Flow123d tutorial 3 – "2D tunnel"

Contents

1 Description

The tutorial models the seepage site 23 m under the surface of the water treatment plant tunnel Bedřichov in the granite rock massif. This seepage site has fast reaction to the precipitation and measurements of various chemical values are available.

The user will learn how to:

- Prescribe time-dependent input data.

The geometry consists of a rectangle 500 × 300 m with a circular hole of diameter 3.6 m placed 23 meters under the surface, which represents a plane perpendicular to the tunnel.

2 Hydraulic model

The hydraulic model was fitted on the shape of the flux field, where it was assumed that the tunnel drains only a part of the model surface. In particular, the model was fitted on the estimated discharge of the seepage site.

We impose the following input data (see Figure 1):

- The hydraulic conductivity of the rock medium is set to 2.59e-2 m/day (= 3e-7 m/s);
- On the surface we prescribe the annual precipitation 2.33e-3 m/day (= 852 mm/yr);
- On the bottom part ".base" we prescribe the pressure 270 m because of assumption of local groundwater flow;
- In the tunnel, the measured flux -9.16e-2 m/day (= -1.06e-6 m/s) is prescribed.

For convenience we use day as the unit of time. The corresponding YAML code is:

```
input_fields:
  - region: rock
    conductivity: 2.59E-02
  - region: .tunnel
    bc_type: total_flux
    bc_flux: -9.16E-02
  - region: .base
    bc_type: dirichlet
    bc_pressure: 270
  - region: .surface
    bc_type: total_flux
    bc_flux: 2.33E-03
```

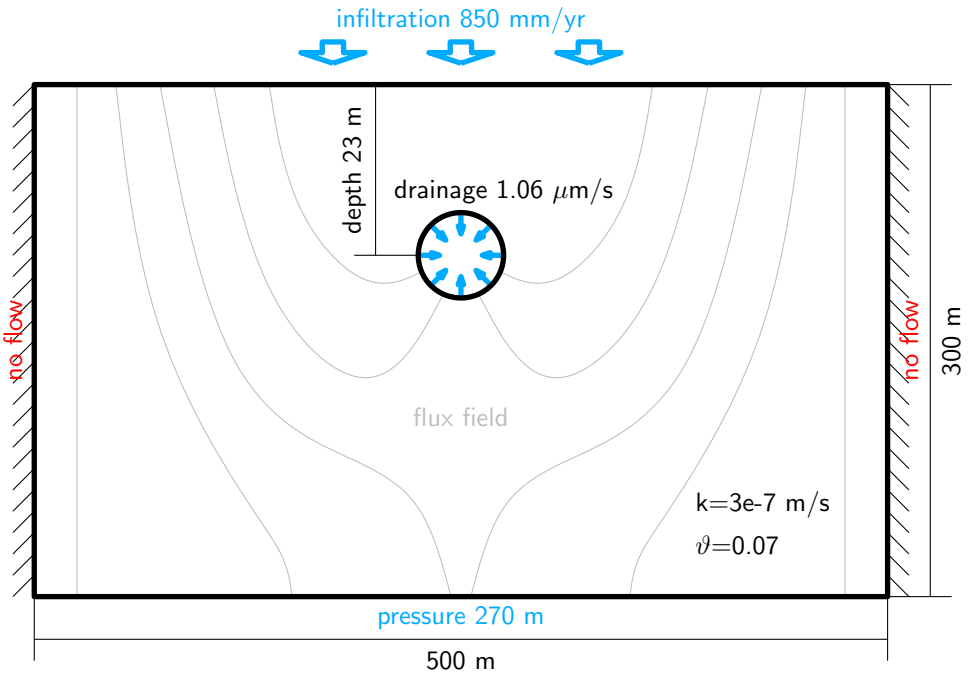

Figure 1: Geometry and boundary condition of model.

The results are shown in Figure 2, where the flux field and the pressure is shown. In the unsaturated layer the piezometric head is depicted.

3 Transport of real isotopes

The stable isotope O-18 was sampled in monthly steps in precipitation at nearby experimental catchment Uhlirska and at the seepage site 23m depth. The measured values are used for the boundary condition on the surface in the transport model as well as reference values in the tunnel.

