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Yijun Li, Stéphane Roux, Cathy Castelain, Lingai Luo, Yilin Fan. A genetic algorithm-based topology optimization method for convective cooling of a heating surface with multiple-peak heat flux. Congrès Français de Thermique SFT 2022, May 2022, Valenciennes, France. hal-03790244

HAL Id: hal-03790244

<https://hal.science/hal-03790244>

Submitted on 28 Sep 2022

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A genetic algorithm-based topology optimization method for convective cooling of a heating surface with multiple-peak heat flux



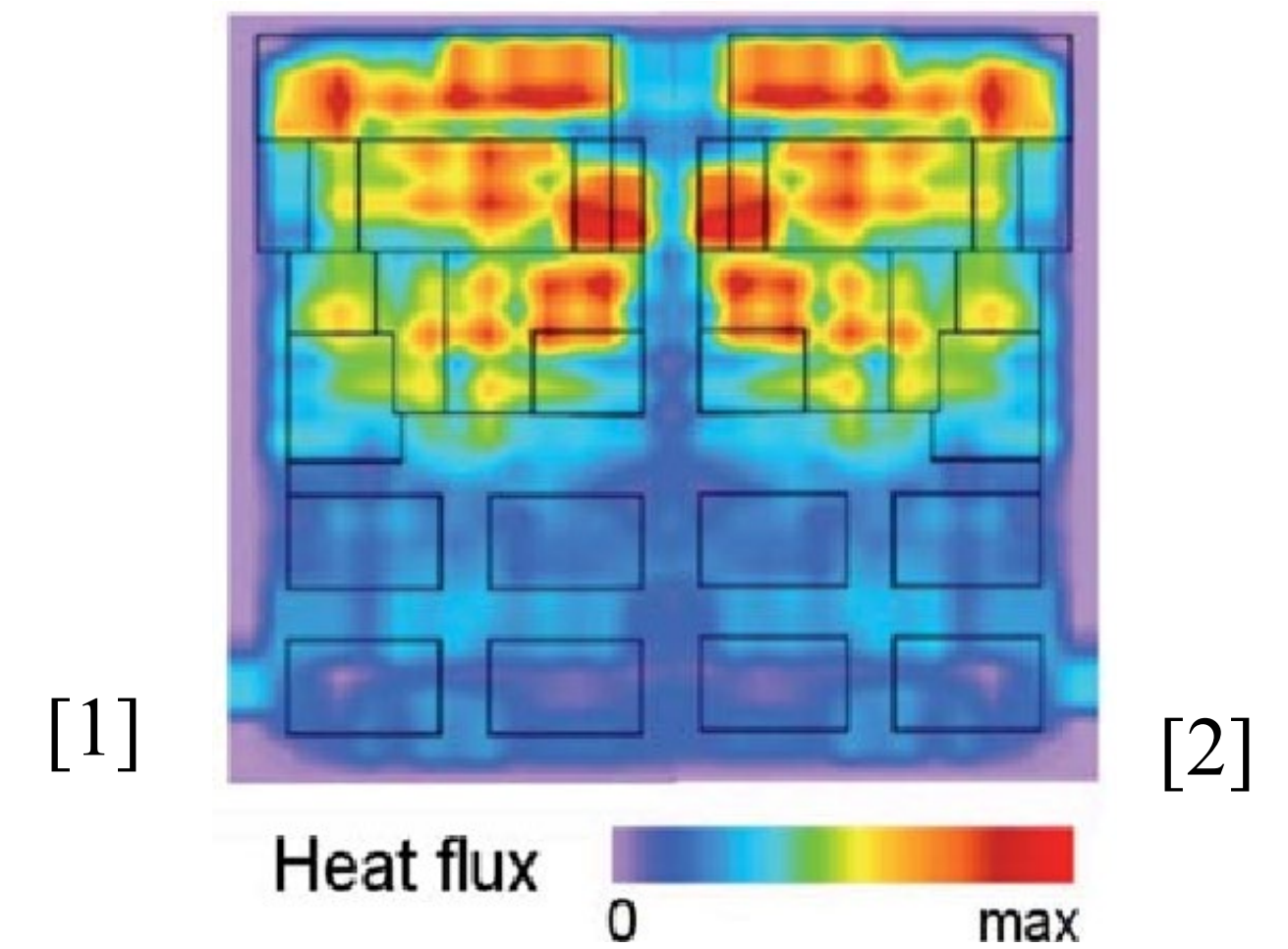
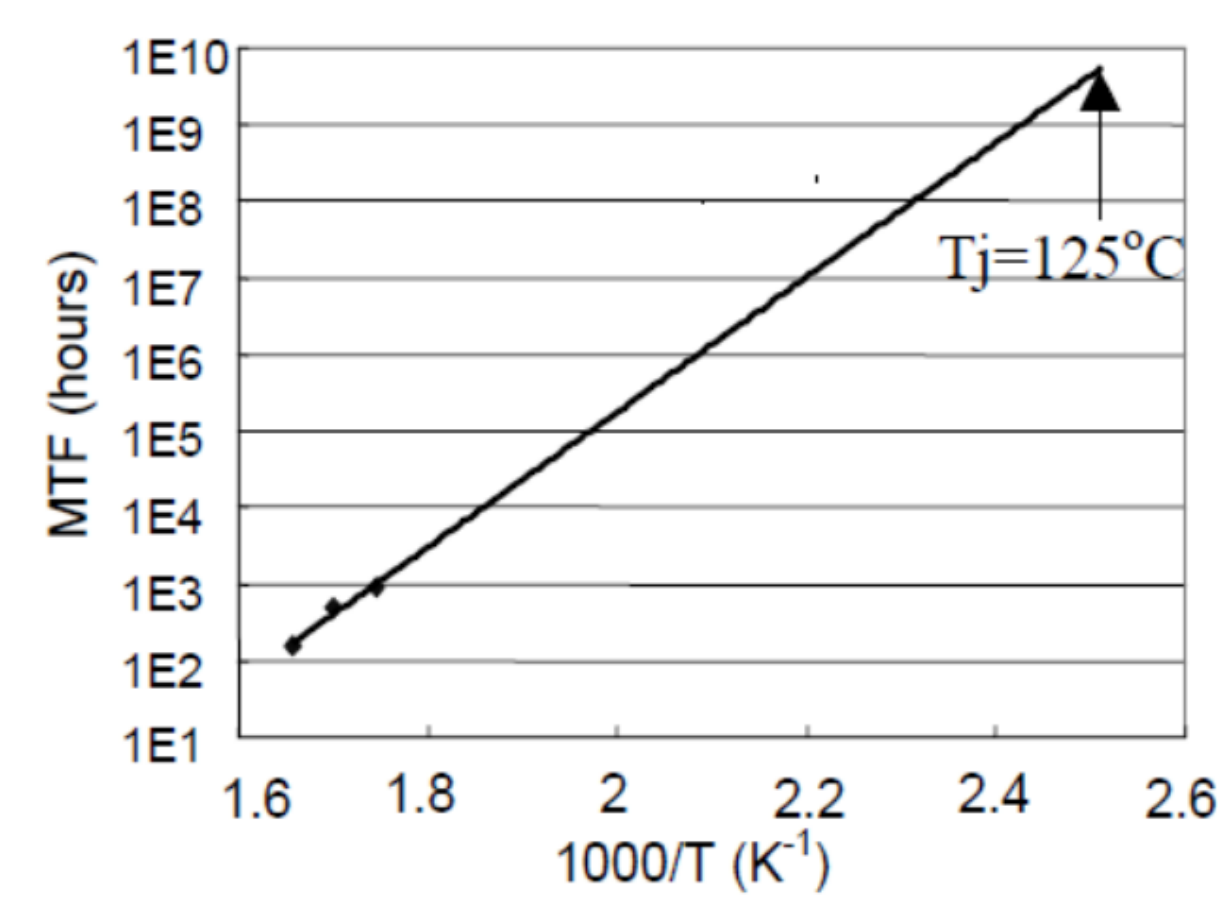
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Context and Objective

