Poster B-19

POLITECNICO DI TORINO

A multi-scale approach for the analysis of open volumetric air receivers

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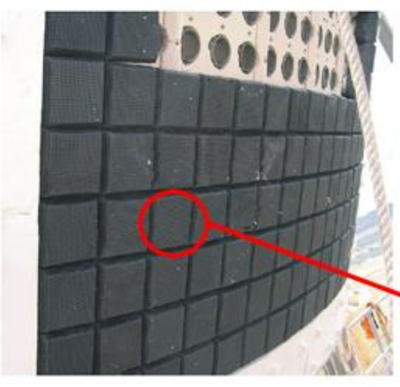
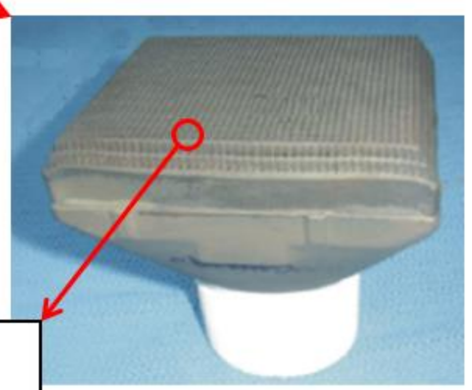
Open Volumetric Receiver

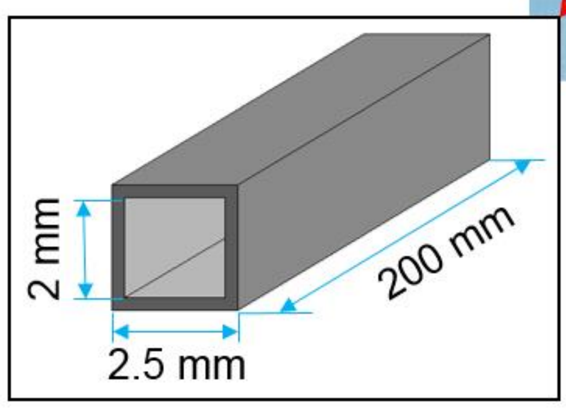
Multiscale Structure



Receiver (Macro-Scale):
Modular structure consisting of several cups.
- Receiver type: SolAIR200
- Dimensions: 6x6 cups (0.61 m^2)



Cup (Meso-Scale):
- Honeycomb (porous) structure
- Square cross-section (0.017 m^2)
- Material: SiSiC

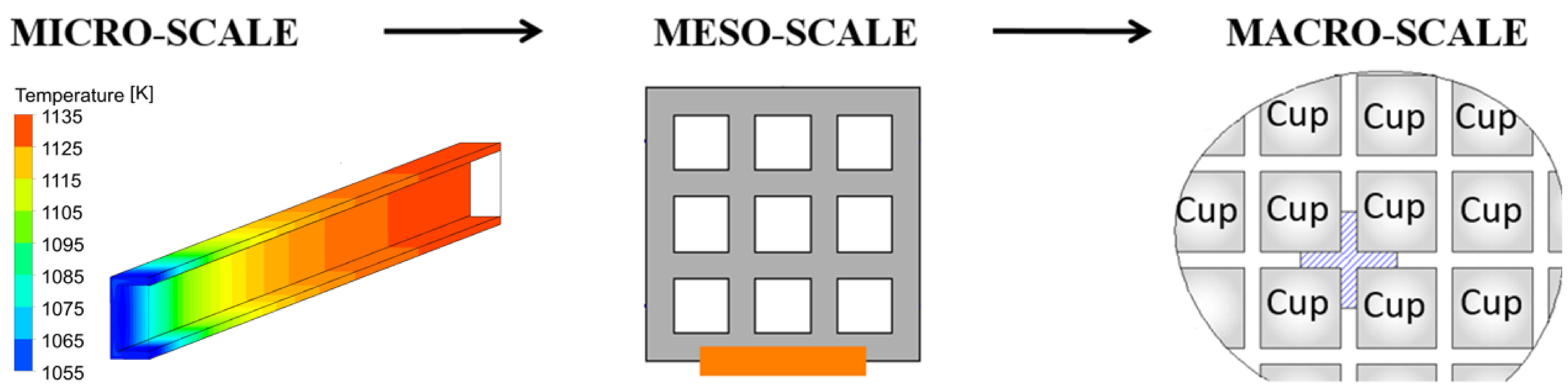


Channel (Micro-Scale):
Basic component that replaced in the space generates the absorber

Multiscale Approach

Idea: Multiscale approach for the analysis!!

