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Mandat	:	ZSoil Day - 2026
Object	:	Large scale geothermal project in Yverdon
Title	:	

Version	:	1
Type	:	Document de travail - PROVISOIRE
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Date	:	9/1/2026
Lieu	:	Lausanne

Outline

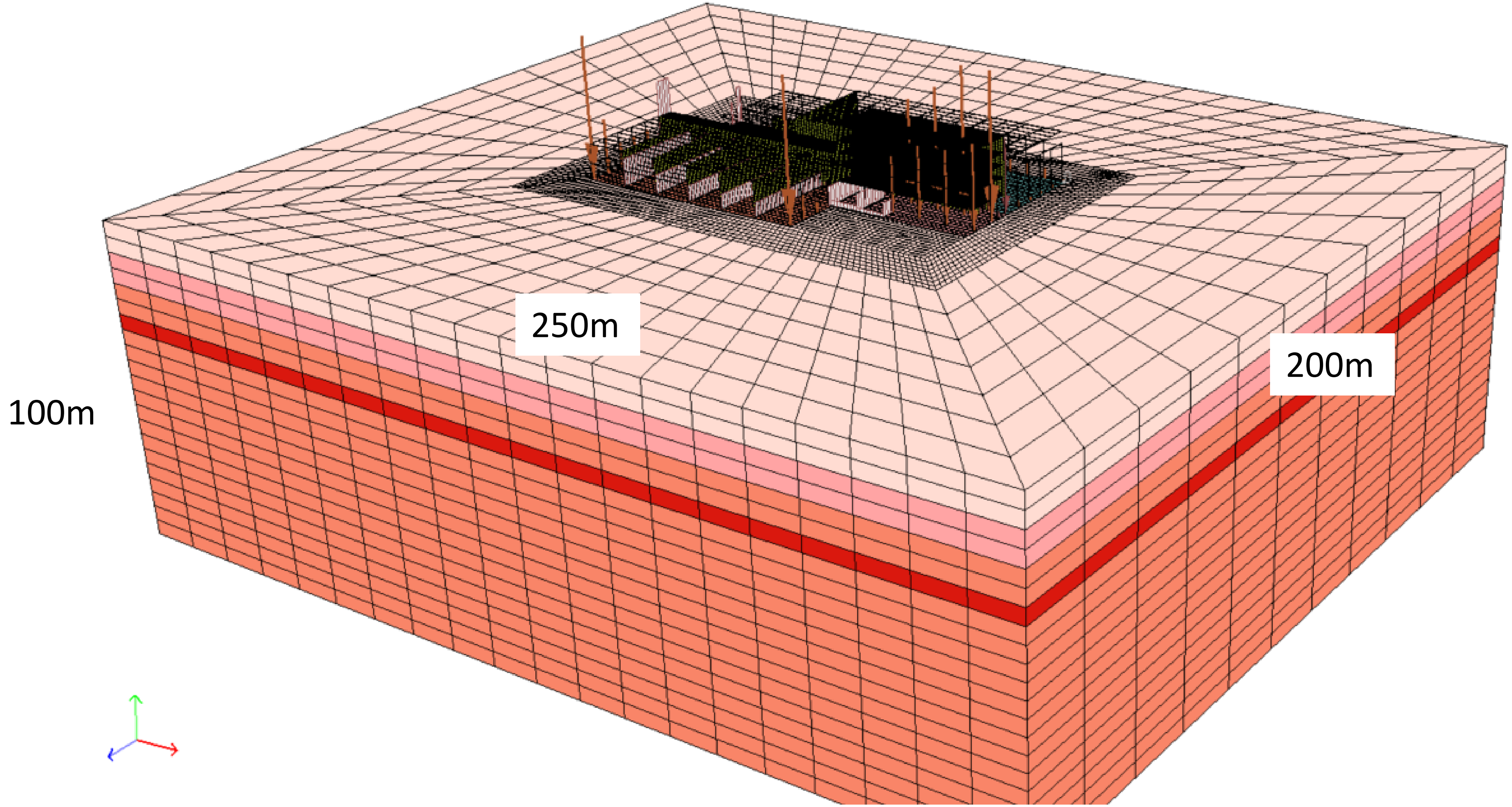
1. **The project** — New engineering school at Yverdon
2. **Foundations – mechanical design** — 3D FE model, ~150 piles, settlement analysis (ELS)
3. **How a borehole heat exchanger works** — Principle, heat pump equation, ZSoil examples
4. **Thermal model over 50 years** — Mesh strategy, time-stepping, heat fluxes, results
5. **Thermo-mechanical effects** — Displacements and normal forces induced by ΔT

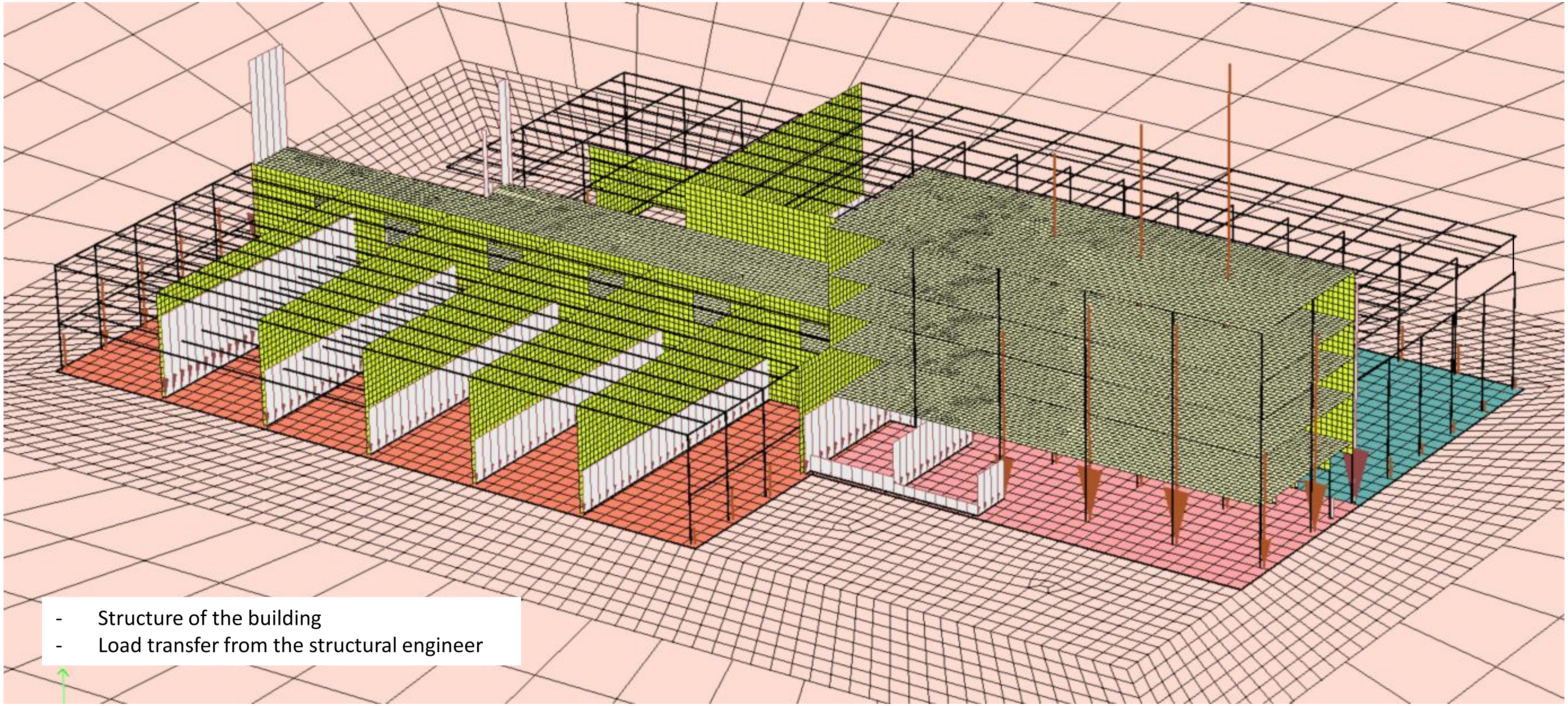
Yverdon 2km

y-parc.ch

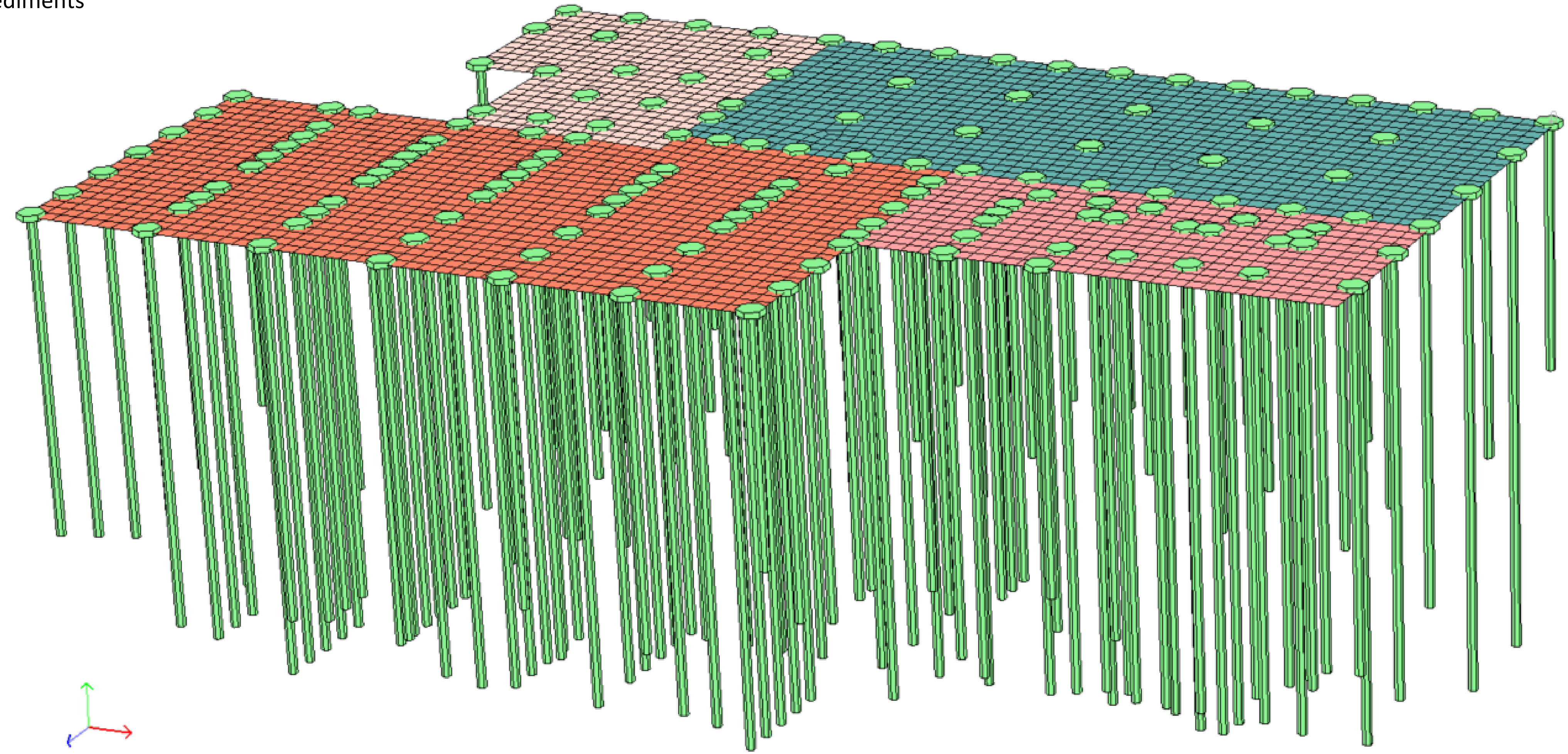
-> New building for an electrical engineering school

3D FE model for settlement analysis – 350’000 nodes




- Structure of the building
- Load transfer from the structural engineer

- Foundation slab : 30cm (ground level ~flat)
- ~150 piles from 20m to 42m
- 10m of Peat with E~1.5MPa then lacustrine sediments

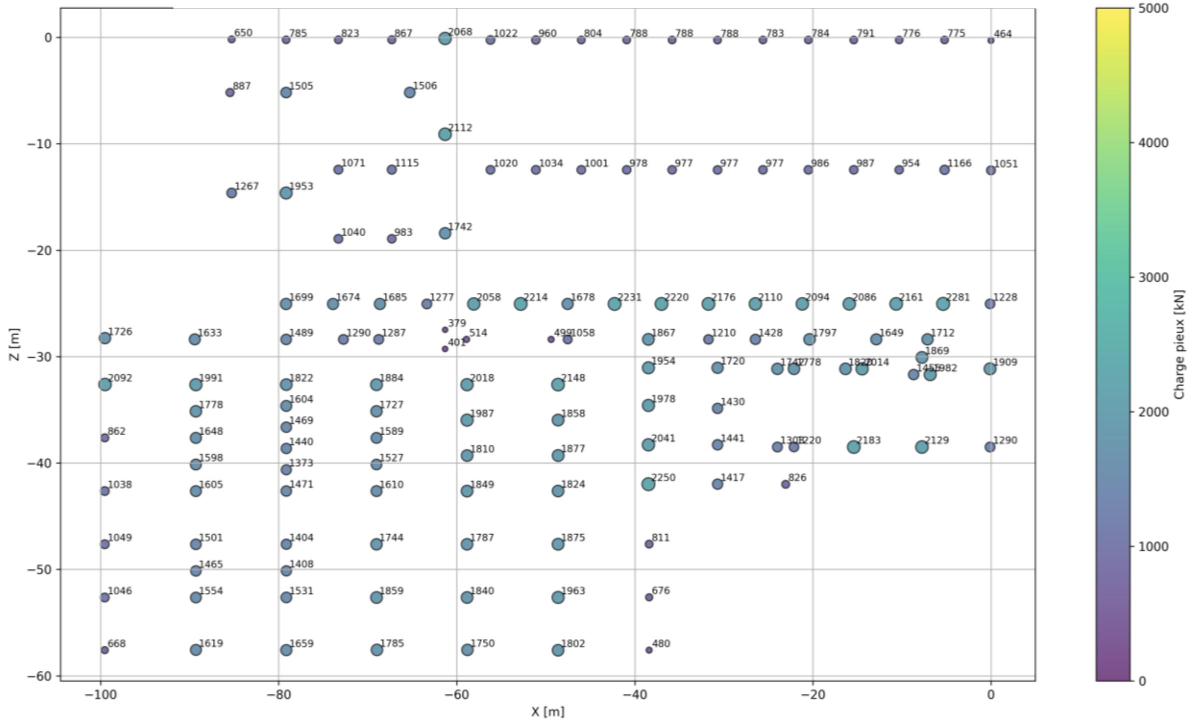


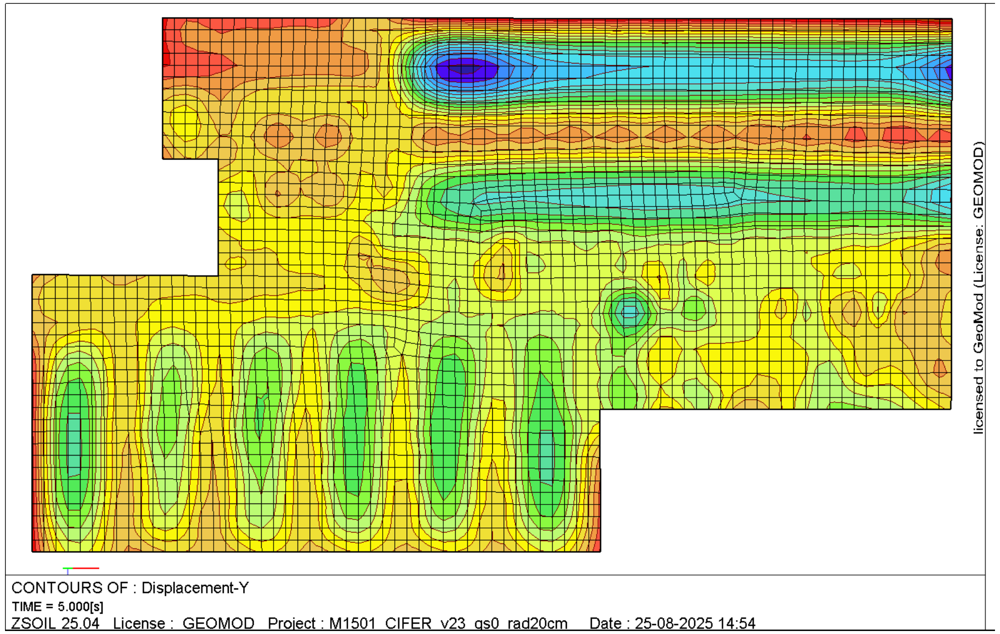
First models : Optimize the design / total length of piles

