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On the development of a solver to model two-phase horizontal flow in a heated pipe

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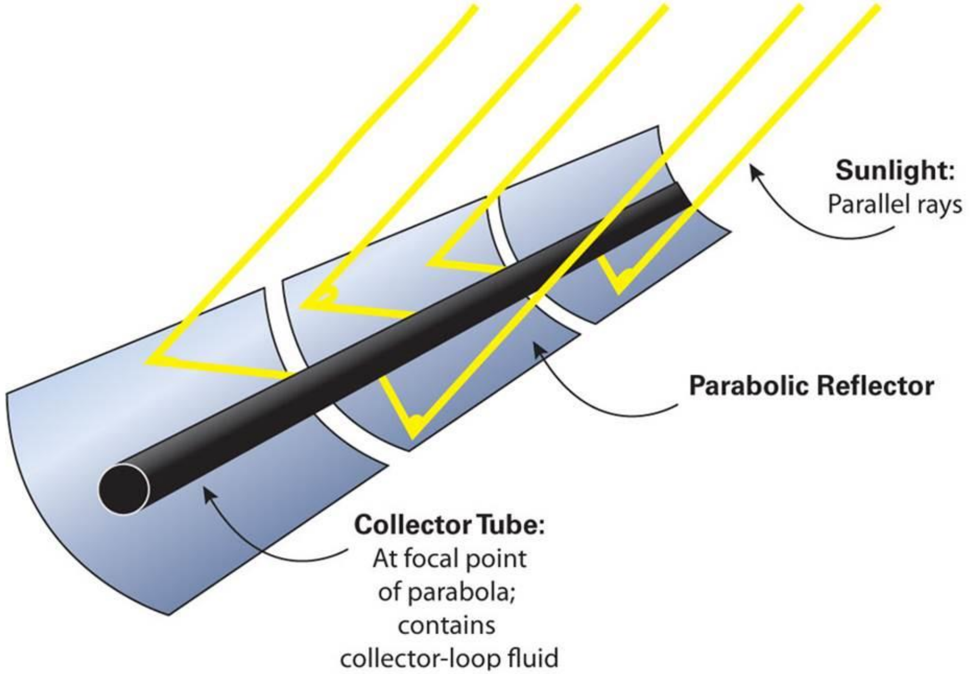
Application: Parabolic trough collector

- Parabolically shaped mirrors concentrate sunlight on absorber tube located in focal line
- Synthetic oil heated in the tubes is used in a heat exchanger unit to generate steam.



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Direct steam generation: Benefits

- Direct steam generation (DSG) in the absorber tubes provides advantages compared to the oil based technology.
- Reduced costs since the oil–water heat exchanger is no longer needed
- Expensive oil replaced by water.
- However, maldistribution of the flow within the horizontal pipes may occur.

Current applications

- Plataforma Solar de Almeria
- 550m long DISS trough collector, thermal power 2MW. Water evaporates directly at pressure up to 100 bars. Heated up to 400 °C.

OpenFOAM

- **Open source Field Operation And Manipulation**
- Open source C++ based library
- Flexibility: Solvers may be modified by user
- No licensing costs
- Some learning curve due to the lack of documentation
- Changes rapidly

OpenFOAM solver

- Standard solver: compressibleTwoPhaseEulerFoam: transient Euler-Euler solver
- Includes: Mass, momentum, and Energy conservation equations
- Momentum and energy transfer between phases
- No phase change

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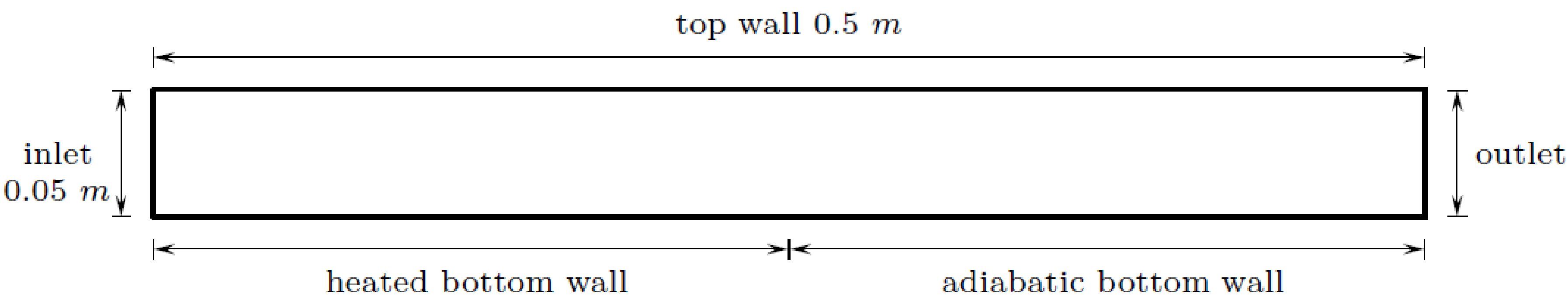
Modifications made to standard solver

