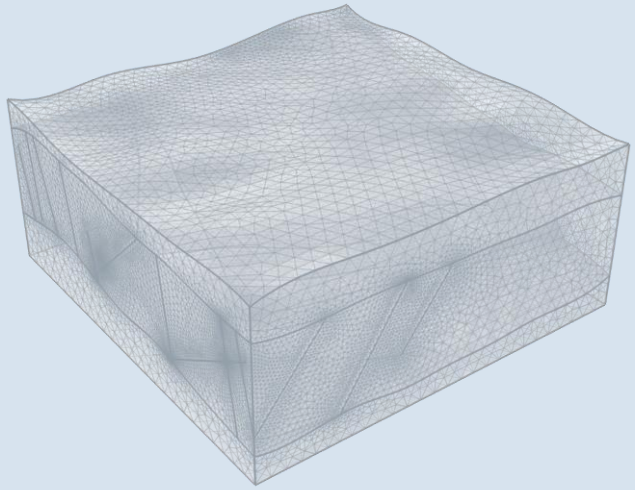


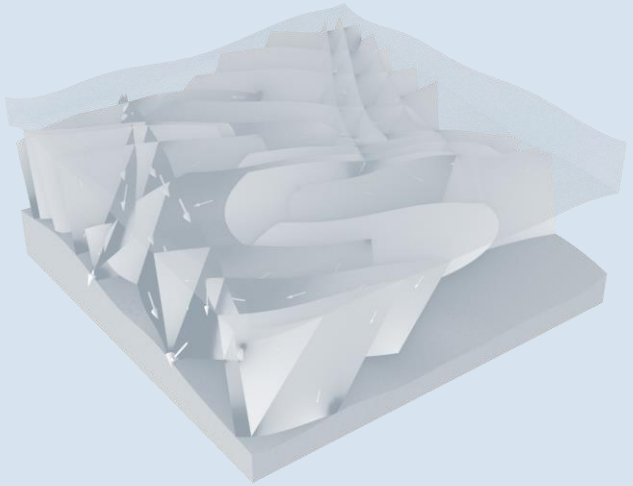
Modeling Workflow

- Create the geometry and DFN
- Assign material properties



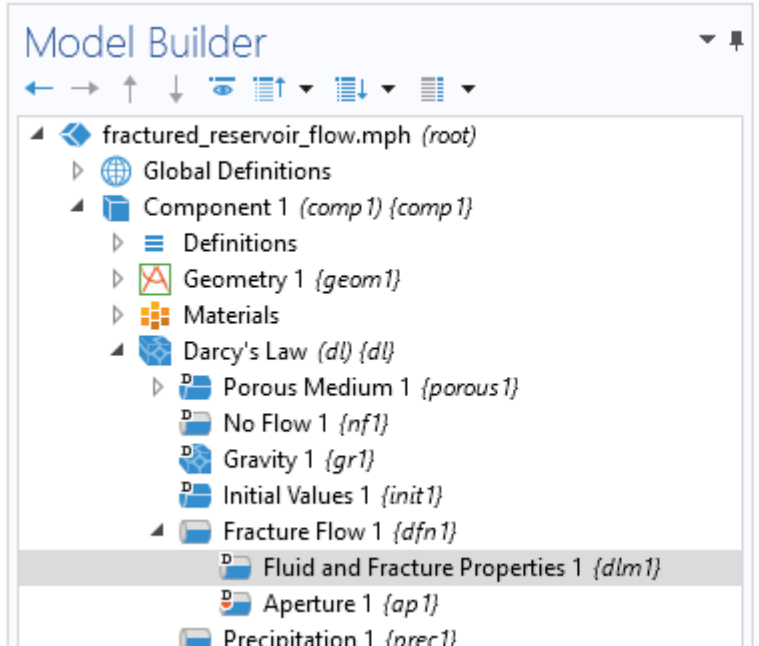


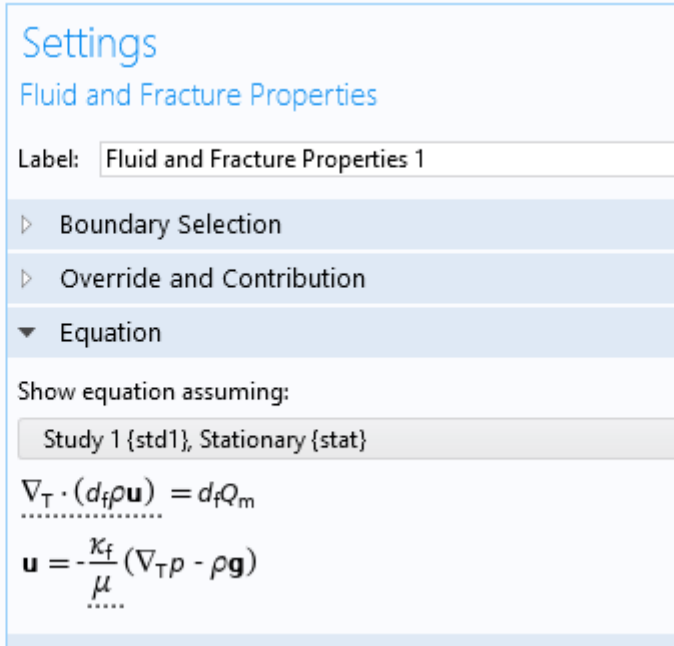