-> ELS calculations

+ discussion with the structural engineer

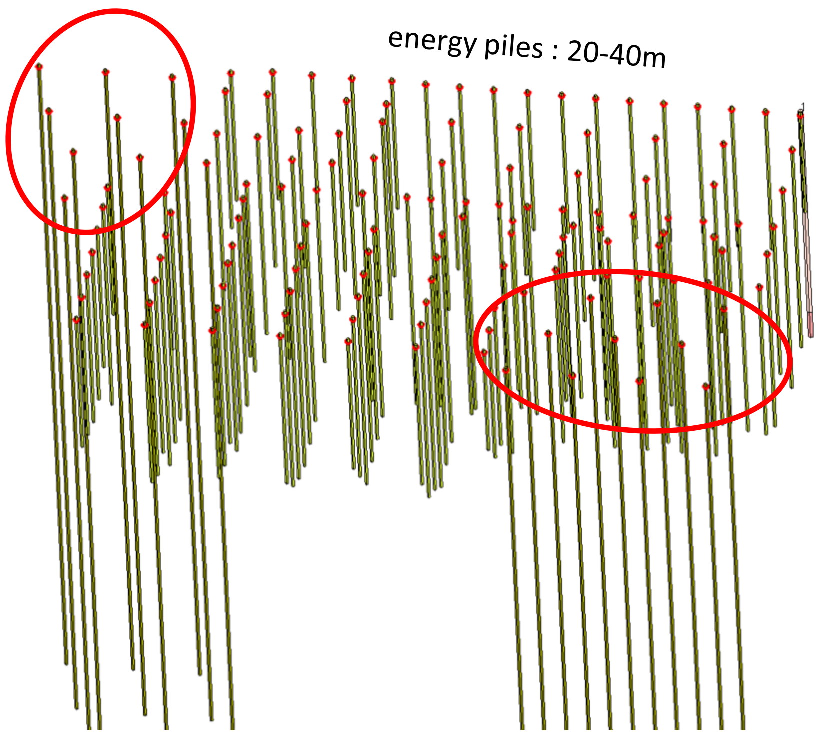
Normal force in the piles, extracted with the SDK module



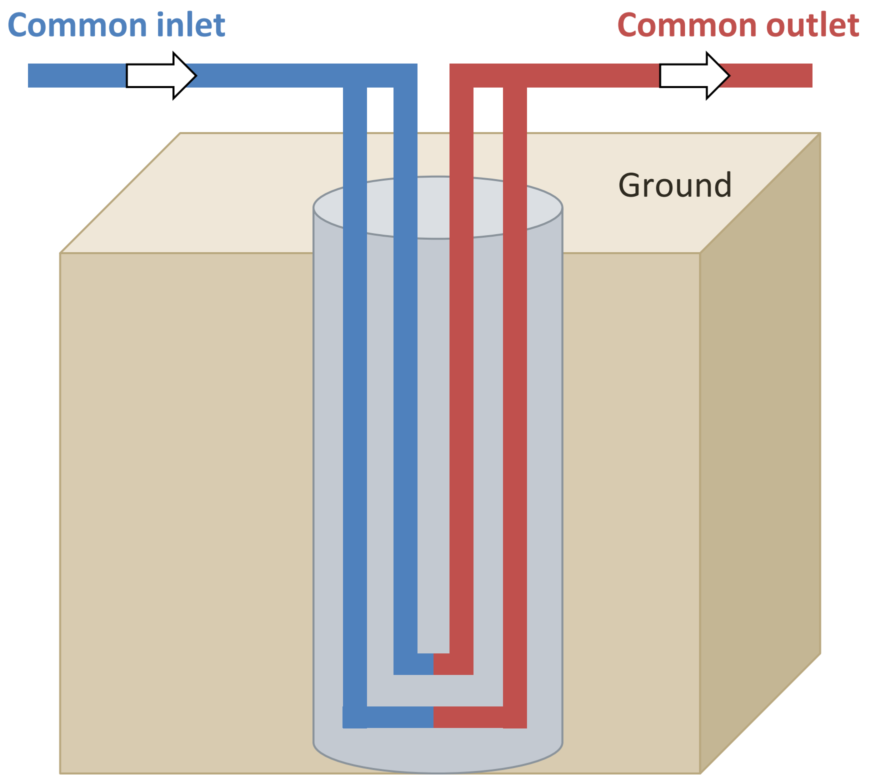


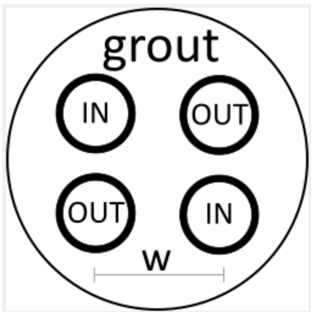
Settlement of the Foundation slab

Second part : thermal analysis

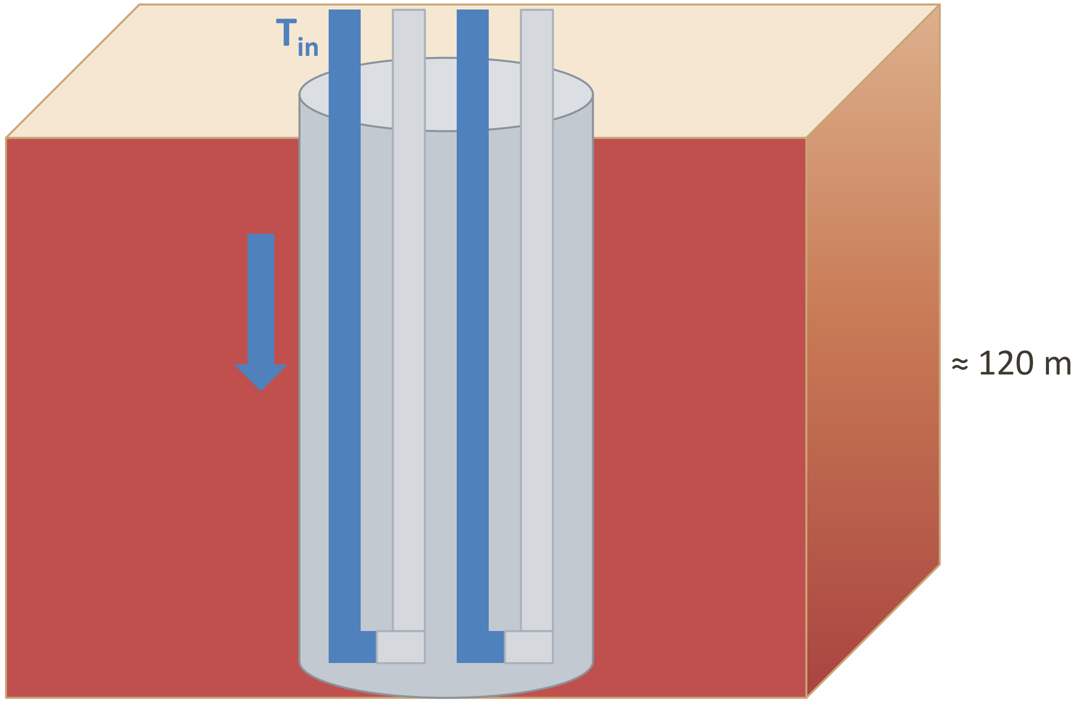


- Some piles are equipped with heat exchangers : 2U, **Ø550, w=35cm**
- Borehole heat exchangers (21 BHE) : 2U, **Ø130, w=6cm**



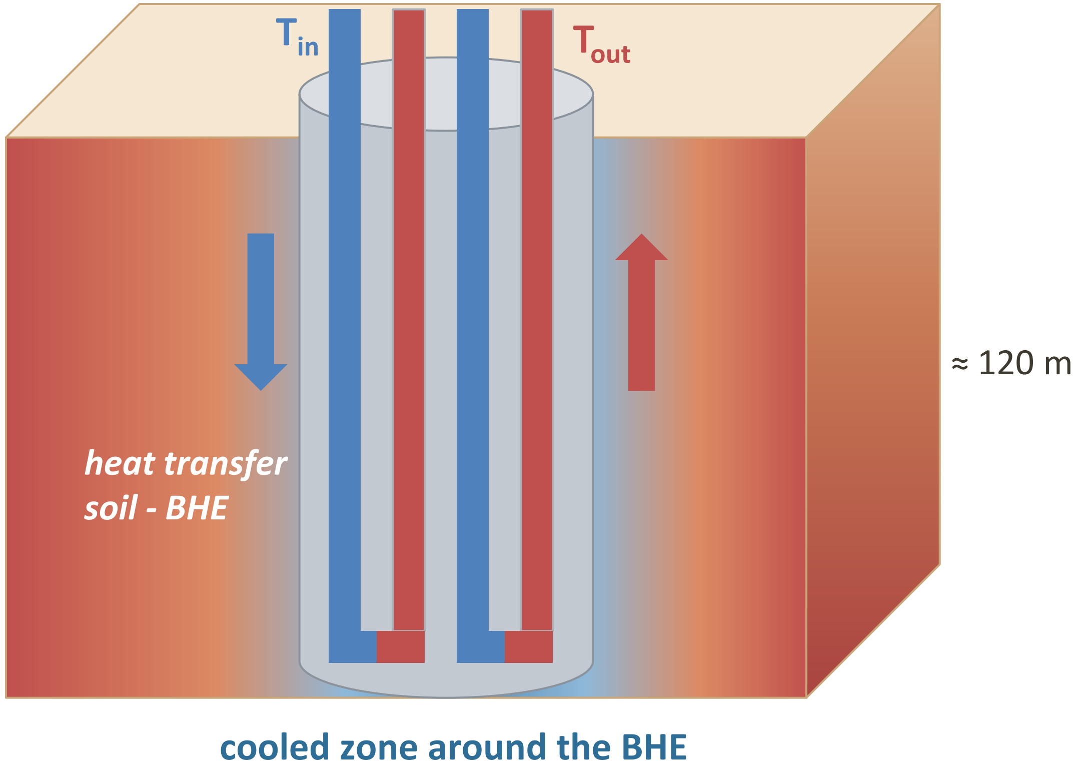


How a BHE works – 1. Cold fluid flows down



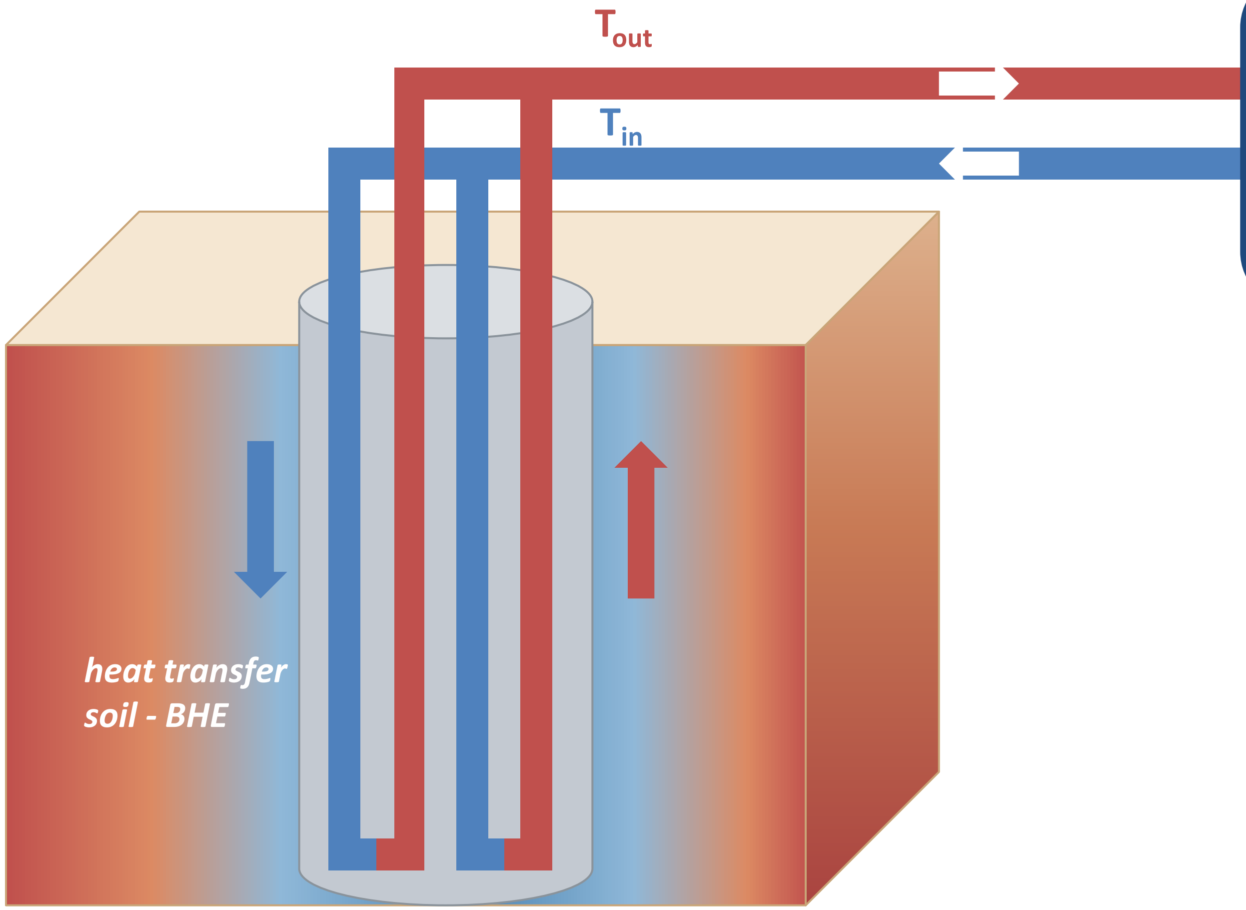
- The heat pump pushes cold fluid into the borehole.
- It flows down the two inflow tubes of the 2U probe.
- The temperature difference between the fluid and the soil is what drives the heat exchange.

