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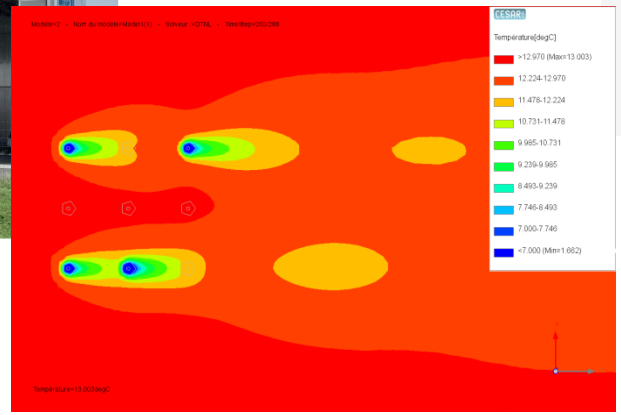

European Geosciences Union

EGU 2020 : Interactions between energy geostructures in the same aquifer

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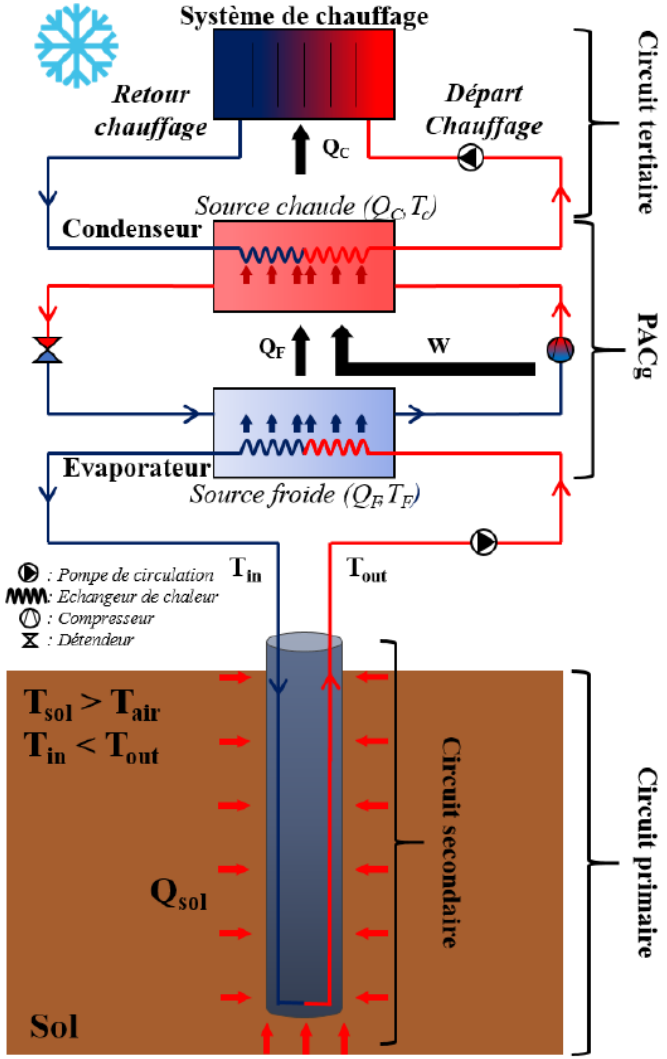
Energy Geostructures

- Geothermal energy is developing as a eco friendly source of energy



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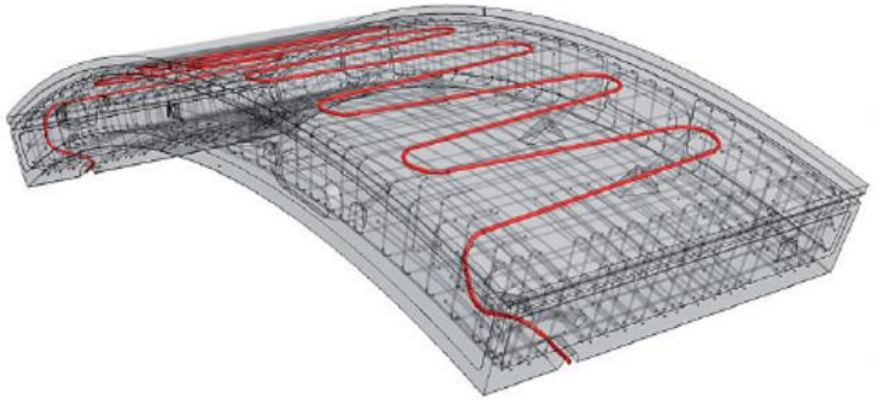
Energy Geostructures

- Geothermal energy is developing as an eco friendly source of energy
- Energy geostructure is a technical and economic solution for large development of geothermal installation
- Several methods developed
  - **Pile**
  - **Tunnel element**
  - **Retaining wall**
  - **Etc.**



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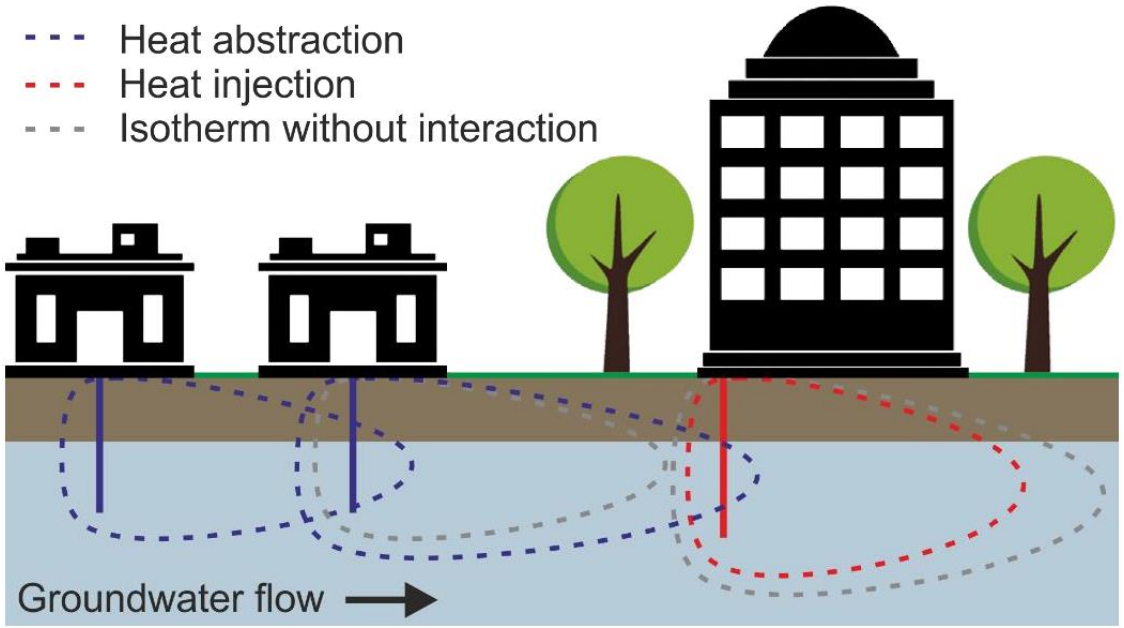
  - **Etc.**
- Interaction between structures



Sense City, a 400 m² test facility

Small city with controlled environment

- Temperature
- Rain / Sun
- Humidity
- Pollution
- Ground water level and displacement

Place for many experiments :

- Building thermal efficiency
- City pollution
- Sensor testing
- Etc.

► Energy geostructures

Energy geostructures installation

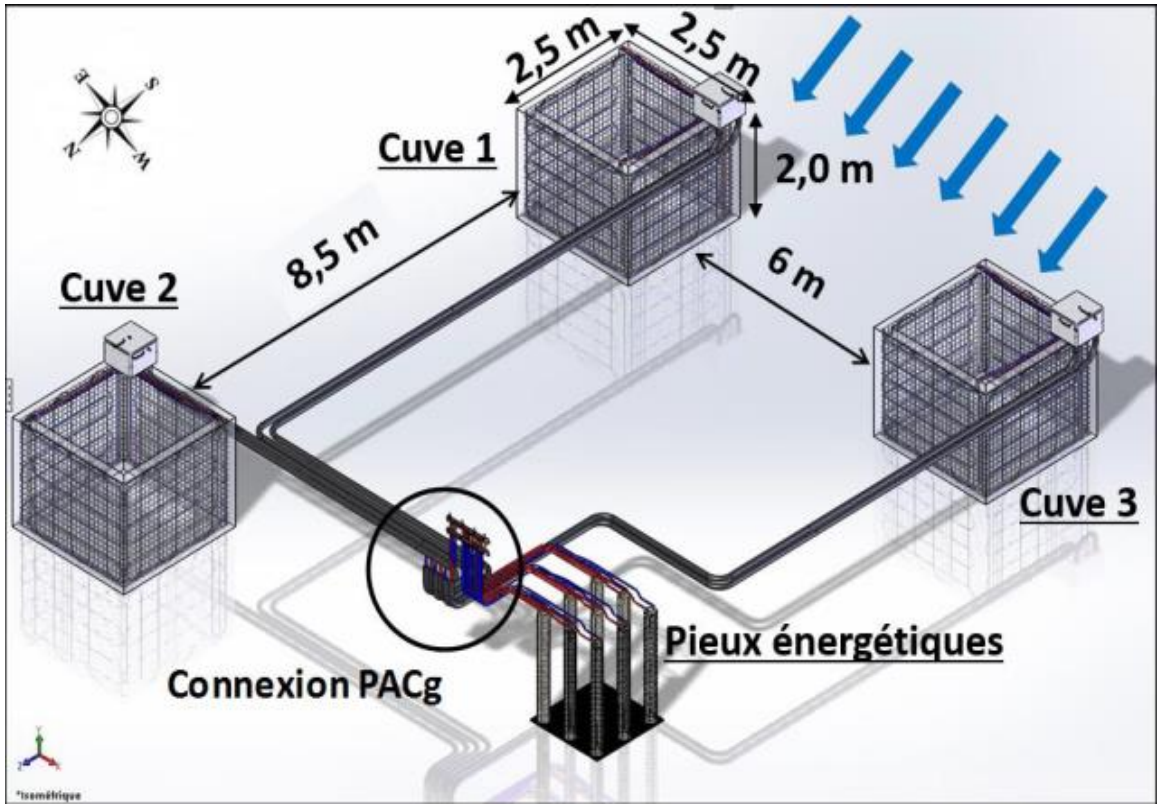
Underground installation :

- 3 cubic retaining wall models
- Group of 9 energy piles

►Independent structures

Instrumentation:

- Optical fibres along the structures
- Conventional sensors
  - **Heat pump fluid**
  - **Piezometric tubes**
  - **Outside of the buildings**
  - **Etc.**



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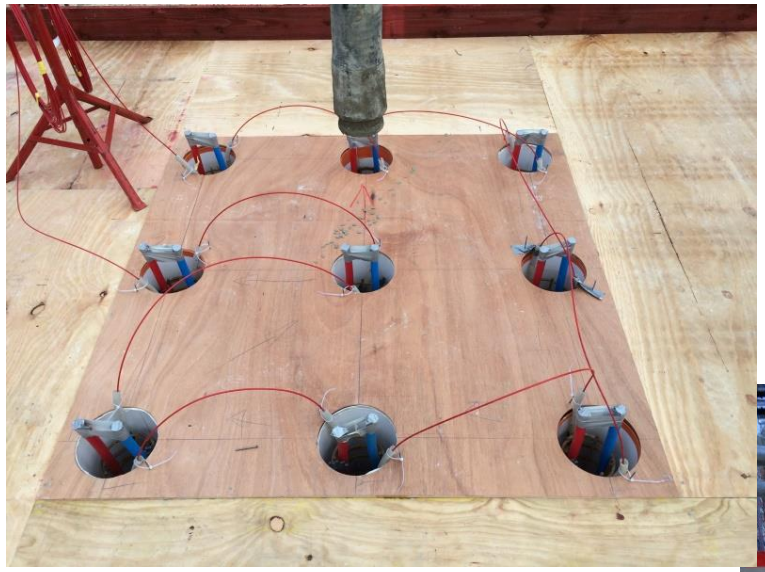
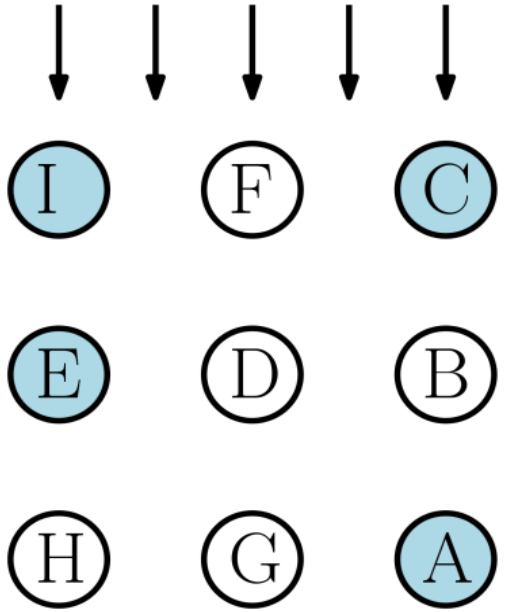


