



Simulation of thermal impacts induced by fires with a coupling OpenFOAM-Cast3m

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C. Ferrier, J-C. Leblanc



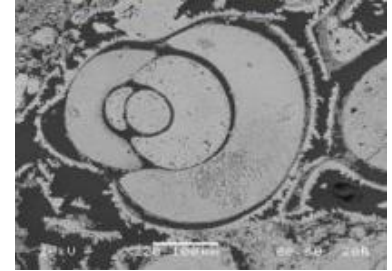
Purposes of CarMoThaP

Archaeological data

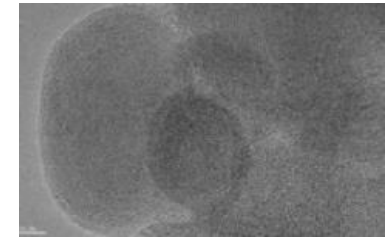


Purposes

Database of microstructure of thermo-alterations



Database of microstructure of fuels

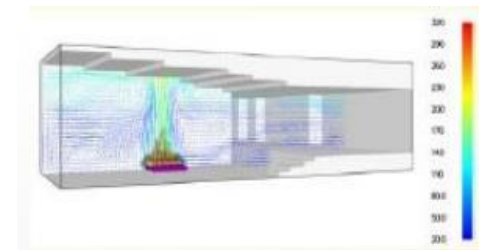


High resolution transmission microscopy of a soot particle

Experimentations



Numerical simulations of fires



Simulation of wall temperatures

CarMoThaP – Studied sites

Bruniquel
(Tarn-et-Garonne)
J. Jaubert



- Middle Paleolithic
- Fuel: bones (and wood ?)
- Speleothems

Chauvet-Pont d'Arc
(Ardèche)
J-M. Geneste



- Painted cave (Aurignacian)
- Fuel: scots pine
- Thermo-alterations on the ceiling
- Softening of the walls

Enlène (Ariège)
R. Begouën



- Habitat
- Magdalenian
- Fuel: bones (and wood ?)

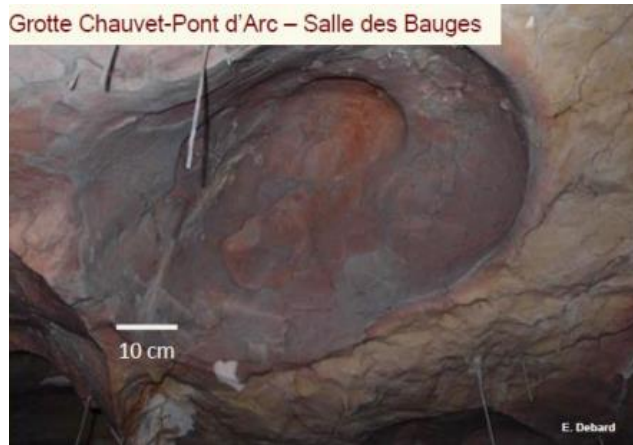
Comarque
(Dordogne)
O. Fuentes



- Painted cave
- Magdalenian and medieval occupation
- Fuel: wood ?

Some questions

Colour change



Spalling



Soot deposit



Chemical reactions

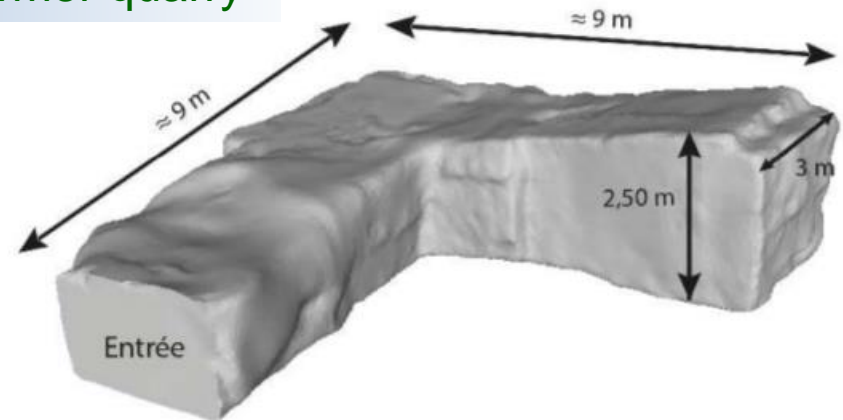
- Red (rubification) ~ 250°C
- Grey ~ 350°C

- Amount of wood
- Source of ignition
- Method of supply
- Number of fires

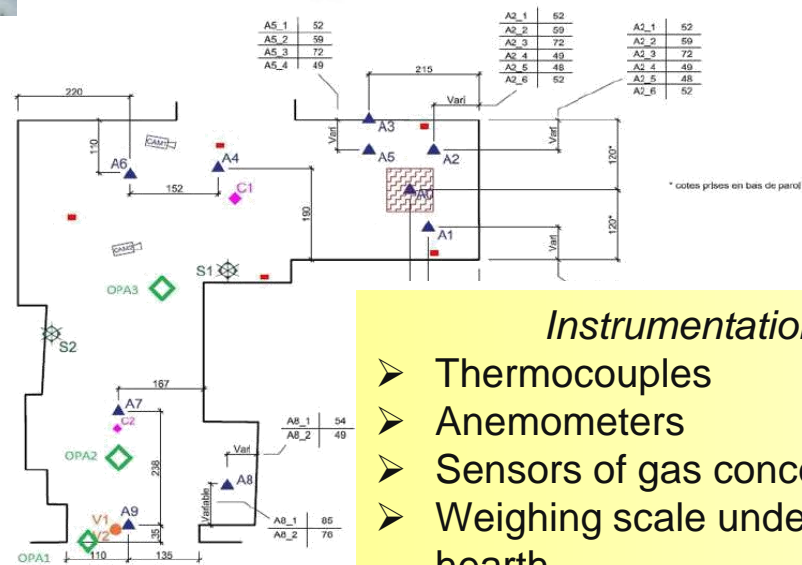


Experimentations

Former quarry



Bundled pinus sylvestris



Instrumentations

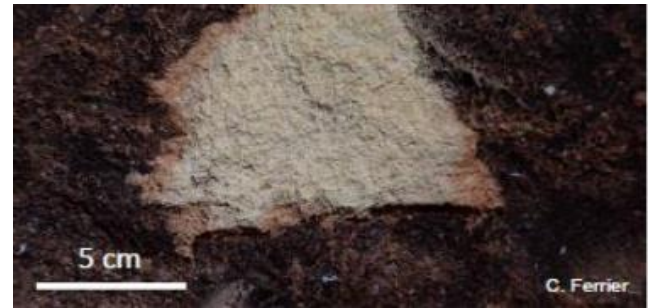
- Thermocouples
- Anemometers
- Sensors of gas concentrations
- Weighing scale under the hearth