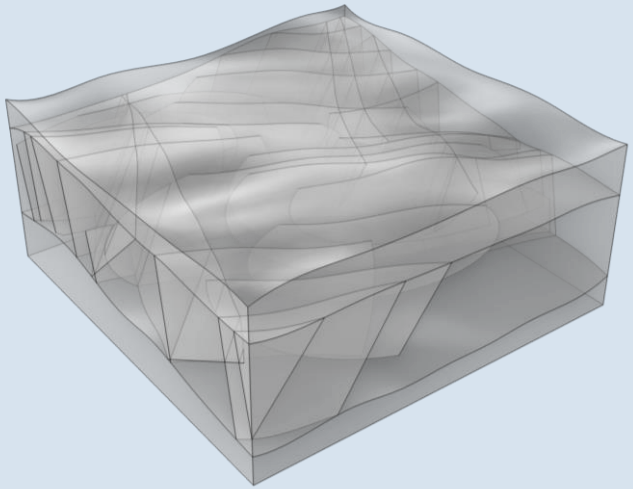


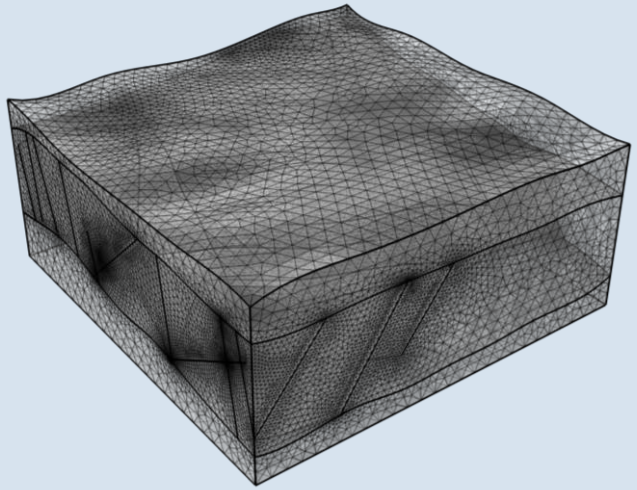
Modeling Workflow

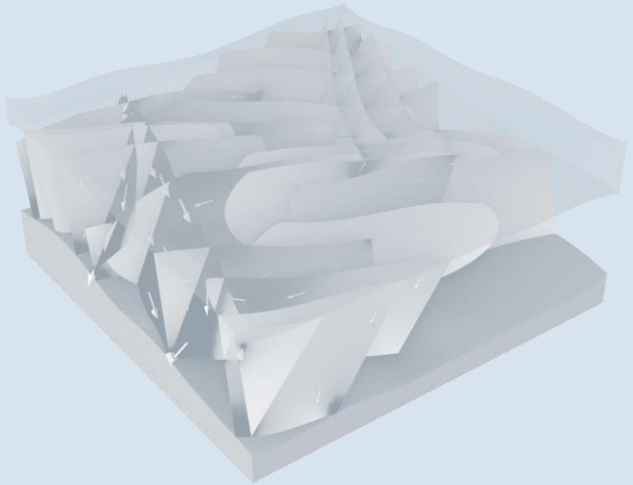
- Create the geometry and DFN
- Assign material properties
- Set up the physics interfaces