Experiment

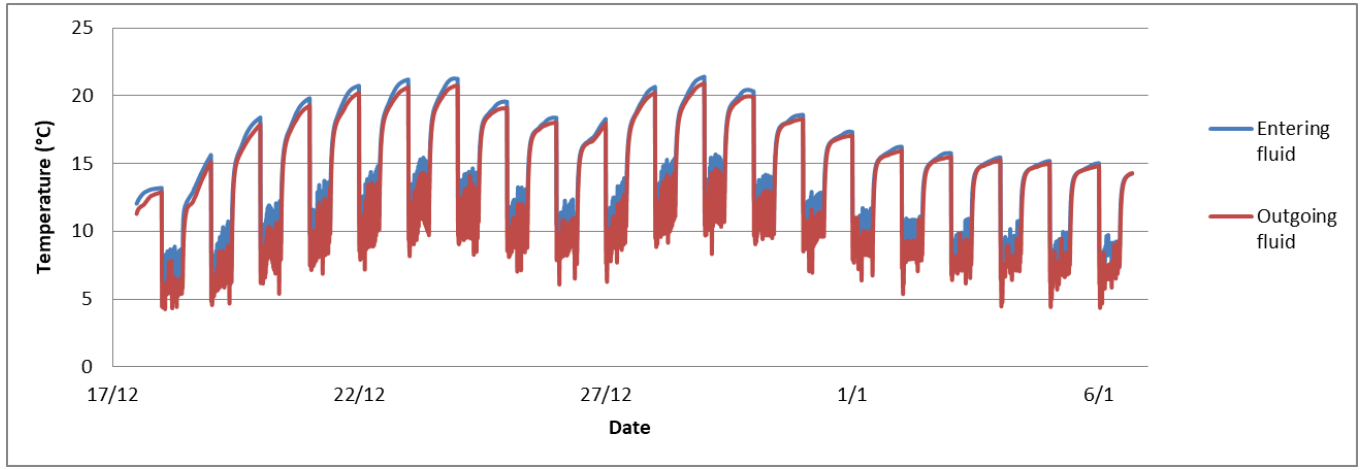
Experiment parameters

- One cube and four piles activated
- Daily cycle of 10h activation
- 1120 W of pumped power
- 1,5 m/day ground water flow speed
- No outside temperature imposed (system failed)



Measurement

- Constant recording of:
  - **Heat pump fluid temperature**
  - **Room temperature**
  - **Outside temperature**
  - **Ground temperature**
- Optical fibres measurement every 4 h



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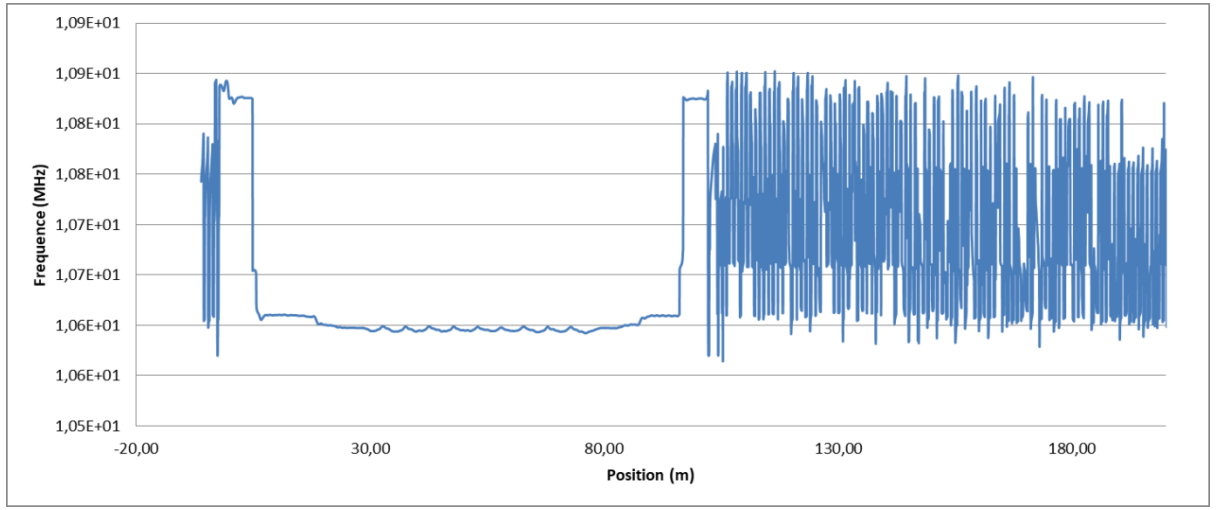
First results

- Fibre measurements of temperature along the piles.



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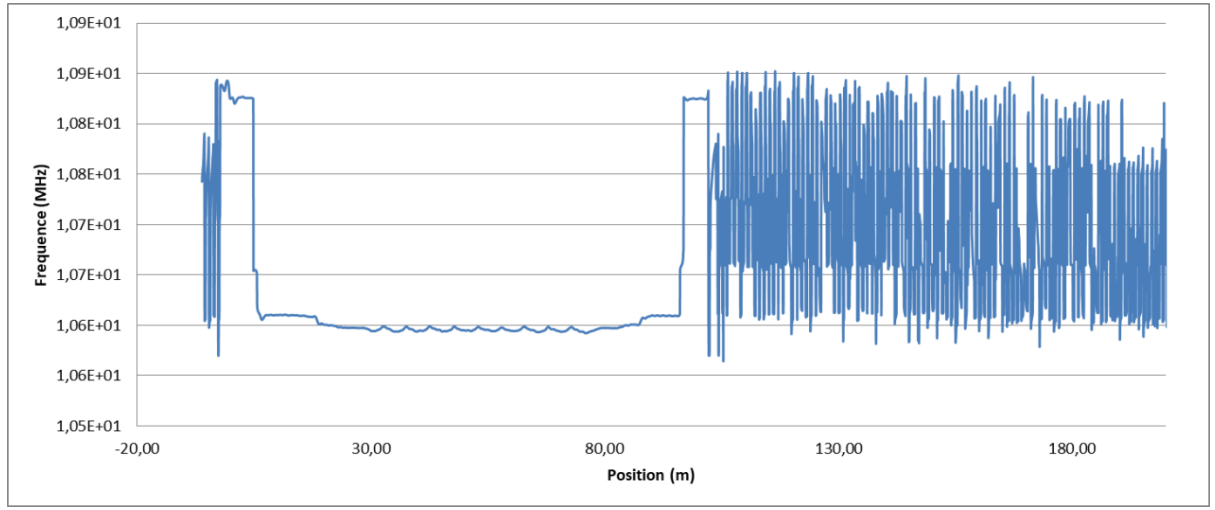

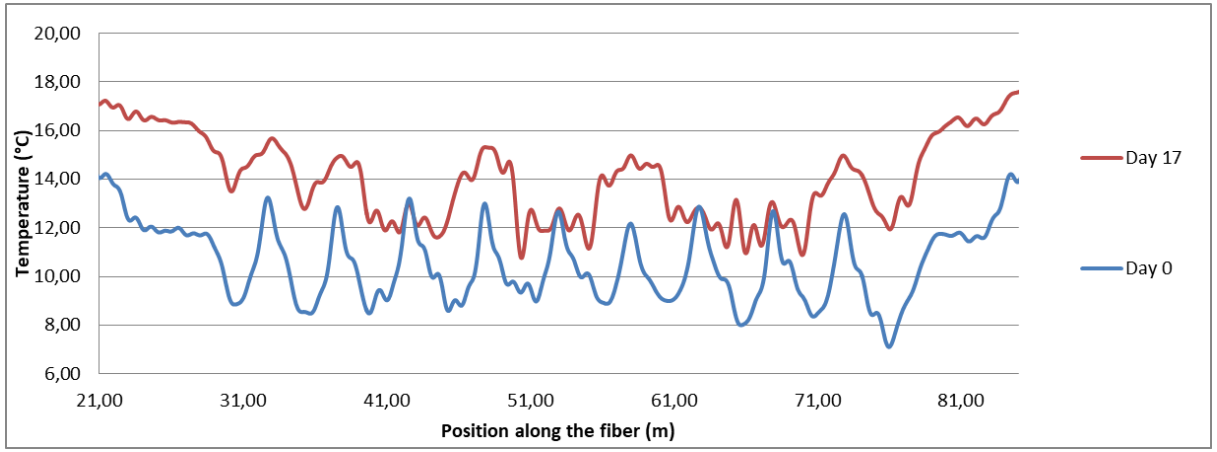

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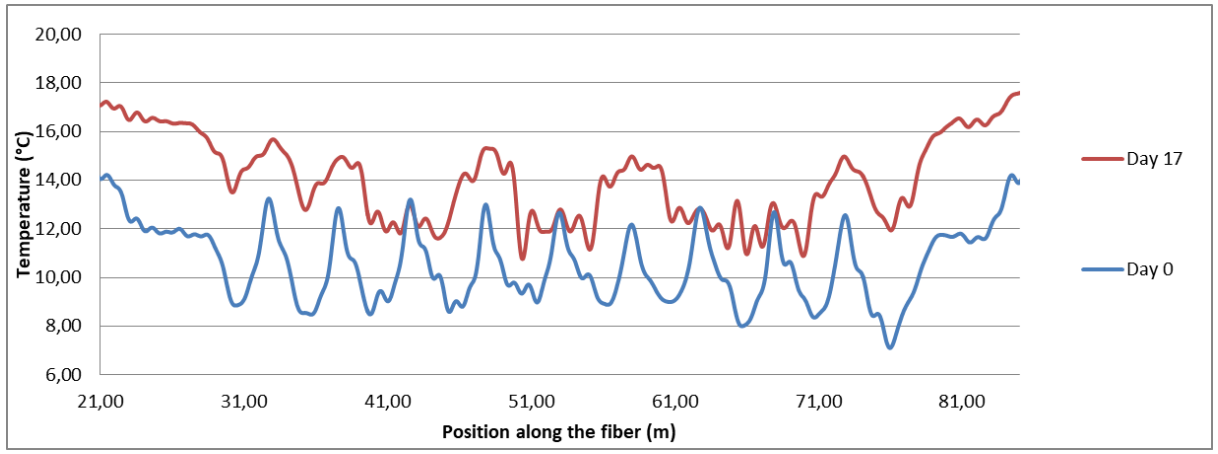

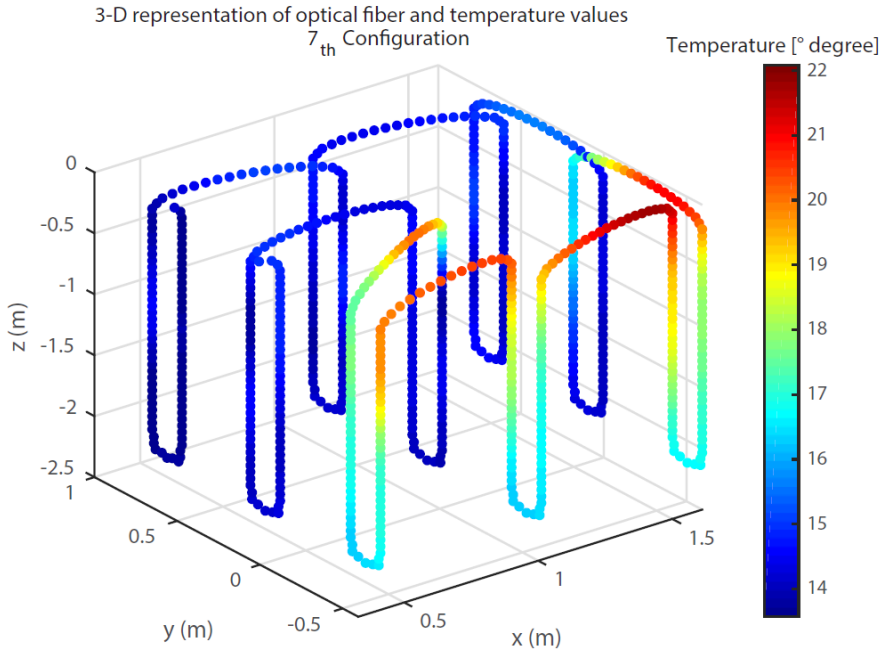

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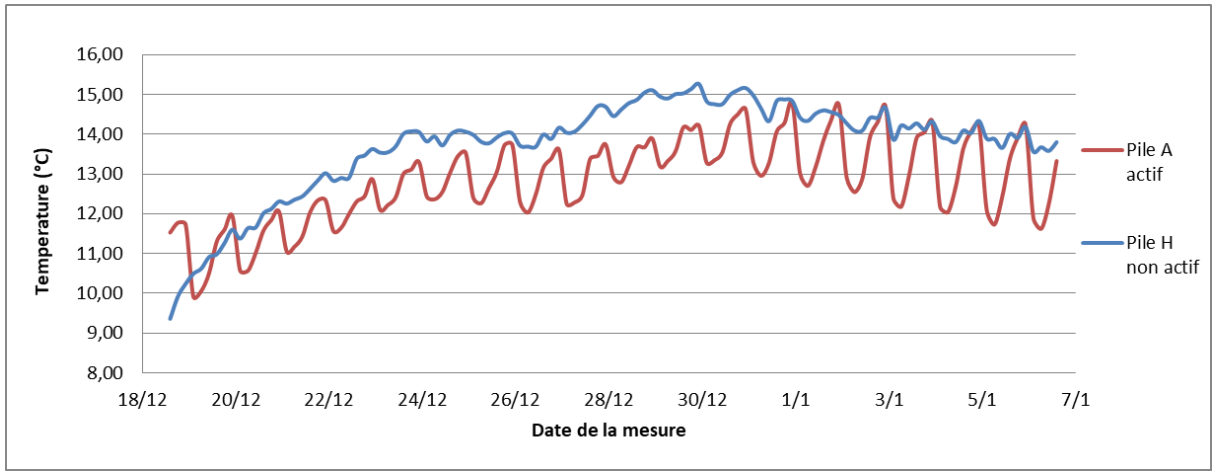
First results

- Fibre measurements of temperature along the piles.

