Model created in COMSOL Multiphysics 6.4

Geothermal Doublet

Introduction

The use of geothermal energy has become an important topic worldwide, not only sparked by the debate on climate change. Particularly in regions with lower geothermal energy, the requirements for geothermal plants are high in order to ensure a continuous and long-term energy supply.

This example of a hydrothermal doublet studies the coupled porous media flow and heat transfer problem using the Darcy's Law and Heat Transfer in Porous Media interfaces. It shows how to set up a system of a layered subsurface with different geological and thermal properties including fractures and the injection and production side of a doublet.

Model Definition

The model geometry (Figure 1) consists of three geological layers ranged by a fault zone. The layers, their elevation, and the fault zone are interpolation functions from an artificial dataset. Different hydraulic and thermal properties are defined for the layers. The evolution of the flow and temperature field over 10 years is studied.

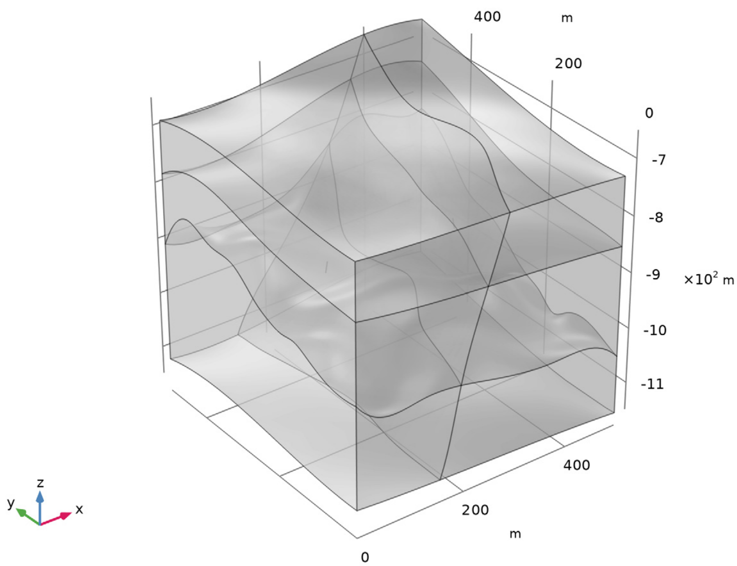


Figure 1: Geometry of the model including three geologic layers, fracture, and the doublet's production and injection side (edges).

FLUID FLOW

The flow in the fracture is in general much faster than in the surrounding porous matrix. The cubic law is a common correlation for modeling fracture flow. It defines the permeability κ_f (m^2) in the fracture according to

$$\kappa_f = \frac{d_f^2}{12 f_f}$$

where d_f (m) is the fracture's aperture and f_f the roughness factor. With this definition, the name cubic law results from the definition of the fracture's transmissivity

$$T_r = d_f k_f = \frac{d_f^3}{12 f_f}.$$

A hydraulic gradient in x direction is applied as boundary condition on the vertical boundaries. Top and bottom boundary are defined as impermeable. Two edges represent the geothermal doublet injection and production side. Injection and pumping is modeled using the Well feature. Water injection is defined using the mass flow rate option with $M_0 = \rho_W \cdot 120$ l/s.

HEAT TRANSFER

An initial geothermal gradient of 0.03 K/m is applied. The vertical boundaries are defined as open boundaries. This means that a temperature condition using the same geothermal gradient is active if $\mathbf{n} \cdot \mathbf{u} < 0$ (inflow) or otherwise $-\mathbf{n} \cdot \mathbf{q} = 0$ (outflow). Analogously to the Fracture Flow boundary condition in the Darcy's Law interface, the heat transfer in the fracture is modeled using the fracture boundary condition of the heat transfer interface.

To model the heat source term caused by the injection well, a line heat source feature is applied according to

$$Q = C_p \frac{M_0}{l}(T_{inj} - T)$$

where C_p (J/(kg·K)) is the water heat capacity, l the well length, $T_{inj} = 278$ K the injection temperature, and T the current temperature.

Results and Discussion

The pressure field is shown in Figure 2.