Thermo-alterations reproduction

Rubification

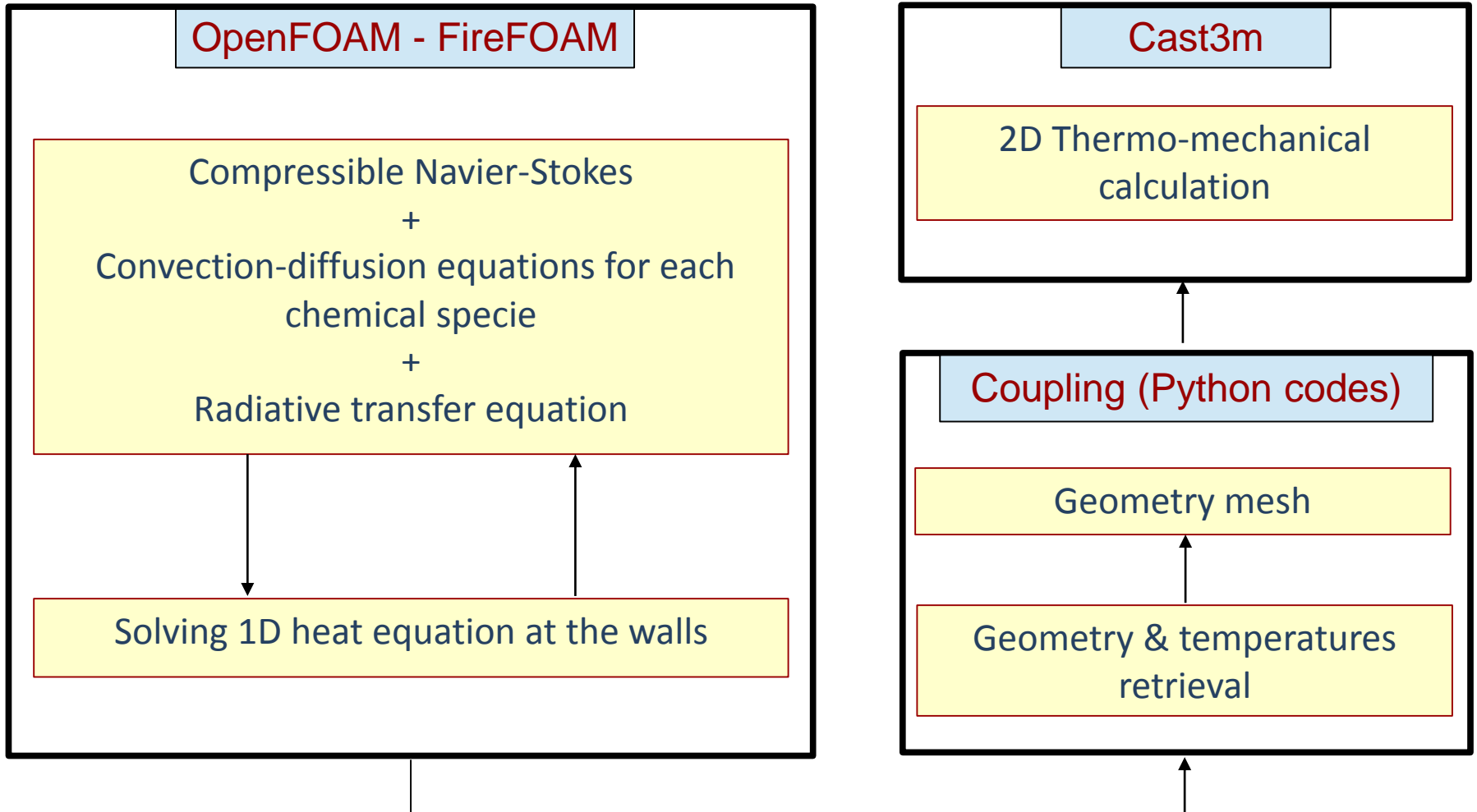


Spalling



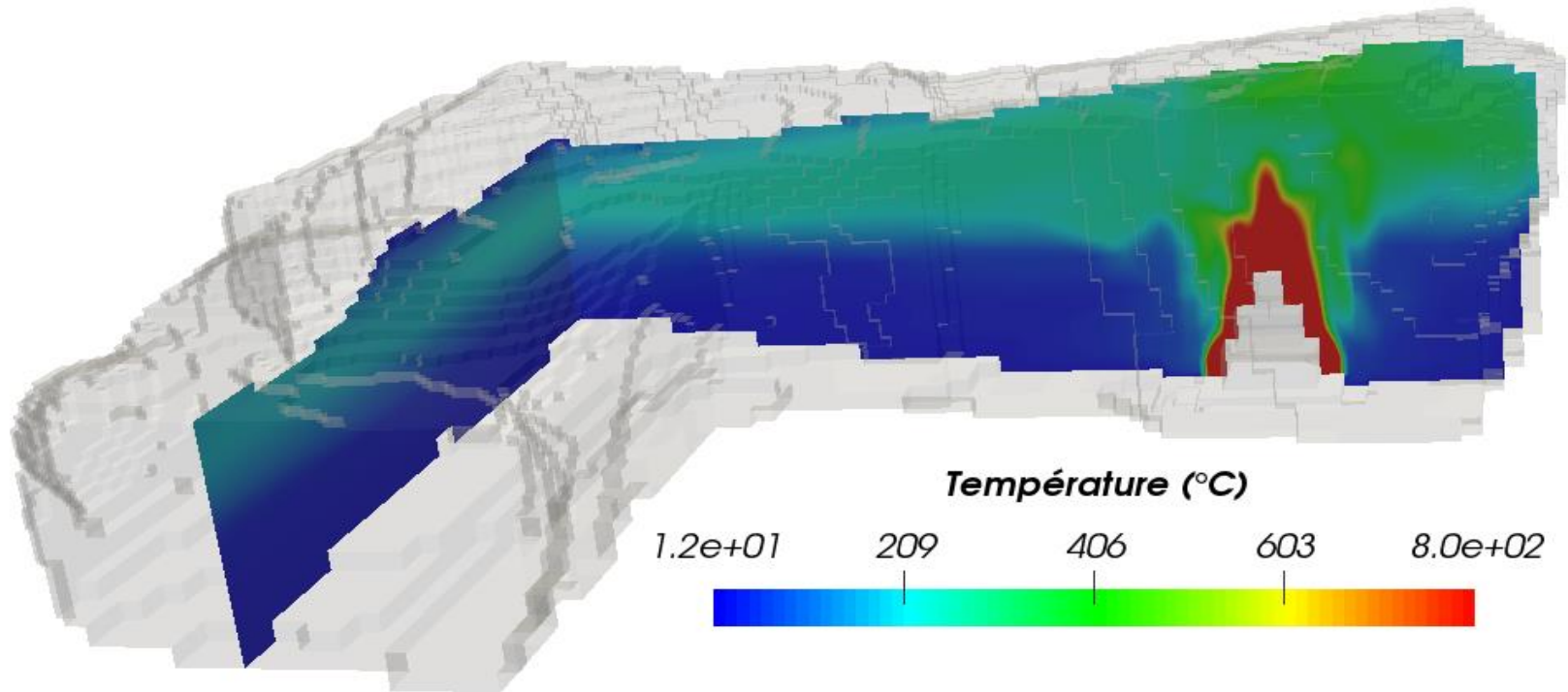
Numerical modelling