- Evolution of temperature during experiment

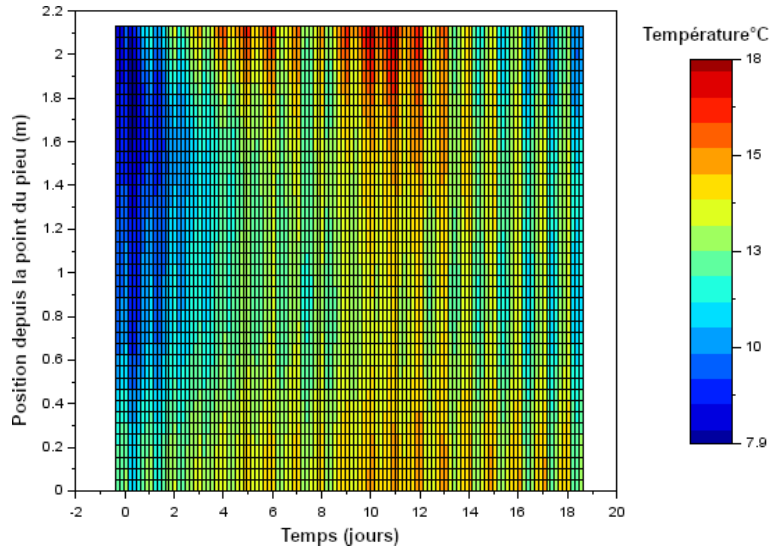


First results

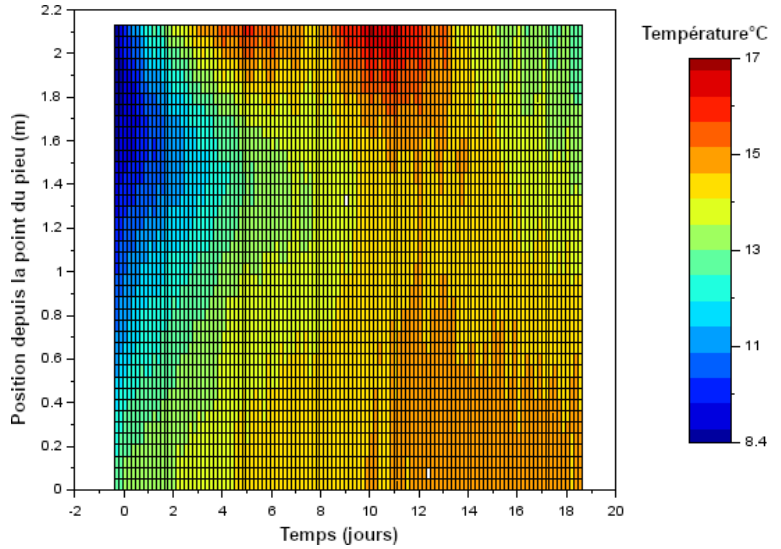
- Fibre measurements of temperature along the piles.

- Evolution of temperature during experiment

- Space time evolution



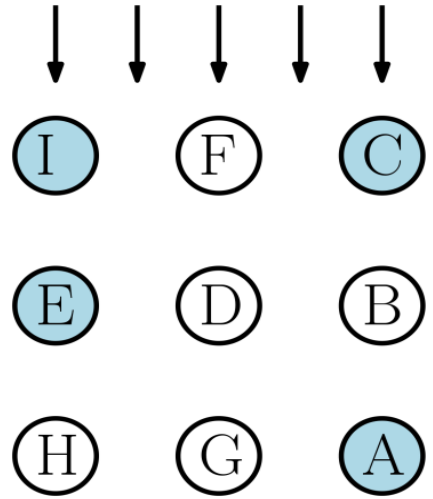
Active pile E

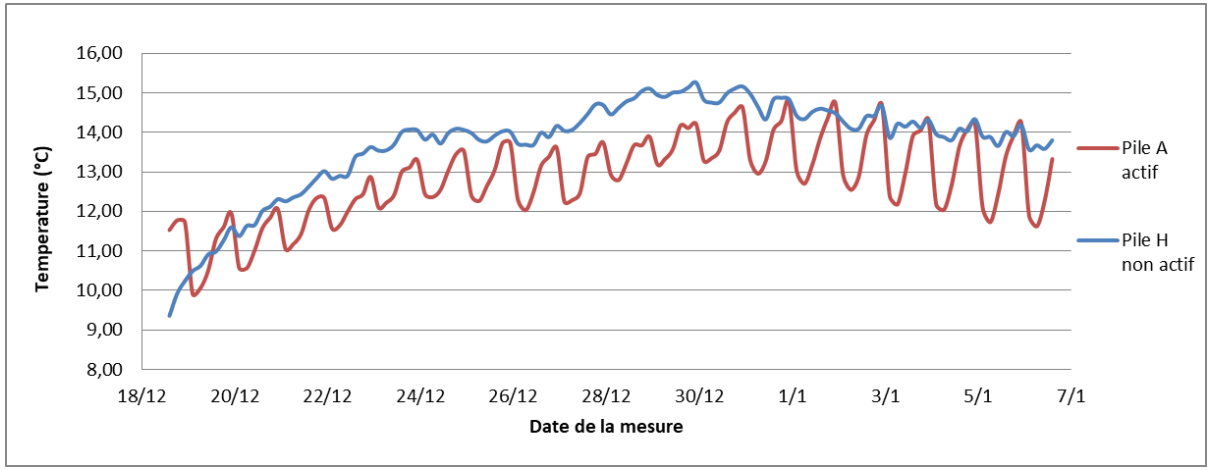


Non active pile H

Measuring interaction between piles

Qualitative comparison show daily reaction of non active pile





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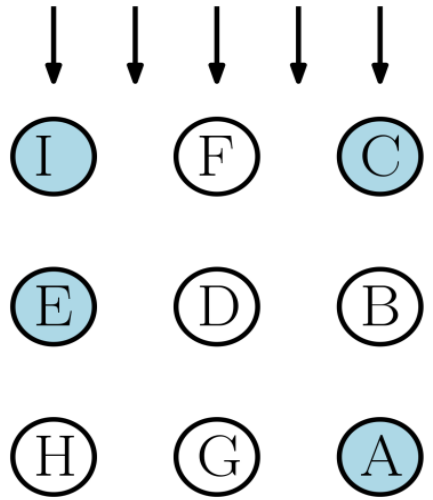

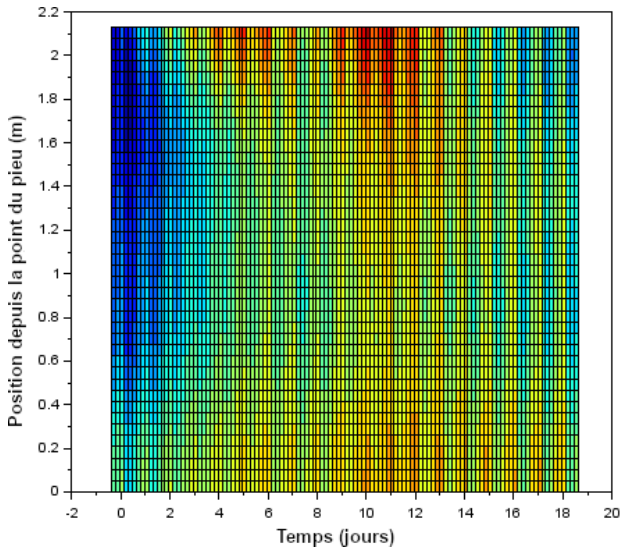

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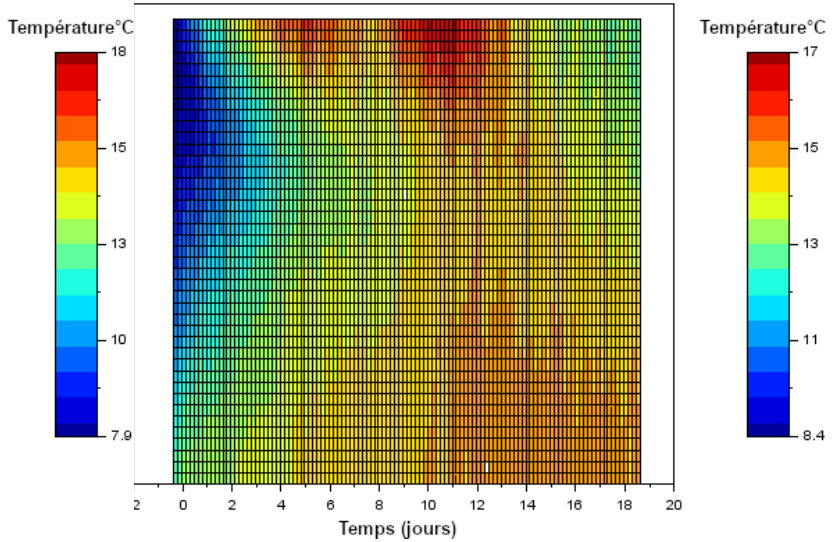

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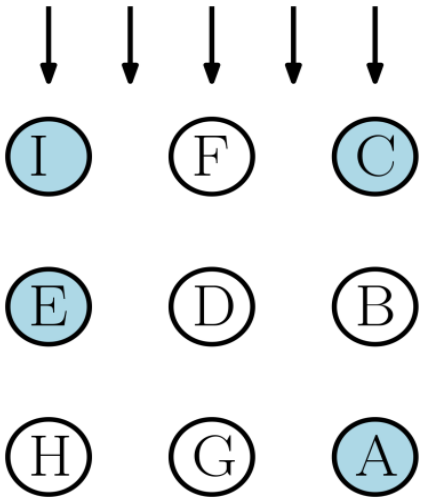
Measuring interaction between piles



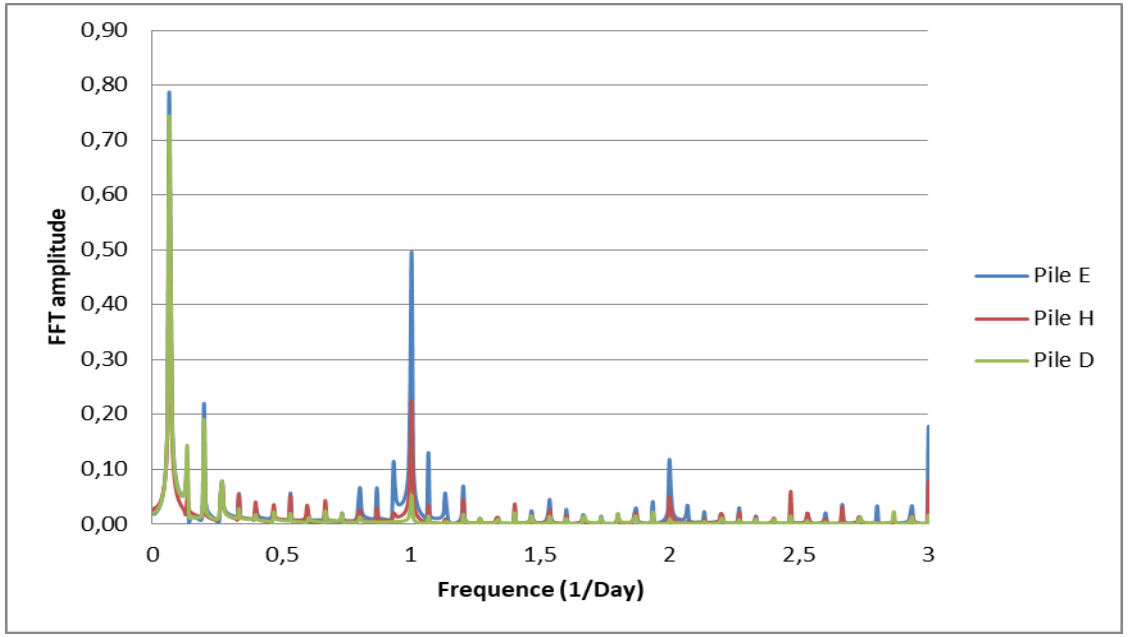
Qualitative comparison show daily reaction of non active pile

FFT analysis of the temperature signal allow to measure daily fluctuation of the temperature

Daily amplitude of

H is 40% of E

D is 8% of E

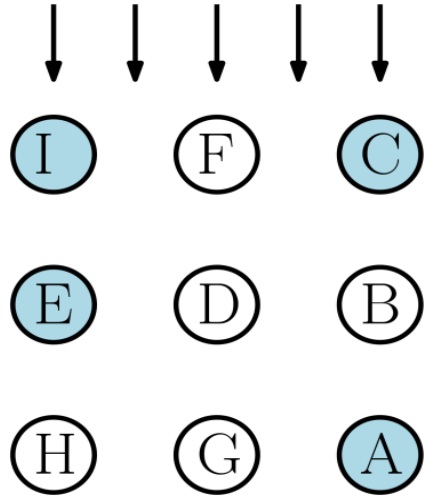


Measuring interaction between piles

Qualitative comparison show daily reaction of non active pile

FFT analysis of the temperature signal allow to measure daily fluctuation of the temperature

Quantitative temperature difference between piles :