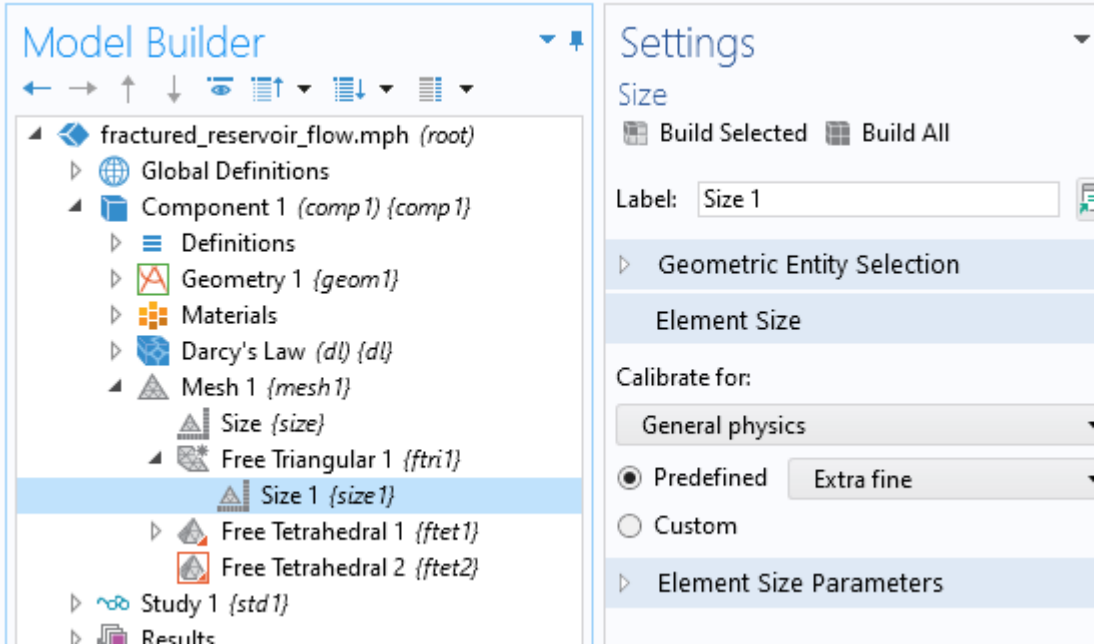


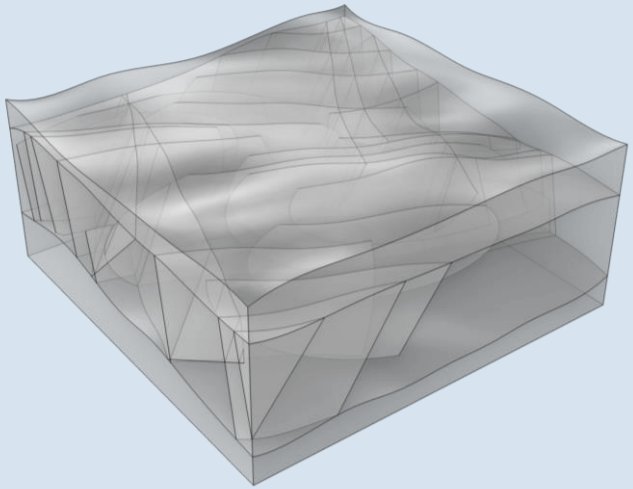


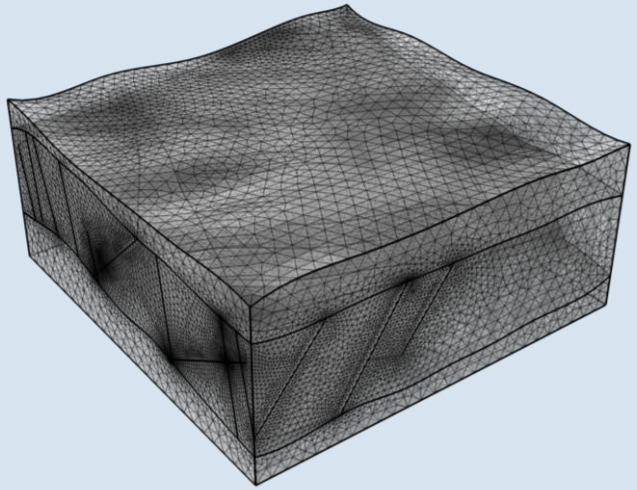


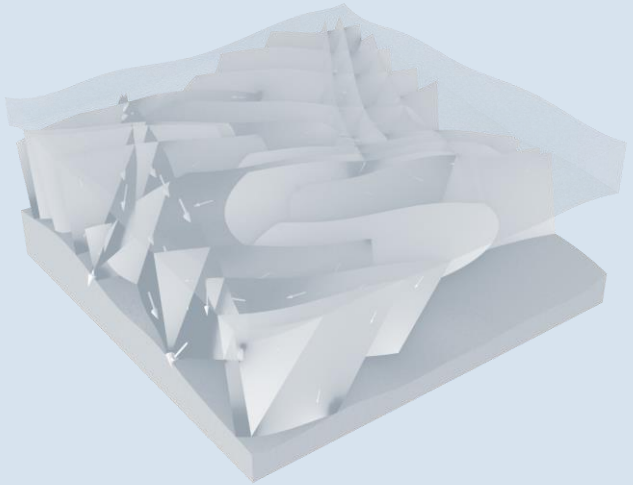
Modeling Workflow

- Create the geometry and DFN
- Assign material properties
- Set up the physics interfaces
- Create the mesh