Rationale: at any scale analyze the relevant phenomena that affect the receiver performance at that scale, which cannot be all considered at the larger scales.



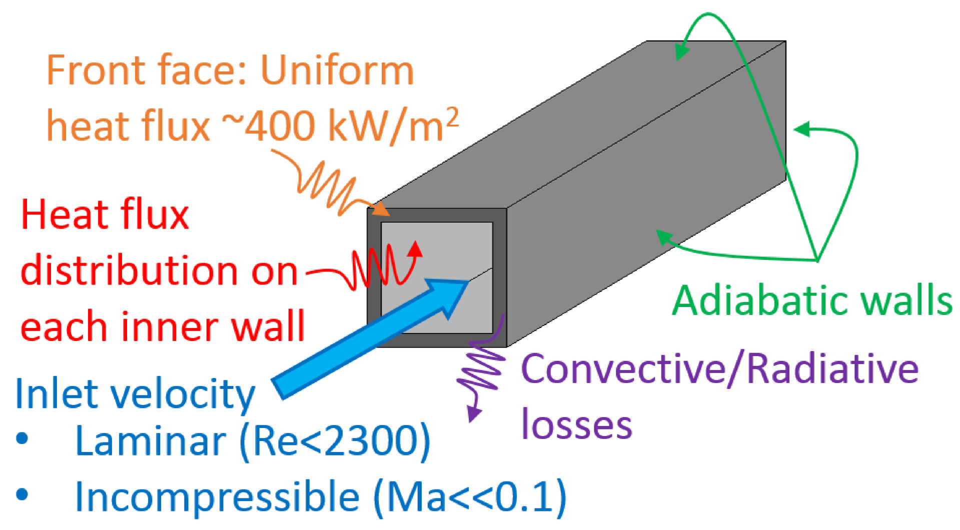
Single channel
- CFD detailed (3D) analysis (Fluent)
- Solid+Fluid domain
- Used to characterize the component

Cup
- Modelica 1D model.
- Input from micro-scale

Receiver
- Modelica 1D model.
- 1D Cups + 1D air return channels

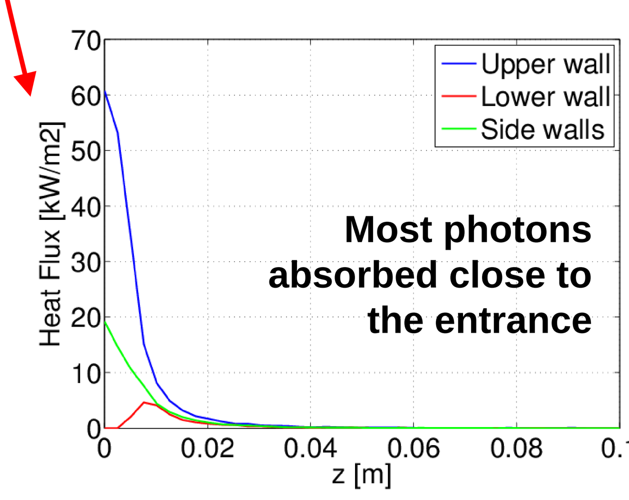
Micro-Scale (single channel)

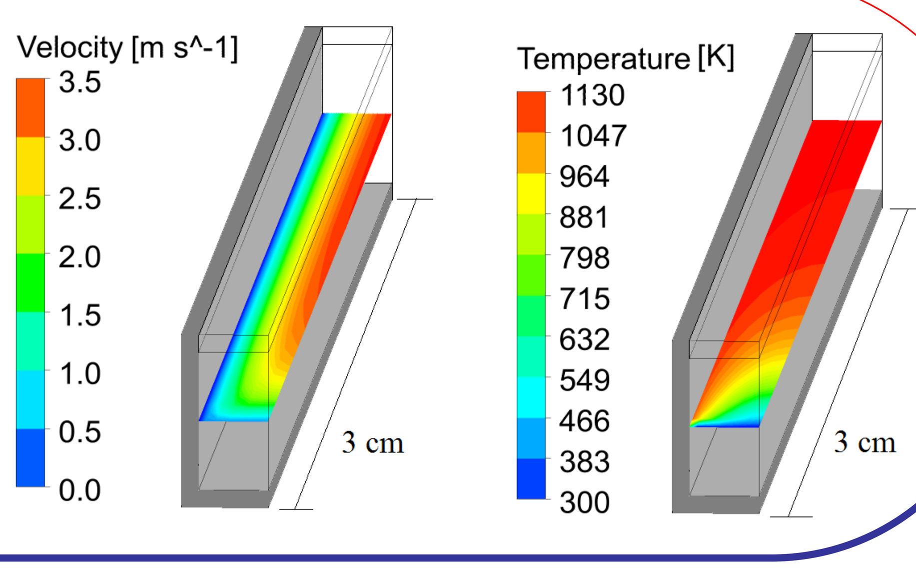
Aim: Characterize the channel from a thermo-fluidynamic point of view