B is 0,20°C cooler than F

H is 0,68°C cooler than G

E is 0,47°C cooler than I
and 0,46°C cooler than C

H is 0,47°C cooler than B

A is 0,10°C cooler than C

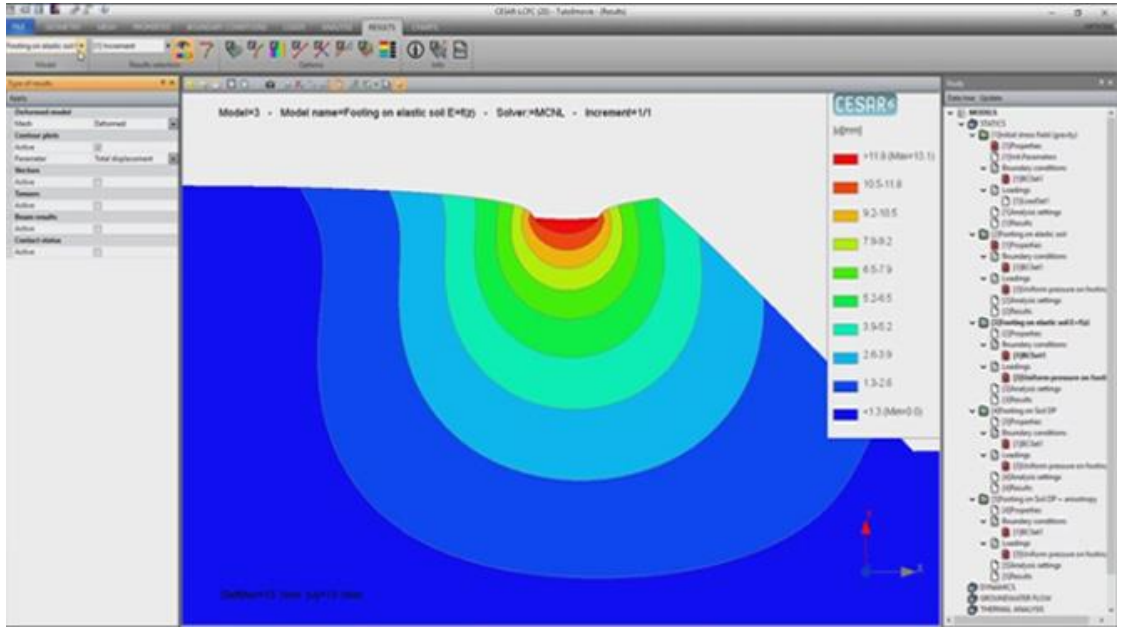
Non active pile H

Numerical Modelling

CESAR-LCPC

FEA Software for Civil Engineering

- FEM software (2D and 3D)
- Development started in the 70's
  by the French LCPC
  → IFSTTAR
  → now Univ. Gustave Eiffel
- Specialized in civil engineering
- Multiple applications:
  - Geotechnics (soil behaviour, nailing, tunnel, etc.)
  - Structures (Concrete, steel, etc.)
  - Hydrology
  - Thermal analysis
  - …



itech http://www.cesar-lcpc.com/fr/

Numerical Modelling

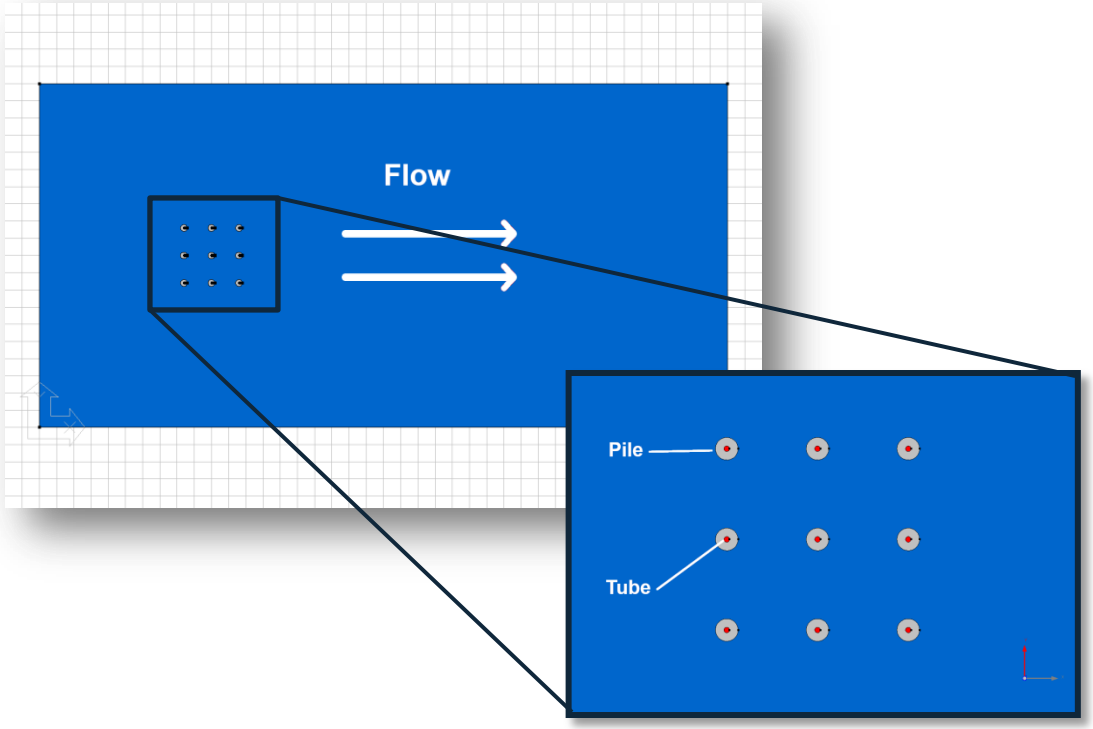
2D analysis representing mid deep situation :

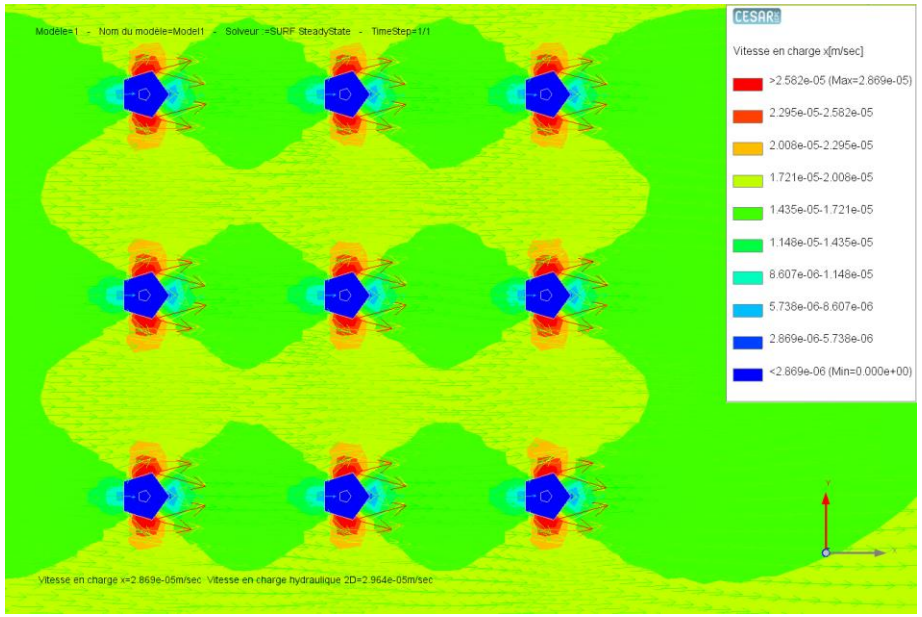
- 10x20m model
- 9 circulars piles
- 70 W per meter in activated piles
- Homogeneous soils
- Cyclic activation (6 day, 10/24h activation)

Hydraulic model :

- Homogeneous soils
- Hydrostatics charge difference
- Average flow of 1,5 m/day

/!\ Coupling hydraulic-thermal model need some manual handling





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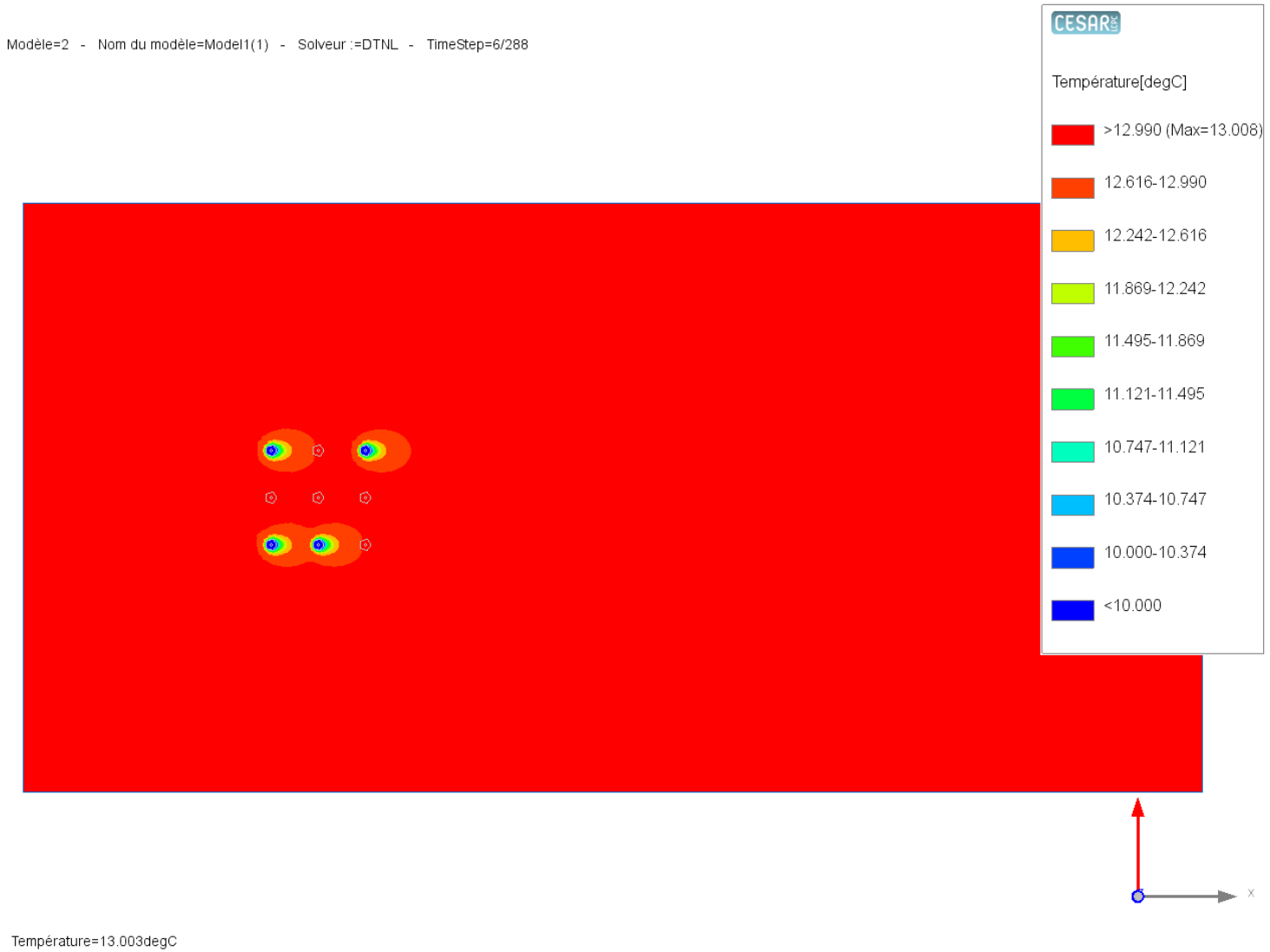
First results



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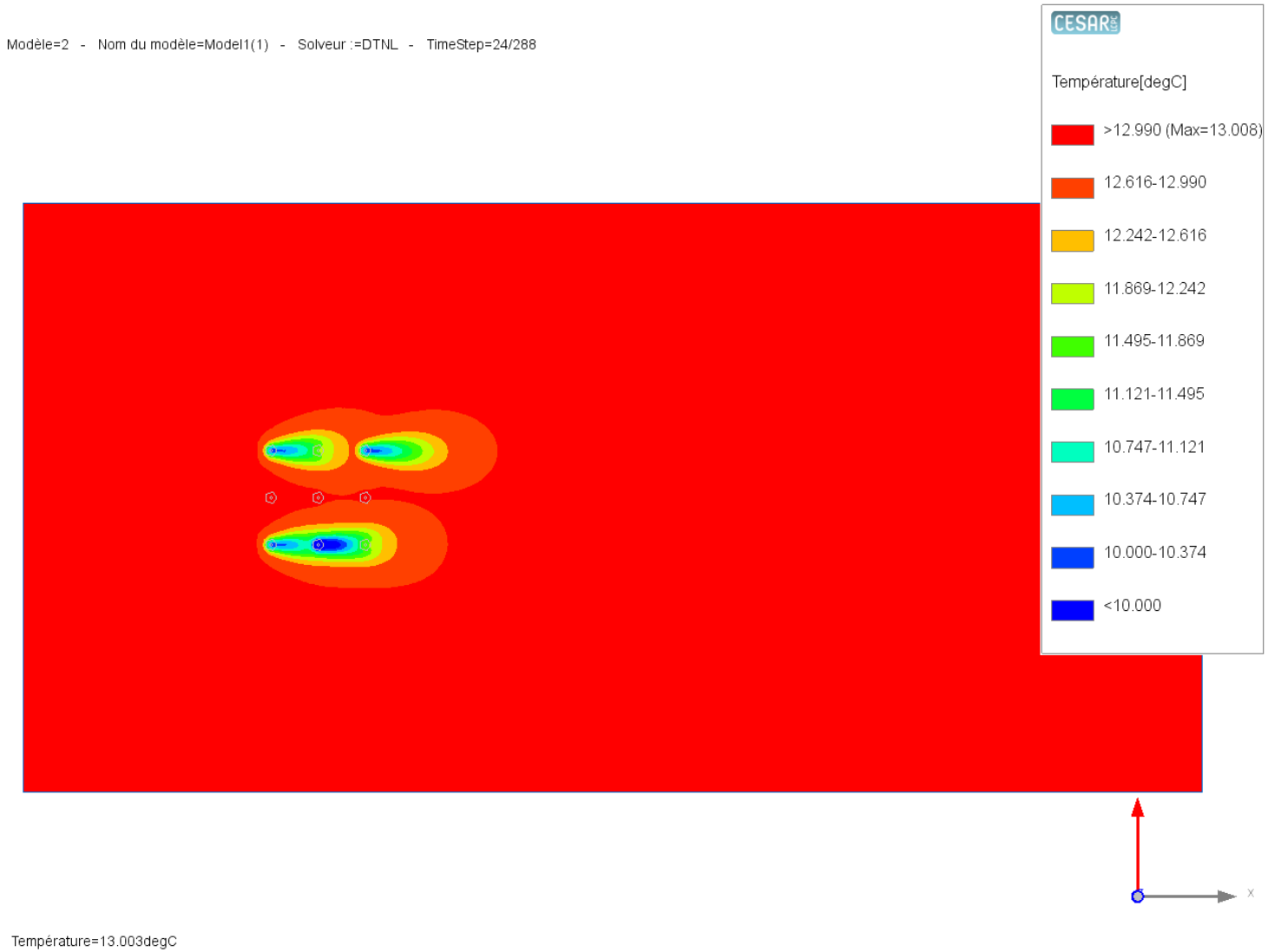