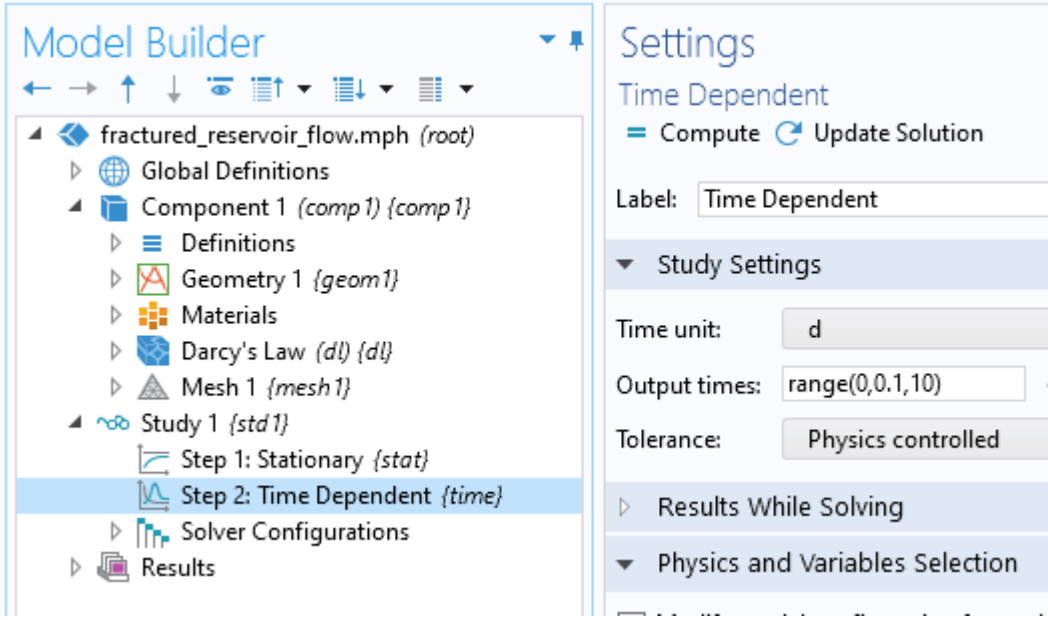


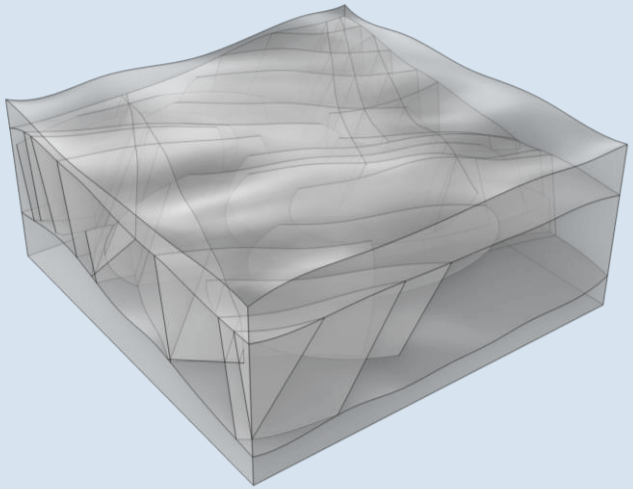


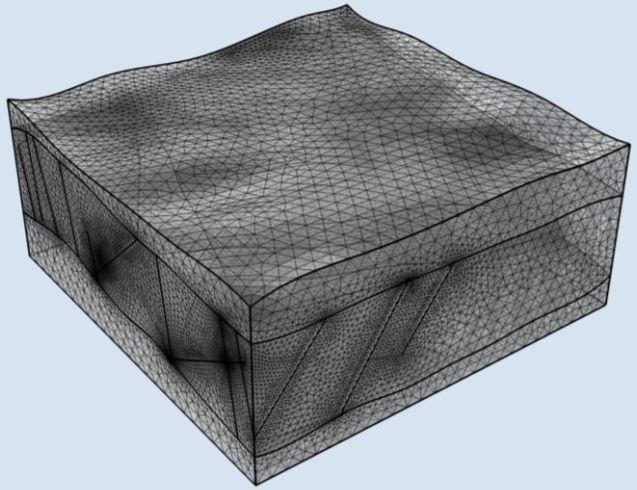


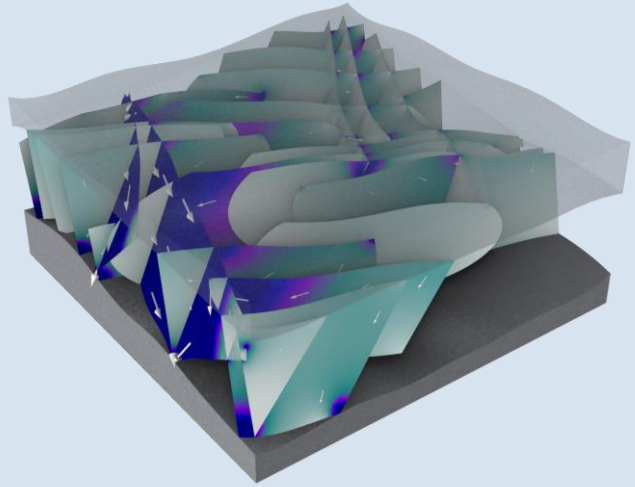
Modeling Workflow

- Create the geometry and DFN
- Assign material properties
- Set up the physics interfaces
- Create the mesh
- Solve