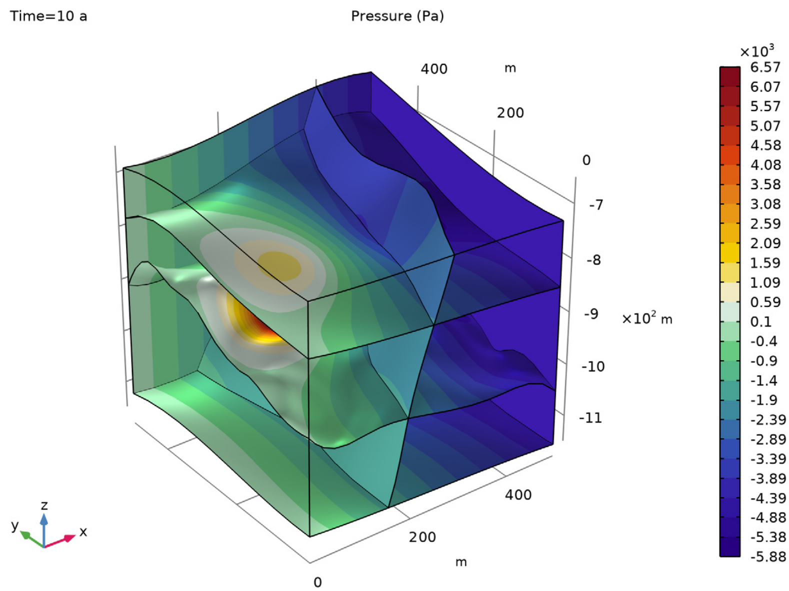


Figure 2: Pressure distribution after 10 years.

Figure 3 shows the temperature distribution in the fracture together with streamlines that visualize the flow field, showing the flow from the injection to the production side of the doublet.

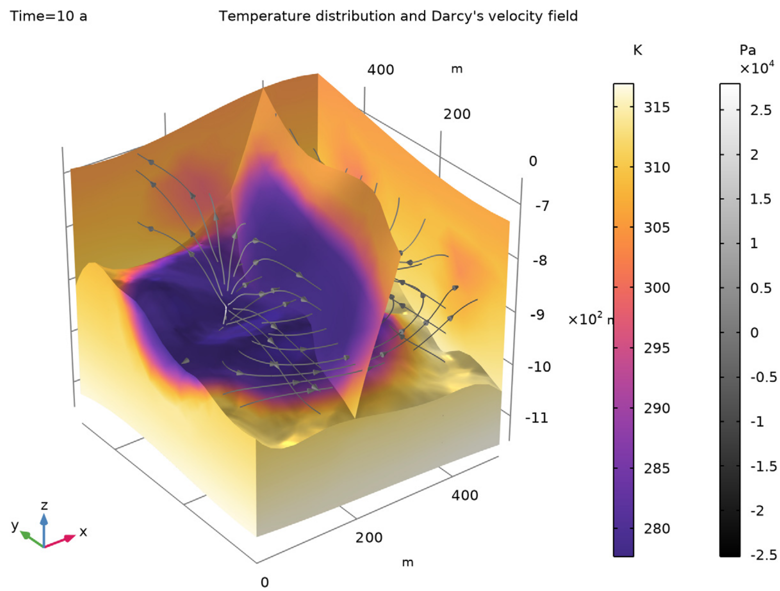


Figure 3: Temperature distribution in the fracture and streamlines for the Darcy velocity field after 10 years.

It is interesting to evaluate the production temperature over time. As shown in Figure 4, the production temperature decreases about 20 K over 10 years. This indicates that the doublet at the operating conditions will not provide a stable long term energy supply and that a different configurations should be tested. This can be done by varying one or more of the parameters in the model to see which setup is more appropriate.

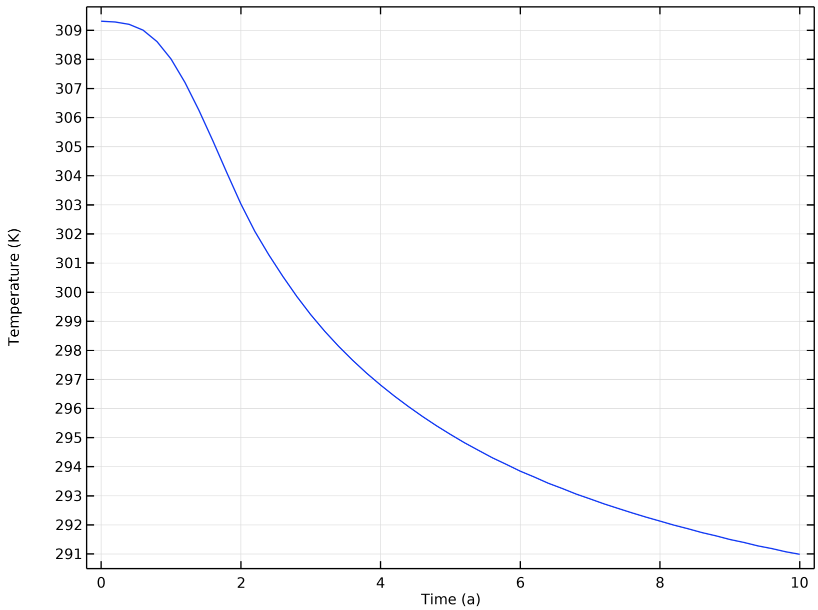


Figure 4: Production temperature over 10 years.

[Figure 5](#) shows the pressure distribution and streamlines of the Darcy velocity field along the fracture.