- Steady state conditions
- Tètouan, Morocco
- 21st June, 12.00 pm
- DNI =1000 W/m2

Optic-CFD analysis, outputs:
- Flow Field → Pressure drop
- Temperature distribution and fluid-solid heat exchange → Local heat transfer coefficient





Tools:
- Optics: Tonatiuh
- CFD: Fluent

Meso-Scale (cup)

Micro-Scale → Meso-Scale (cup 1D model – porous medium approximation)

Hydraulic model

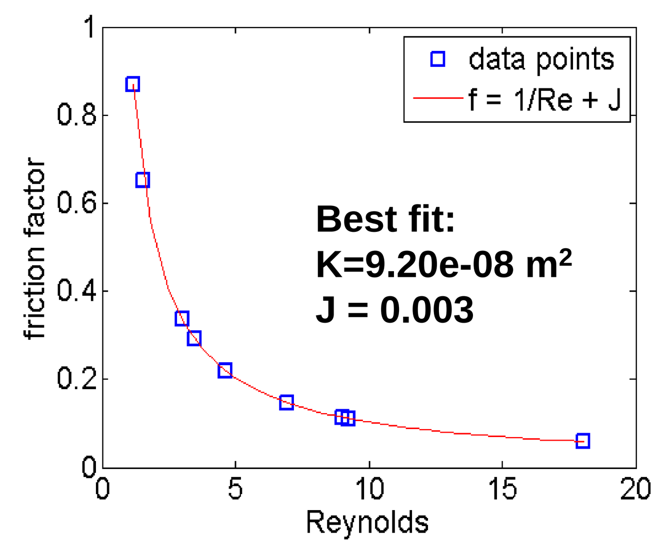
Darcy-Forchheimer law

$$\frac{\partial p}{\partial z} = -\frac{\mu}{K}\varphi u - \frac{J}{\sqrt{K}}\rho\varphi^2 u^2$$

$$f_k = \frac{1}{Re_k} + J$$

$$f_k = \frac{\Delta p}{\Delta z}\beta\frac{\sqrt{(K)}\rho_{out}A_{fluid}^2}{(dm/dt)^2}\frac{1}{\varphi^2}$$

$$Re_k = \frac{(dm/dt)\varphi\sqrt{(K)}}{\mu A_{fluid}}$$



Needed characterization:
- Porosity (φ) = 0.64
- Permeability (K)
- Inertial coefficient (J)