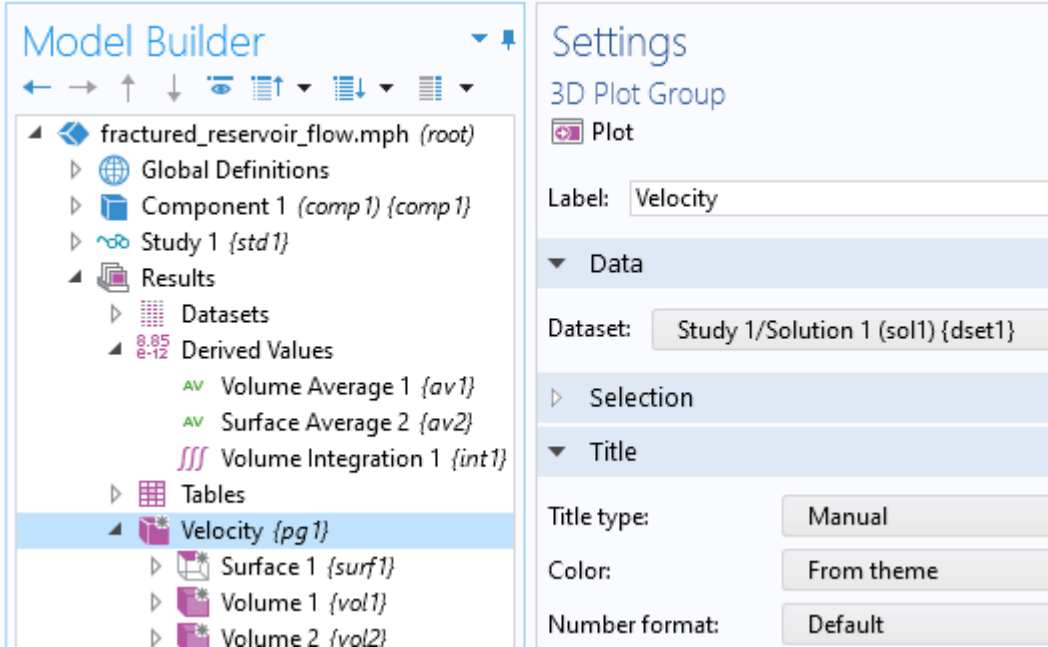






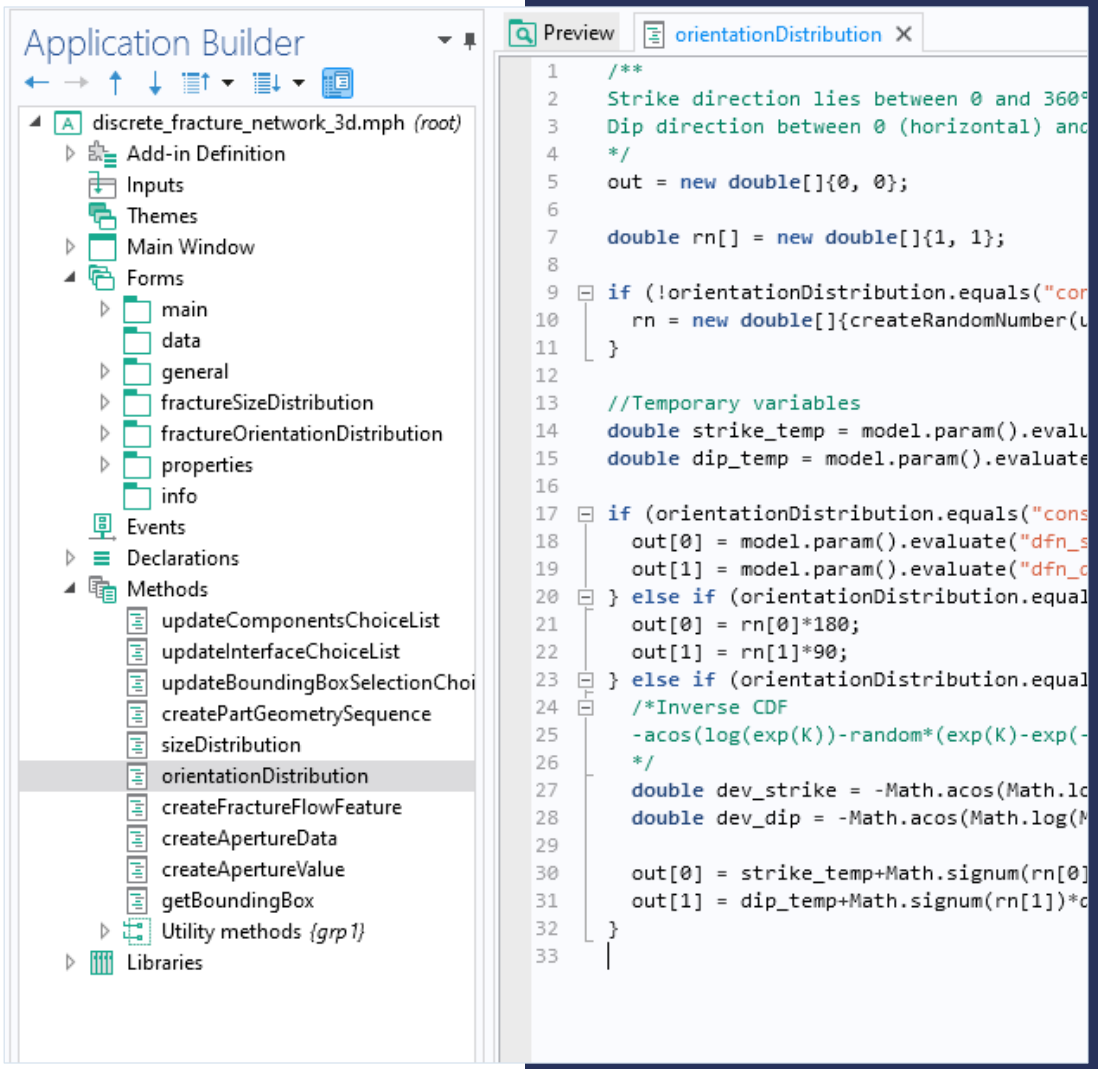
Modeling Workflow

- Create the geometry and DFN
- Assign material properties
- Set up the physics interfaces
- Create the mesh
- Solve
- Postprocessing



Further Steps

- Make it Multiphysics:
  - Add other physics interfaces to consider heat transfer as well
- Modify the Add-in:
  - The code of the add-in is accessible and you can modify it using the Application Builder
  - Basic programming skills are helpful
- Send feedback



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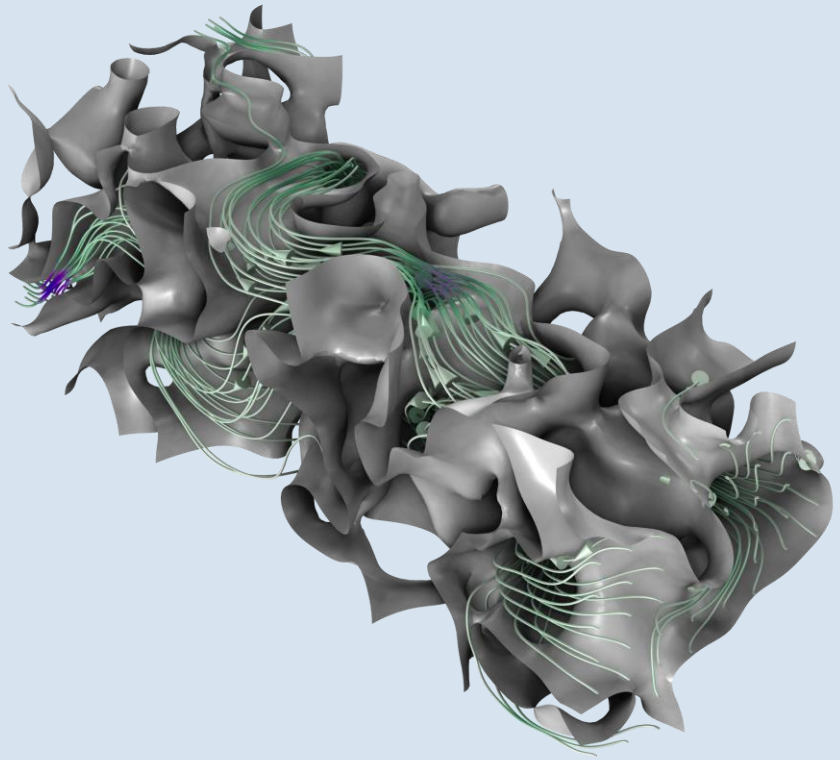
Summary & Outlook

The COMSOL Multiphysics Software – where are we now and what



From Geometry to Postprocessing

Complete Modeling Workflow integrated in one software environment.

Versatile & Specialized

General-purpose software based on advanced numerical tools.

Specialized features for modeling fractured reservoirs.

Where to go next

Improve functionality of DFN add-in.

Enhance underlying methods for more stability.

Therefore we need your feedback!

Thank You for Your Attention

See you at our virtual booth or visit us at www.comsol.com.