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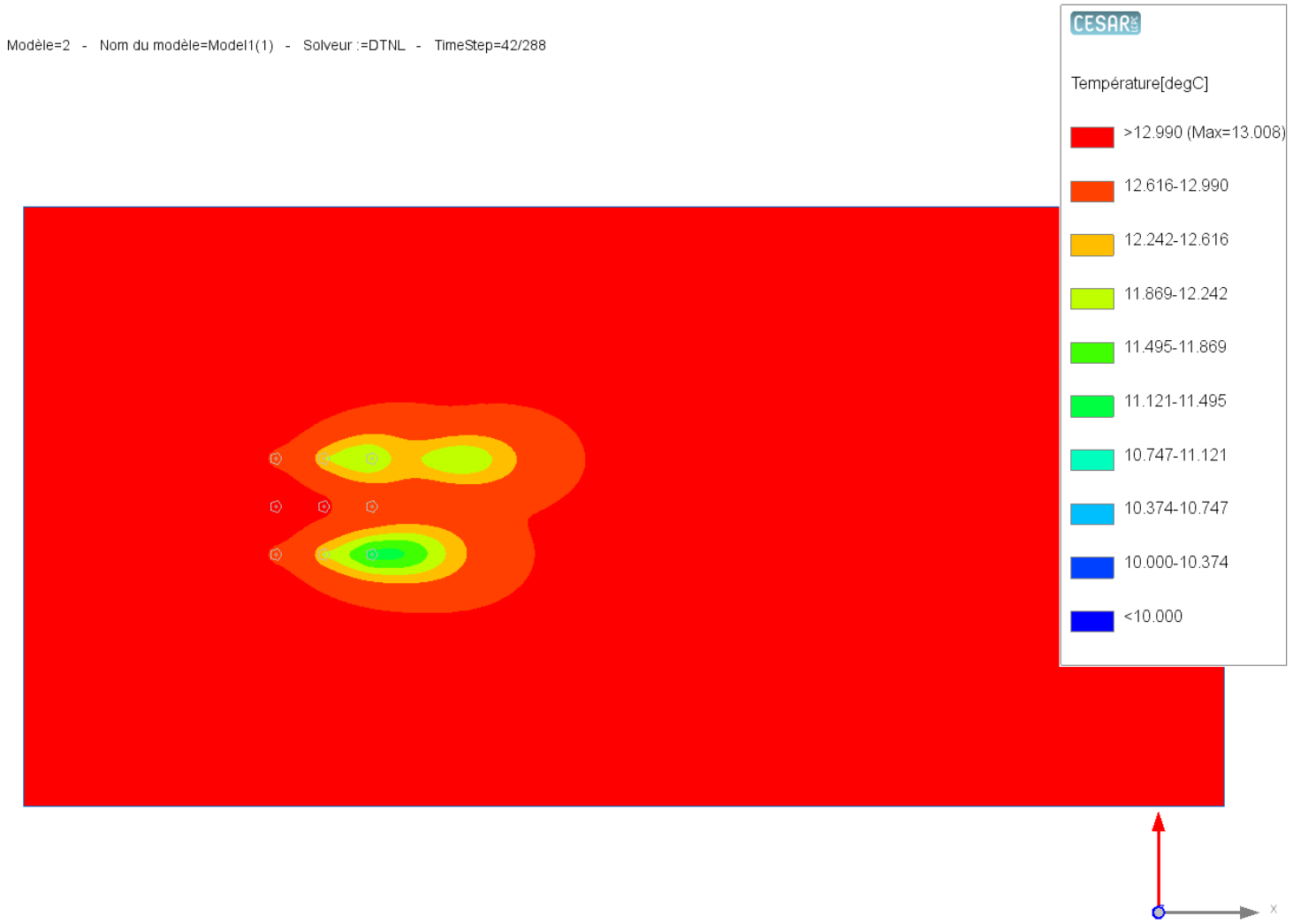

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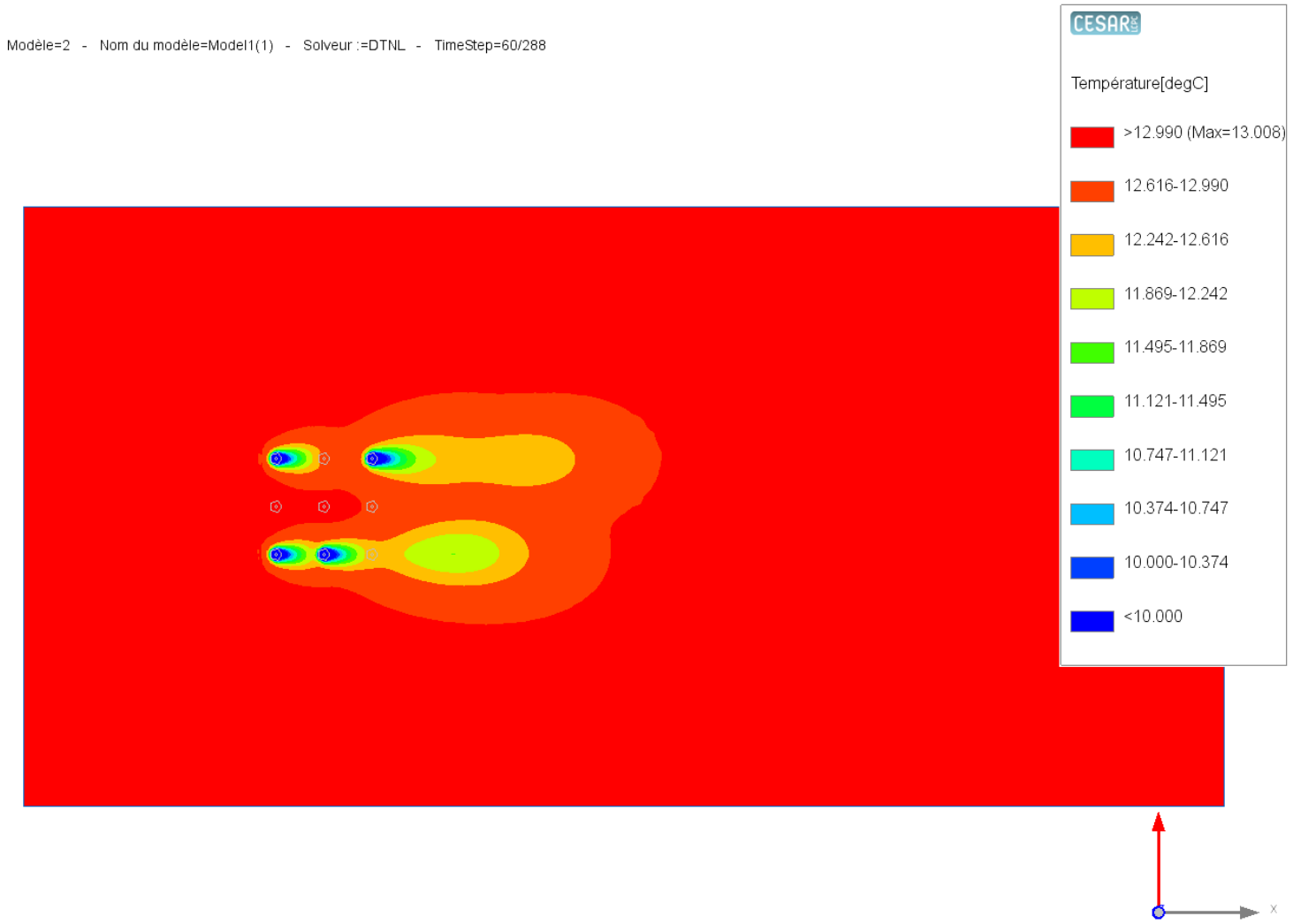

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First results

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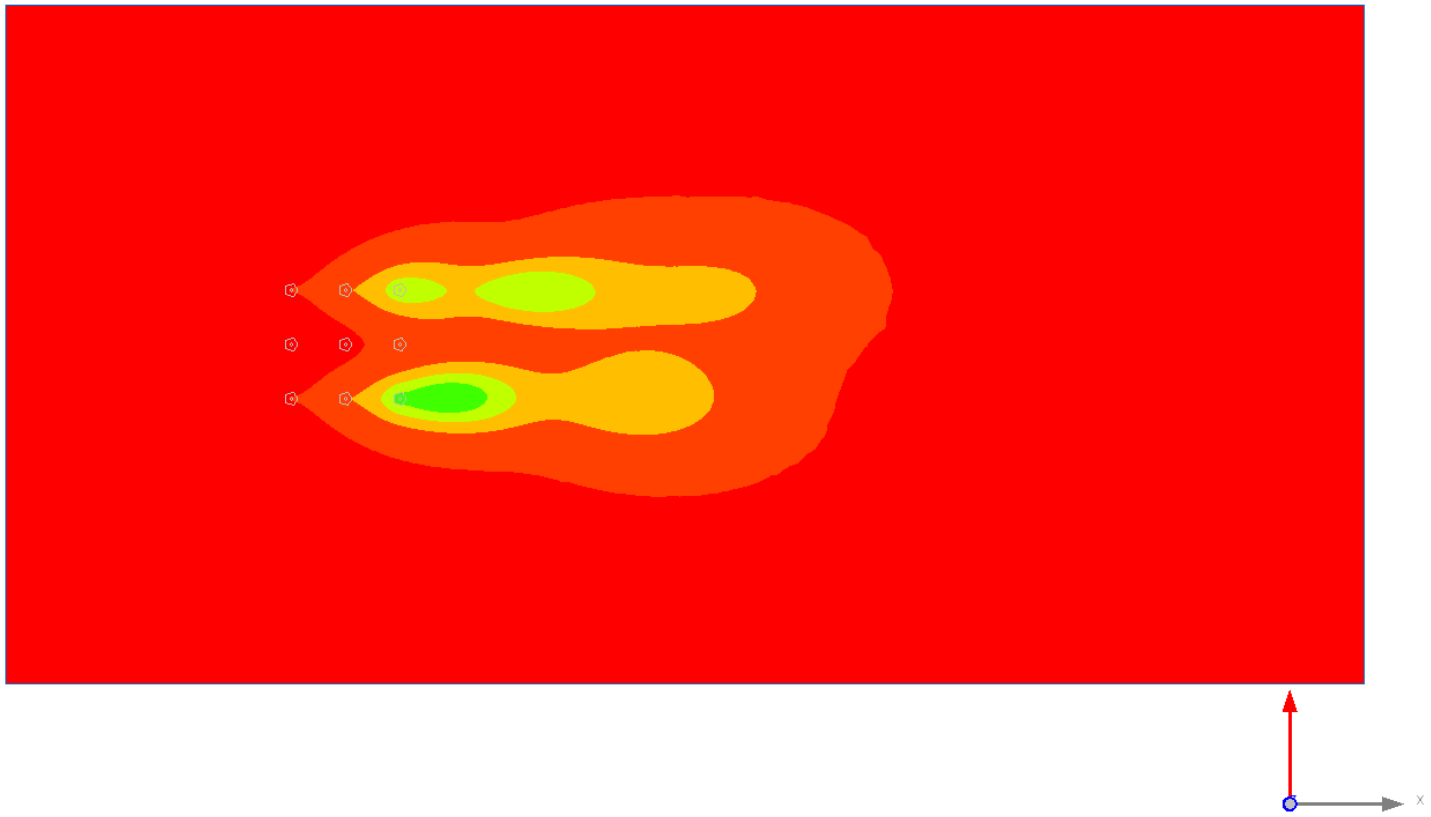
First results