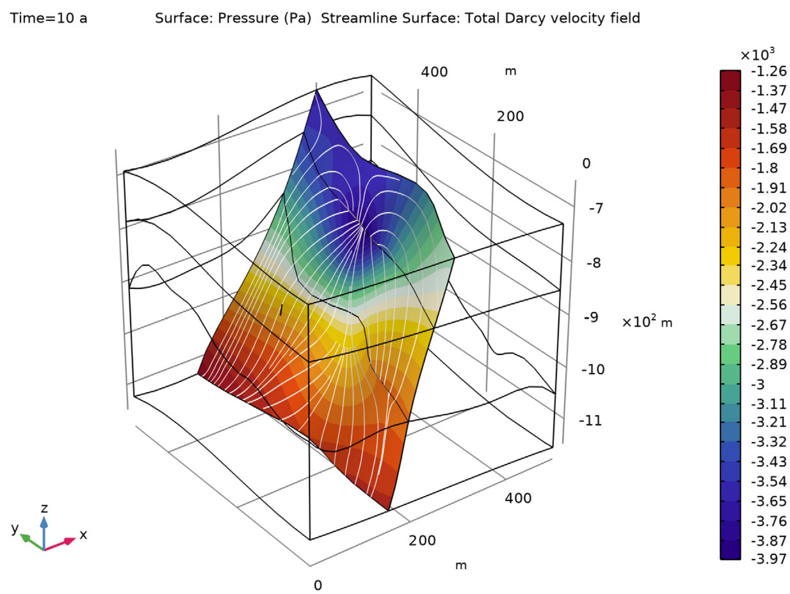


Figure 5: Pressure distribution and velocity streamlines just along the fracture after 10 years.

Application Library path: `Subsurface_Flow_Module/Heat_Transfer/geothermal_doublet`

Modeling Instructions

From the **File** menu, choose **New**.

NEW

In the **New** window, click **Model Wizard**.

MODEL WIZARD

1 In the **Model Wizard** window, click **3D**.

2 In the **Select Physics** tree, select **Fluid Flow** > **Porous Media and Subsurface Flow** > **Darcy's Law (dl)**.

3 Click **Add**.

4 In the **Select Physics** tree, select **Heat Transfer** > **Porous Media** > **Heat Transfer in Porous Media (ht)**.

5 Click **Add**.

6 Click **Done**.

ROOT

Start with loading the parameterized geometry sequence into the model.

GEOMETRY 1

1 In the **Geometry** toolbar, click **Insert Sequence** and choose **Insert Sequence**.

2 Browse to the model's Application Libraries folder and double-click the file `geothermal_doublet_geom_sequence.mph`.

3 In the **Geometry** toolbar, click **Build All**.

The geometry parameters that are used were added to the **Parameters** list automatically. Add a few more parameters that are used to set up the physics interfaces.

GLOBAL DEFINITIONS

Parameters 1

1 In the **Model Builder** window, under **Global Definitions** click **Parameters 1**.

2 In the **Settings** window for **Parameters**, locate the **Parameters** section.

3 In the table, enter the following settings:

Name	Expression	Value	Description
r_bore	1[m]	1 m	Borehole skin zone radius
pump	120[l/s]	0.12 m^3/s	Pumping rate
deltaH	1[mm/m]	0.001	Hydraulic head gradient
T_top	283[K]	283 K	Surface temperature
T_inj	278[K]	278 K	Injection temperature
delta_Tz	0.03[K/m]	0.03 K/m	Geothermal gradient
d_f	0.2[cm]	0.002 m	Fracture thickness
f_f	1.6	1.6	Fracture roughness factor

Selections help to improve the whole modeling process. Define them now and use them later where needed.

DEFINITIONS

Injection well

1 In the **Model Builder** window, expand the **Component 1 (comp1)** > **Definitions** node.

2 Right-click **Definitions** and choose **Selections** > **Explicit**.

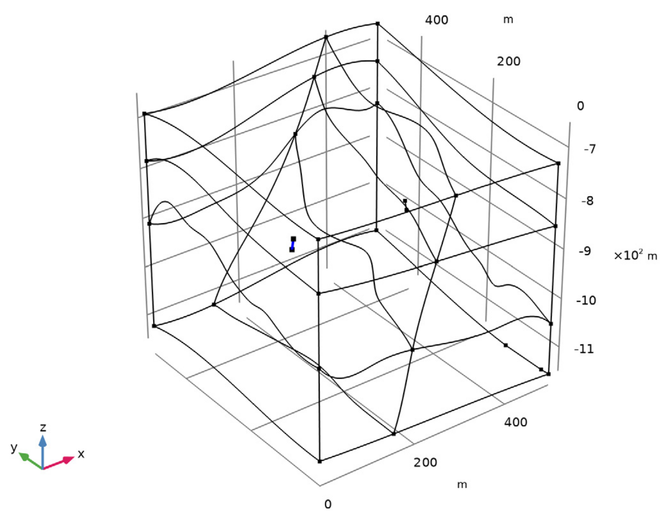
3 In the **Settings** window for **Explicit**, locate the **Input Entities** section.