Open source software



OpenFOAM results

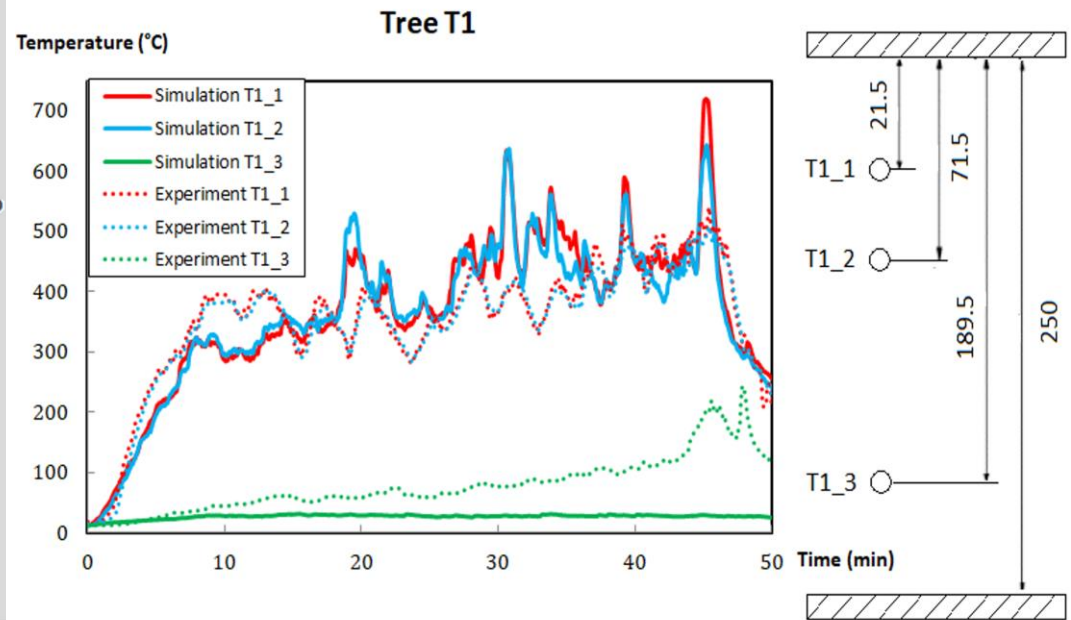
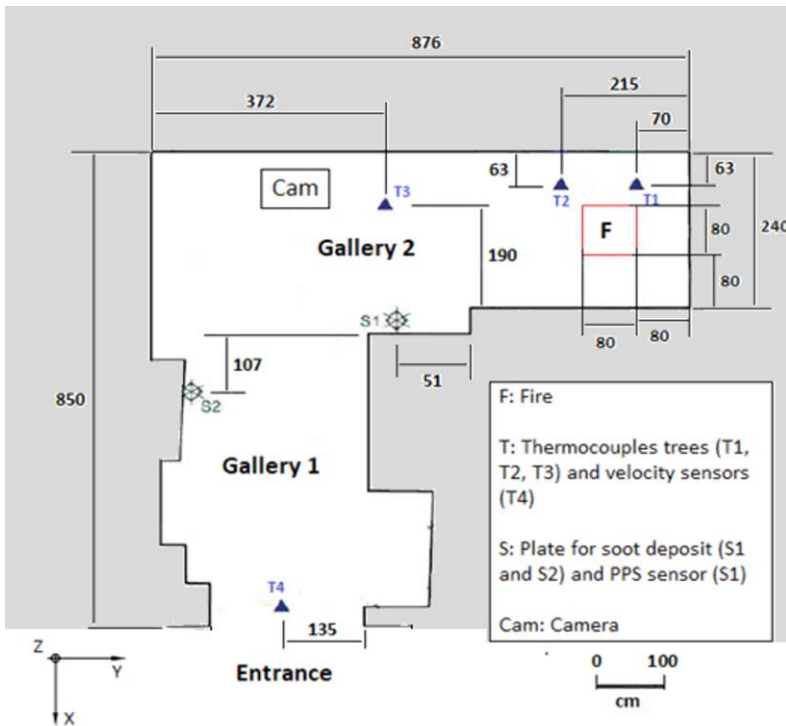
40 minutes after the ignition