Modèle=2 - Nom du modèle=Model1(1) - Solveur :=DTNL - TimeStep=96/288



Température=13.003degC

First results

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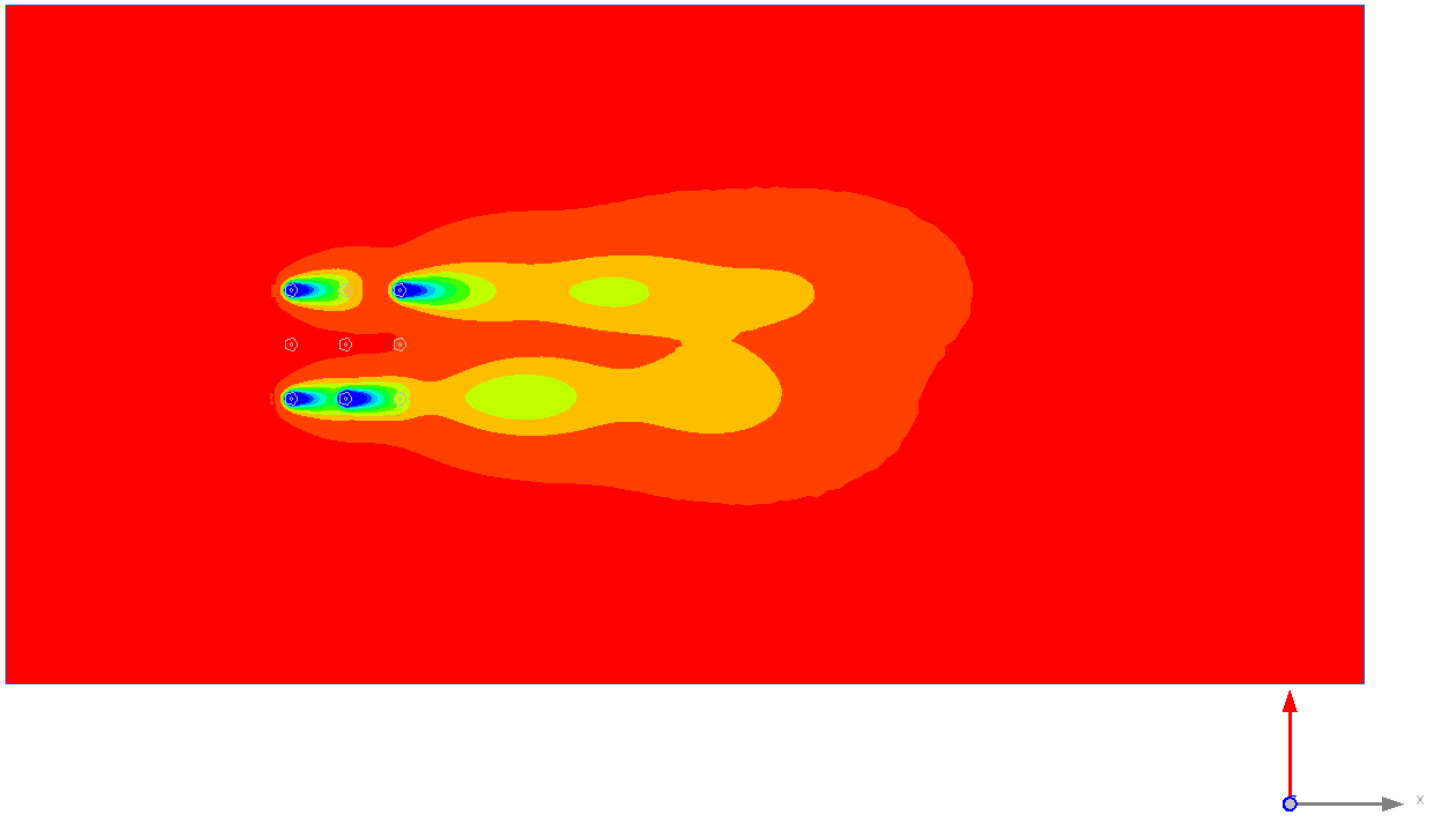

Température=13.003degC

First results

First results

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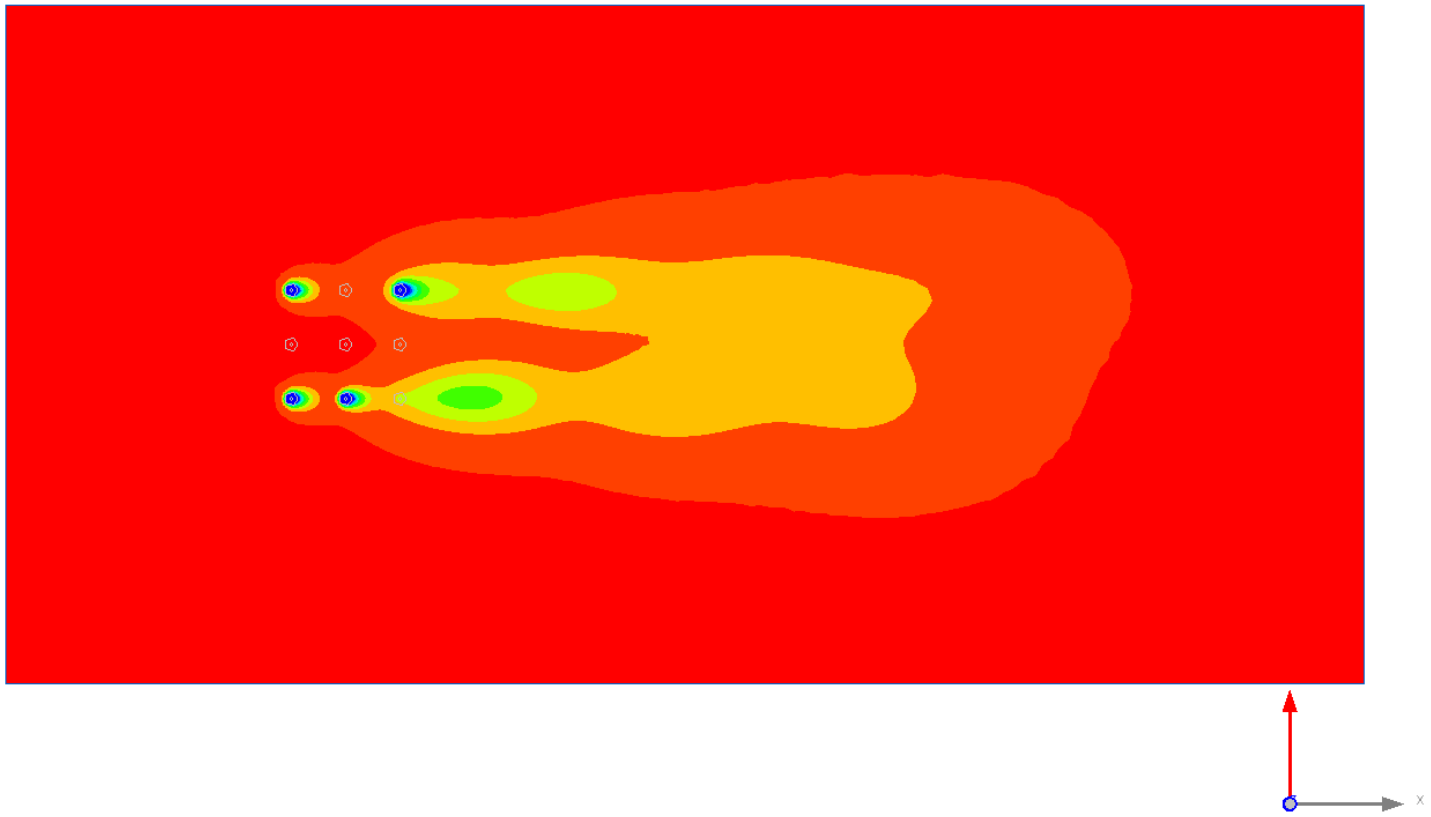

Température=13.003degC

First results

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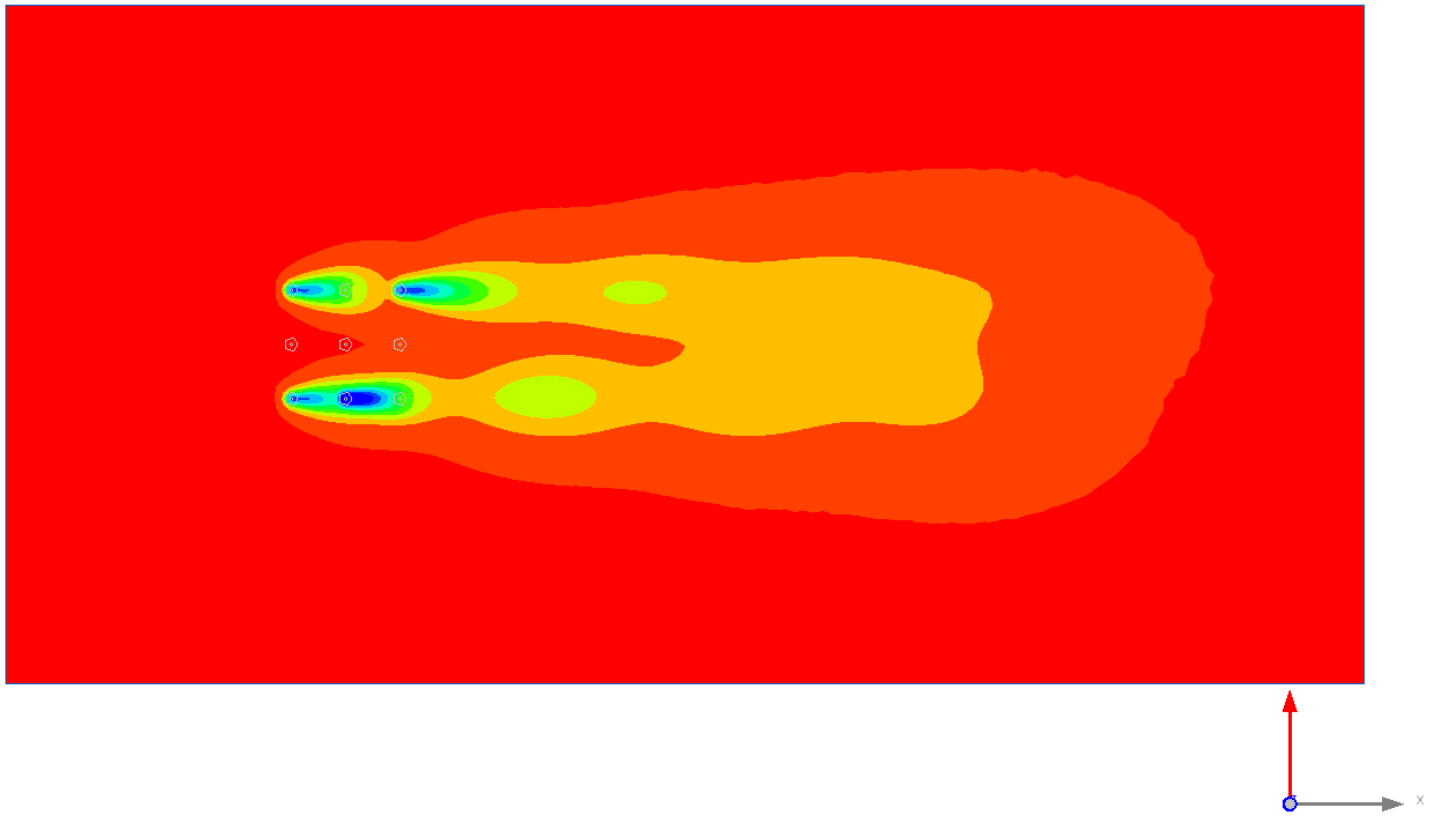

Température=13.003degC

First results

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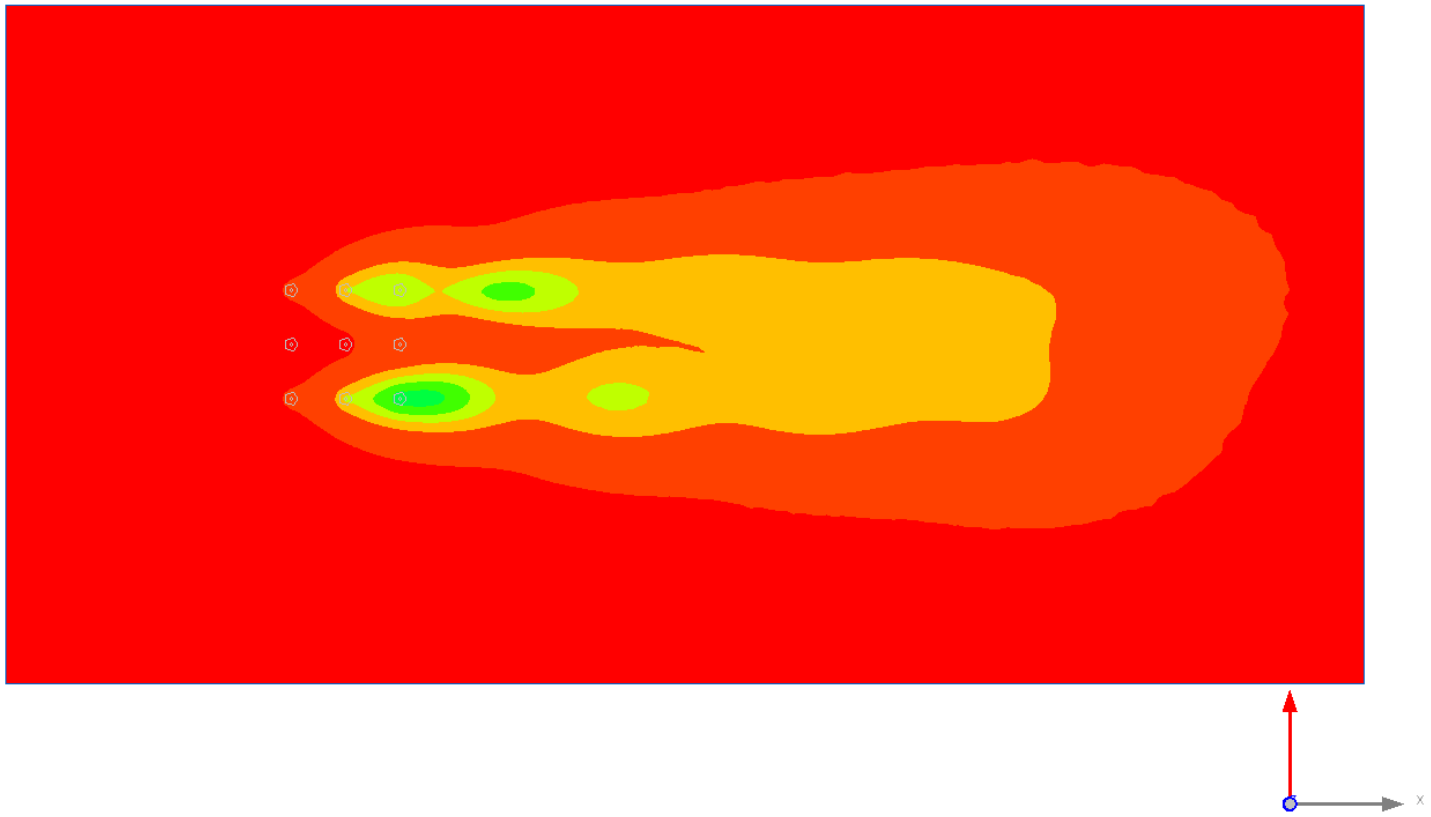