4 From the **Geometric entity level** list, choose **Edge**.

5 Click the **Wireframe Rendering** button in the **Graphics** toolbar.

6 Select Edge 19 only.

7 In the **Label** text field, type `Injection well`.



Production well

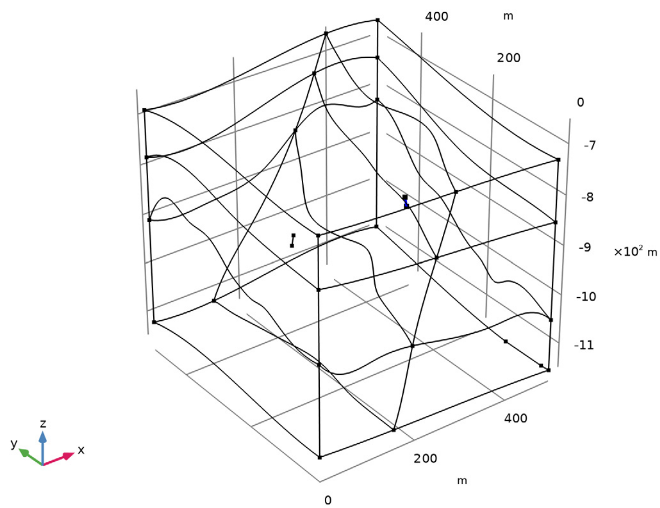
1 In the **Definitions** toolbar, click **Explicit**.

2 In the **Settings** window for **Explicit**, locate the **Input Entities** section.

3 From the **Geometric entity level** list, choose **Edge**.

4 Select Edge 37 only.

5 In the **Label** text field, type `Production well`.



Top layer

1 In the **Definitions** toolbar, click **Explicit**.

2 Select Domains 3 and 6 only.

3 In the **Settings** window for **Explicit**, type `Top layer` in the **Label** text field.

Middle layer

1 In the **Definitions** toolbar, click **Explicit**.

2 Select Domains 2 and 5 only.

3 In the **Settings** window for **Explicit**, type `Middle layer` in the **Label** text field.

Bottom layer

1 In the **Definitions** toolbar, click **Explicit**.

2 Select Domains 1 and 4 only.

3 In the **Settings** window for **Explicit**, type `Bottom layer` in the **Label** text field.

Fracture

1 In the **Definitions** toolbar, click **Explicit**.

2 In the **Settings** window for **Explicit**, locate the **Input Entities** section.

3 From the **Geometric entity level** list, choose **Boundary**.

4 Select Boundary 21 only.

5 Select the **Group by continuous tangent** checkbox. This automatically adds all boundaries that belong to the large fault zone.

6 In the **Label** text field, type `Fracture`.

Outer boundaries

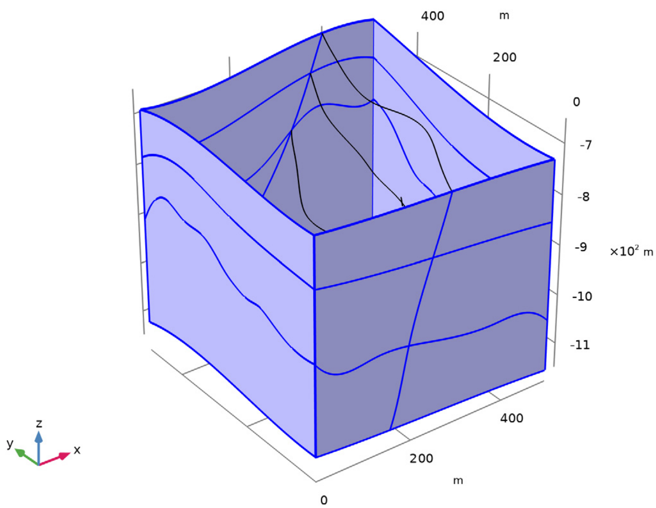
1 In the **Definitions** toolbar, click **Explicit**.

2 In the **Settings** window for **Explicit**, type `Outer boundaries` in the **Label** text field.

3 Locate the **Input Entities** section. From the **Geometric entity level** list, choose **Boundary**.

4 Select the **Group by continuous tangent** checkbox.

5 Select any face on each side. Automatically all faces of this side will be added to the selection.



GLOBAL DEFINITIONS

Add materials to the materials node, but do not define their properties at this point. After setting up the physics interface COMSOL Multiphysics automatically detects which material properties are needed.

ADD MATERIAL

1 In the **Materials** toolbar, click **Add Material** to open the **Add Material** window.

2 Go to the **Add Material** window.

3 In the tree, select **Built-in > Water, liquid**.

4 Click the **Add to Global Materials** button in the window toolbar.

5 In the **Materials** toolbar, click **Add Material** to close the **Add Material** window.

MATERIALS

Upper Aquitard

1 In the **Model Builder** window, under **Component 1 (comp1)** right-click **Materials** and choose **More Materials > Porous Material**.