- Rate of evaporation:

$$\Gamma_{gf} \propto \frac{(T_f - T_{sat})}{h_{fg}}$$

- T_{sat}: = function of the static pressure
- h_{fg} : = enthalpy of formation

Geometry and boundary conditions



- Uniform block mesh: 500x50 cells
- Time step: 1e-04 s
- Relaxation 0.1 and later 0.3

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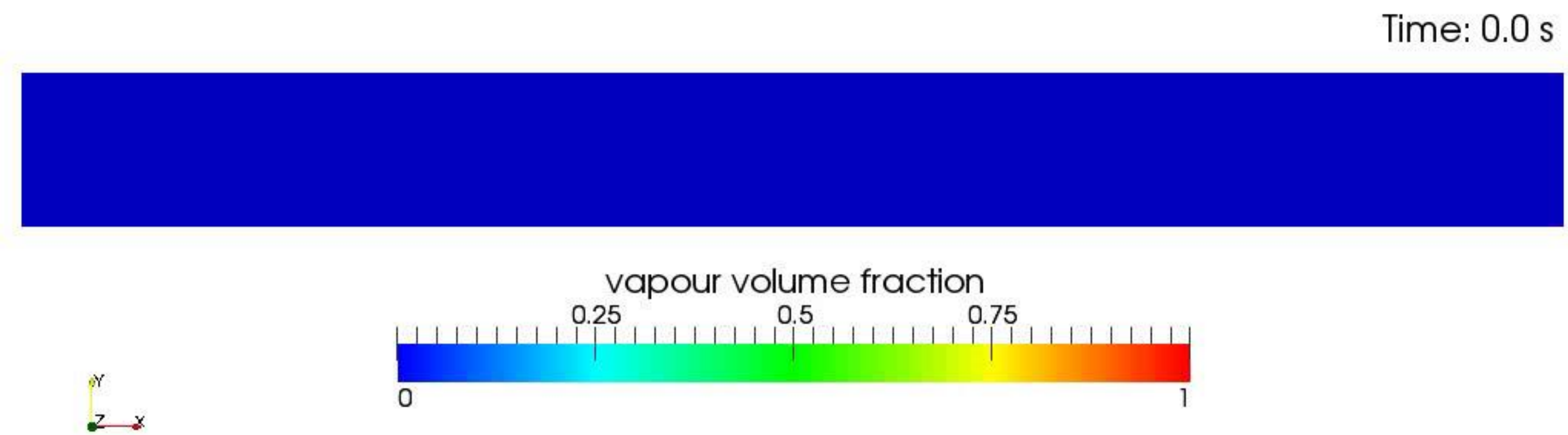
Simulation: Vapour volume fraction