How a BHE works – 2. The ground warms the fluid / the fluid cools the soil



- The ground is warmer than the fluid Heat crosses the grout and the pipe wall into the fluid.
- The fluid warms up along the pipe : T_out > T_in.
- The soil around the probe cools down

How a BHE works – 3. The loop is closed by the heat pump

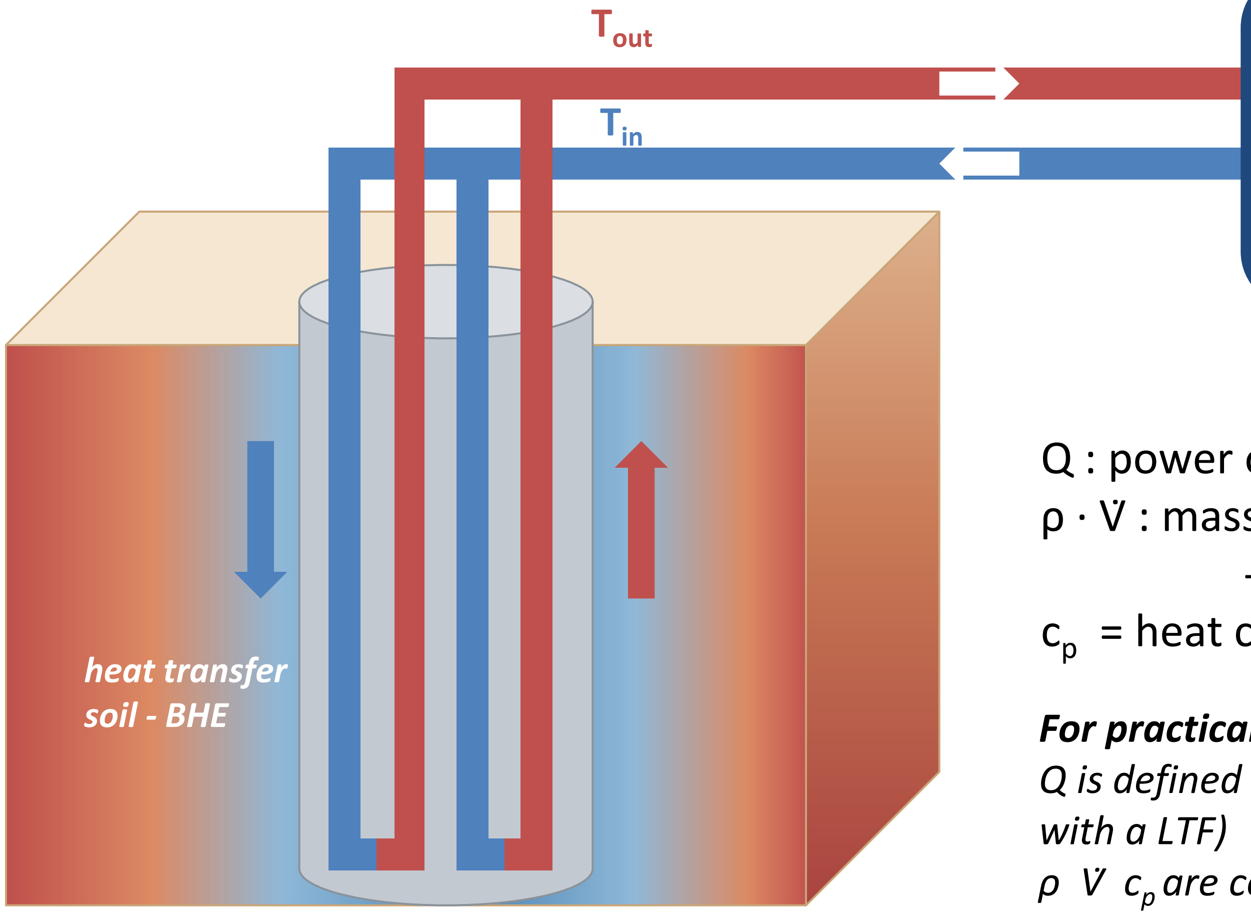


cooled zone around the BHE

HEAT PUMP

$$Q = \rho \cdot \dot{V} \cdot c_p \cdot (T_{out} - T_{in})$$

How a BHE works – 3. The loop is closed by the heat pump



cooled zone around the BHE

HEAT PUMP

$$Q = \rho \cdot \dot{V} \cdot c_p \cdot (T_{out} - T_{in})$$

Q : power of the heat pump at a given time [W]

$\rho \cdot \dot{V}$: mass of fluid through the pump in 1s

-> key parameter is the flow in the BHE

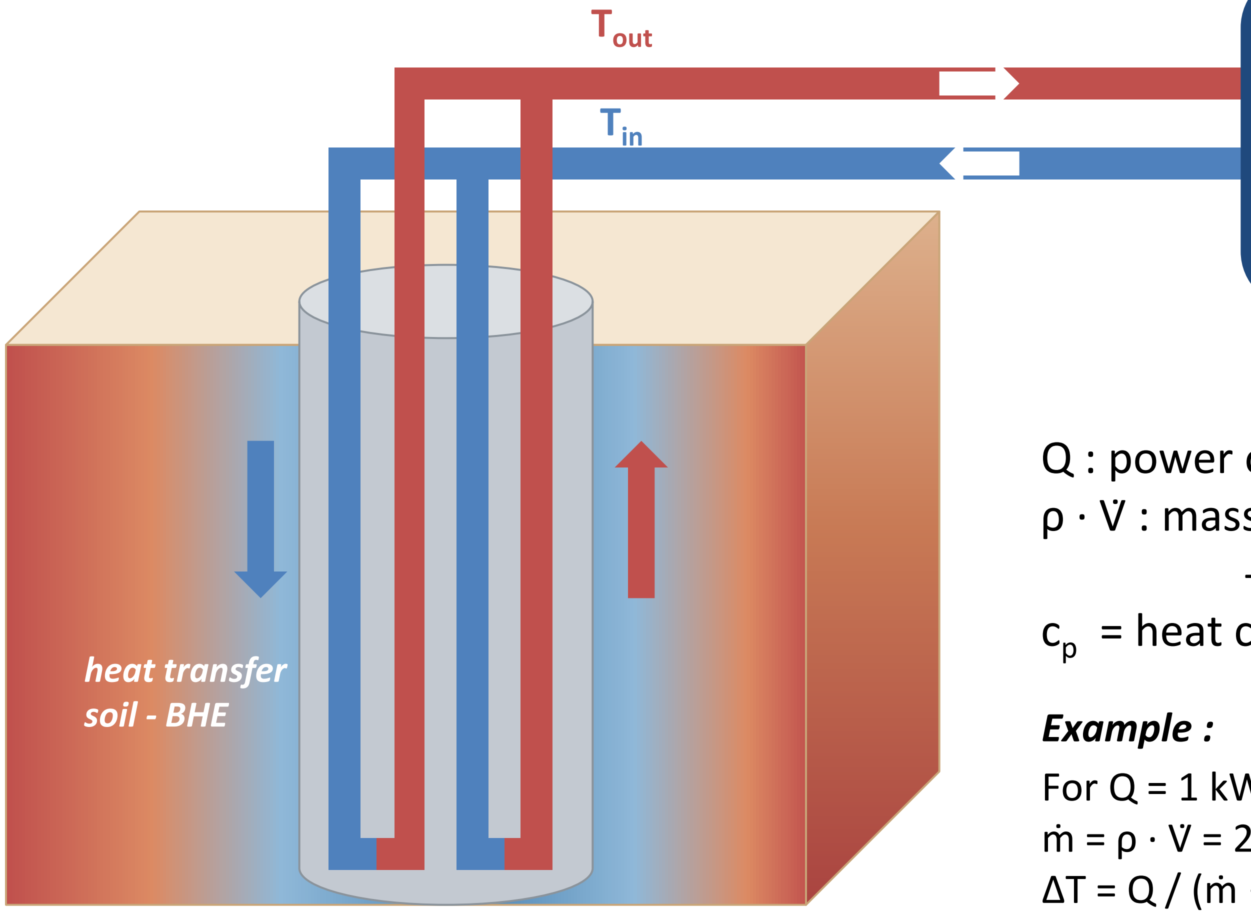
c_p = heat capacity of the fluid

For practical cases :

Q is defined in the ZSoil preprocessor (it can be controlled with a LTF)

ρ $\dot{V}$ c_p are constants defined in material window

How a BHE works – 3. The loop is closed by the heat pump



cooled zone around the BHE

HEAT PUMP

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Q : power of the heat pump at a given time [W]

$\rho \cdot \dot{V}$: mass of fluid through the pump in 1s

-> key parameter is the flow in the BHE

c_p = heat capacity of the fluid

Example :

For Q = 1 kW, $\dot{V}$ = 20 m³/day :

$\dot{m} = \rho \cdot \dot{V}$ = 20 000 / 86 400 = 0.231 kg/s

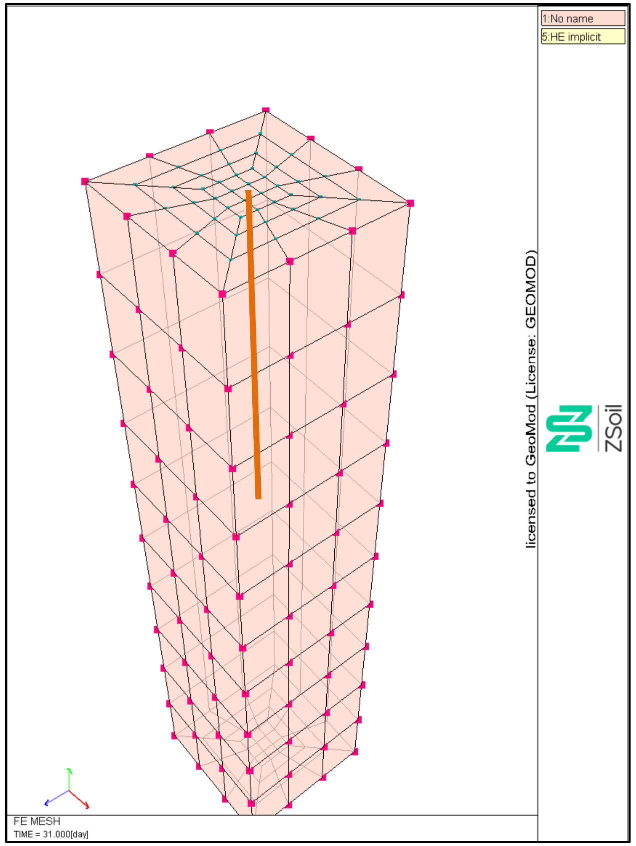
$\Delta T = Q / (\dot{m} \cdot c_p)$ = 1 000 / (0.231 × 4 185) ≈ 1.0 °C

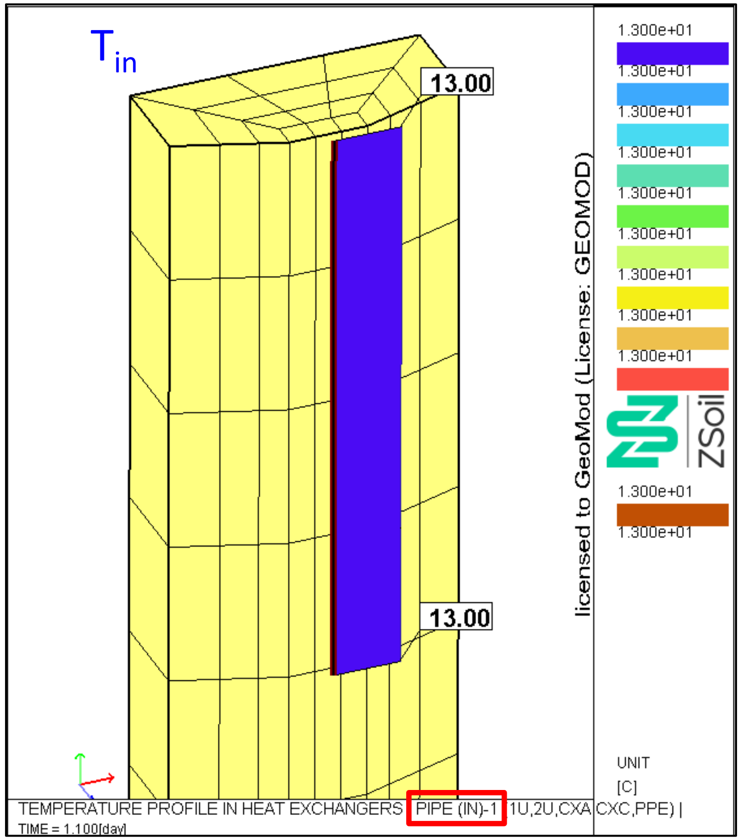
→ $T_{out} - T_{in}$ ≈ 1.0 °C

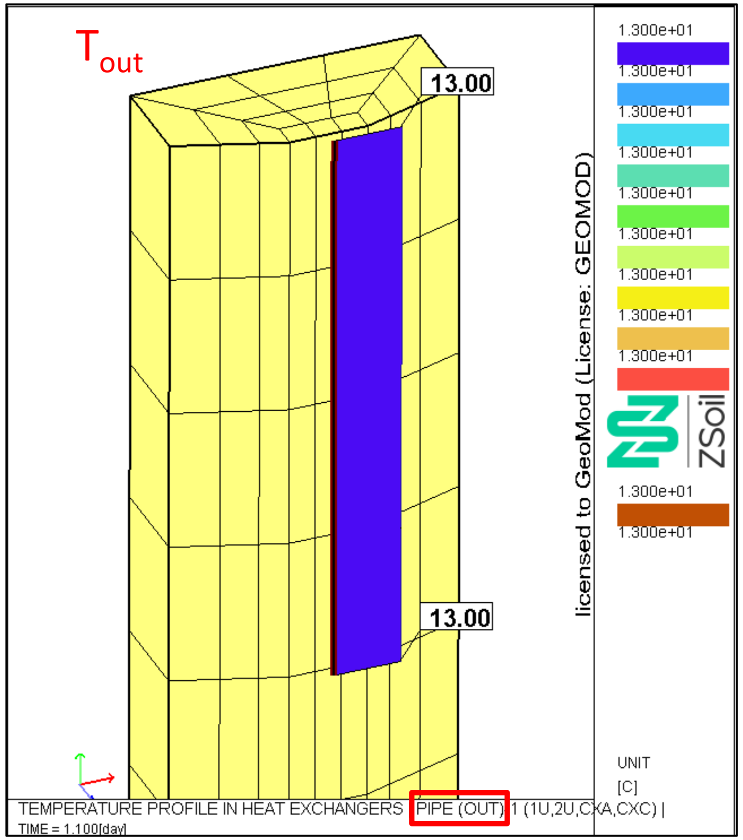
ZSoil example

Temperature soil = 13° (fixed at the external nodes)

With no flux (Q=0 W) :