2 In the **Settings** window for **Porous Material**, type `Upper Aquitard` in the **Label** text field.

Aquifer

1 Right-click **Materials** and choose **More Materials > Porous Material**.

2 In the **Settings** window for **Porous Material**, type `Aquifer` in the **Label** text field.

3 Locate the **Geometric Entity Selection** section. From the **Selection** list, choose **Middle layer**.

Lower aquitard

1 Right-click **Materials** and choose **More Materials > Porous Material**.

2 In the **Settings** window for **Porous Material**, locate the **Geometric Entity Selection** section.

3 From the **Selection** list, choose **Bottom layer**.

4 In the **Label** text field, type `Lower aquitard`.

Fracture

1 Right-click **Materials** and choose **More Materials > Material Link**.

2 In the **Settings** window for **Material Link**, type `Fracture` in the **Label** text field.

3 Locate the **Geometric Entity Selection** section. From the **Geometric entity level** list, choose **Boundary**.

4 From the **Selection** list, choose **Fracture**.

DARCY'S LAW (DL)

Now, set up the physics interfaces. This determines which material properties are required.

Fracture 1

1 In the **Physics** toolbar, click **Boundaries** and choose **Fracture**.

2 In the **Settings** window for **Fracture**, locate the **Boundary Selection** section.

3 From the **Selection** list, choose **Fracture**.

4 Locate the **Aperture** section. In the d_f text field, type `d_f`.

Fracture Material 1

1 In the **Model Builder** window, click **Fracture Material 1**.
2 In the **Settings** window for **Fracture Material**, locate the **Fracture Material Properties** section.
3 From the ε_p list, choose **User defined**. In the associated text field, type `0.6`.
4 From the **Permeability model** list, choose **Cubic law**.
5 In the f_f text field, type `f_f`.

Hydraulic Head 1

1 In the **Physics** toolbar, click **Boundaries** and choose **Hydraulic Head**.
2 In the **Settings** window for **Hydraulic Head**, locate the **Boundary Selection** section.
3 From the **Selection** list, choose **Outer boundaries**.
4 Locate the **Hydraulic Head** section. In the H_0 text field, type `-deltaH*x`.

Use the **Well** feature to define the injection and production side of the doublet.

Well 1

1 In the **Physics** toolbar, click **Edges** and choose **Well**.
2 In the **Settings** window for **Well**, locate the **Edge Selection** section.
3 From the **Selection** list, choose **Injection well**.
4 Locate the **Well** section. In the d_w text field, type `2*r_bore`.
5 From the **Specify** list, choose **Mass flow**.
6 Locate the **Mass Flow** section. In the M_0 text field, type `pump*dl.rho`.

The expression `dl.rho` refers to the water density that is defined by Darcy's Law interface.

Well 2

1 In the **Physics** toolbar, click **Edges** and choose **Well**.
2 In the **Settings** window for **Well**, locate the **Edge Selection** section.
3 From the **Selection** list, choose **Production well**.
4 Locate the **Well** section. In the d_w text field, type `2*r_bore`.
5 From the **Well type** list, choose **Production**.
6 From the **Specify** list, choose **Mass flow**.
7 Locate the **Mass Flow** section. In the M_0 text field, type `pump*dl.rho`.

HEAT TRANSFER IN POROUS MEDIA (HT)

Fluid 1

1 In the **Model Builder** window, under **Component 1 (comp1)** > **Heat Transfer in Porous Media (ht)** > **Porous Medium 1** click **Fluid 1**.
2 In the **Settings** window for **Fluid**, locate the **Heat Convection** section.
3 From the **u** list, choose **Total Darcy velocity field (dl)**.

Porous Matrix 1

1 In the **Model Builder** window, click **Porous Matrix 1**.
2 In the **Settings** window for **Porous Matrix**, locate the **Matrix Properties** section.
3 From the **Define** list, choose **Solid phase properties**.

Initial Values 1

Define the geothermal gradient as initial temperature distribution.

1 In the **Model Builder** window, under **Component 1 (comp1)** > **Heat Transfer in Porous Media (ht)** click **Initial Values 1**.
2 In the **Settings** window for **Initial Values**, locate the **Initial Values** section.
3 In the T text field, type `T_top-0.03[K/m]*z`.

Open Boundary 1

1 In the **Physics** toolbar, click **Boundaries** and choose **Open Boundary**.
2 In the **Settings** window for **Open Boundary**, locate the **Boundary Selection** section.
3 From the **Selection** list, choose **Outer boundaries**.
4 Locate the **Upstream Properties** section. In the T_{ustr} text field, type `T_top-delta_Tz*z`.

Fracture 1

1 In the **Physics** toolbar, click **Boundaries** and choose **Fracture**.
2 In the **Settings** window for **Fracture**, locate the **Boundary Selection** section.
3 From the **Selection** list, choose **Fracture**.
4 Locate the **Shell Properties** section. From the **Shell type** list, choose **Nonlayered shell**. In the L_{th} text field, type `d_f`.
5 Locate the **Fluid Material** section. From the list, choose **Water, liquid (mat1)**.
6 Locate the **Heat Convection** section. From the **u** list, choose **Total Darcy velocity field (dl)**.
7 Locate the **Porous Material** section. From the θ_p list, choose **Volume fraction (dl/frac1)**.