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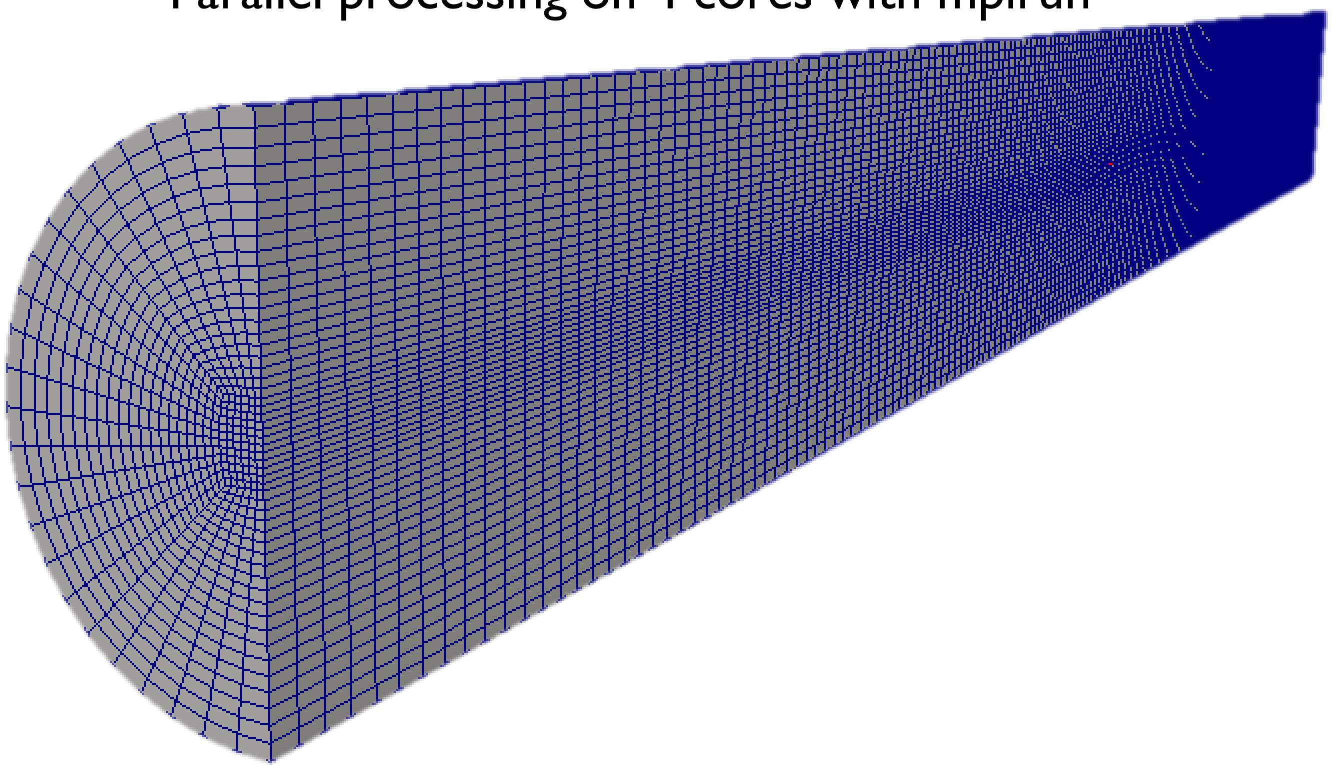
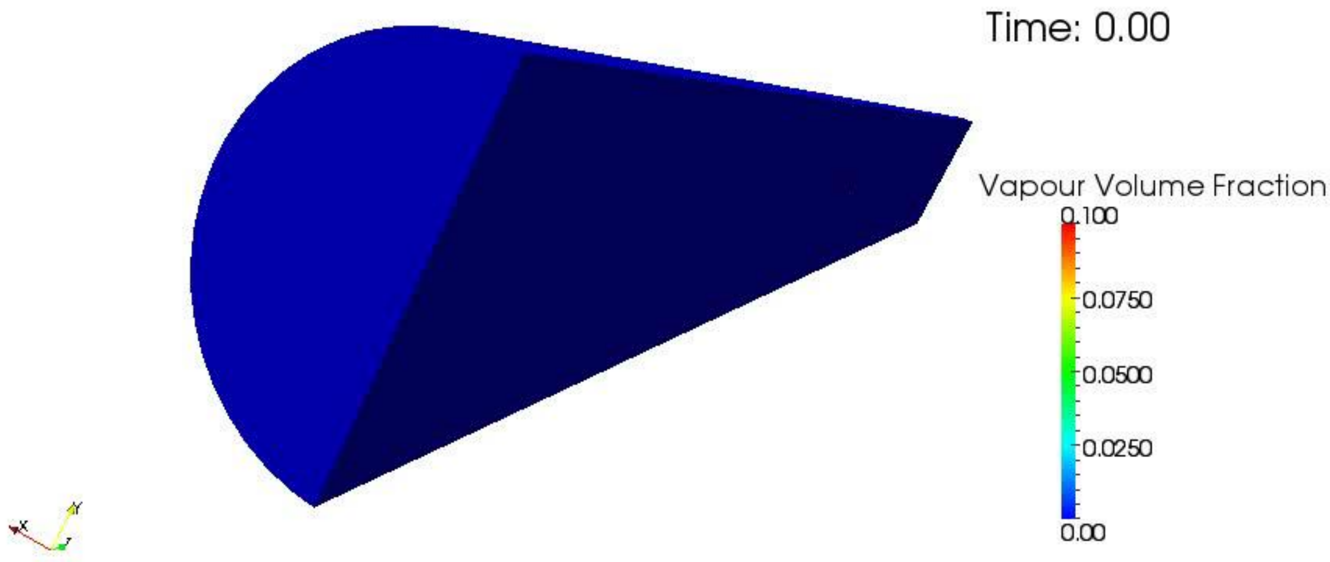
3D Simulation: Grid