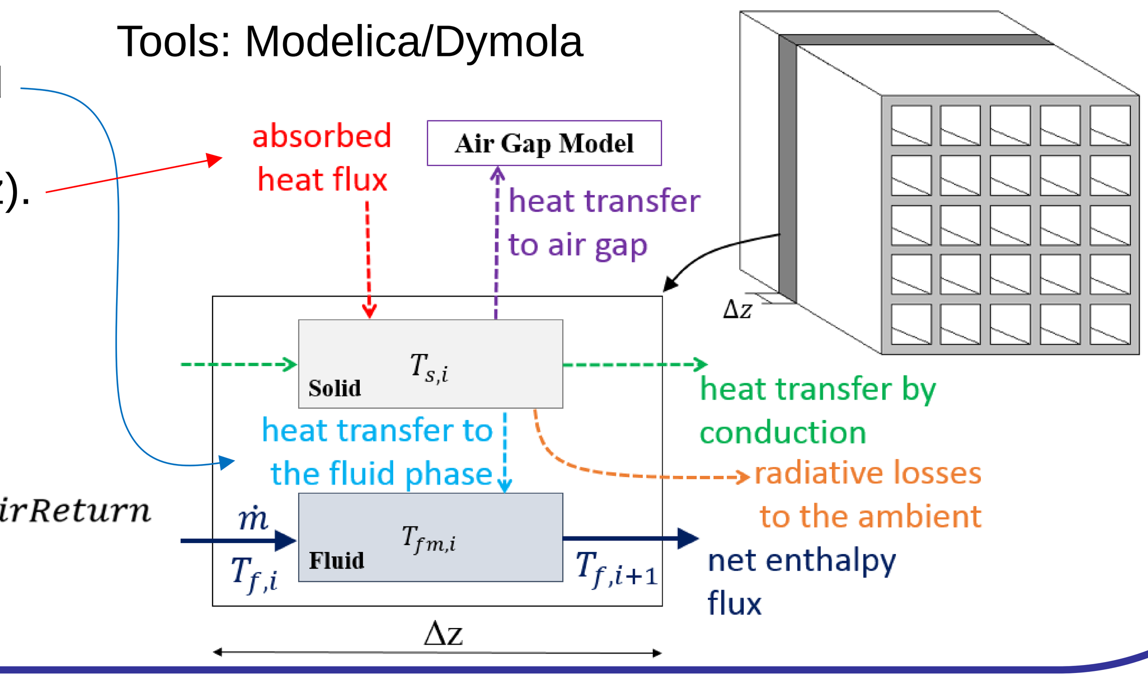
Non-equilibrium thermal model

Input from Micro-Scale:
- Local h_z [W/m^{2}K] (solid phase ↔ air flow)
- Heat load (function of z).

Tools: Modelica/Dymola

Dynamic Energy Balance (solid phase):

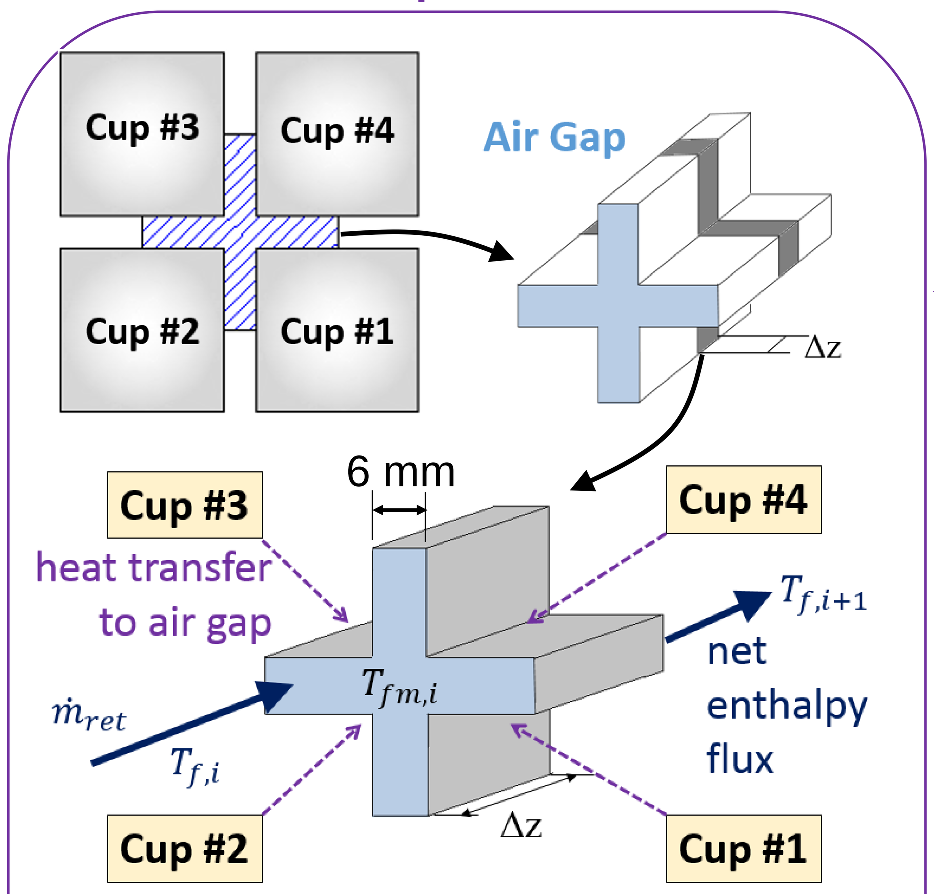
$$\Phi_{abs} = \rho V c\frac{dT}{dt} + \Phi_{loss} + \Delta\Phi_{cond} + \Phi_{fluid} + \Phi_{airReturn}$$