3.1 Input

We use the value 0.067 for porosity. The initial concentration of O-18 is set to -10.5 kg/m^3:

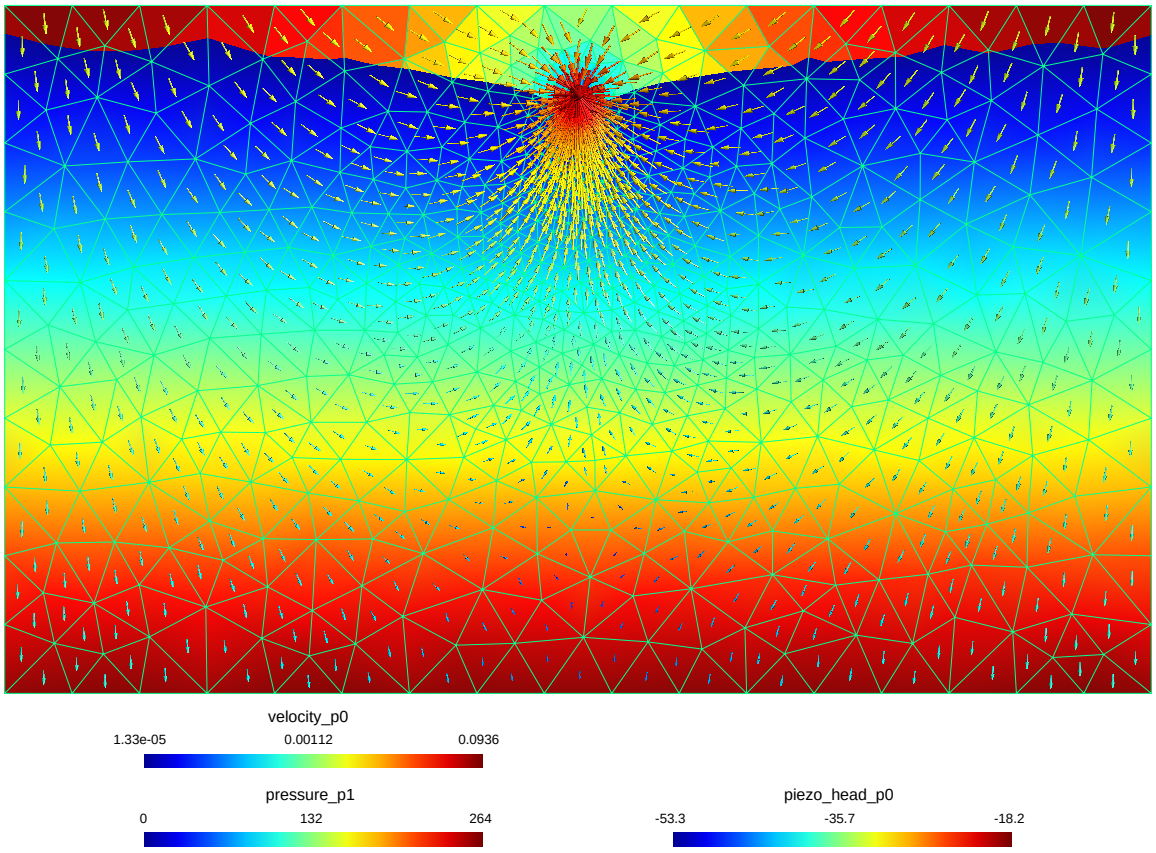

Figure 2: Pressure, boundary of water level and piezometric head in unsaturated zone and flux field.

```
transport: !Solute_Advection_FV
  input_fields:
    - region: rock
      porosity: 0.067
      init_conc: -10.5
```

The monthly measured values of δ18O [per mil V-SMOW] on the surface from the period 1/2006 till 6/2013 are supplied as the boundary condition:

```
    - region: .surface
      bc_conc: -12.85443
      time: 11
    - region: .surface
      bc_conc: -14.00255
      time: 42
    - region: .surface
      bc_conc: -12.80081
      time: 72
    - region: .surface
      bc_conc: -12.34748
      time: 103
  ...
```

3.2 Results

In Figure 3, the computed mass flux through tunnel is compared to the measured data. The evolution of the transported substance is depicted in Figure 4.