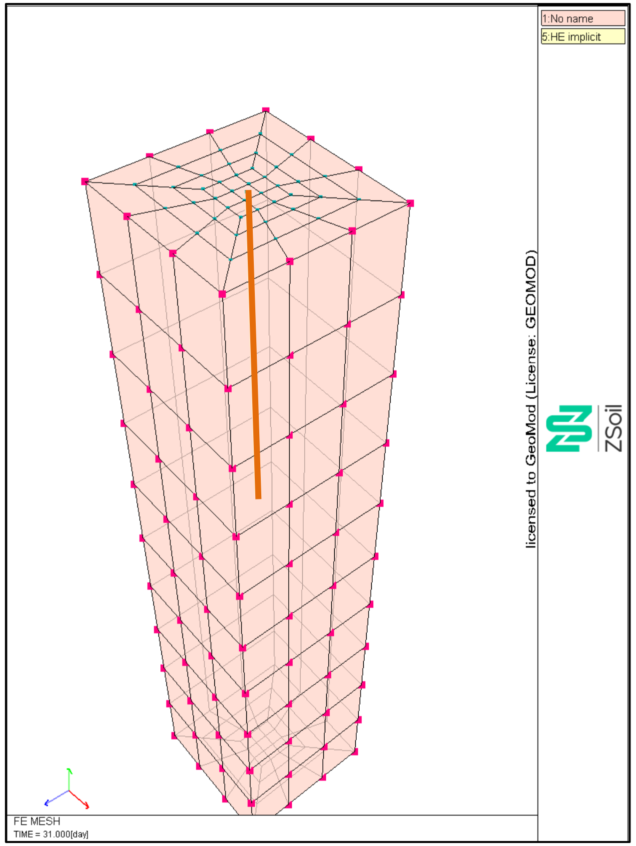


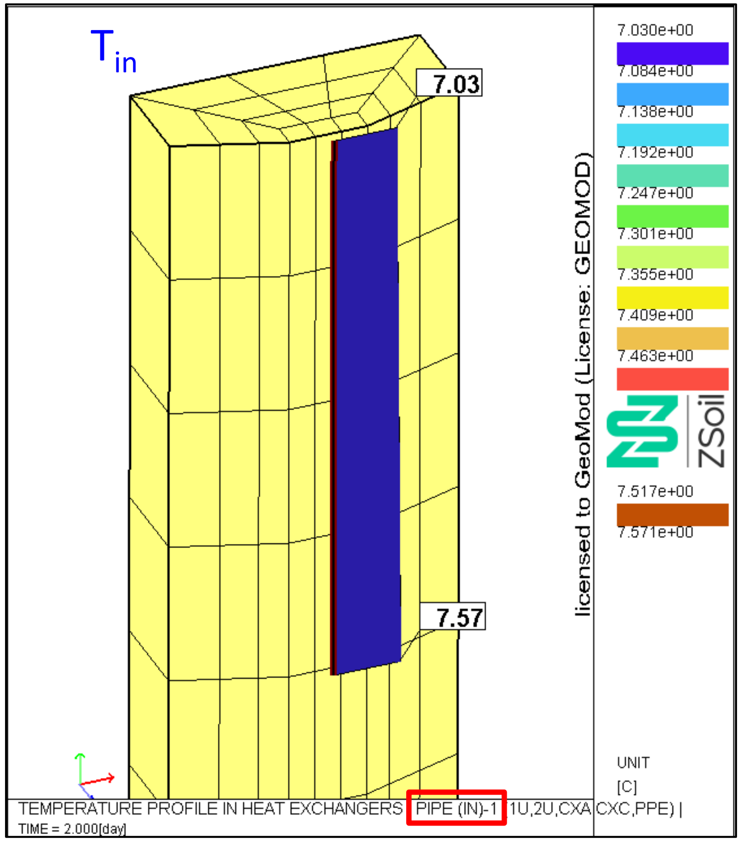


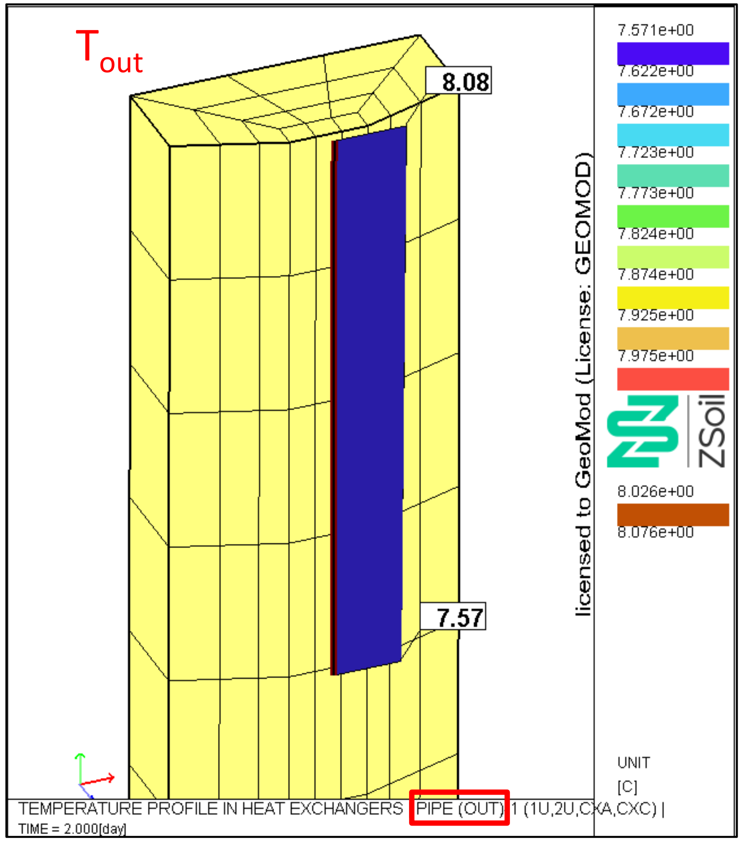
ZSoil example

Temperature soil = 13° (fixed at the external nodes)

With a constant flux (Q=1kW) :



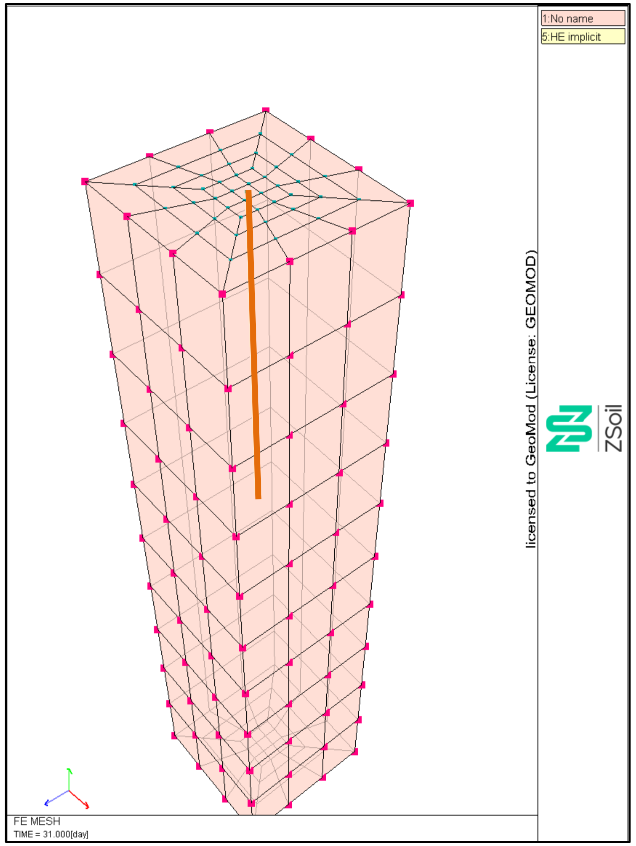


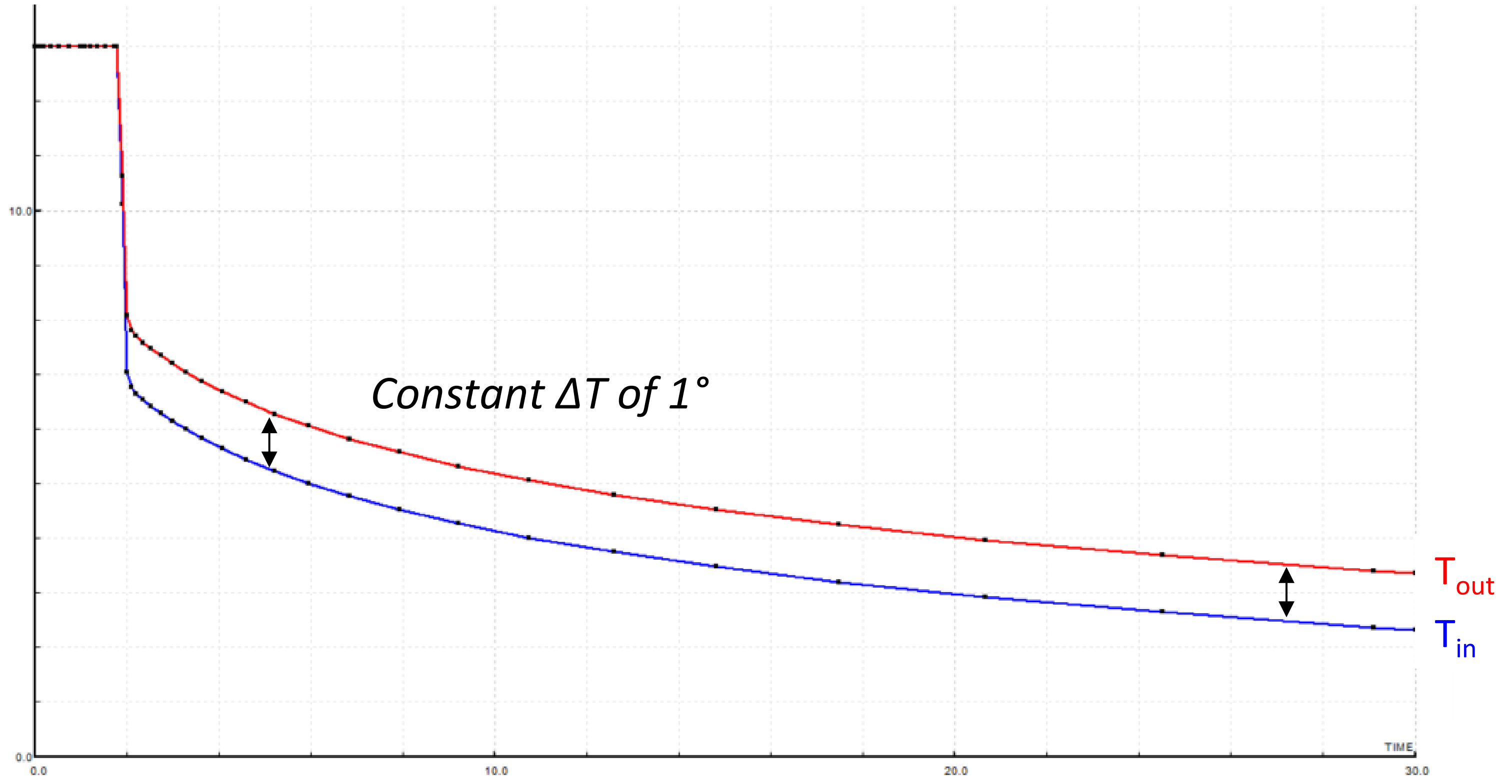


ZSoil example

Temperature soil = 13° (fixed at the external nodes)

With a constant flux (Q=1kW) applied 30 days:





Aim of the thermal model

2 items in Swiss norms SIA :

- temperature of the fluid should stay positive after 50 years
- mean temperature of the soil and ground water should not too be modified from the initial one (different values for ΔT, from 1° to 3°)

+ help in the design the field of BHE : e.g. adding heat exchangers when building piles costs a lot of time

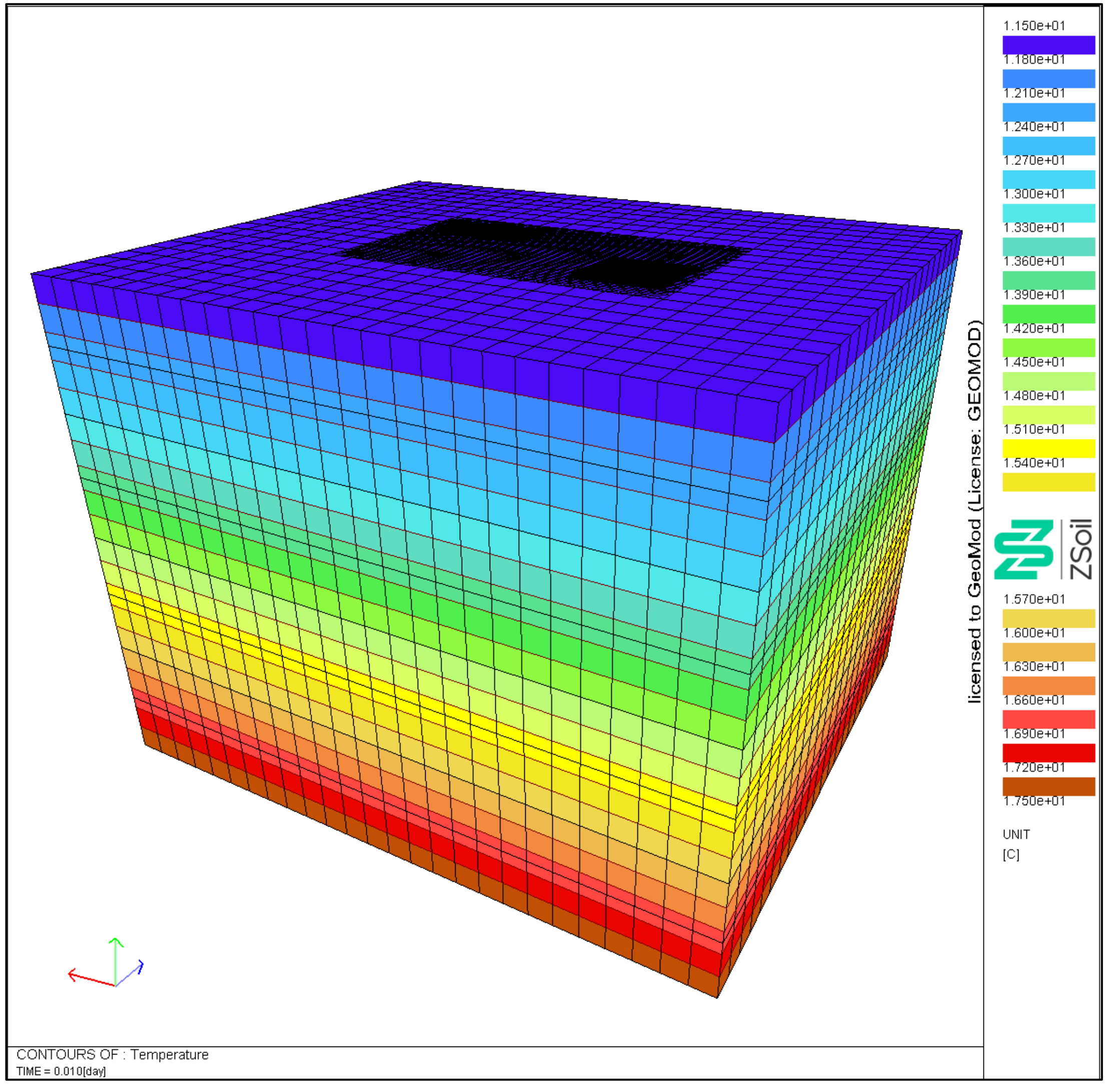
Remark : this models only the thermal aspects (no hydraulic consideration etc…)