- Grid generation with m4 GNU preprocessor
- Geometry: Cylinder, 5 cm diameter, 0.5 m length
- 110 000 cells
- Parallel processing on 4 cores with mpirun

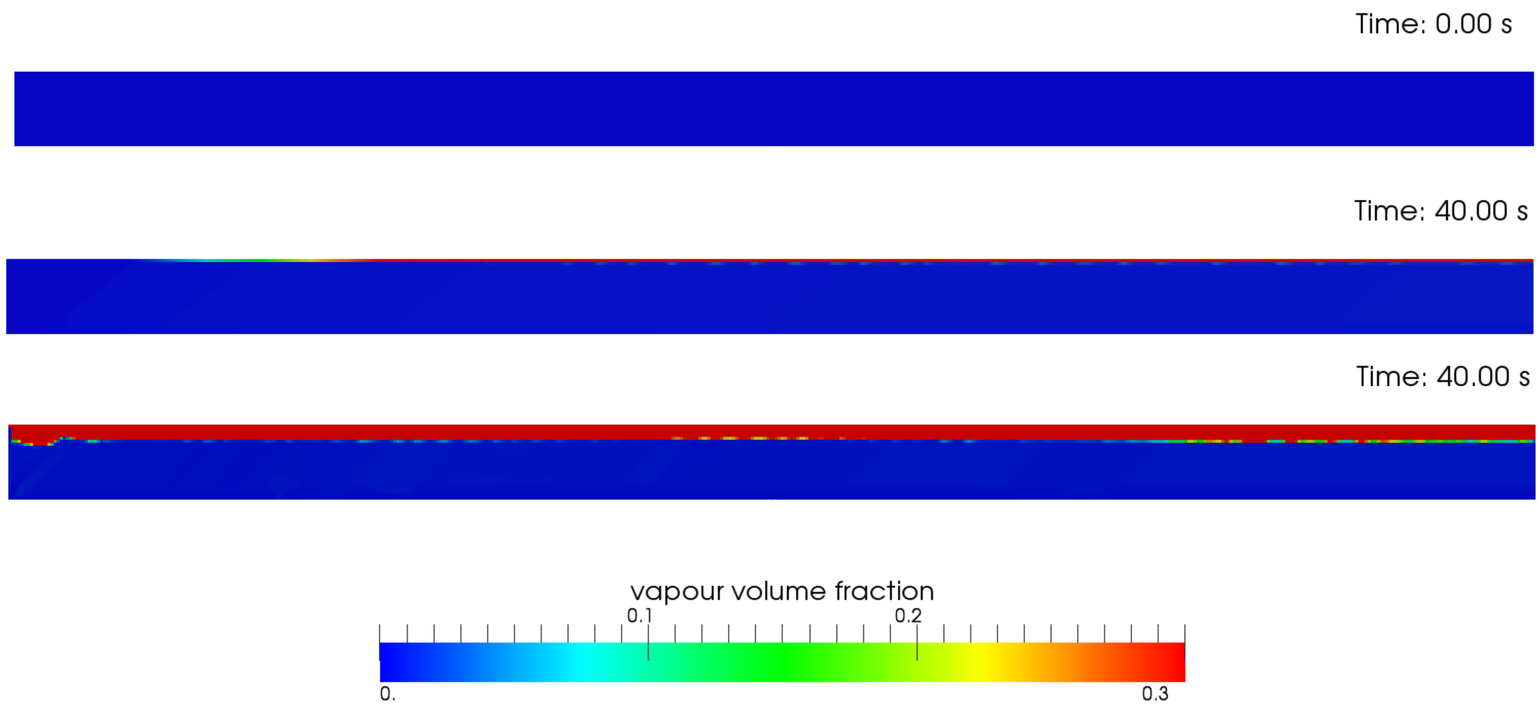


3D Simulations: Vapour volume fraction



Mapped boundary conditions

- We want to simulate a LONG pipe (200 m)
- Simulate short section and use outlet conditions as inlet conditions for second section



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Future work

- Accurate correlation for evaporation
- Mapped conditions (3D)
- Turbulence
- Simulations running on GPU

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