Température=13.003degC

First results

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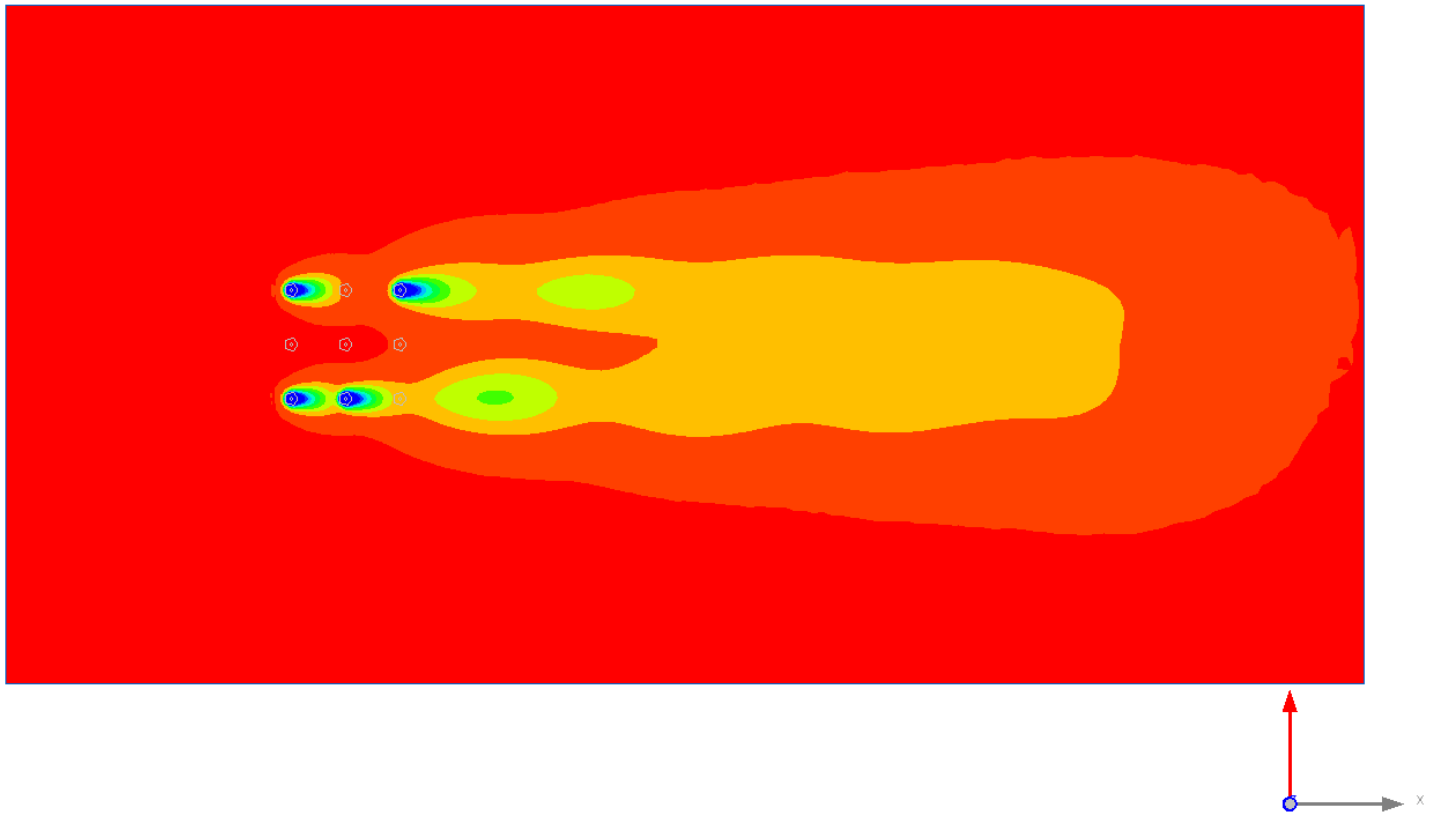
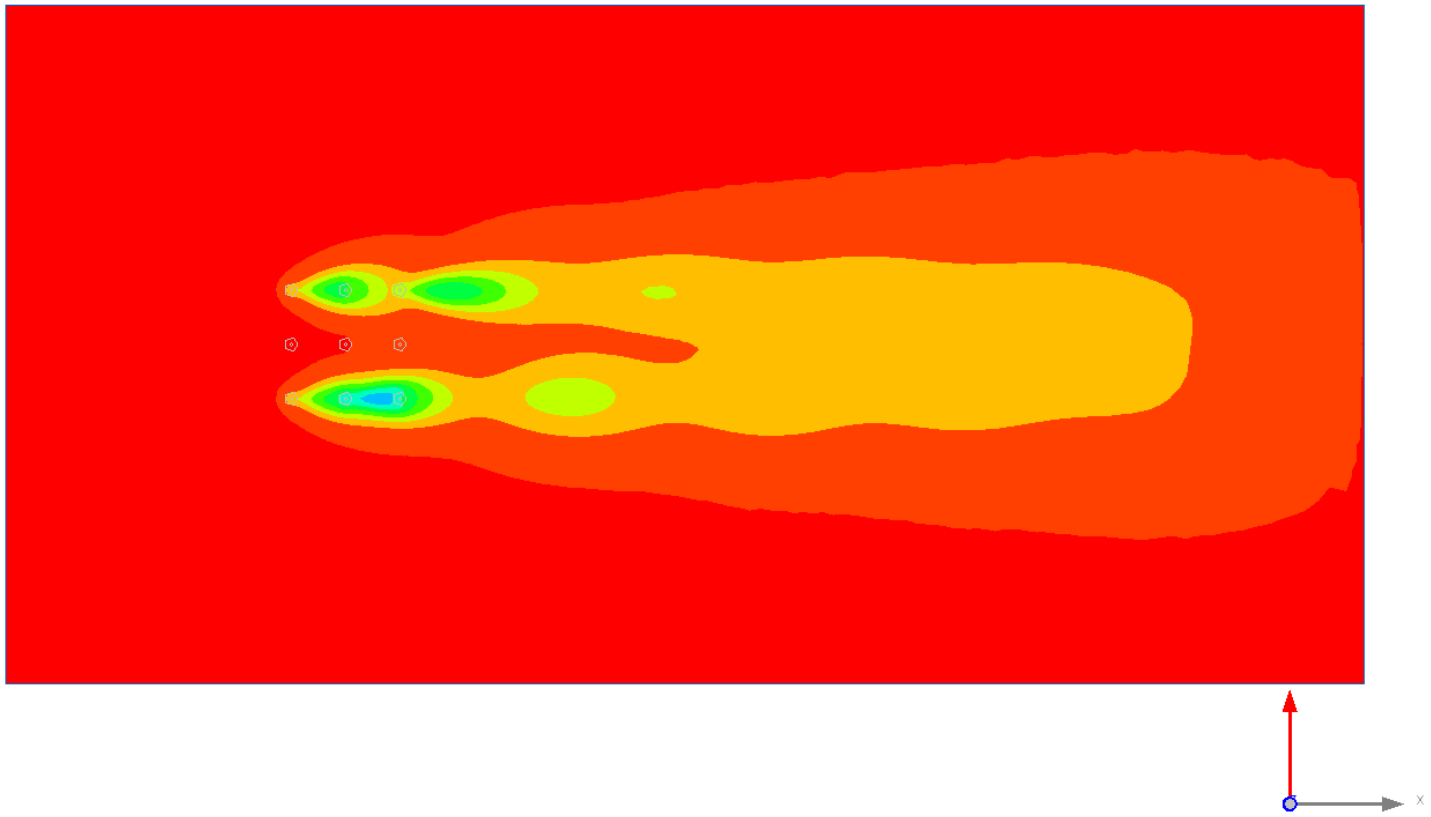