ZSoil model : setup

Ground, top = 11.5 °C

3°C / 100m

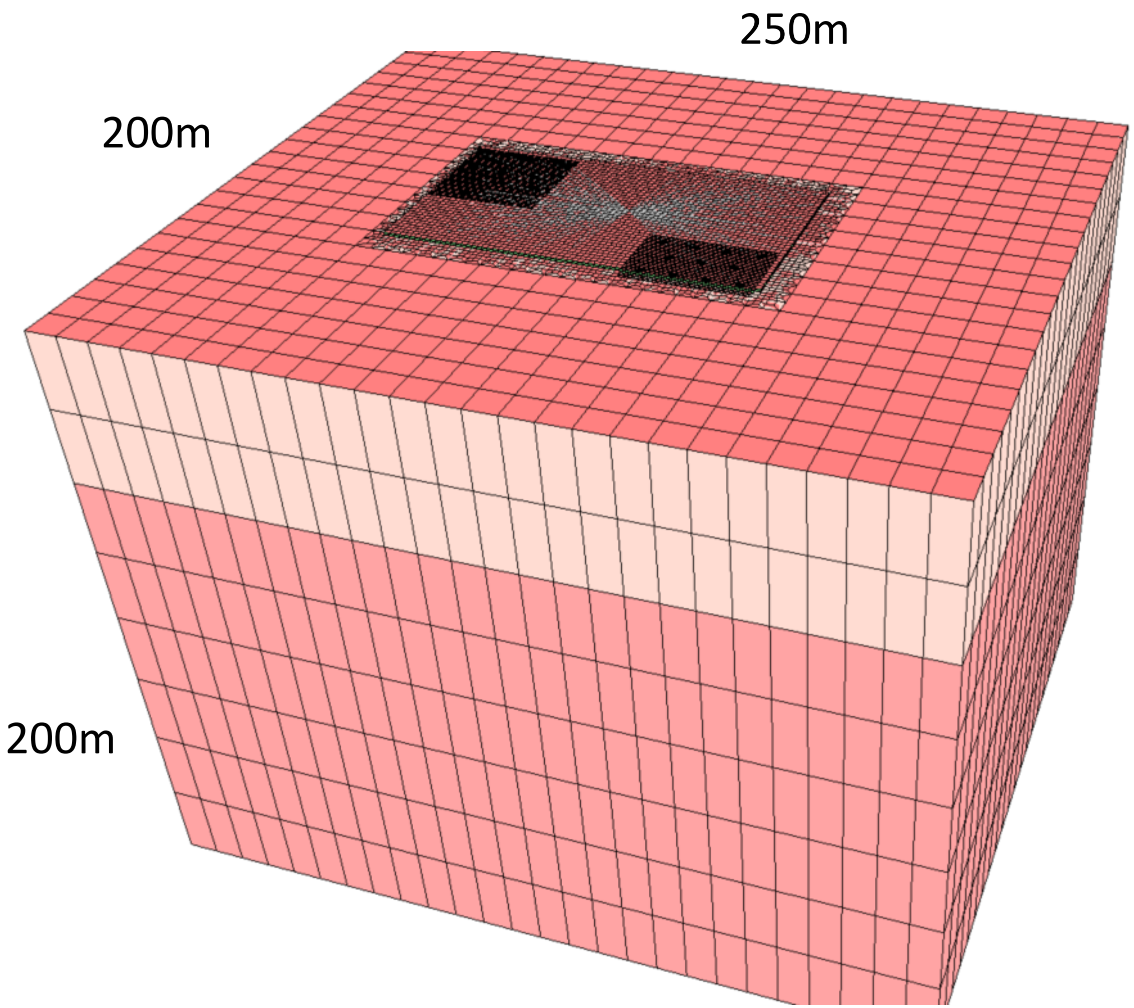
Ground, at 200m = 17.5 °C

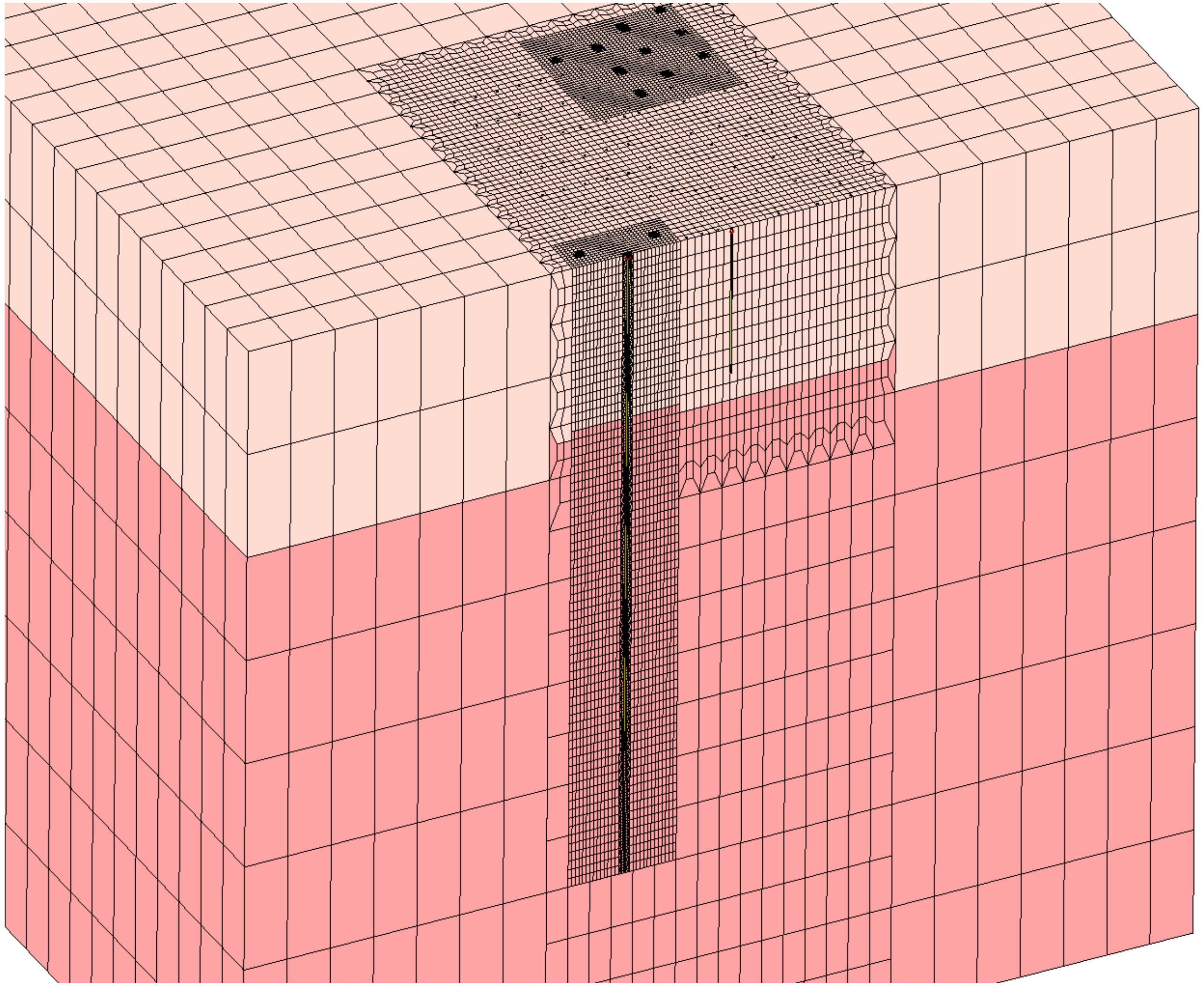


- BC on the external faces, with vertical gradient of -0.03°/m
- Initial temperature on box, with respect to the gradient
- Driver : initial state, then transient for 50 years

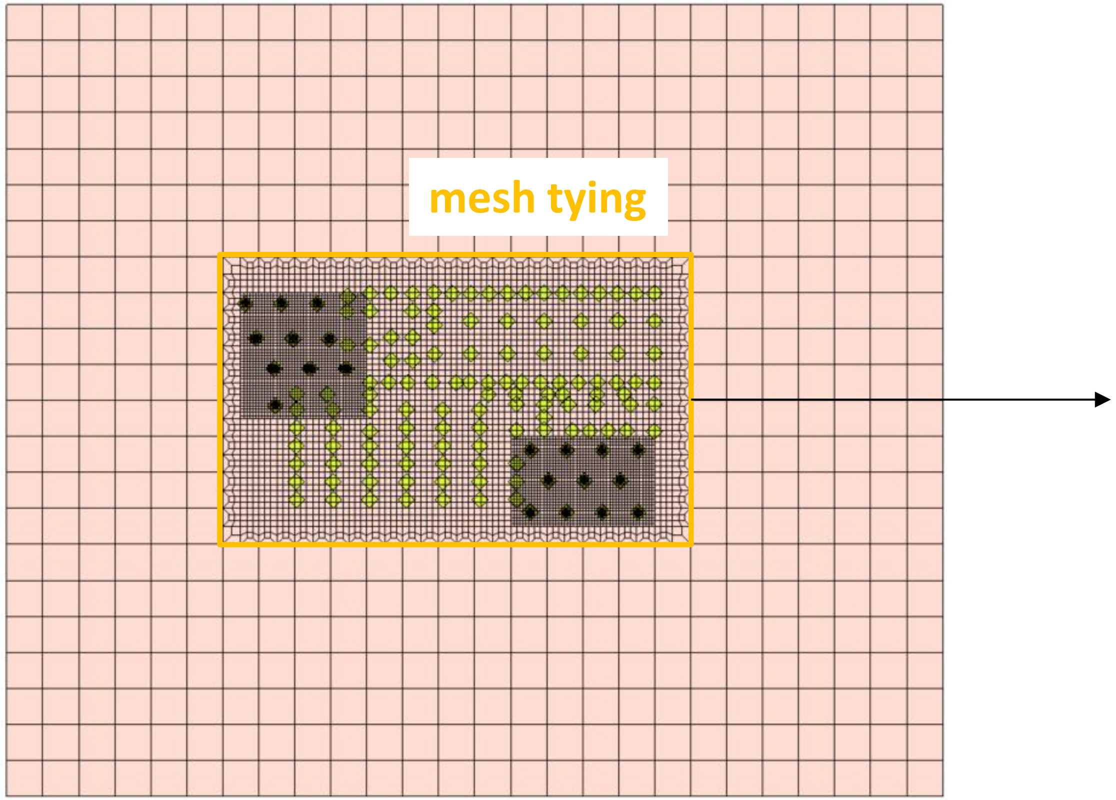
ZSoil model : focus on the mesh

550'000 elements … but computation is fast (2 iterations per time step)