Entrance

Comparison of the results

1/2

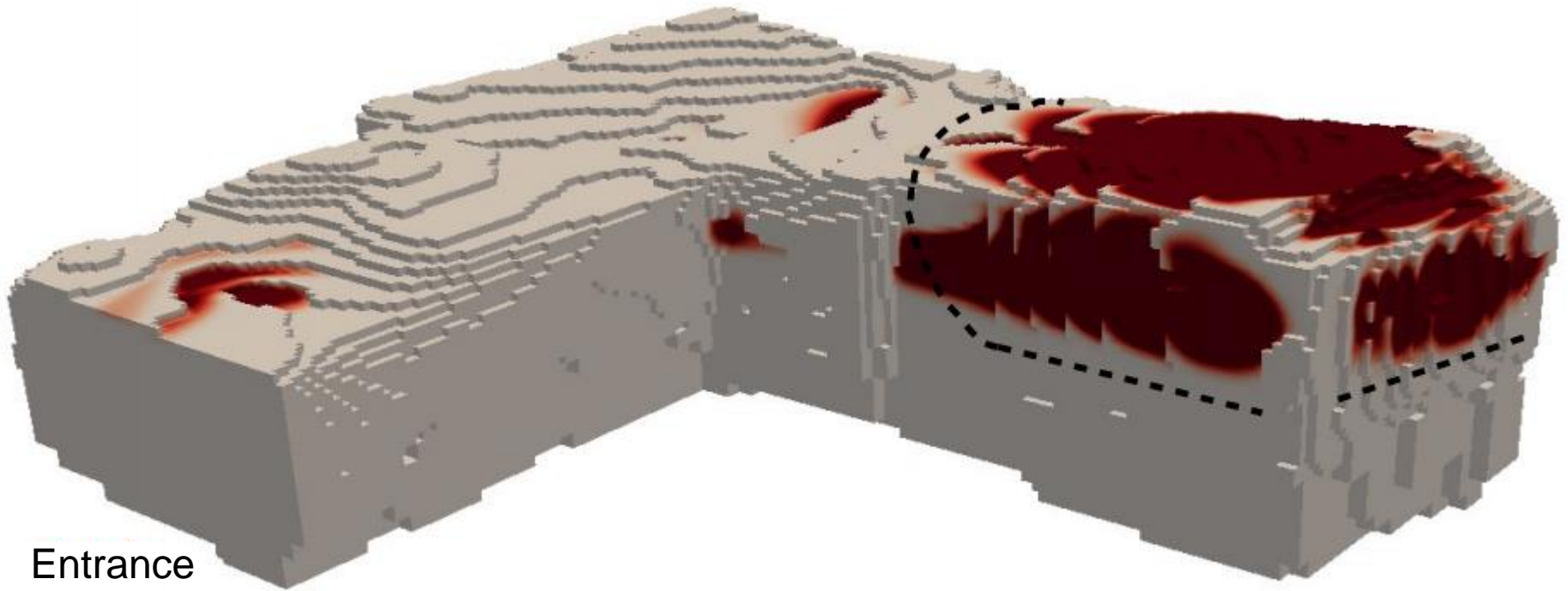


Comparison of the results

2/2

Rubification
250 °C – 10 min

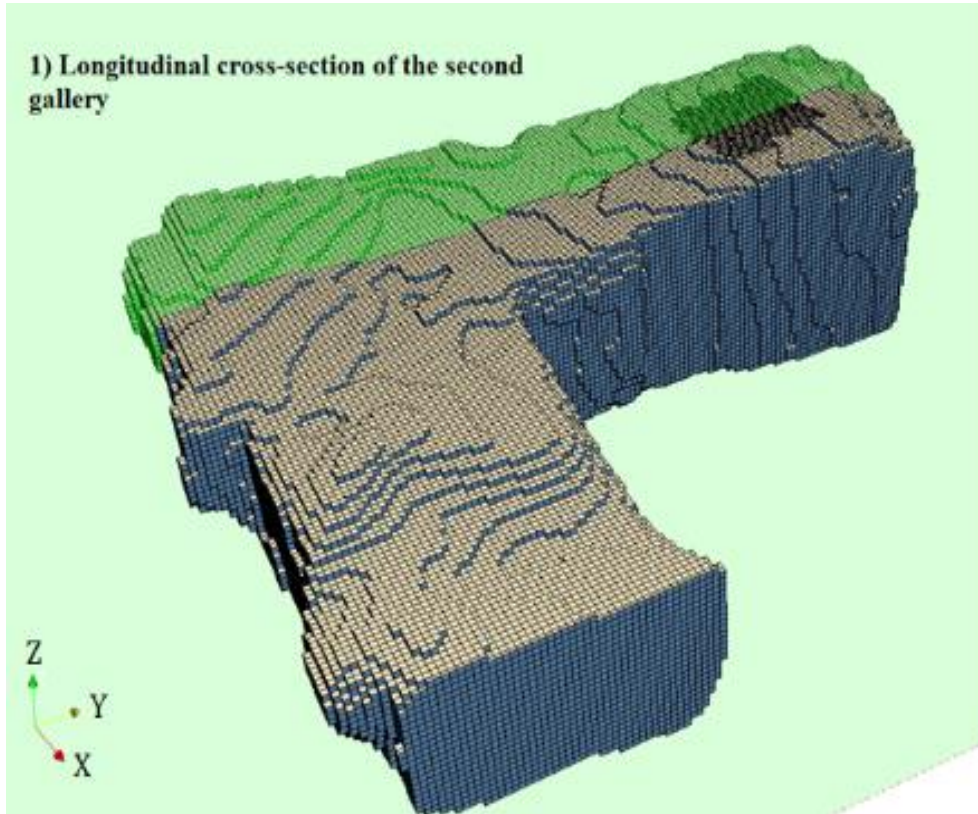
- Numerical rubification
- - - Experimental rubification