Température=13.003degC

First results

Modèle=2 - Nom du modèle=Model1(1) - Solveur :=DTNL - TimeStep=222/288



Température=13.003degC

First results

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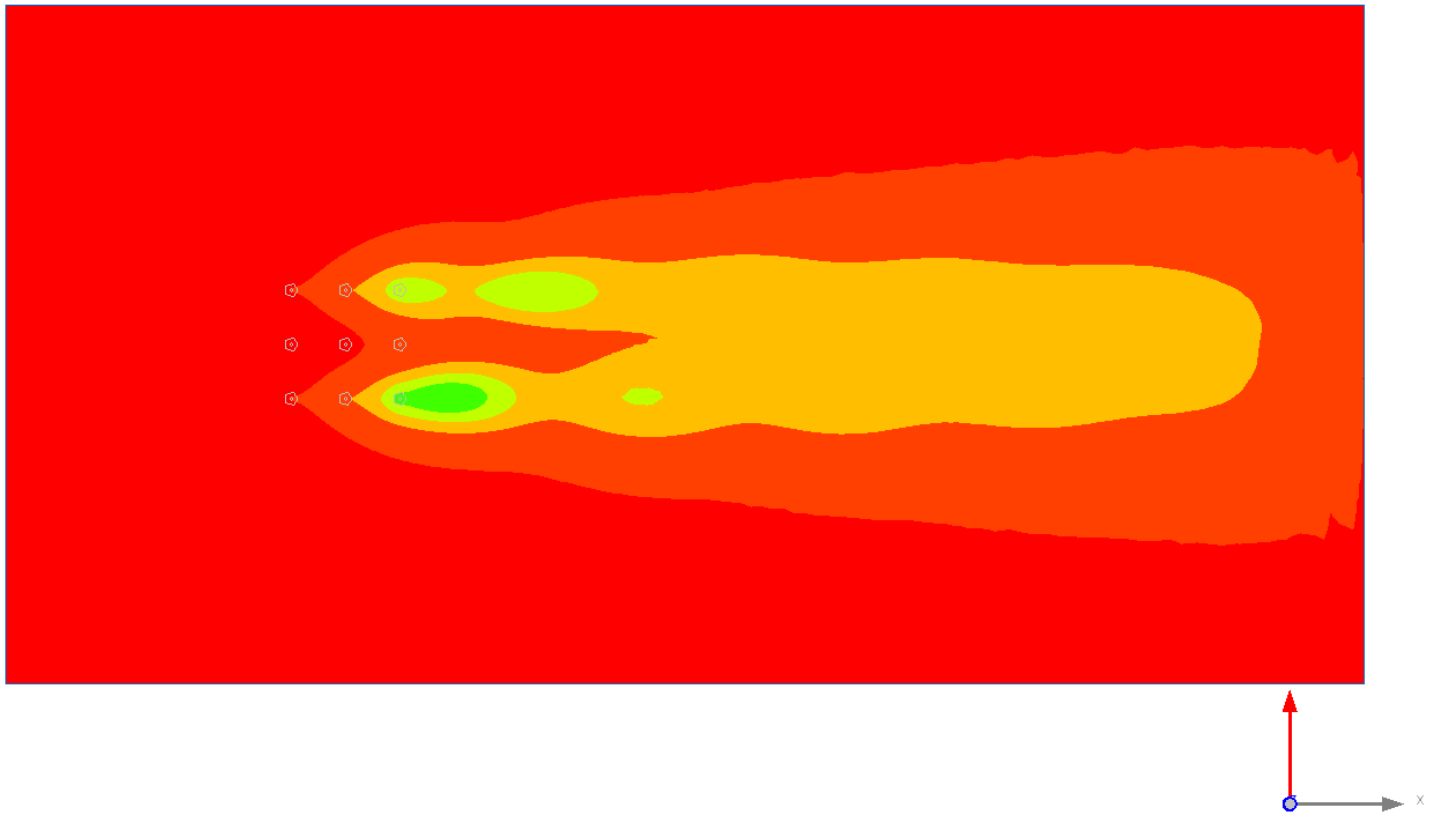
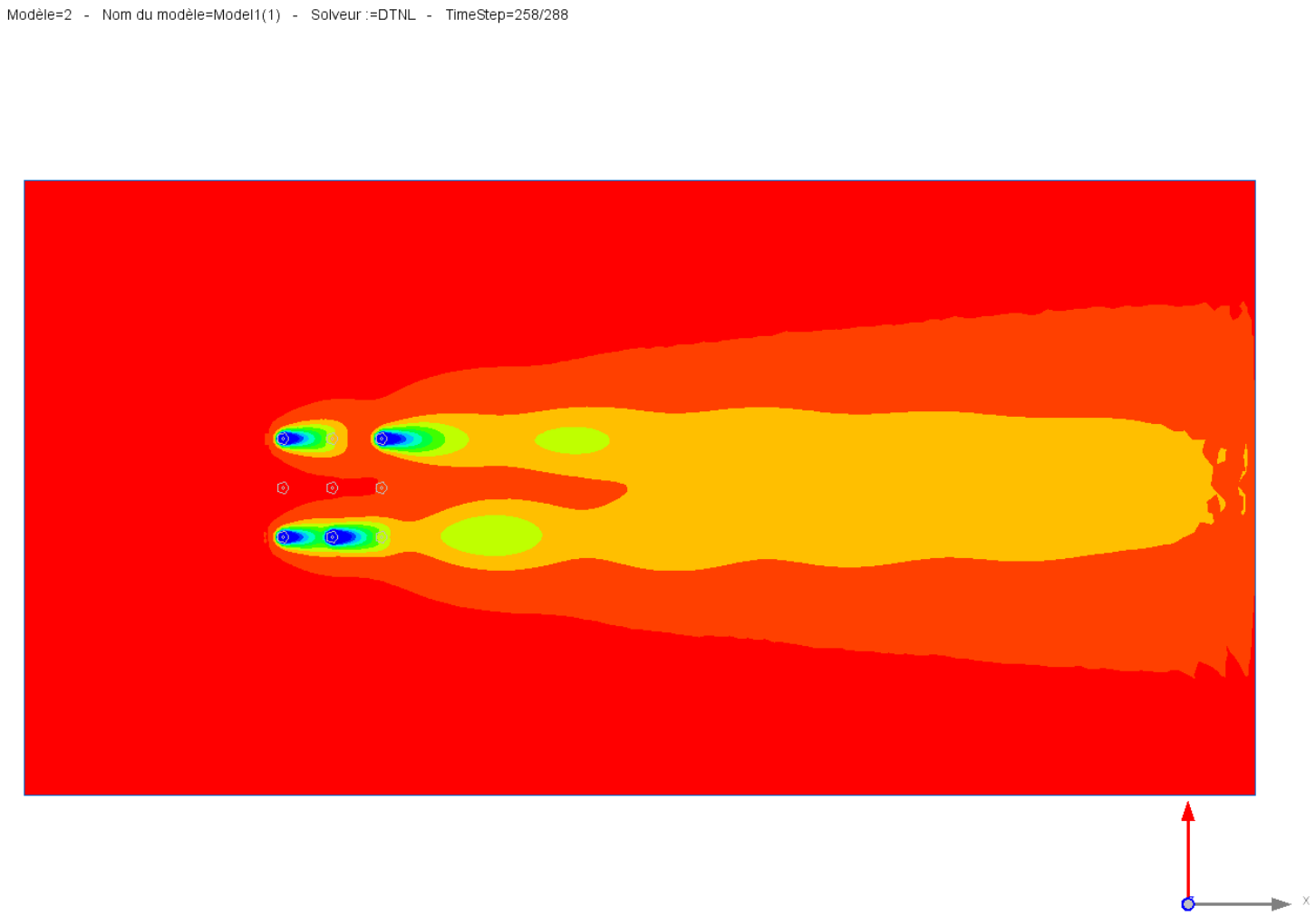
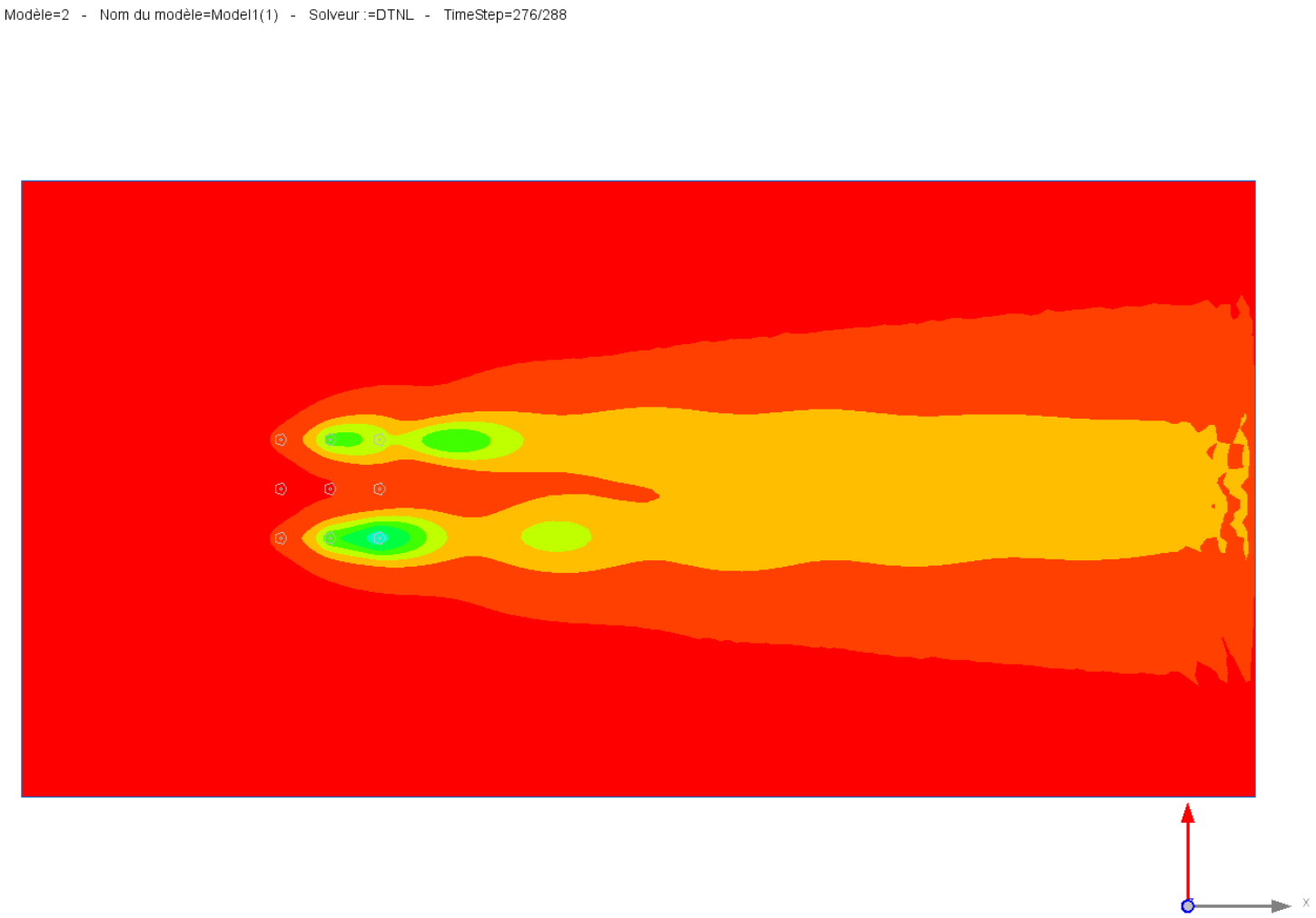


Température=13.003degC

First results



First results



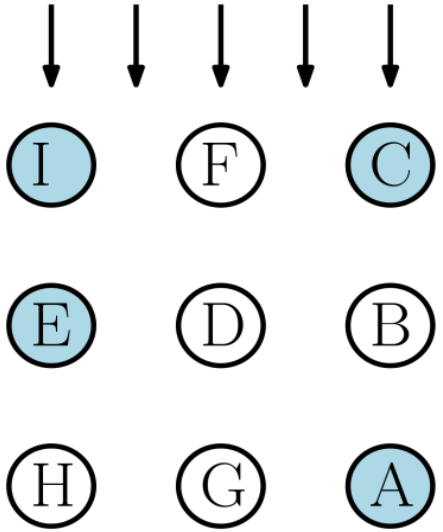
Comparative results

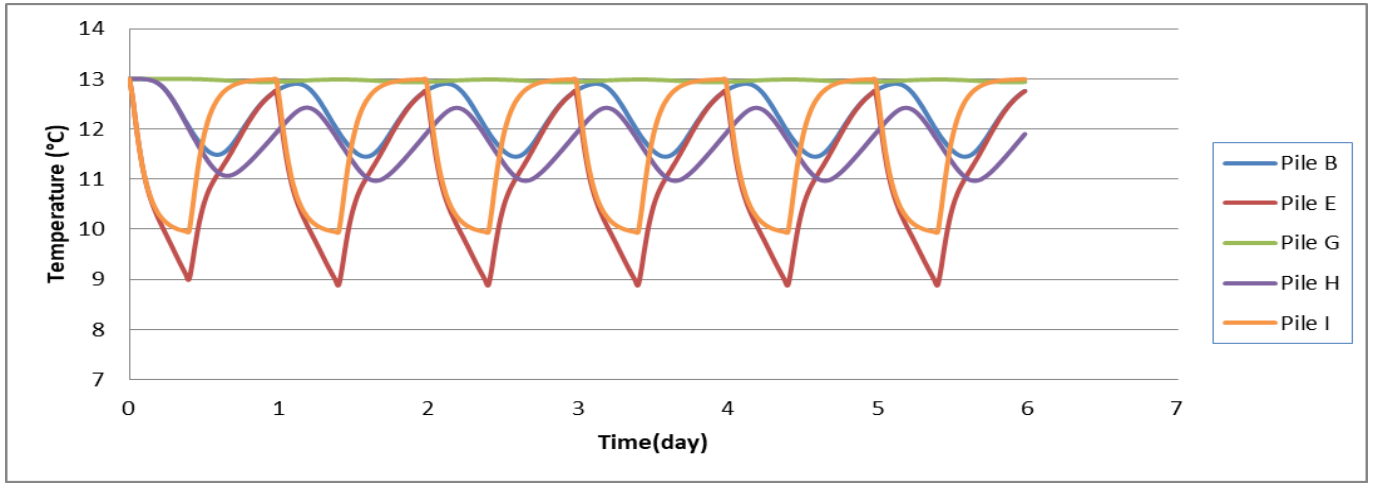
Temperature is measured in each piles

Cyclic behaviour are observed with different amplitude

Qualitative results :

- Pile I : typical behaviour of an active pile
- Pile B and H: under influence
  => time shift in behaviour
- Pile E : cumulative behaviour
- Pile G: barely affected





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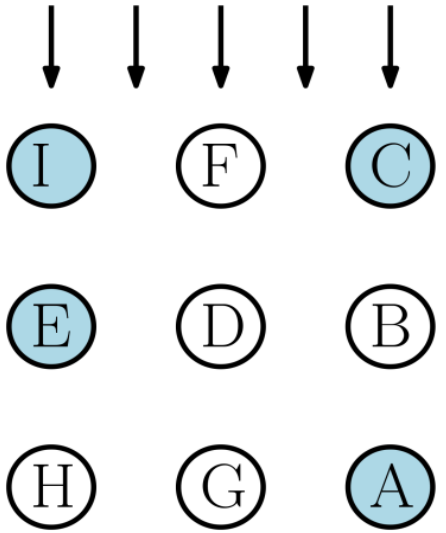
Comparative results

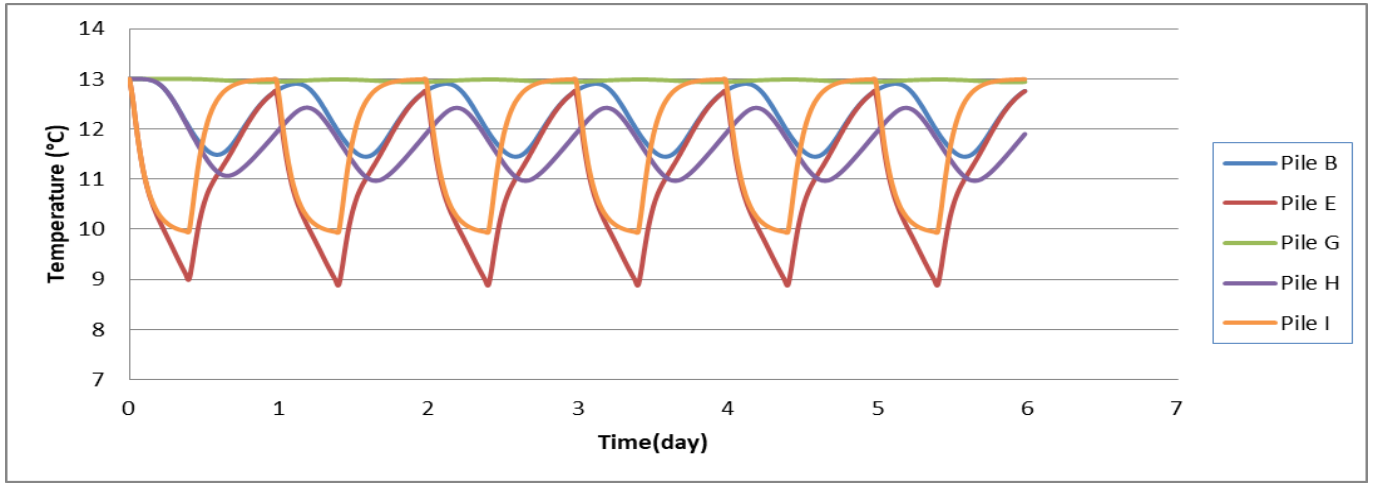
Quantitative result:

- Thermal amplitude :
  - I and E: 3°C and 4°C
  - H and B: ~ 1,4°C (40% of I, consistent experiment)
  - G: 0,05°C (1/27 of B amplitude, consistent with Peclet number)

- Mean temperature :
  - E is 0,75°C cooler than I or C
  - H is 0,51°C cooler than B
  - B is 0,72°C cooler than G
  - H is 1,23°C cooler than G

=>Consistent with experiment





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Conclusion

- Sense City a large facilities of 400m² equipped with energy geostrcutures models
- Optical fibres allow precise monitoring of the temperature along the energy pile
- Physical modelling shows interaction between energy piles (FFT analysis, temperature comparison, etc.)
- Numerical modelling with CESAR-LCPC is able to reproduce Hydraulic-thermal interaction with geo structure

- Future experiment will study other case of interaction
- Numerical model is a promising tool to study complex situations and solicitations
- It gives more complex results including thermal mapping outside the instrumented zone

Thank you for your attention

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