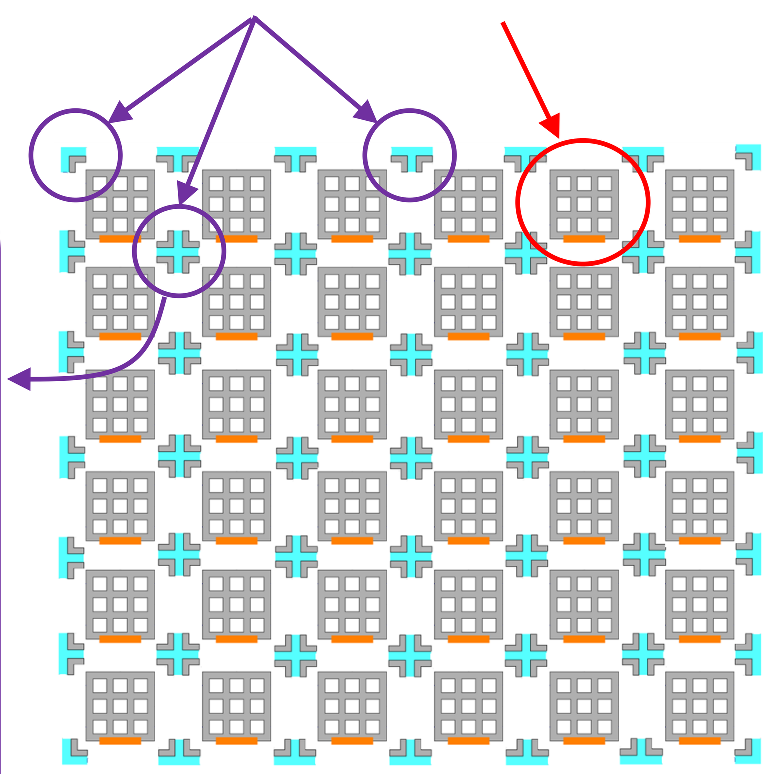
Macro-Scale (whole receiver)

Meso-Scale → Macro-Scale (coupling between Air Gaps and Cups)

Air Gap 1D Model



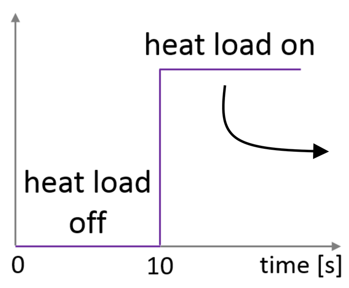
- Cross-shaped air gap (4 adjacent cups)
- No interactions among adjacent air gaps
- Counter flow thermal coupling with cups

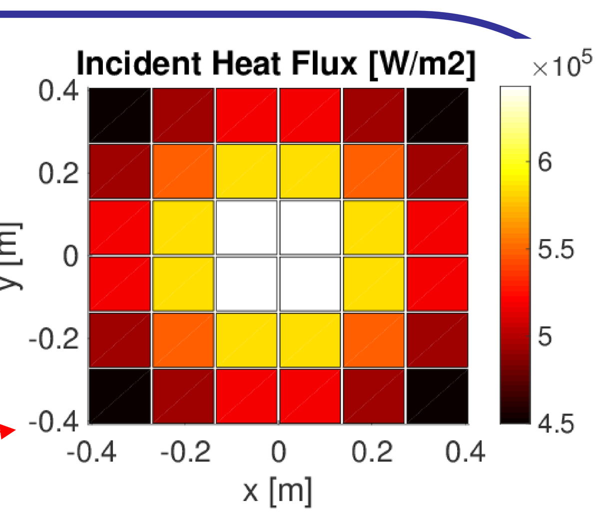


Aim of the Macro-Scale model:
- Consider the effect of the return air on the receiver performance
- Consider the non-uniform heat flux distribution on the front face

Test case: Plant start up (**step** variation)