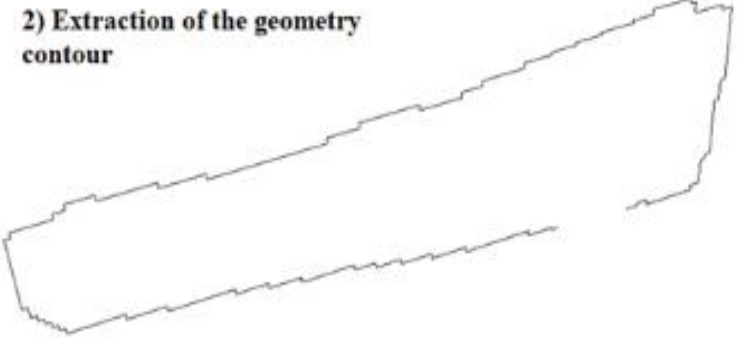
Coupling OpenFOAM-Cast3m

1st step – Defining the boundary geometry

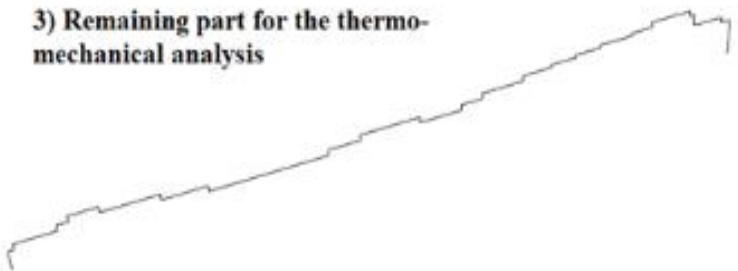
1/4



2) Extraction of the geometry contour

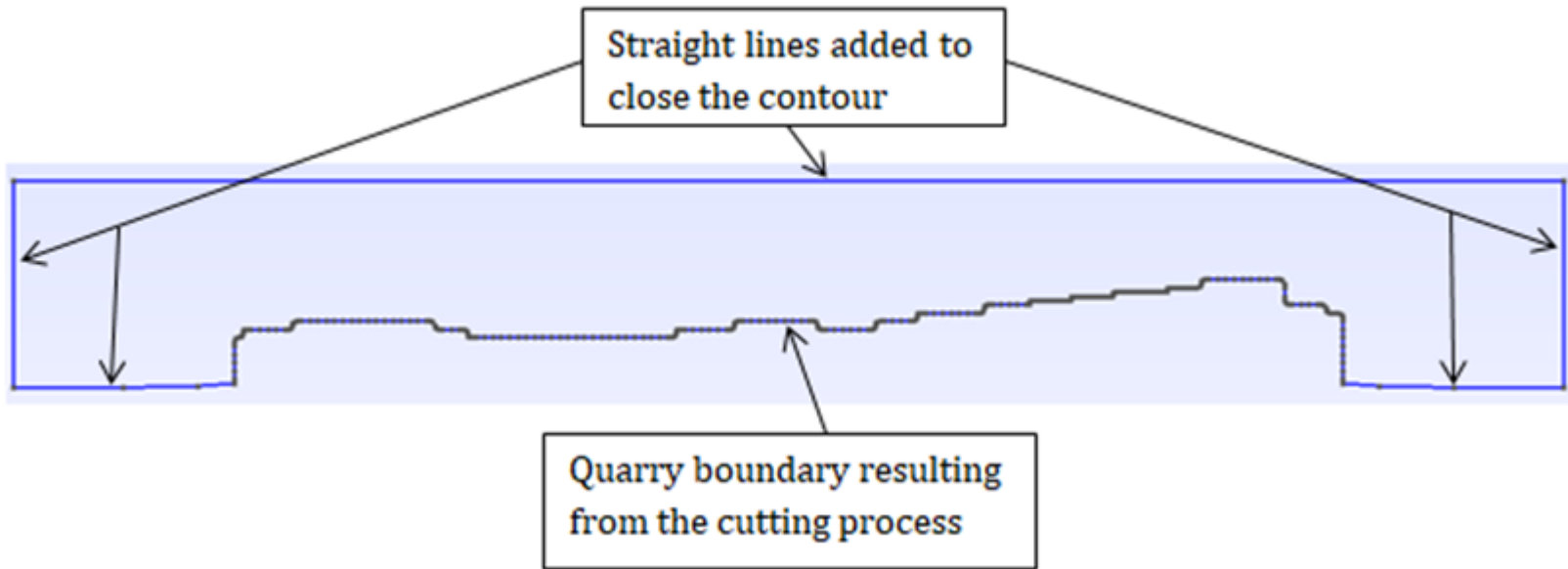


3) Remaining part for the thermo-mechanical analysis



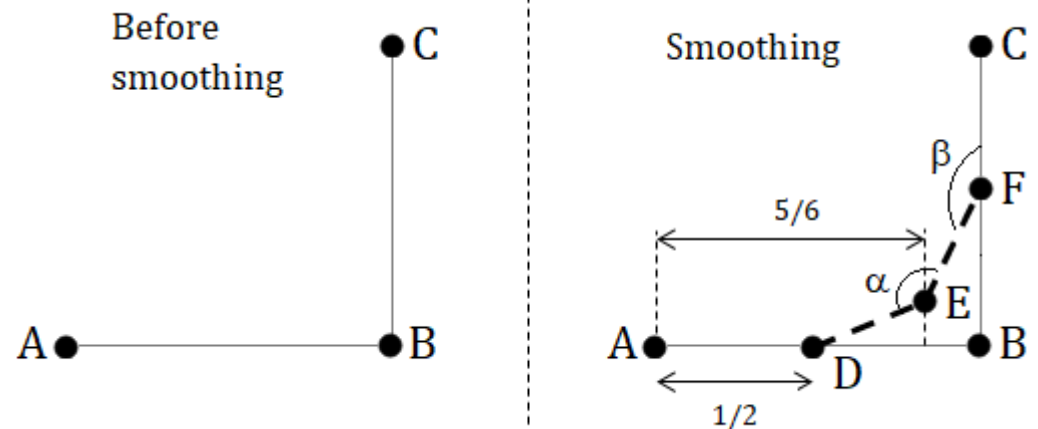
Coupling OpenFOAM-Cast3m

2nd step 2/4 Smoothing



Right-angle \rightarrow Stress singularity

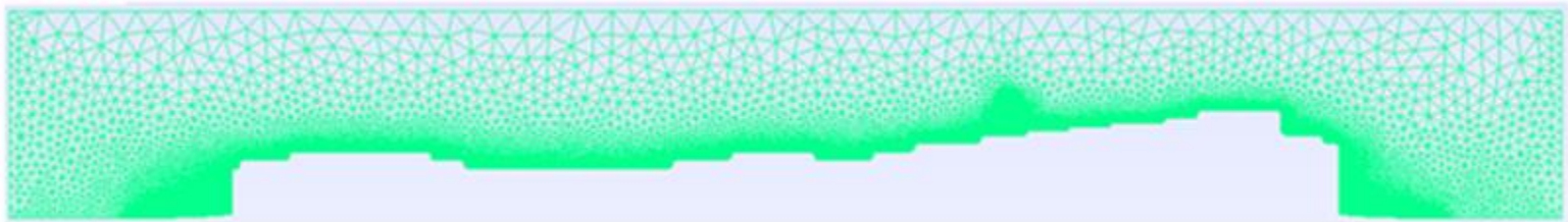