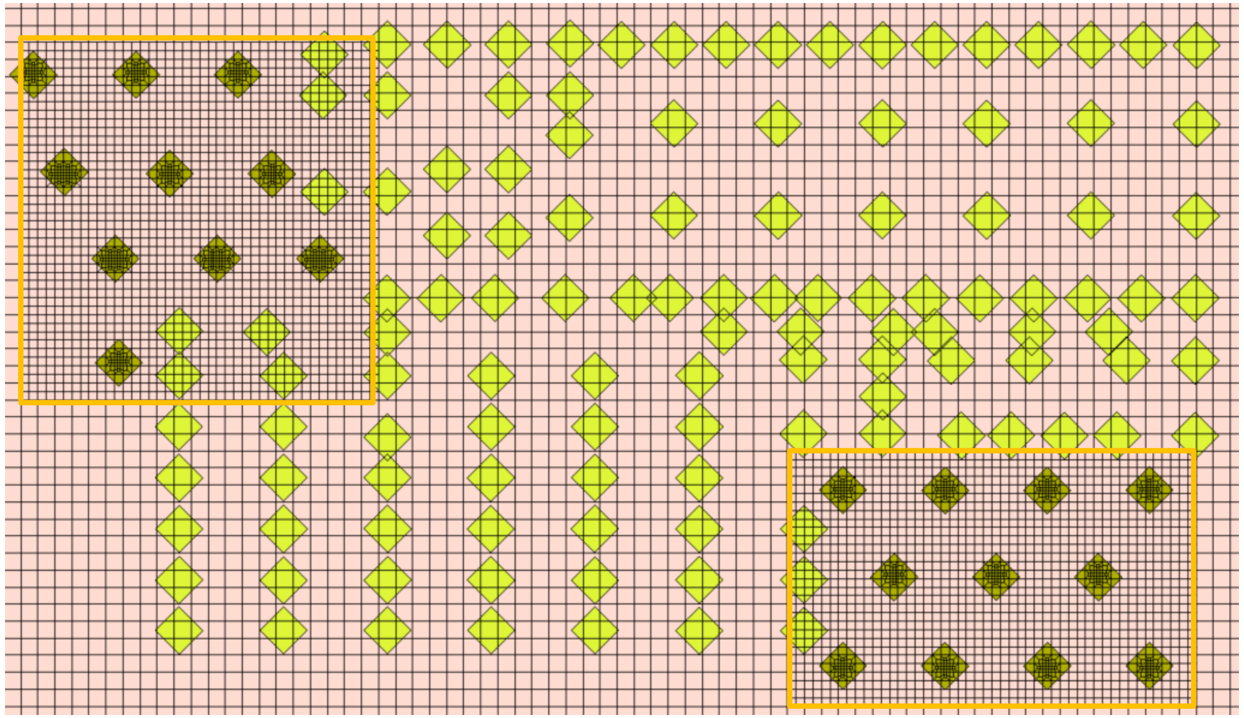


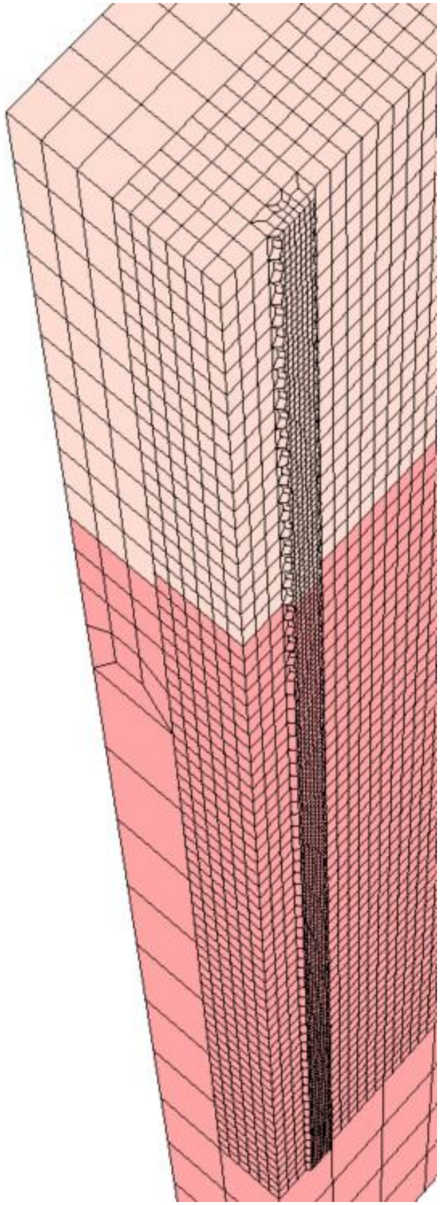


Outer zone :
10m*10m*25m



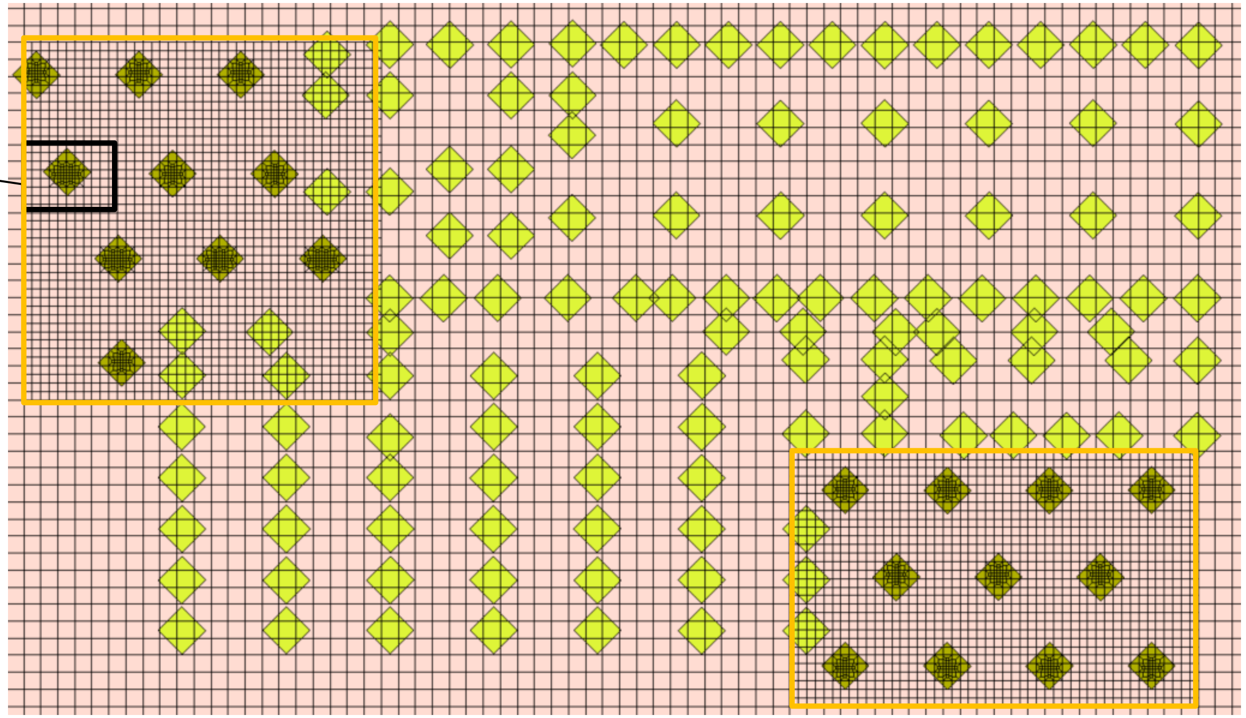
around piles :
1.6m*1.6m * 4m





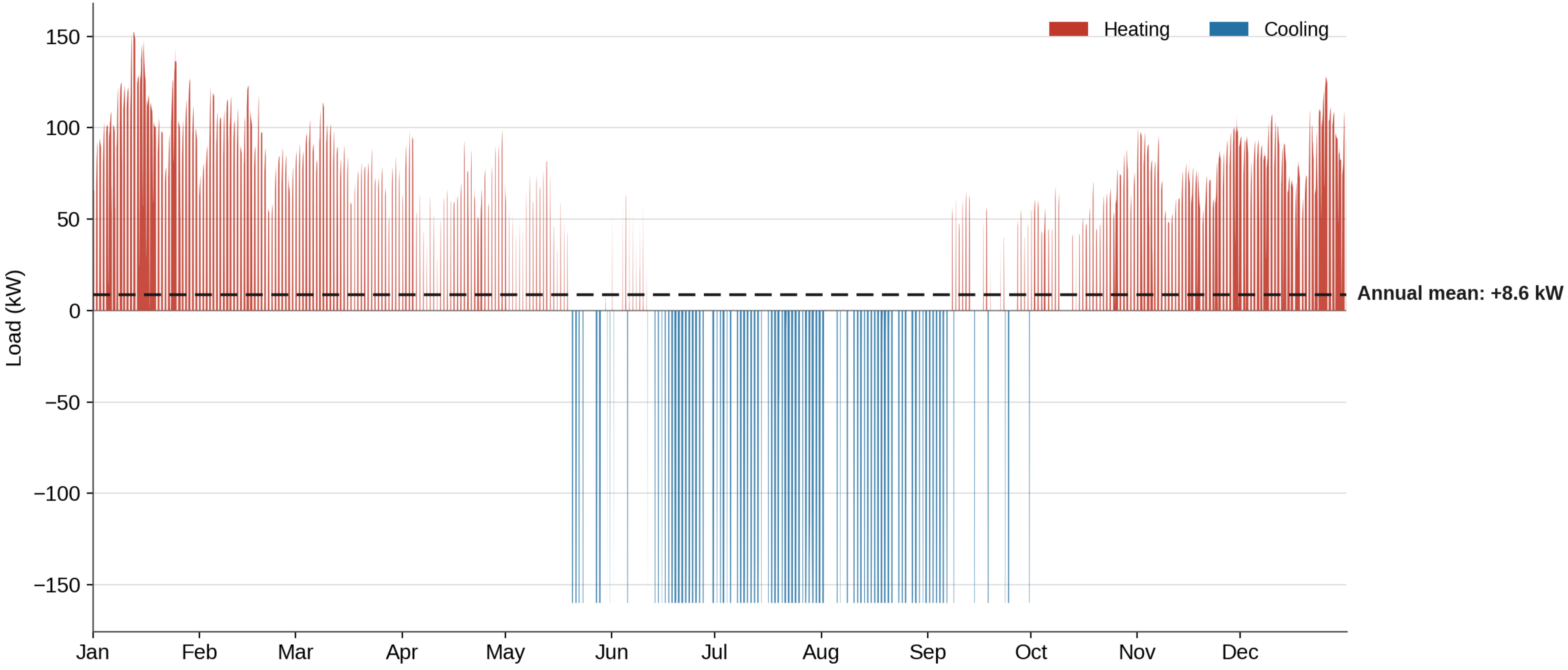
around BHE :
0.3m*0.3m*0.7m

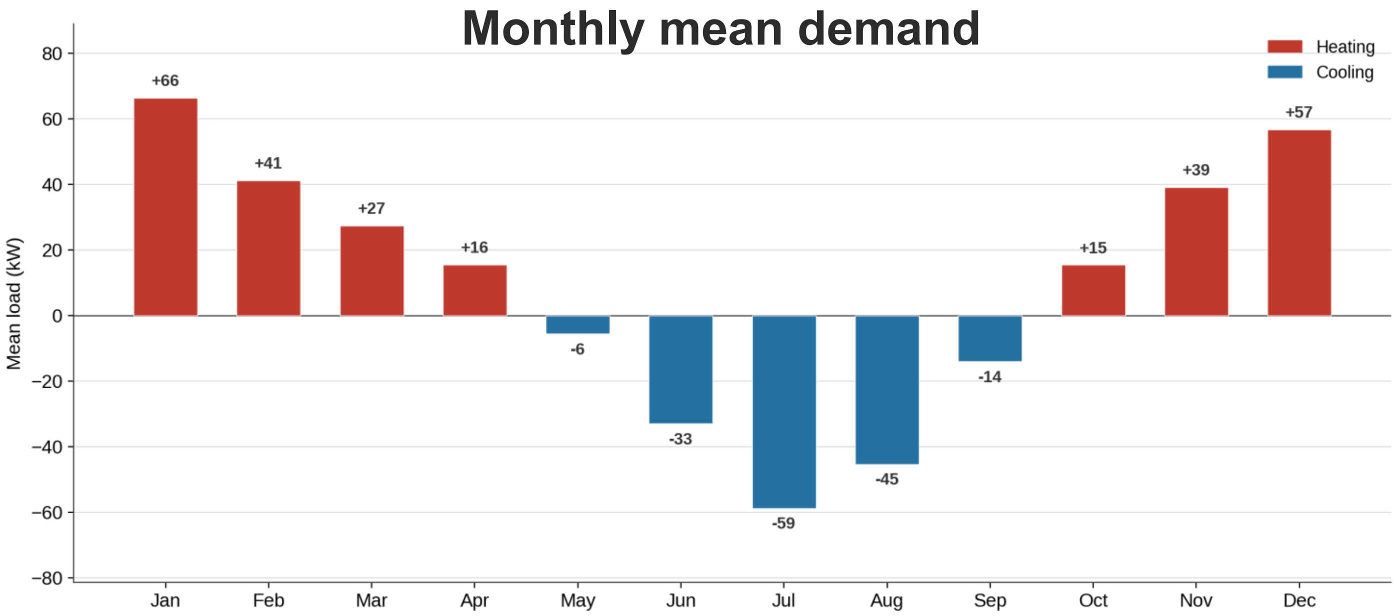
- mesh tying for the zone
- mesh refinement for each BHE

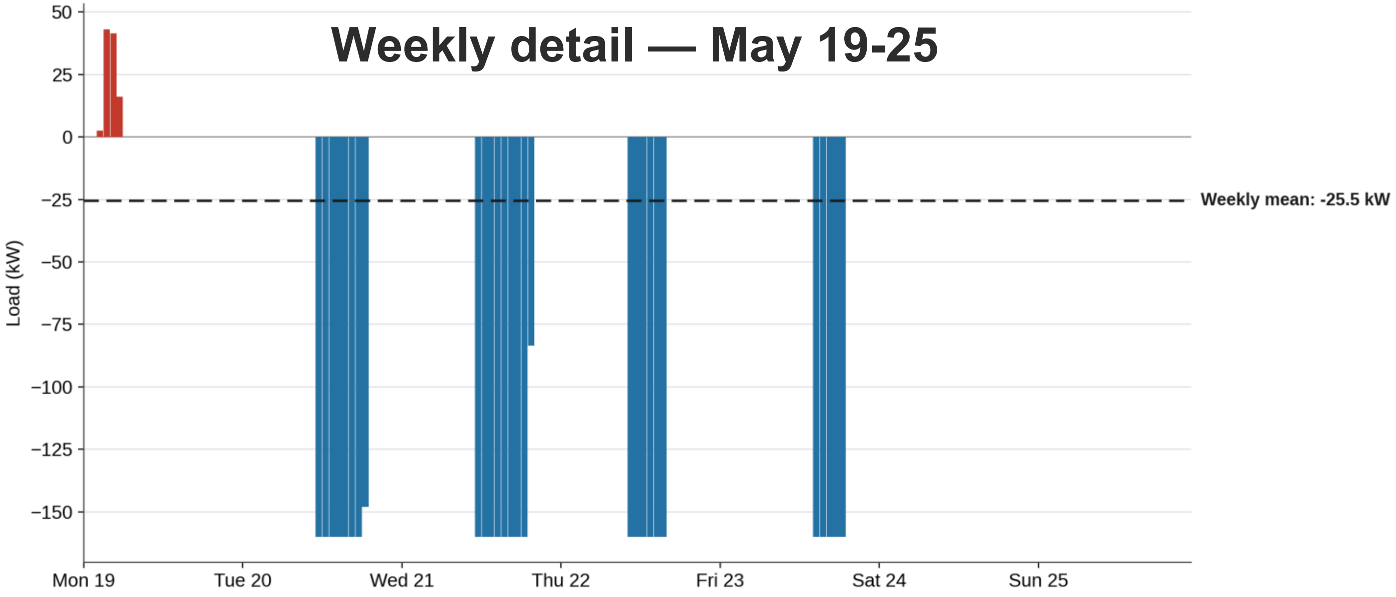


ZSoil model : time steps

- Initial state at T0 : usual gradient of temperature with depth
- BHE appear at T1 : circulation of fluid, without the heat pump (steady state)
- 50 years of transient analysis : the power of the heat pump varies throughout the year




Monthly mean demand
Heating
Cooling
Mean load (kW)
80
60
40
20
0
−20
−40
−60
−80
+66
+41
+27
+16
-6
-33
-59
-45
-14
+15
+39
+57
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

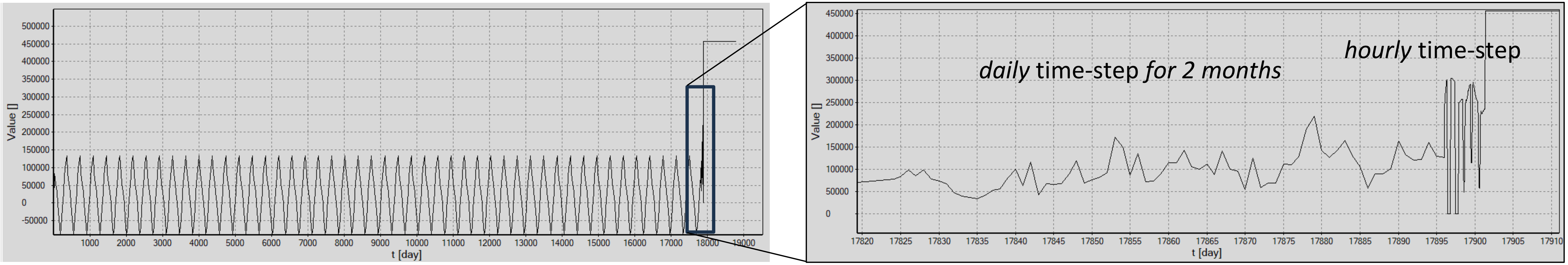

Weekly detail — May 19-25
Load (kW)
50
25
0
−25
−50
−75
−100
−125
−150
Weekly mean: -25.5 kW
Mon 19
Tue 20
Wed 21
Thu 22
Fri 23
Sat 24
Sun 25

ZSoil model : time steps

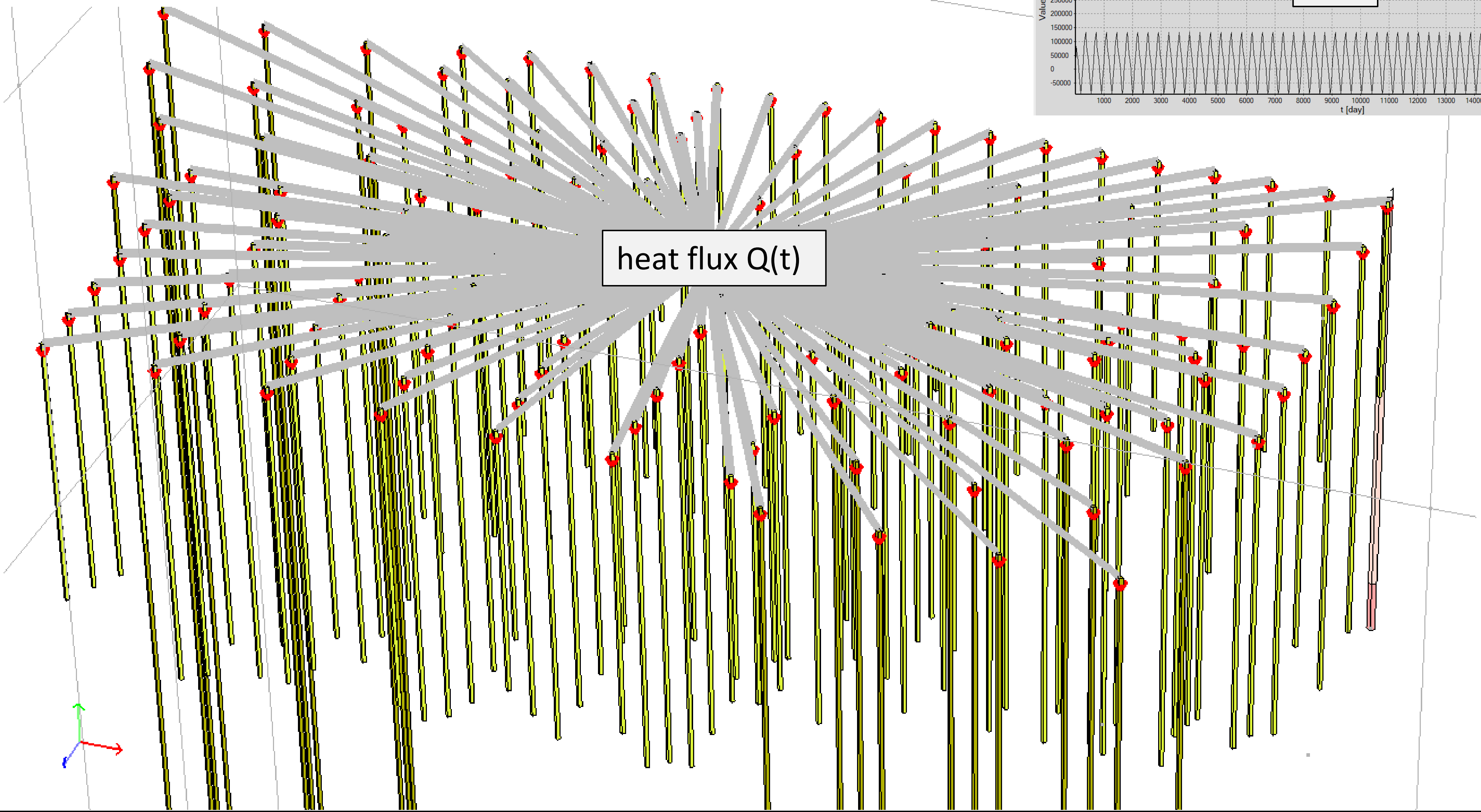
- Years 0 to 48 are not critical : the aim is to reach the correct average temperature field
- Year 49 : the minimum temperature is reached in winter

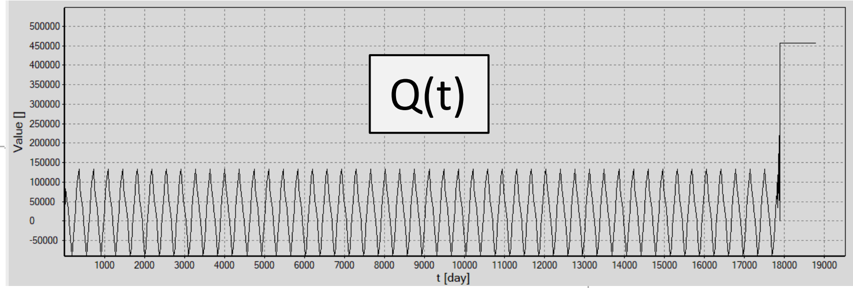
One time-step per month with the mean power

One time-step per week or per day for first tests, then when critical point is identified : 1 time-step per hour