8 Locate the **Heat Conduction, Porous Matrix** section. From the k_p list, choose **User defined**. In the associated text field, type `3`.

9 Locate the **Thermodynamics, Porous Matrix** section. From the ρ_p list, choose **User defined**. In the associated text field, type `1.2e3`.

10 From the $C_{p,p}$ list, choose **User defined**. In the associated text field, type `800`.

Line Heat Source 1

1 In the **Physics** toolbar, click **Edges** and choose **Line Heat Source**.

2 In the **Settings** window for **Line Heat Source**, locate the **Edge Selection** section.

3 From the **Selection** list, choose **Injection well**.

4 Locate the **Line Heat Source** section. In the Q_l text field, type `mat1.def.Cp*dl.well1.Ml*(T_inj-T)`.

5 Locate the **Heat Source Radius** section. Select the **Specify heat source radius** checkbox.

6 In the R text field, type `r_bore`.

MATERIALS

Now you can define the material properties.

Upper Aquitard (pmat1)

1 In the **Model Builder** window, under **Component 1 (comp1)** > **Materials** click **Upper Aquitard (pmat1)**.

2 In the **Settings** window for **Porous Material**, locate the **Homogenized Properties** section.

3 In the table, enter the following settings:

Property	Variable	Value	Unit	Property group
Permeability	kappa_iso ; kappaii = kappa_iso, kappaij = 0	1e-10[cm^2]	m²	Basic

4 Locate the **Phase-Specific Properties** section. Click **Add Required Phase Nodes**.

Solid 1 (pmat1.solid1)

1 In the **Model Builder** window, click **Solid 1 (pmat1.solid1)**.

2 In the **Settings** window for **Solid**, locate the **Solid Properties** section.

3 In the θ_s text field, type `0.9`.

4 From the **Material** list, choose **Locally defined**.

5 Locate the **Material Contents** section. In the table, enter the following settings:

Property	**Variable**	**Value**	**Unit**	**Property group**
Density	rho	1300	kg/m³	Basic
Heat capacity at constant pressure	Cp	900	J/(kg·K)	Basic
Thermal conductivity	k_iso ; kii = k_iso, kij = 0	2	W/(m·K)	Basic

Aquifer (pmat2)

1 In the **Model Builder** window, under **Component 1 (comp1)** > **Materials** click **Aquifer (pmat2)**.

2 In the **Settings** window for **Porous Material**, locate the **Homogenized Properties** section.

3 In the table, enter the following settings:

Property	**Variable**	**Value**	**Unit**	**Property group**
Permeability	kappa_iso ; kappaii = kappa_iso, kappaij = 0	`1e-6[cm^2]`	m²	Basic

4 Locate the **Phase-Specific Properties** section. Click **Add Required Phase Nodes**.

Solid 1 (pmat2.solid1)

1 In the **Model Builder** window, click **Solid 1 (pmat2.solid1)**.

2 In the **Settings** window for **Solid**, locate the **Solid Properties** section.

3 From the **Material** list, choose **Locally defined**.

4 In the θ_s text field, type `0.6`.

5 Locate the **Material Contents** section. In the table, enter the following settings:

Property	**Variable**	**Value**	**Unit**	**Property group**
Density	rho	1900	kg/m³	Basic
Heat capacity at constant pressure	Cp	850	J/(kg·K)	Basic
Thermal conductivity	k_iso ; kii = k_iso, kij = 0	3	W/(m·K)	Basic

Lower aquitard (pmat3)

1 In the **Model Builder** window, under **Component 1 (comp1)** > **Materials** click **Lower aquitard (pmat3)**.

2 In the **Settings** window for **Porous Material**, locate the **Homogenized Properties** section.

3 In the table, enter the following settings:

Property	**Variable**	**Value**	**Unit**	**Property group**
Permeability	kappa_iso ; kappaii = kappa_iso, kappaij = 0	`1e-7[cm^2]`	m^2	Basic

4 Locate the **Phase-Specific Properties** section. Click **Add Required Phase Nodes**.

Solid 1 (pmat3.solid1)

1 In the **Model Builder** window, click **Solid 1 (pmat3.solid1)**.

2 In the **Settings** window for **Solid**, locate the **Solid Properties** section.

3 In the θ_s text field, type `0.7`.

4 From the **Material** list, choose **Locally defined**.

5 Locate the **Material Contents** section. In the table, enter the following settings:

Property	**Variable**	**Value**	**Unit**	**Property group**
Density	rho	2300	kg/m^3	Basic
Heat capacity at constant pressure	Cp	850	J/(kg·K)	Basic
Thermal conductivity	k_iso ; kii = k_iso, kij = 0	`3.5`	W/(m·K)	Basic

MESH 1

Adjust the default mesh settings slightly to make sure, that the injection and production well are resolved properly.