Smoothing process \rightarrow



Coupling OpenFOAM-Cast3m

3rd step – Geometry mesh

Mesh performed by GMSH
according to user settings



4th step – Thermal boundary conditions

Boundary line
temperature



Temperature of the
closest OpenFOAM
boundary face

5th step – Writing the .dgibi file

Coupling OpenFOAM-Cast3m

4/4

6th step – Run Cast3m

Thermal modelling

- Isotropic
- Thermal properties depending on temperature

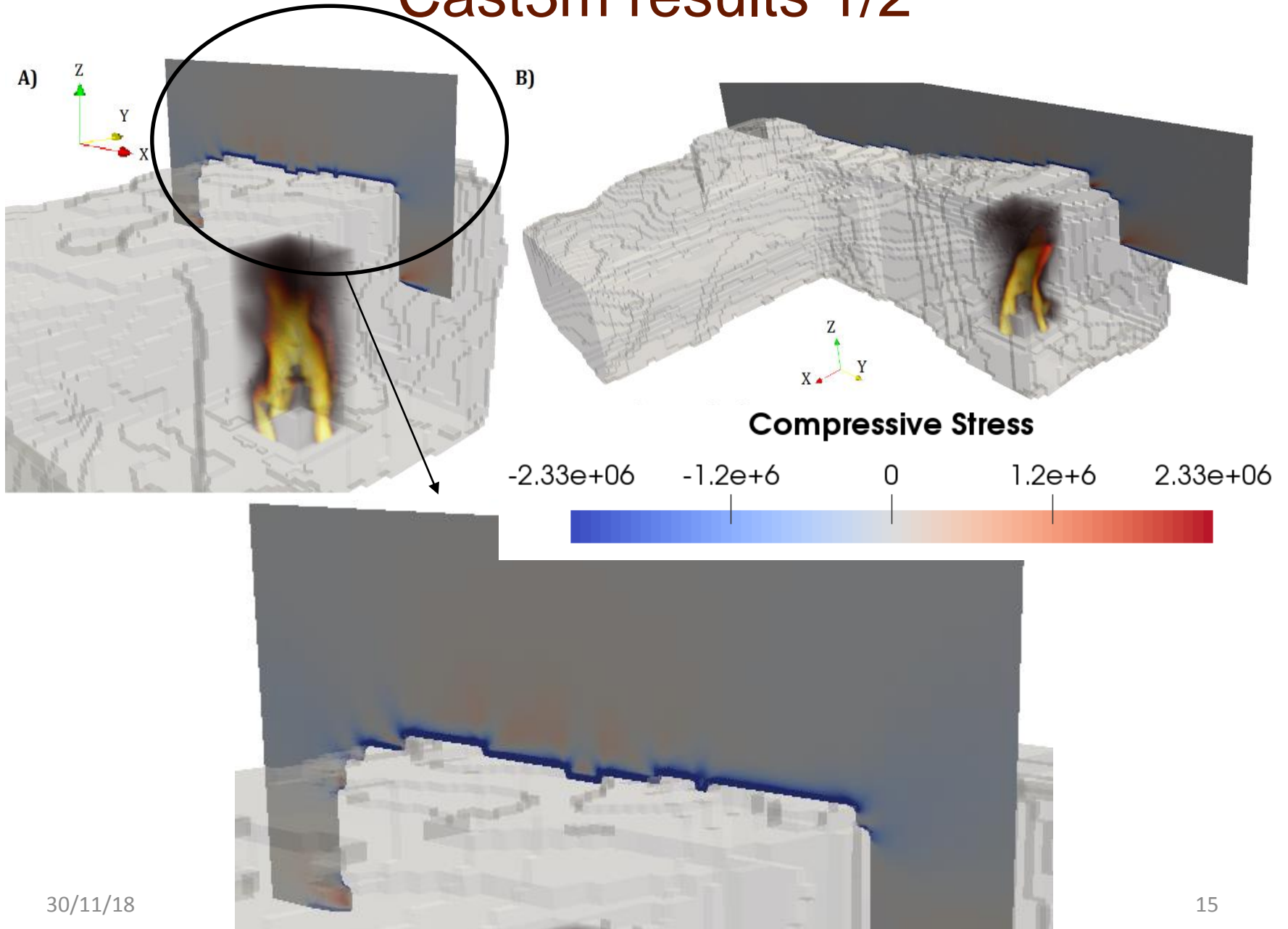