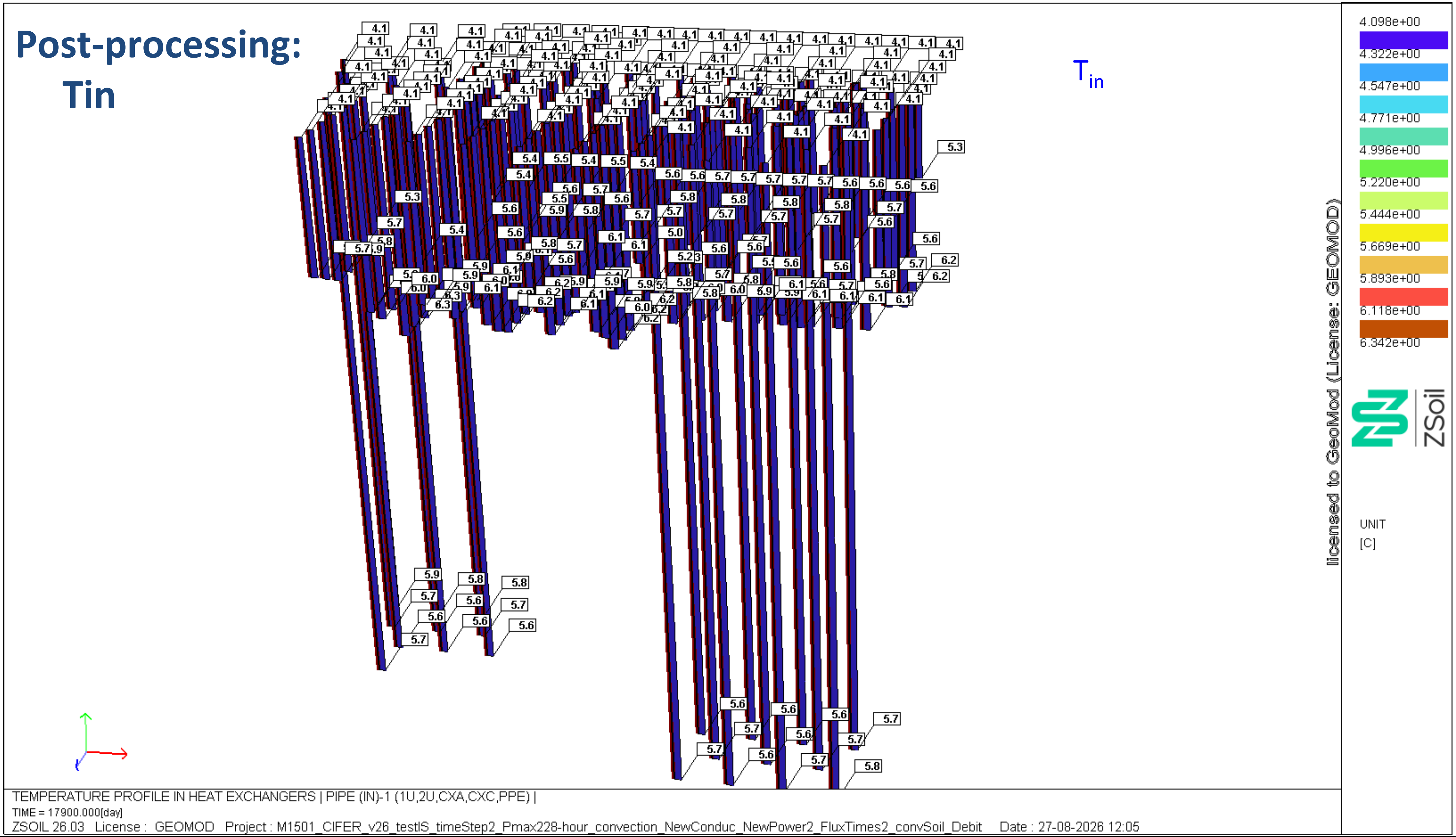


ZSoil model : heat fluxes in prepro



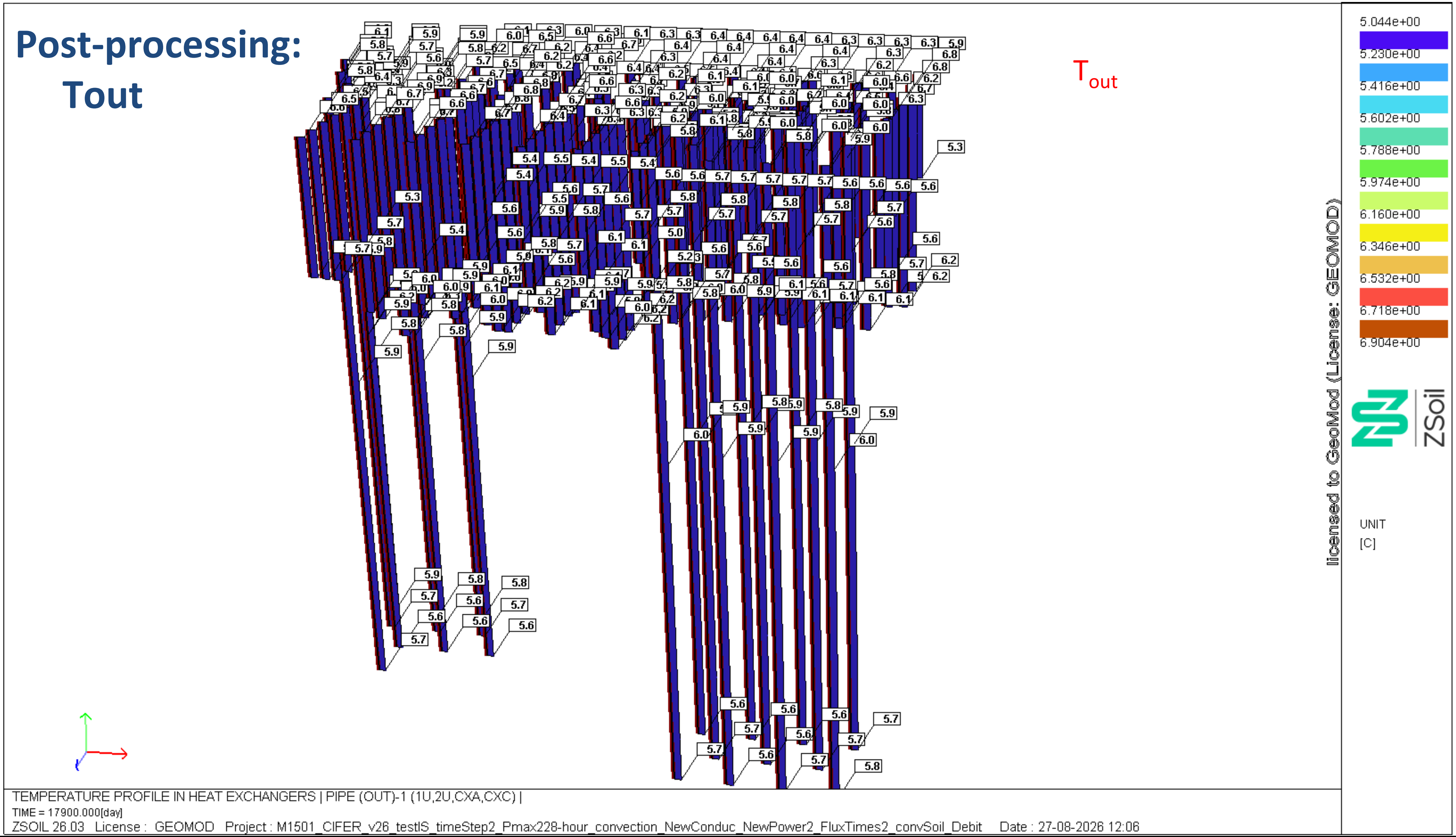


Post-processing:
Tin

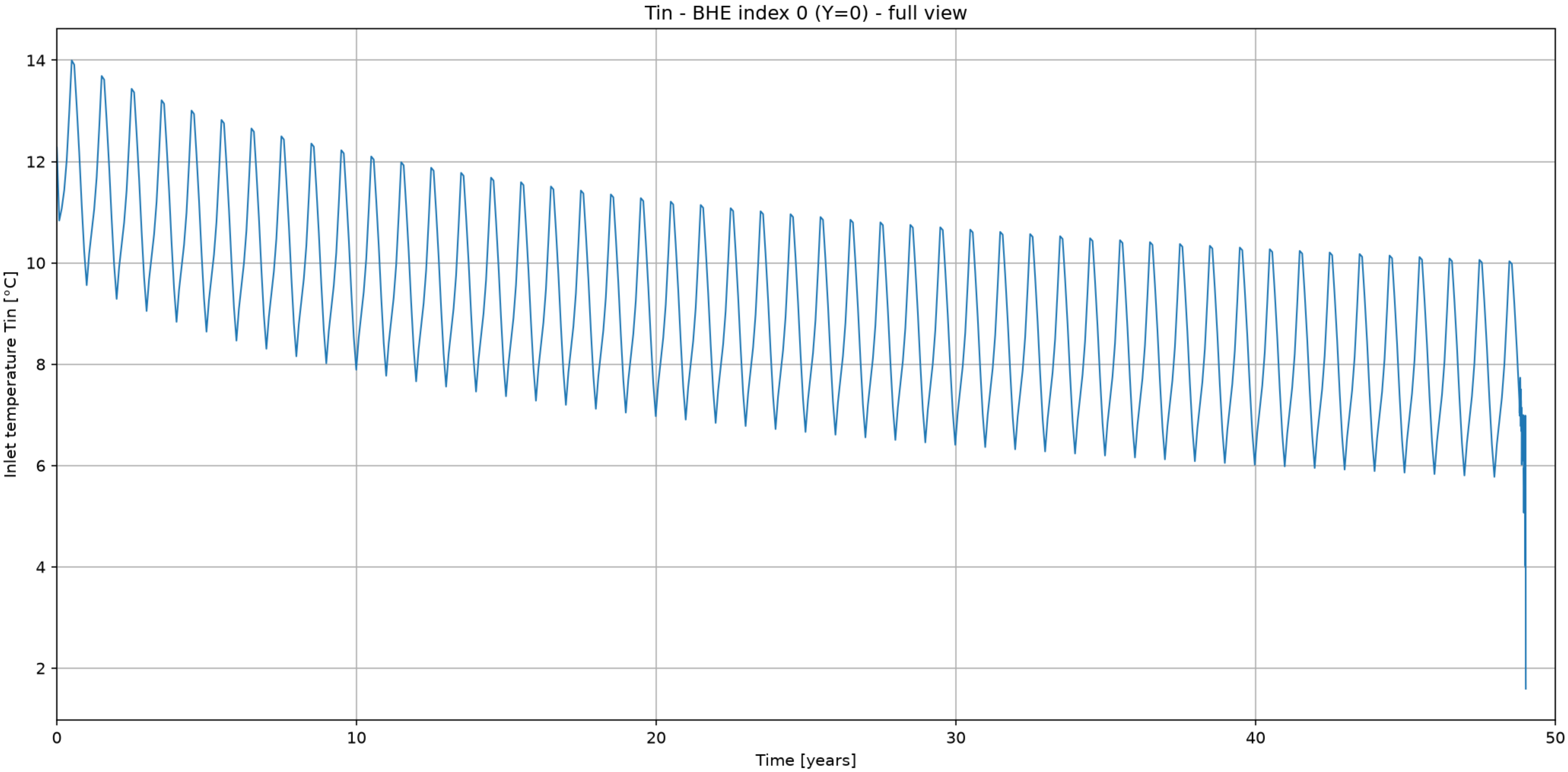


Post-processing: Tout

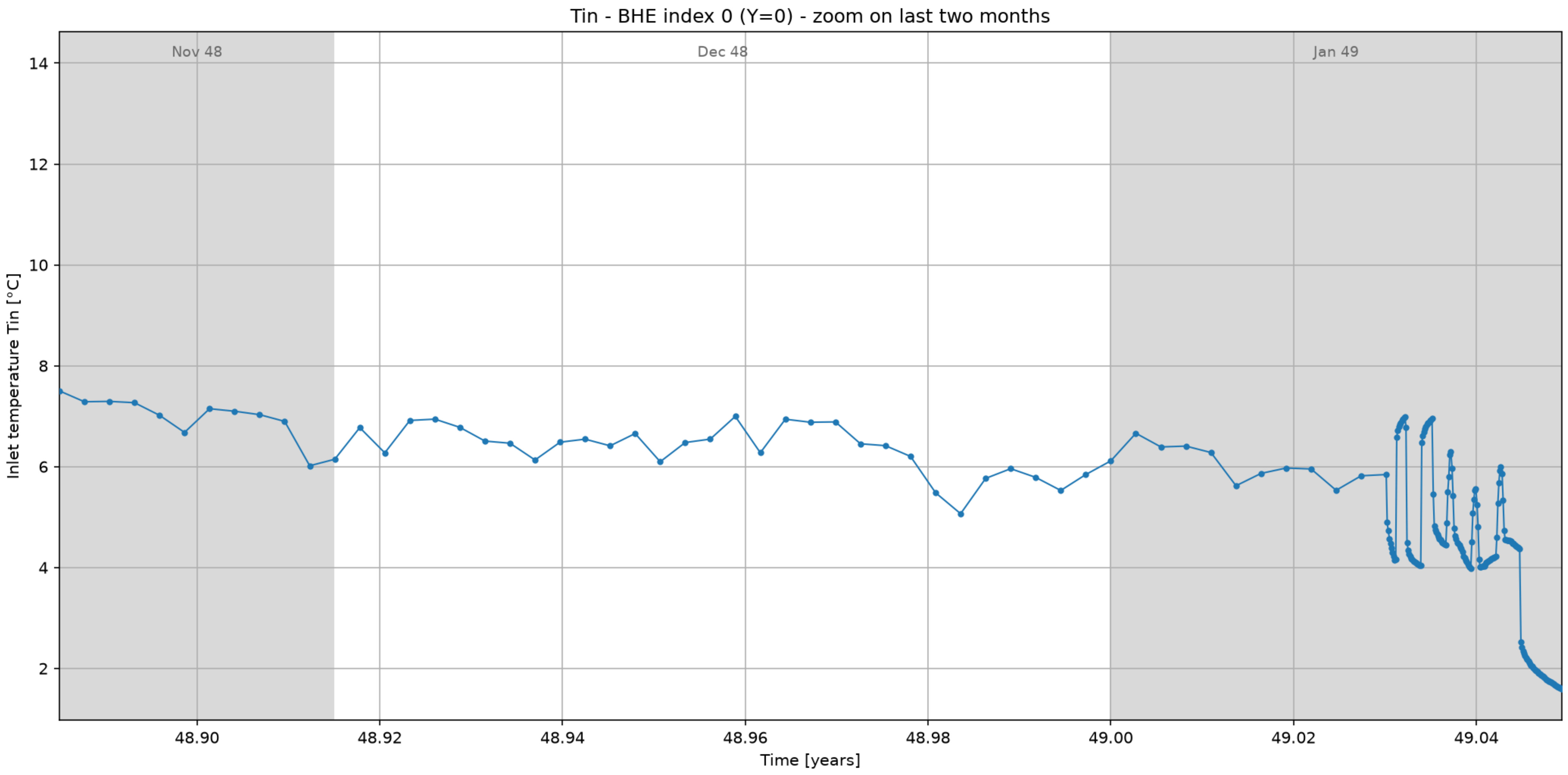
T_{out}



GEOMOD

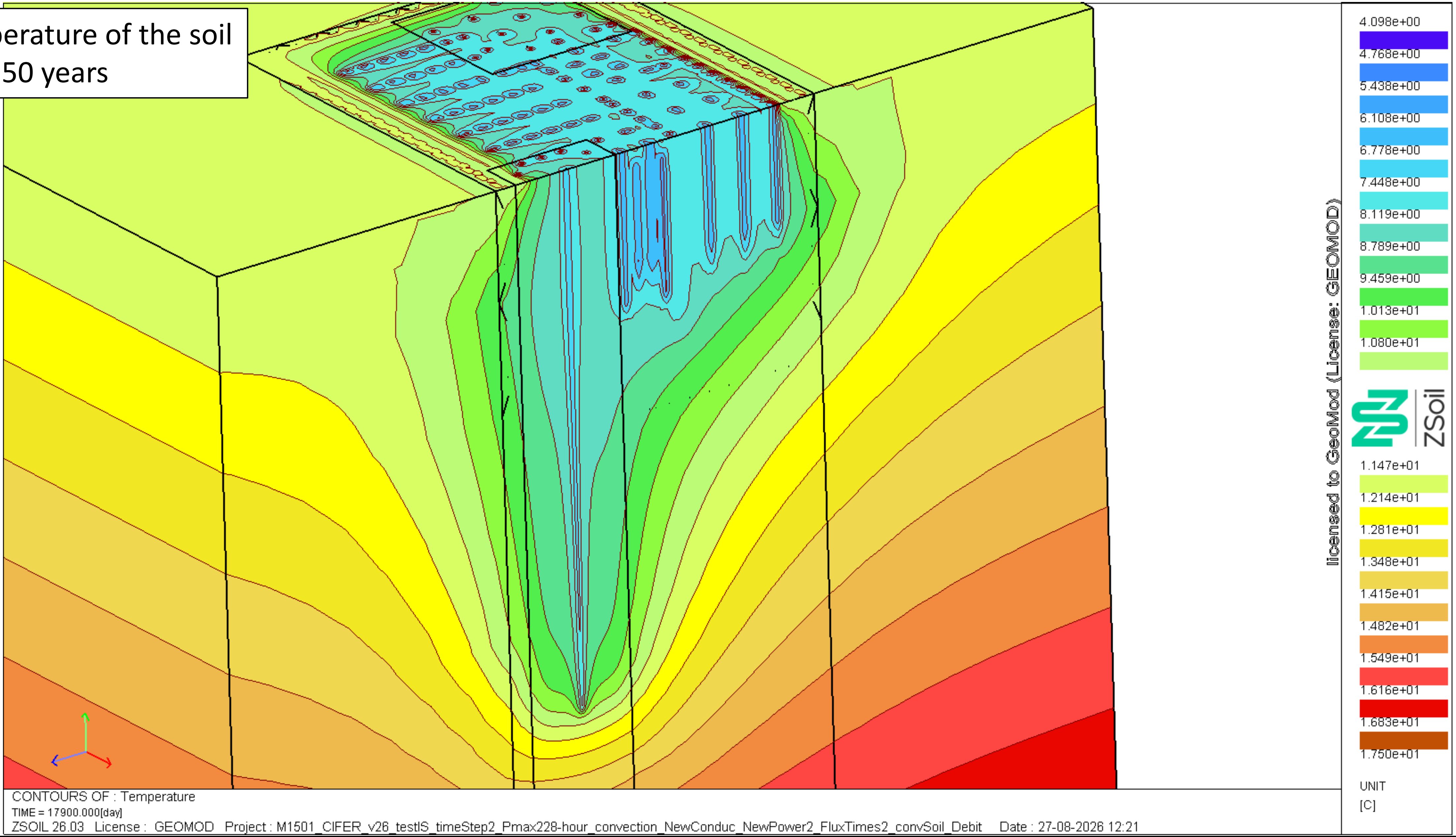


Tin of a heat exchanger

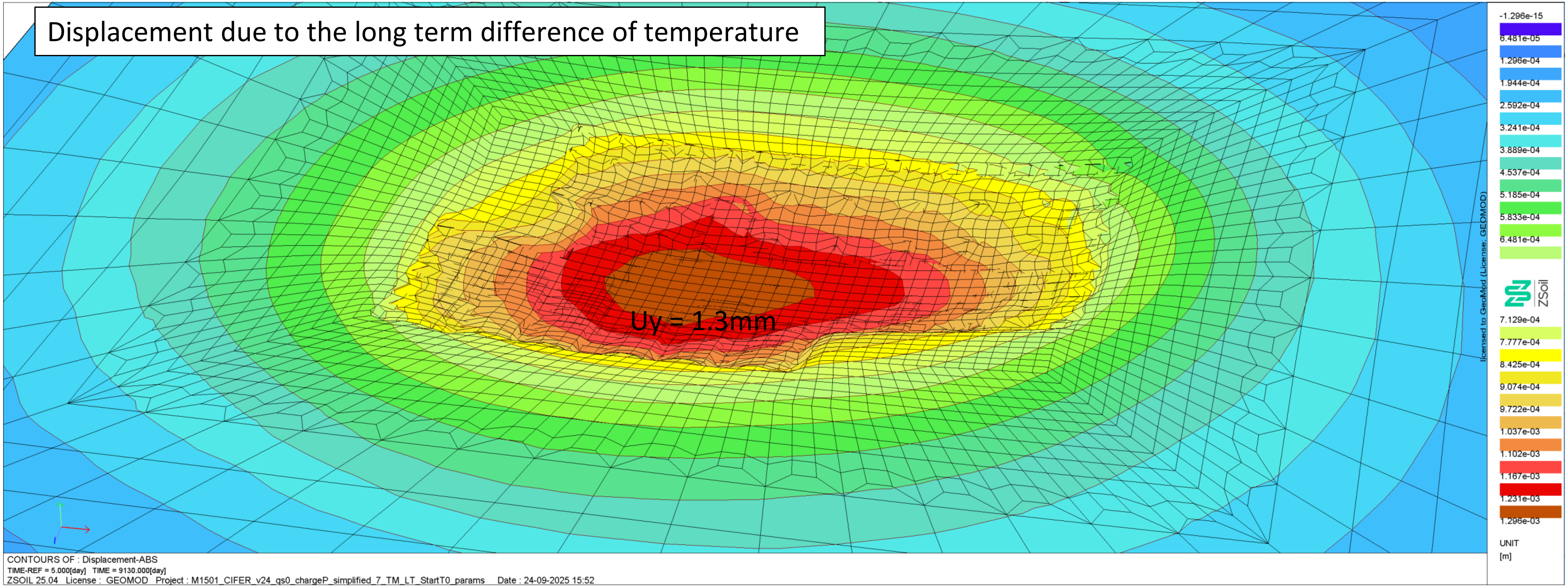


Tin of a heat exchanger : zoom on last iterations

Temperature of the soil after 50 years



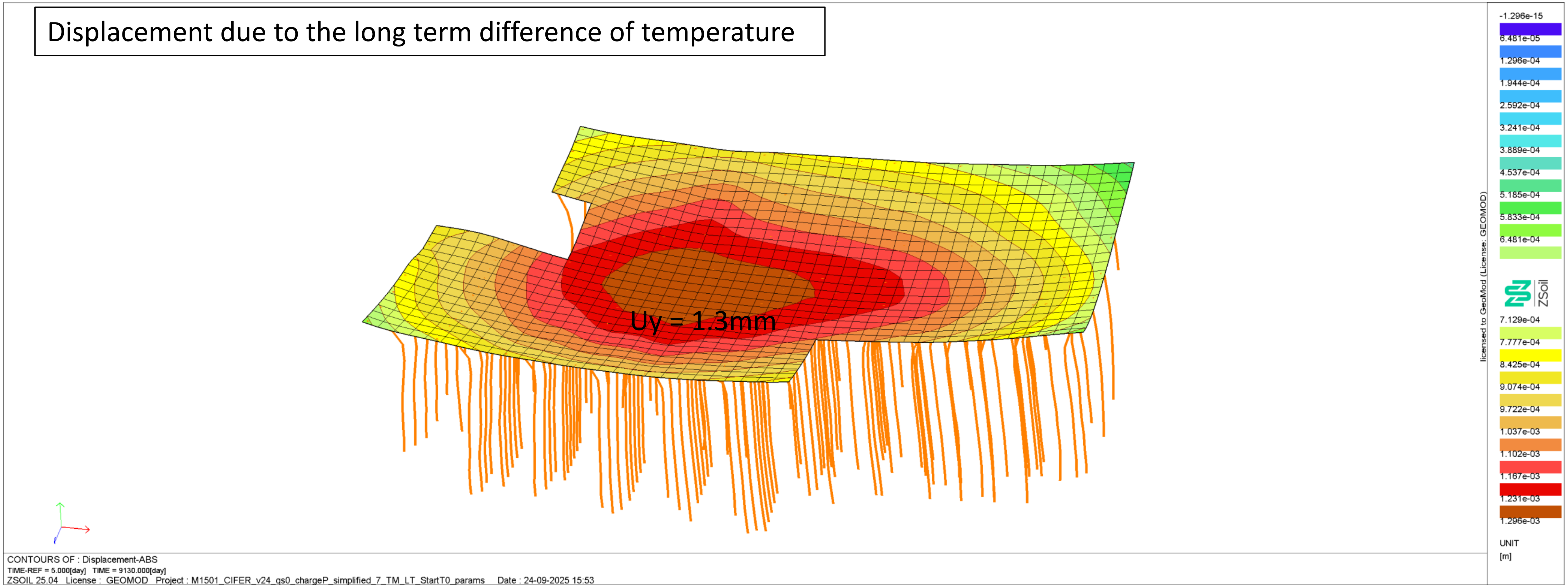
Thermo-mechanical model



For a pile D600 of 40m, with a ΔT=10° :

- maximal displacement : 4mm
- maximal normal force : 850kN

Thermo-mechanical model

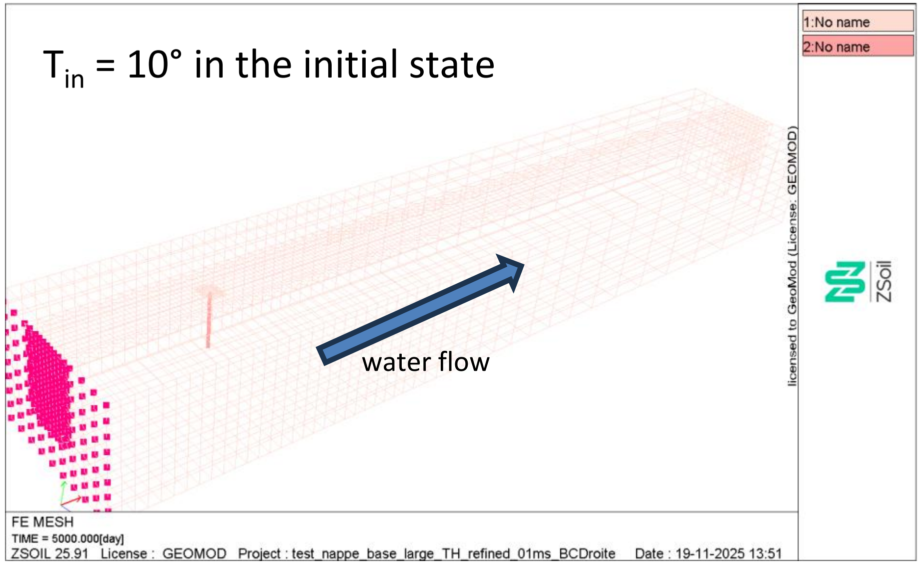