1 In the **Model Builder** window, under **Component 1 (comp1)** click **Mesh 1**.

2 In the **Settings** window for **Mesh**, locate the **Physics-Controlled Mesh** section.

3 From the **Element size** list, choose **Fine**.

4 Locate the **Sequence Type** section. From the list, choose **User-controlled mesh**.

Distribution 1

1 In the **Model Builder** window, right-click **Free Tetrahedral 1** and choose **Distribution**.

2 Select Edges 19 and 37 only.

3 In the **Settings** window for **Distribution**, click **Build All**.

ADD STUDY

1 In the **Home** toolbar, click **Add Study** to open the **Add Study** window.

2 Go to the **Add Study** window.

3 Find the **Studies** subsection. In the **Select Study** tree, select **General Studies** > **Stationary**.

4 Find the **Physics interfaces in study** subsection. In the table, clear the **Solve** checkbox for **Heat Transfer in Porous Media (ht)**.

5 Click the **Add Study** button in the window toolbar.

6 In the **Home** toolbar, click **Add Study** to close the **Add Study** window.

STUDY 1

Step 1: Stationary

1 In the **Settings** window for **Stationary**, locate the **Physics and Variables Selection** section.

2 Select the **Modify model configuration for study step** checkbox.

3 In the tree, select **Component 1 (comp1)** > **Darcy's Law (dl)** > **Well 1** and **Component 1 (comp1)** > **Darcy's Law (dl)** > **Well 2**.

4 Click **Disable**.

This first stationary step results in a groundwater flow field which serves as a starting point for the subsequent time dependent analysis of the performance of the geothermal doublet.

Step 2: Time Dependent

1 In the **Study** toolbar, click **Time Dependent**.

2 In the **Settings** window for **Time Dependent**, locate the **Study Settings** section.

3 From the **Time unit** list, choose **a**.

4 In the **Output times** text field, type `range(0,0.2,10)`.

5 In the **Model Builder** window, click **Study 1**.

6 In the **Settings** window for **Study**, locate the **Study Settings** section.

7 Clear the **Generate default plots** checkbox.

Solution 1 (sol1)

1 In the **Study** toolbar, click **Show Default Solver**.

2 In the **Model Builder** window, expand the **Solution 1 (sol1)** node, then click **Time-Dependent Solver 1**.

3 In the **Settings** window for **Time-Dependent Solver**, click to expand the **Time Stepping** section.

4 From the **Maximum step constraint** list, choose **Constant**.

Constraining the maximum time step ensures that the transient behavior of the whole system is resolved properly.

5 In the **Study** toolbar, click **Compute**.

RESULT TEMPLATES

Add the pressure plot from **Result Templates**, and modify it to create Figure 2.

1 In the **Results** toolbar, click **Result Templates** to open the **Result Templates** window.

2 Go to the **Result Templates** window.

3 In the tree, select **Study 1/Solution 1 (sol1)** > **Darcy's Law** > **Pressure (dl)**.

4 Click the **Add Result Template** button in the window toolbar.

5 In the **Results** toolbar, click **Result Templates** to close the **Result Templates** window.

RESULTS

Selection 1

1 In the **Model Builder** window, expand the **Pressure (dl)** node.

2 Right-click **Surface** and choose **Selection**.

3 In the **Settings** window for **Selection**, locate the **Selection** section.

4 From the **Selection** list, choose **All boundaries**, and remove the top and front boundaries, which corresponds to:

5 Select Boundaries 3, 6, 9, 11–16, 18, 20, 21, 23, and 25–29 only.

6 In the **Pressure (dl)** toolbar, click **Plot**.

Temperature and Flow Field

Create the plot in Figure 3 as follows:

1 In the **Results** toolbar, click **3D Plot Group**.

2 In the **Settings** window for **3D Plot Group**, type `Temperature and Flow Field` in the **Label** text field.

Surface 1

1 Right-click **Temperature and Flow Field** and choose **Surface**.

2 In the **Settings** window for **Surface**, locate the **Expression** section.

3 In the **Expression** text field, type T.

4 Locate the **Coloring and Style** section. From the **Color table** list, choose **HeatCameraLight**.

Selection 1

1 Right-click **Surface 1** and choose **Selection**.

2 In the **Settings** window for **Selection**, locate the **Selection** section.

3 From the **Selection** list, choose **Outer boundaries**.

4 Select Boundaries 3, 11–13, 15, 16, and 25–29 only.

Surface 2

1 In the **Model Builder** window, under **Results** > **Temperature and Flow Field** right-click **Surface 1** and choose **Duplicate**.