Mechanical modelling

- Isotropic
- Elastic
- Mechanical properties depending on temperature

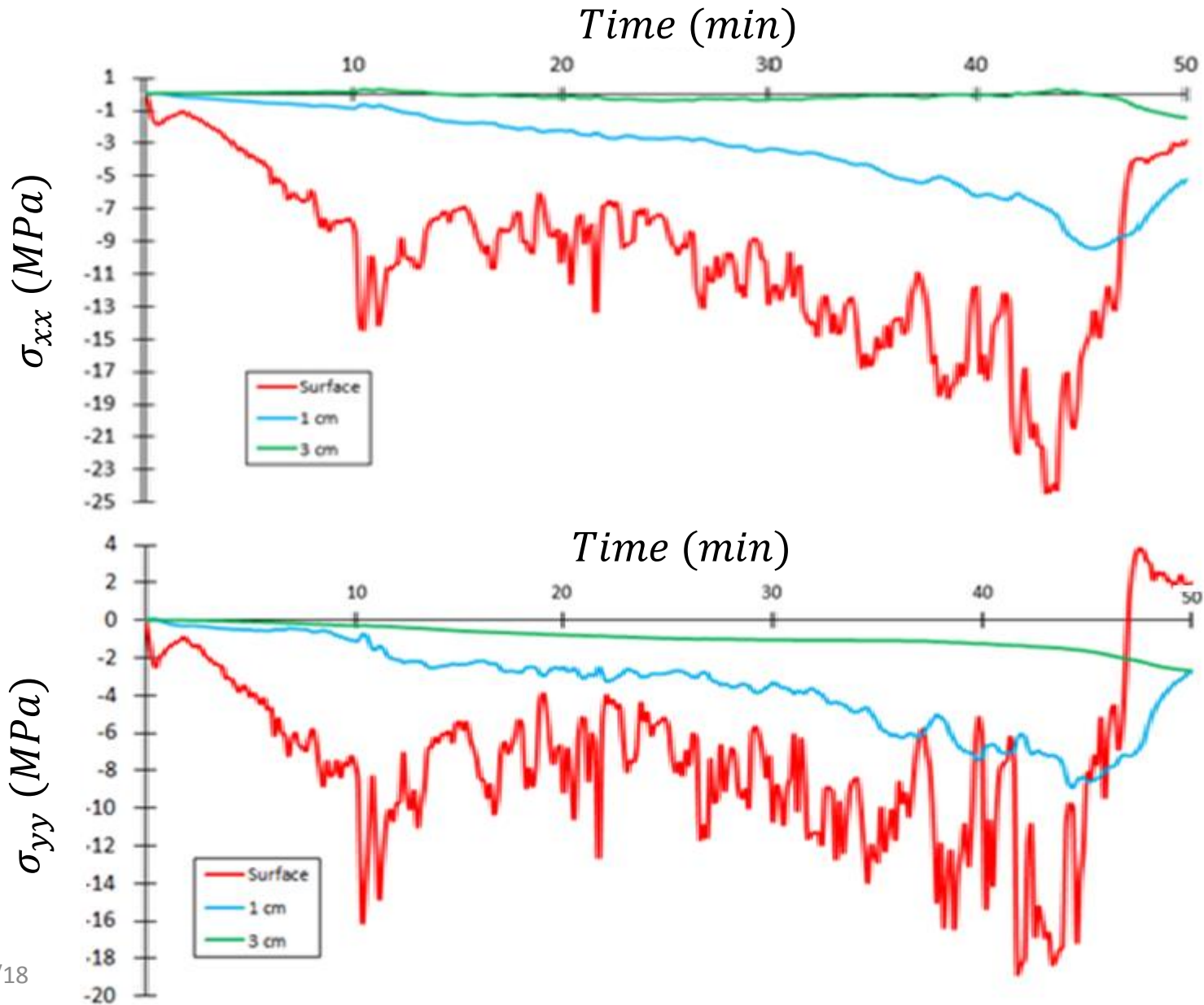
7th step – Post processing

- VTK output → ParaView
- OpenFOAM and Cast3m simulations → same post-processing

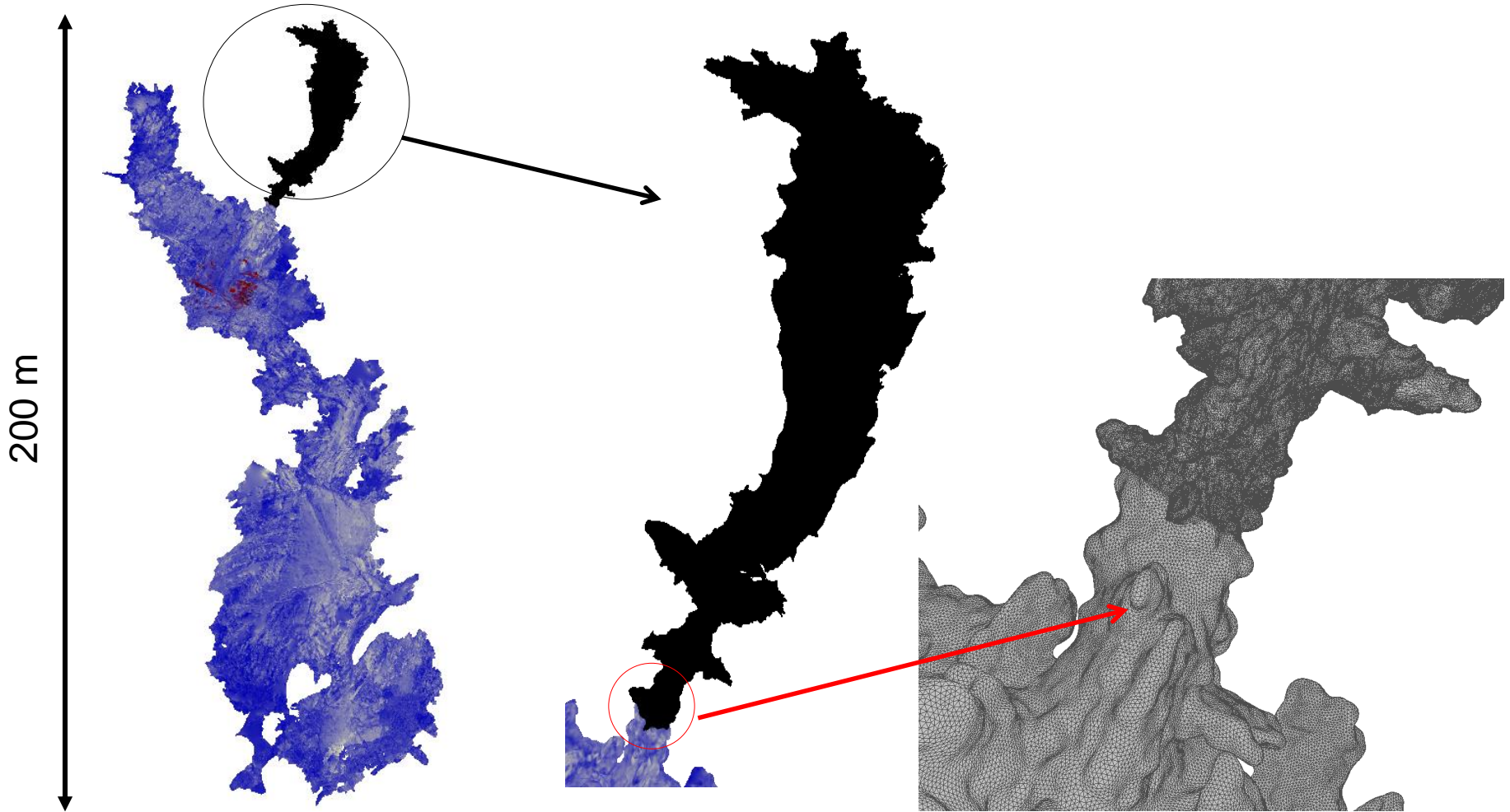
Cast3m results 1/2



Cast3m results 2/2



The Chauvet-Pont d'Arc cave



Ministère de la Culture
DRAC Auvergne – Rhône-Alpes
Archéotranfert UMS 3657 (P. Mora)