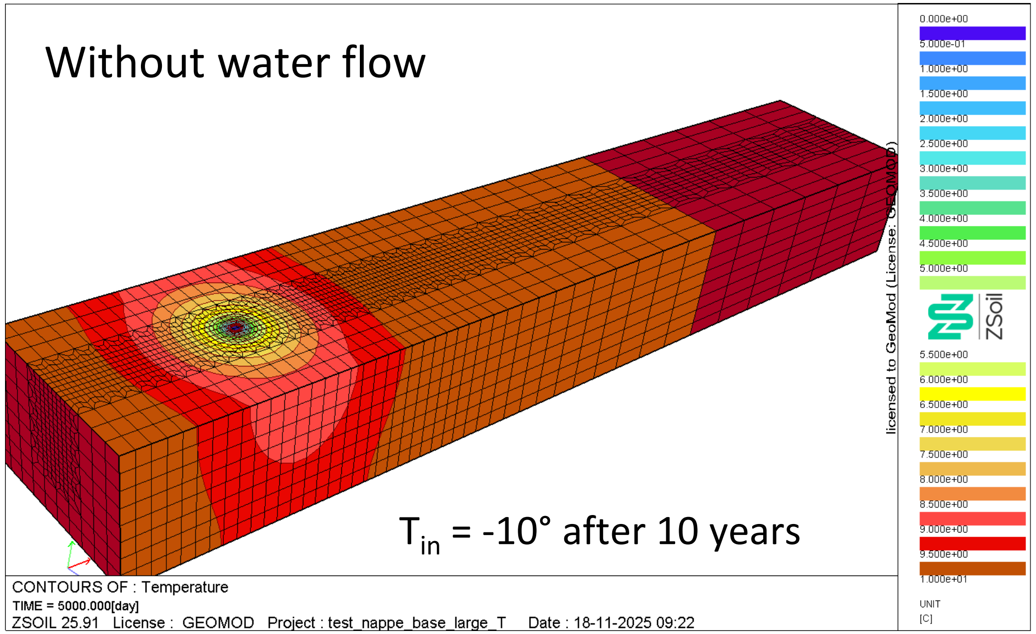
For a pile D600 of 40m, with a ΔT=10° :

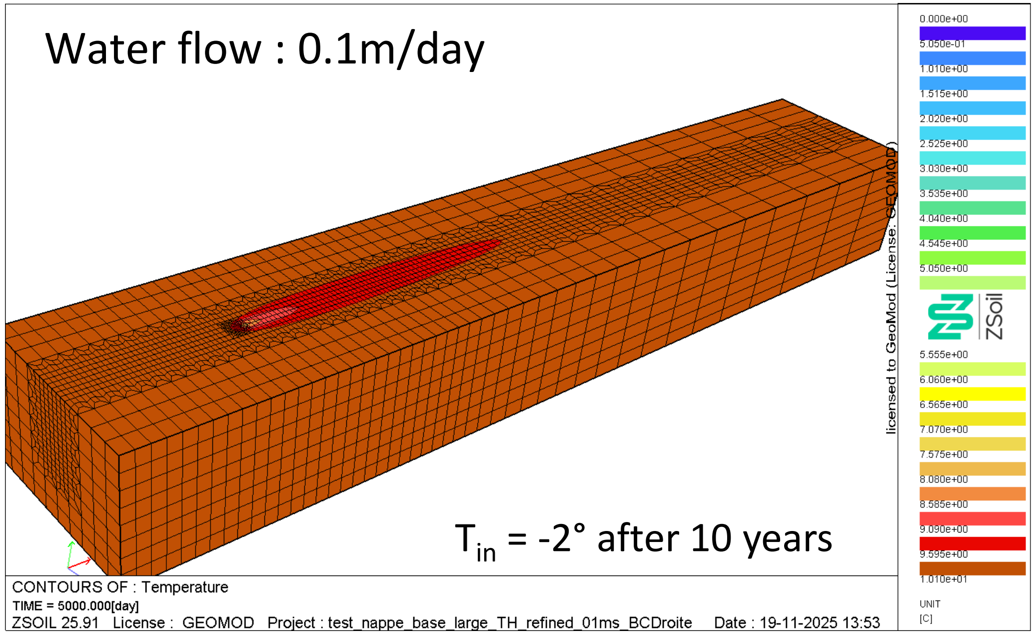
- maximal displacement : 4mm
- maximal normal force : 850kN

To go further :

Take into account the underground water flow







Key take-aways

- ZSoil covers the whole problem: settlement of ~150 piles, 50 years of heat extraction, and the resulting thermo-mechanical effects.
- The time-stepping strategy is the real design choice: monthly steps to build the correct mean temperature field, refined to hourly steps only around the critical winter period.
- it is always useful to test the implementation (load function, parameters of the BHE etc..) on a smaller model