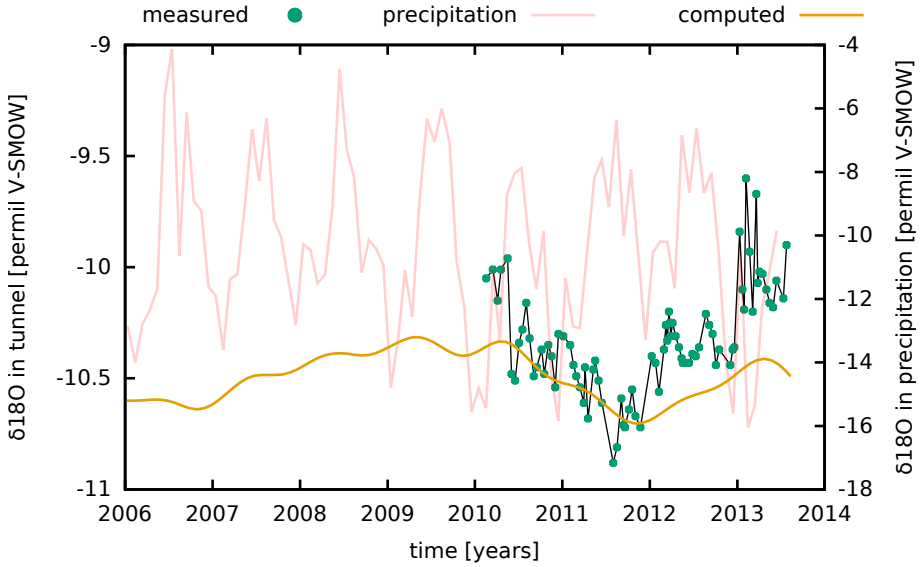

Figure 3: Concentration of O-18 on the seepage site 23m under the surface.

4 The control file

Below is the complete YAML source.