Thermo-alterations in the Megaloceros gallery

Spalling

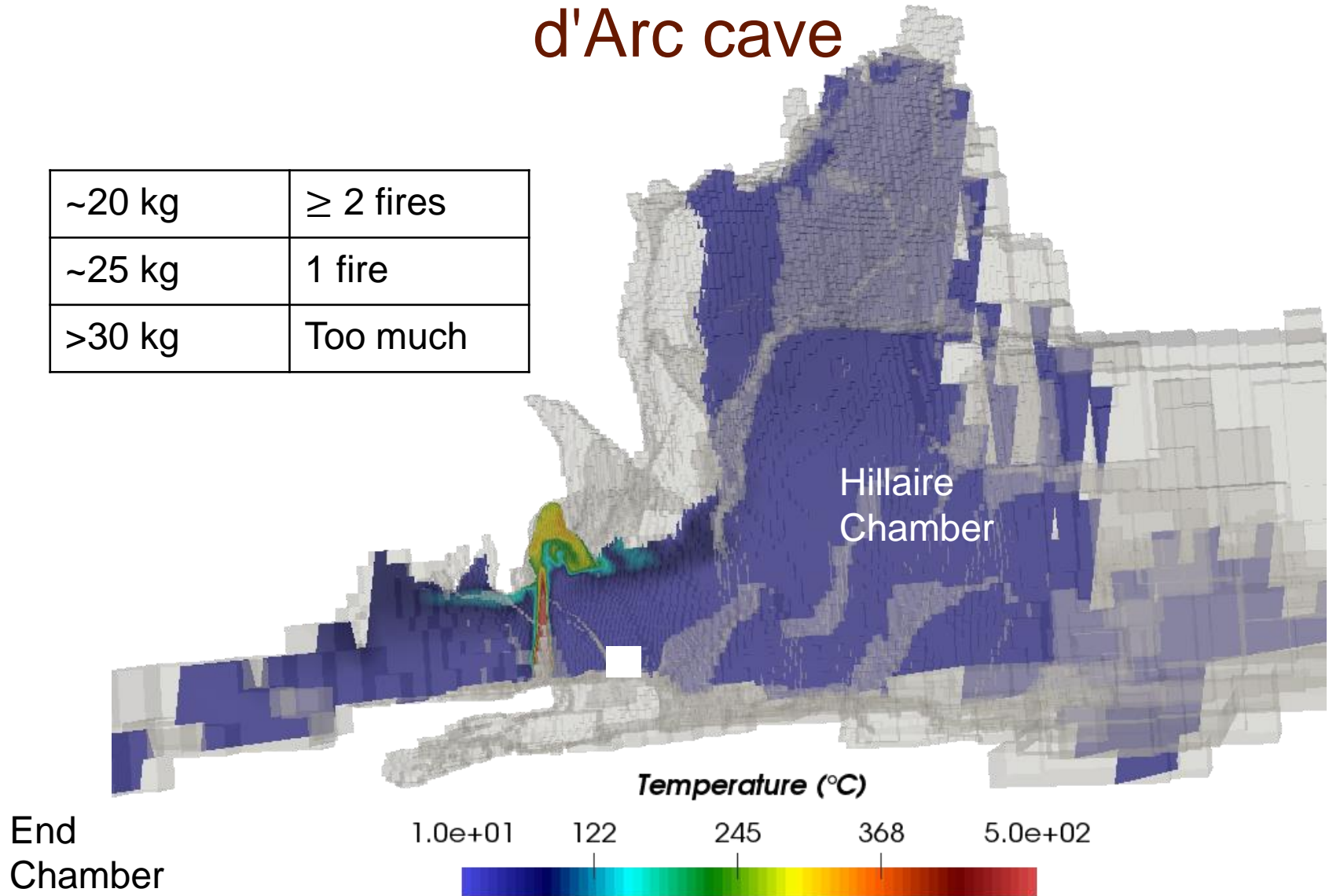


~ 1,50 m

Grey colour
350°C – 10 min

Simulation in the Chauvet-Pont d'Arc cave

~20 kg	≥ 2 fires
~25 kg	1 fire
>30 kg	Too much



Conclusion

Construction of a fluid-structure coupling

Open-source
3D OpenFOAM → 2D Cast3m

Application to the Chauvet-Pont d'Arc fires

Simulation of scenarios

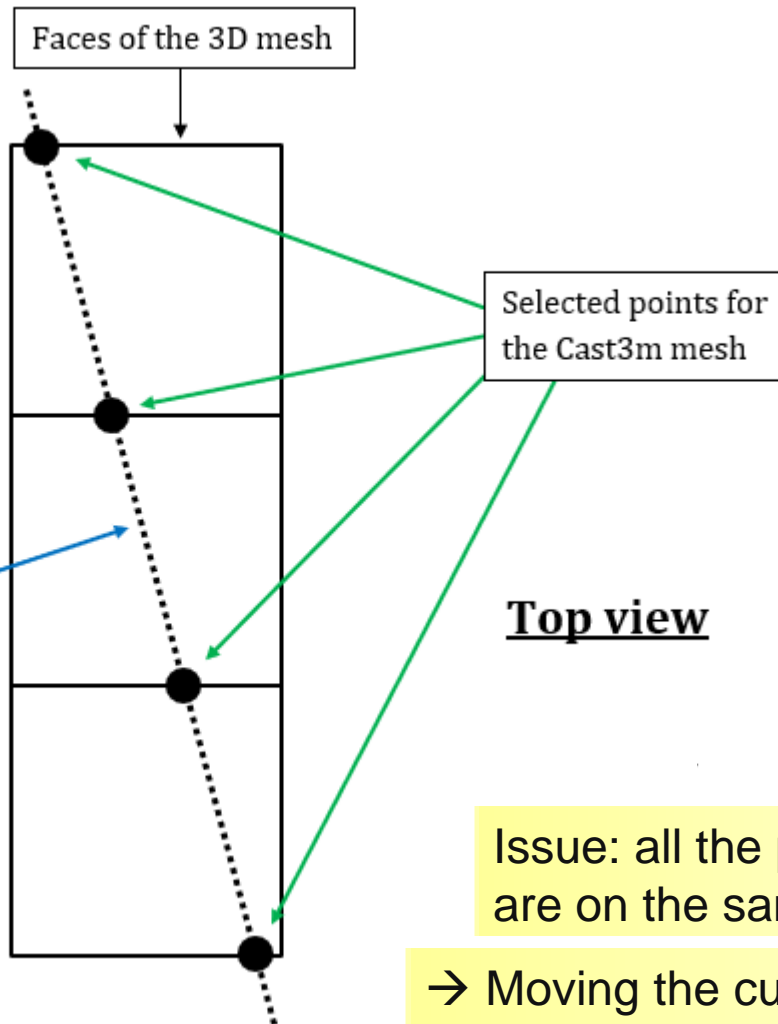
Amount of wood
Source of ignition
Supply method
Number of fires



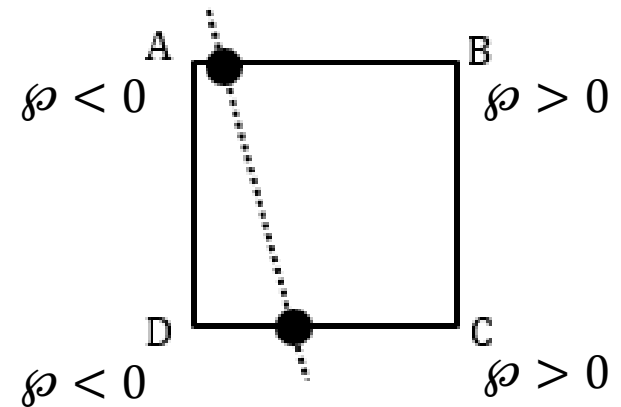
Function(s) of the fires in the Chauvet-Pont d'Arc cave ?

Appendix A

Points acquisition

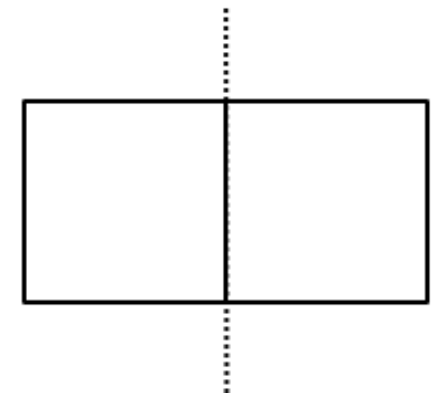


Based on the cartesian equation of the cutting plane
 $\varphi = ax + by + cz + d$



Issue: all the points are on the same side

→ Moving the cutting plane

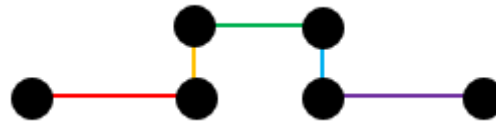


Appendix B






Process to connect the points

Connection to the closest point

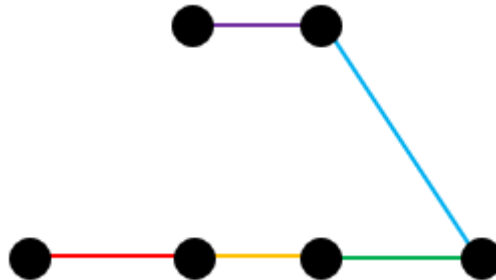
1st case



Sequence of steps

- 1) 
- 2) 
- 3) 
- 4) 
- 5) 

2nd case



Some issues can occur

→ Moving the cutting plane