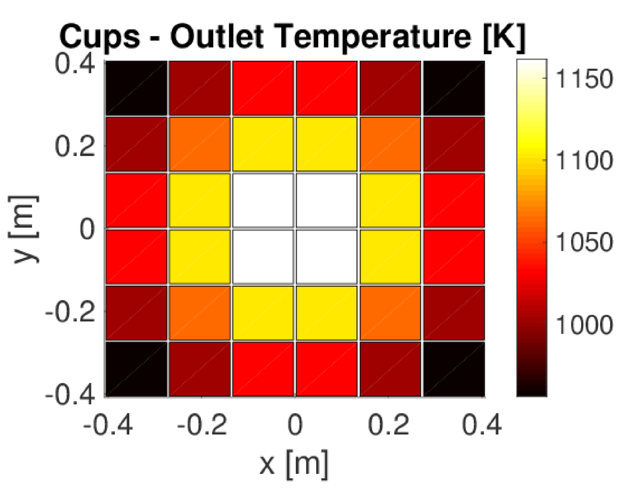
Simulation setting:
- 36 cups
- Uniform mass flow rate distribution among the cups = 0.0094 kg/s.
- Air Return Ratio (ARR) = 40% [1]
- T_inlet for the air gap = 393 K [2]
- **Thermal Driver**: Non-uniform heat flux distribution [3]

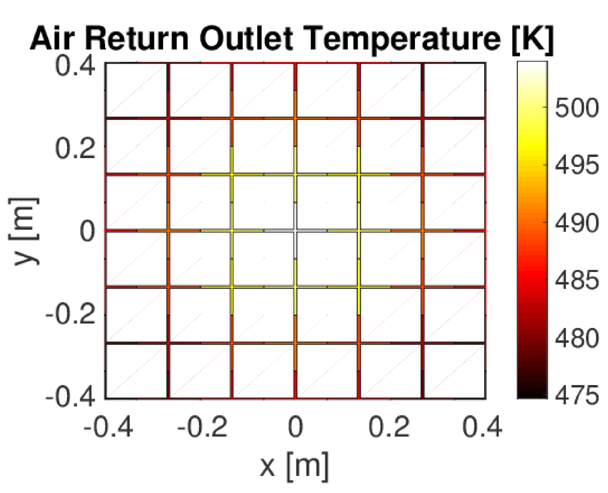




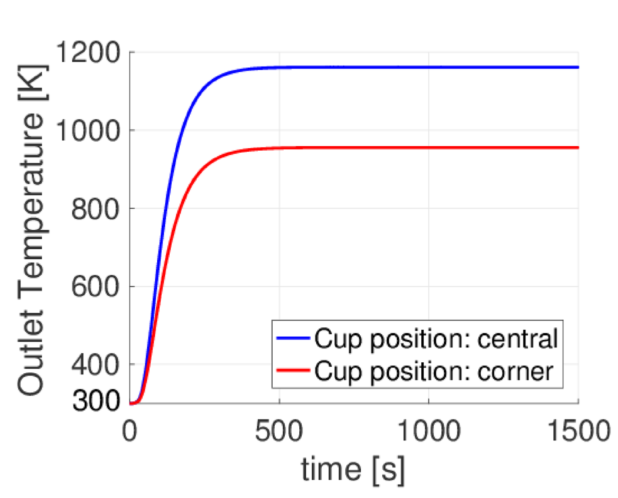
Results example

Temperature distribution at the end time (steady state)





Temperature evolution



Conclusion: A novel multiscale approach is used for the evaluation of the (dynamic) performance of open volumetric air receivers. First receiver model implemented and successfully tested.

Perspective: Include the receiver model in a plant model with the main components

References:

[1] F.M. Téllez, et al., SolAir 200 project, Technical report, Plataforma Solar de Almeria, 2003.

[2] http://sfera2.sollab.eu/uploads/images/networking/SFERA%20SUMMER%20SCHOOL%202014%20-%20PRESENTATIONS/SolarTowerReceivers%20-%20Bernhard%20Hoffschmidt.pdf

[3] http://sfera.sollab.eu/downloads/Schools/Heat_Flux_Measurement_Jesus_Ballestrin_SFERA2013.pdf

SolarPACES 2016 international conference, October 11-14 2016, Abu Dhabi, UAE