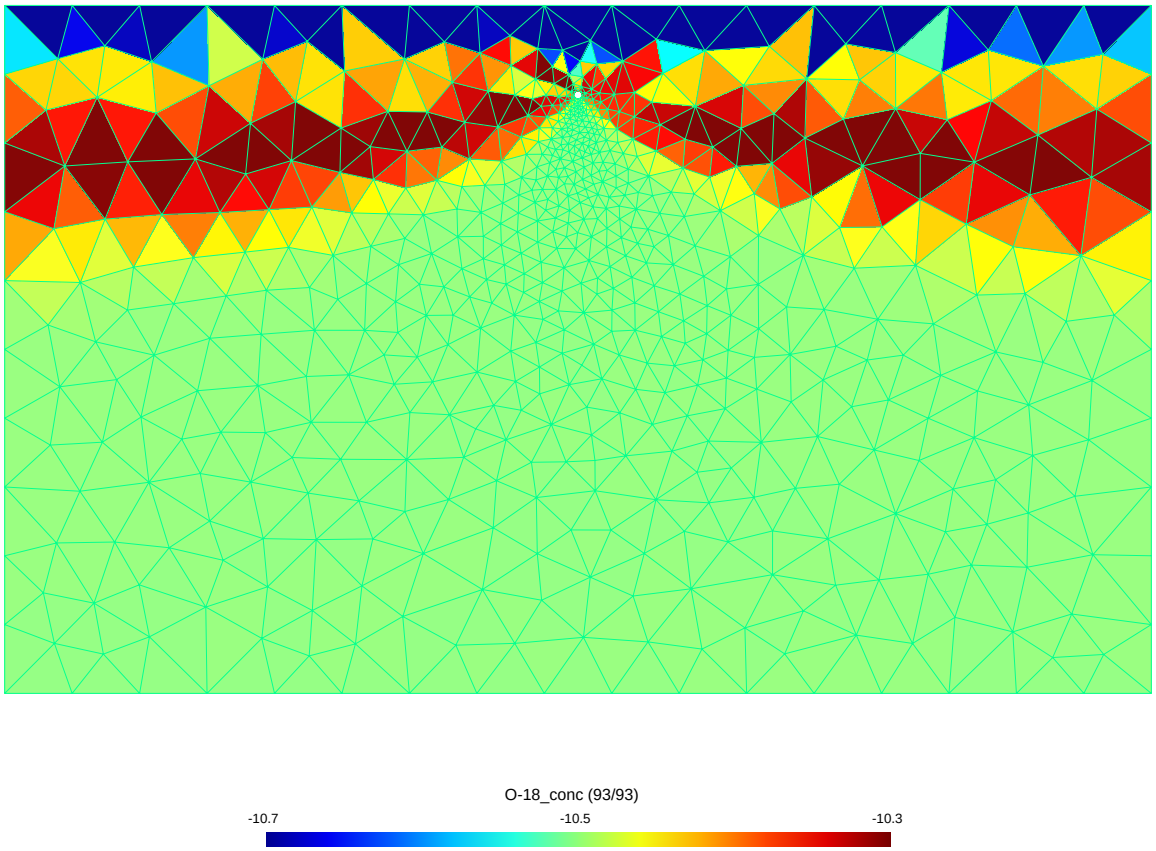

Figure 4: Transport of isotopes in two-dimensional model.

```
flow123d_version: 1.8.9
problem: !Coupling_Sequential
  description: Example 2 inspirated of real locality - 2D model of the tunnel with transport
  mesh:
    mesh_file: 03_mesh.msh
  flow_equation: !Flow_Darcy_MH
    nonlinear_solver:
      linear_solver: !Petsc
        a_tol: 1.0e-15
        r_tol: 1.0e-15
    input_fields:
      - region: rock
        conductivity: 2.59E-02
      - region: .tunnel
        bc_type: total_flux
        bc_flux: -9.16E-02
      - region: .base
        bc_type: dirichlet
        bc_pressure: 270
      - region: .surface
        bc_type: total_flux
        bc_flux: 2.33E-03
    balance: true
    output:
      output_stream:
        file: flow.msh
        format: !gmsh
          variant: ascii
      output_fields:
        - piezo_head_p0
        - pressure_p0
        - pressure_p1
        - velocity_p0
  solute_equation: !Coupling_OperatorSplitting
    transport: !Solute_Advection_FV
      input_fields:
        - region: rock
          porosity: 0.067
          init_conc: -10.5
        - region: .surface
          bc_conc: -12.85443
          time: 11
        - region: .surface
          bc_conc: -14.00255
          time: 42
        - region: .surface
          bc_conc: -12.80081
          time: 72
        - region: .surface
          bc_conc: -12.34748
          time: 103
        - region: .surface
          bc_conc: -11.69056
          time: 134
```

```
- region: .surface
  bc_conc: -5.57036
  time: 166
- region: .surface
  bc_conc: -4.12469
  time: 196
- region: .surface
  bc_conc: -10.64047
  time: 227
- region: .surface
  bc_conc: -6.13211
  time: 257
- region: .surface
  bc_conc: -8.91885
  time: 287
- region: .surface
  bc_conc: -9.2128
  time: 318
- region: .surface
  bc_conc: -11.60327
  time: 348
- region: .surface
  bc_conc: -11.90417
  time: 379
- region: .surface
  bc_conc: -13.59872
  time: 410
- region: .surface
  bc_conc: -11.38297
  time: 438
- region: .surface
  bc_conc: -11.22253
  time: 469.5
- region: .surface
  bc_conc: -9.12168
  time: 499
- region: .surface
  bc_conc: -6.64882
  time: 530.5
- region: .surface
  bc_conc: -8.28722
  time: 560
- region: .surface
  bc_conc: -6.29825
  time: 591
- region: .surface
  bc_conc: -9.52325
  time: 622
- region: .surface
  bc_conc: -10.06889
  time: 652.5
- region: .surface
  bc_conc: -11.45036
  time: 683
```

```
- region: .surface
  bc_conc: -12.81734
  time: 713.5
- region: .surface
  bc_conc: -10.28309
  time: 744
- region: .surface
  bc_conc: -10.45338
  time: 774.5
- region: .surface
  bc_conc: -11.5138
  time: 804
- region: .surface
  bc_conc: -11.23509
  time: 835.5
- region: .surface
  bc_conc: -9.20653
  time: 865
- region: .surface
  bc_conc: -4.75257
  time: 896.5
- region: .surface
  bc_conc: -7.29354
  time: 926
- region: .surface
  bc_conc: -8.18397
  time: 957.5
- region: .surface
  bc_conc: -11.17229
  time: 988
- region: .surface
  bc_conc: -10.13945
  time: 1018.5
- region: .surface
  bc_conc: -10.41511
  time: 1049
- region: .surface
  bc_conc: -10.92845
  time: 1079.5
- region: .surface