2 In the **Settings** window for **Surface**, click to expand the **Inherit Style** section.

3 From the **Plot** list, choose **Surface 1**.

Selection 1

1 In the **Model Builder** window, expand the **Surface 2** node, then click **Selection 1**.

2 In the **Settings** window for **Selection**, locate the **Selection** section.

3 From the **Selection** list, choose **Fracture**.

Volume 1

1 In the **Model Builder** window, right-click **Temperature and Flow Field** and choose **Volume**.

2 In the **Settings** window for **Volume**, locate the **Expression** section.

3 In the **Expression** text field, type T.

4 Click to expand the **Inherit Style** section. From the **Plot** list, choose **Surface 1**.

Selection 1

1 Right-click **Volume 1** and choose **Selection**.

2 In the **Settings** window for **Selection**, locate the **Selection** section.

3 From the **Selection** list, choose **Bottom layer**.

Temperature and Flow Field

In the **Model Builder** window, under **Results** click **Temperature and Flow Field**.

Streamline Multislice 1

1 In the **Temperature and Flow Field** toolbar, click **More Plots** and choose **Streamline Multislice**.
2 In the **Settings** window for **Streamline Multislice**, locate the **Multiplane Data** section.
3 Find the **X-planes** subsection. In the **Planes** text field, type `2`.
4 Find the **Y-planes** subsection. In the **Planes** text field, type `0`.
5 Find the **Z-planes** subsection. From the **Entry method** list, choose **Coordinates**.
6 In the **Coordinates** text field, type `depth_w`.
7 Locate the **Streamline Positioning** section. From the **Positioning** list, choose **Uniform density**.
8 Locate the **Coloring and Style** section. Find the **Point style** subsection. From the **Type** list, choose **Arrow**.
9 Click to expand the **Quality** section. From the **Evaluation settings** list, choose **Manual**.
10 From the **Recover** list, choose **Everywhere**.
11 In the **Temperature and Flow Field** toolbar, click **Plot**.

This recovers the accurate derivatives for the streamlines.

Color Expression 1

1 Right-click **Streamline Multislice 1** and choose **Color Expression**.
2 In the **Settings** window for **Color Expression**, locate the **Coloring and Style** section.
3 From the **Color table** list, choose **GrayScale**.

Streamline Multislice 1

1 In the **Model Builder** window, click **Streamline Multislice 1**.
2 In the **Settings** window for **Streamline Multislice**, locate the **Coloring and Style** section.
3 Find the **Point style** subsection.
4 Select the **Scale factor** checkbox. In the associated text field, type `4000000`.

Temperature and Flow Field

1 In the **Model Builder** window, click **Temperature and Flow Field**.
2 In the **Settings** window for **3D Plot Group**, click to expand the **Title** section.
3 From the **Title type** list, choose **Manual**.
4 In the **Title** text area, type `Temperature distribution and Darcy's velocity field`.
5 Locate the **Plot Settings** section. Clear the **Plot dataset edges** checkbox.

6 Locate the **Color Legend** section. Select the **Show units** checkbox.

7 In the **Temperature and Flow Field** toolbar, click **Plot**.

Evaluate the production temperature and compare with Figure 4.

Line Average 1

1 In the **Results** toolbar, click **More Derived Values** and choose **Average** > **Line Average**.

2 In the **Settings** window for **Line Average**, click **Replace Expression** in the upper-right corner of the **Expressions** section. From the menu, choose **Component 1 (comp1)** > **Heat Transfer in Porous Media** > **Temperature** > **T - Temperature - K**.

3 Select Edge 37 only.

4 Click **Evaluate**.

TABLE 1

1 Go to the **Table 1** window.

2 Click the **Table Graph** button in the window toolbar.

RESULTS

Production Temperature

1 In the **Model Builder** window, under **Results** click **1D Plot Group 3**.

2 In the **Settings** window for **1D Plot Group**, type `Production Temperature` in the **Label** text field.

Temperature and Flow Field

To get a plot showing the pressure and velocity distribution along the fracture, add a plot from the **Result Templates** window and slightly adjust it to look like Figure 5.

RESULT TEMPLATES

1 In the **Results** toolbar, click **Result Templates** to open the **Result Templates** window.

2 Go to the **Result Templates** window.

3 In the tree, select **Study 1/Solution 1 (sol1)** > **Darcy's Law** > **Pressure Along Fracture (dl)**.

4 Click the **Add Result Template** button in the window toolbar.

5 In the **Results** toolbar, click **Result Templates** to close the **Result Templates** window.

RESULTS

Streamline Surface 1

1 In the **Pressure Along Fracture (dl)** toolbar, click **More Plots** and choose **Streamline Surface**.
2 In the **Settings** window for **Streamline Surface**, locate the **Surface Selection** section.
3 From the **Selection** list, choose **Fracture**.
4 Locate the **Streamline Positioning** section. From the **Positioning** list, choose **Magnitude controlled**.
5 In the **Minimum density level** text field, type 0.
6 In the **Maximum density level** text field, type 7.
7 Locate the **Coloring and Style** section. Find the **Point style** subsection. From the **Color** list, choose **White**.
8 In the **Pressure Along Fracture (dl)** toolbar, click **Plot**.