  bc_conc: -14.78398
  time: 1110
- region: .surface
  bc_conc: -13.24067
  time: 1141.5
- region: .surface
  bc_conc: -11.10512
  time: 1169
- region: .surface
  bc_conc: -12.54885
  time: 1199.5
- region: .surface
  bc_conc: -8.90522
  time: 1230
```

```
- region: .surface
  bc_conc: -6.32787
  time: 1261.5
- region: .surface
  bc_conc: -7.05611
  time: 1292
- region: .surface
  bc_conc: -6.0089
  time: 1323.5
- region: .surface
  bc_conc: -7.05956
  time: 1355
- region: .surface
  bc_conc: -10.84582
  time: 1385.5
- region: .surface
  bc_conc: -12.256
  time: 1417
- region: .surface
  bc_conc: -15.56566
  time: 1447.5
- region: .surface
  bc_conc: -14.80394
  time: 1477.9
- region: .surface
  bc_conc: -15.43502
  time: 1508.3
- region: .surface
  bc_conc: -11.08503
  time: 1538.7
- region: .surface
  bc_conc: -13.34144
  time: 1565
- region: .surface
  bc_conc: -8.72689
  time: 1595
- region: .surface
  bc_conc: -8.04992
  time: 1626
- region: .surface
  bc_conc: -7.87742
  time: 1656
- region: .surface
  bc_conc: -10.21281
  time: 1687
- region: .surface
  bc_conc: -11.67132
  time: 1718
- region: .surface
  bc_conc: -9.86934
  time: 1748
- region: .surface
  bc_conc: -14.29788
  time: 1779
```

```
- region: .surface
  bc_conc: -15.83779
  time: 1809
- region: .surface
  bc_conc: -11.34214
  time: 1840
- region: .surface
  bc_conc: -12.86511
  time: 1871
- region: .surface
  bc_conc: -12.93357
  time: 1899
- region: .surface
  bc_conc: -10.51149
  time: 1930
- region: .surface
  bc_conc: -8.19156
  time: 1960
- region: .surface
  bc_conc: -7.615
  time: 1991
- region: .surface
  bc_conc: -9.10695
  time: 2021
- region: .surface
  bc_conc: -6.36307
  time: 2052
- region: .surface
  bc_conc: -10.0023
  time: 2083
- region: .surface
  bc_conc: -7.9214
  time: 2113
- region: .surface
  bc_conc: -10.62
  time: 2144
- region: .surface
  bc_conc: -13.28369
  time: 2174
- region: .surface
  bc_conc: -10.53405
  time: 2205
- region: .surface
  bc_conc: -10.18778
  time: 2236
- region: .surface
  bc_conc: -10.20346
  time: 2265
- region: .surface
  bc_conc: -11.66542
  time: 2296
- region: .surface
  bc_conc: -6.83685
  time: 2326
```

```
    - region: .surface
      bc_conc: -8.64656
      time: 2357
    - region: .surface
      bc_conc: -6.62866
      time: 2387
    - region: .surface
      bc_conc: -8.66687
      time: 2418
    - region: .surface
      bc_conc: -8.02979
      time: 2449
    - region: .surface
      bc_conc: -10.50304
      time: 2479
    - region: .surface
      bc_conc: -14.00857
      time: 2510
    - region: .surface
      bc_conc: -15.60331
      time: 2540
    - region: .surface
      bc_conc: -10.49306
      time: 2571
    - region: .surface
      bc_conc: -16.0443
      time: 2602
    - region: .surface
      bc_conc: -15.3727
      time: 2630
    - region: .surface
      bc_conc: -12.28302
      time: 2661
    - region: .surface
      bc_conc: -11.15953
      time: 2691
    - region: .surface
      bc_conc: -9.84281
      time: 2722
output_stream:
  time_step: 30
  file: transport.msh
  format: !gmsh
    variant: ascii
substances: 0-18
time:
  end_time: 2780
balance:
  cumulative: true
```