- The heat-generating surface with a multiple-peak heat flux is commonly encountered in many thermal devices, including electronic components, PV/T panels, Lithium-ion battery packs of electric vehicles, etc.
- The temperature hot spots and overheating due to inefficient cooling would cause an increased failure rate, decreased performance and the threatened safety of components.
- The single-phase fluid-cooled heat sink is often used to handle this issue due to its design simplicity, effective cooling performance, and compact size.

Objective: optimization of flow circuit configurations in heat sinks for the efficient convective cooling of a heating surface with multiple-peak heat flux by an original **genetic algorithm-based topology optimization (GATO)** method

MTF (mean time to failure)

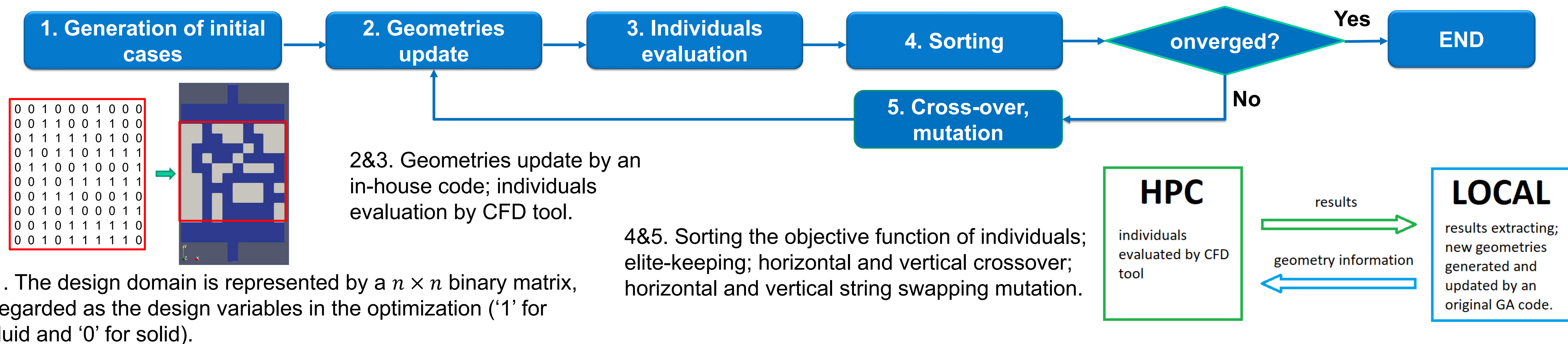


[1] Leung et al. GaAs Reliability Workshop, pp. 87-88, 1999; [2] Thomas Brunswiler. Interlayer Thermal Management of High-Performance Microprocessor Chip Stacks (2012). Cuvillier Verlag

GATO Method

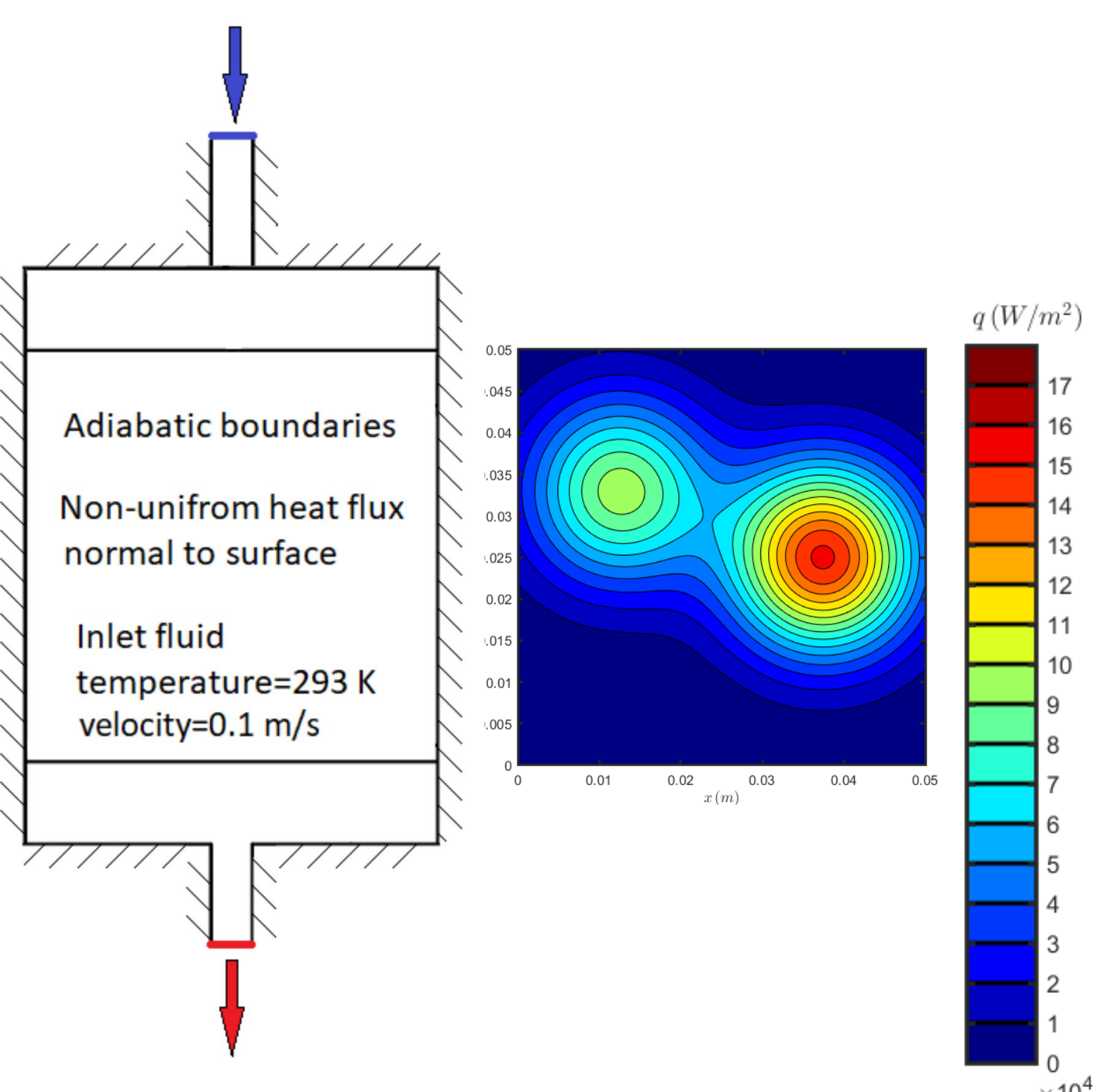
Basic principle:

The GATO method is applied to determine the best allocation of fluid and solid cells in the design domain based on the defined objective (minimizing the peak temperature (T_{max}) at the heating surface) and under the constraints of: (1) the constant ratio of fluid/solid cells and (2) full connectivity of all the fluid elements.

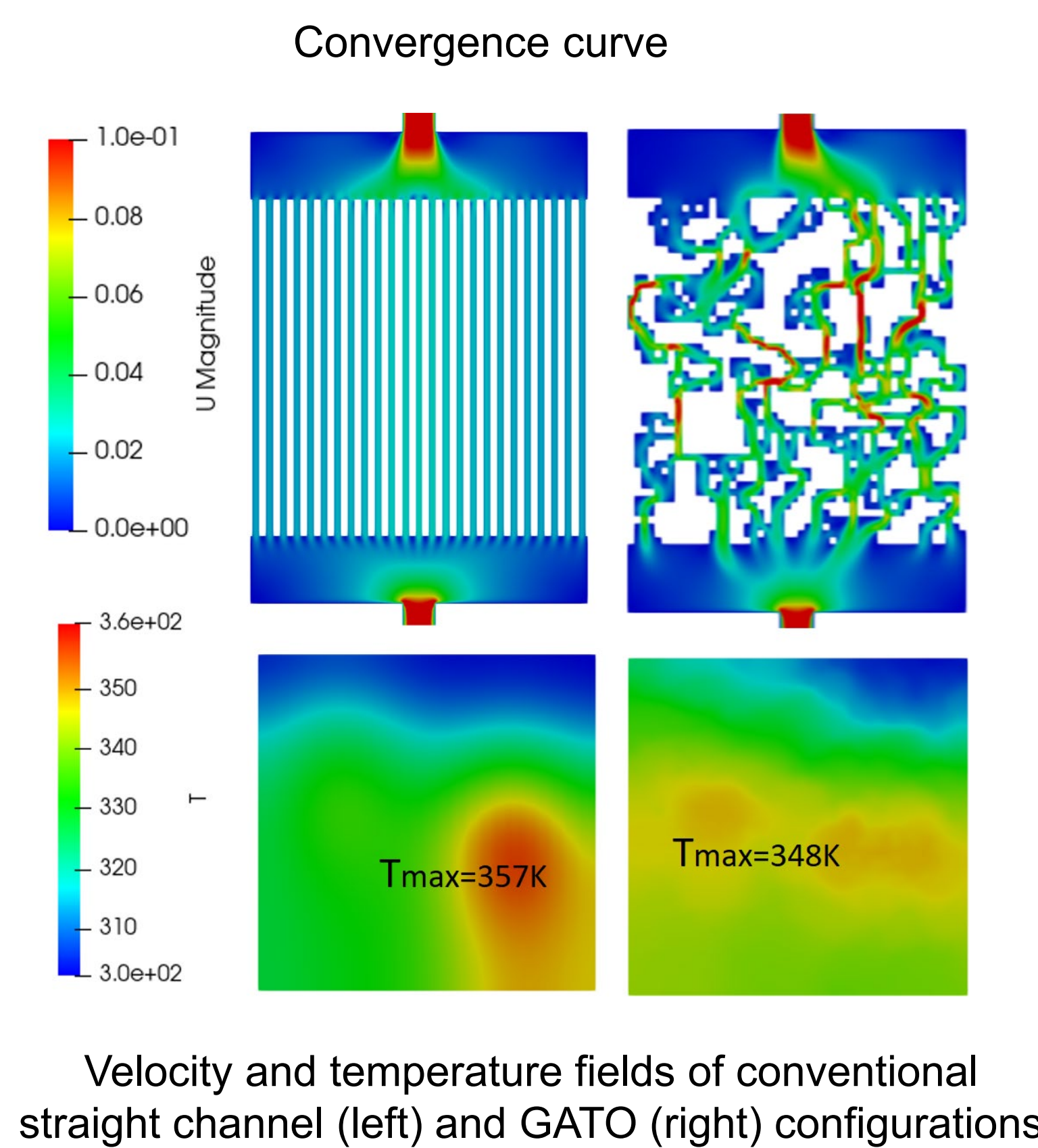
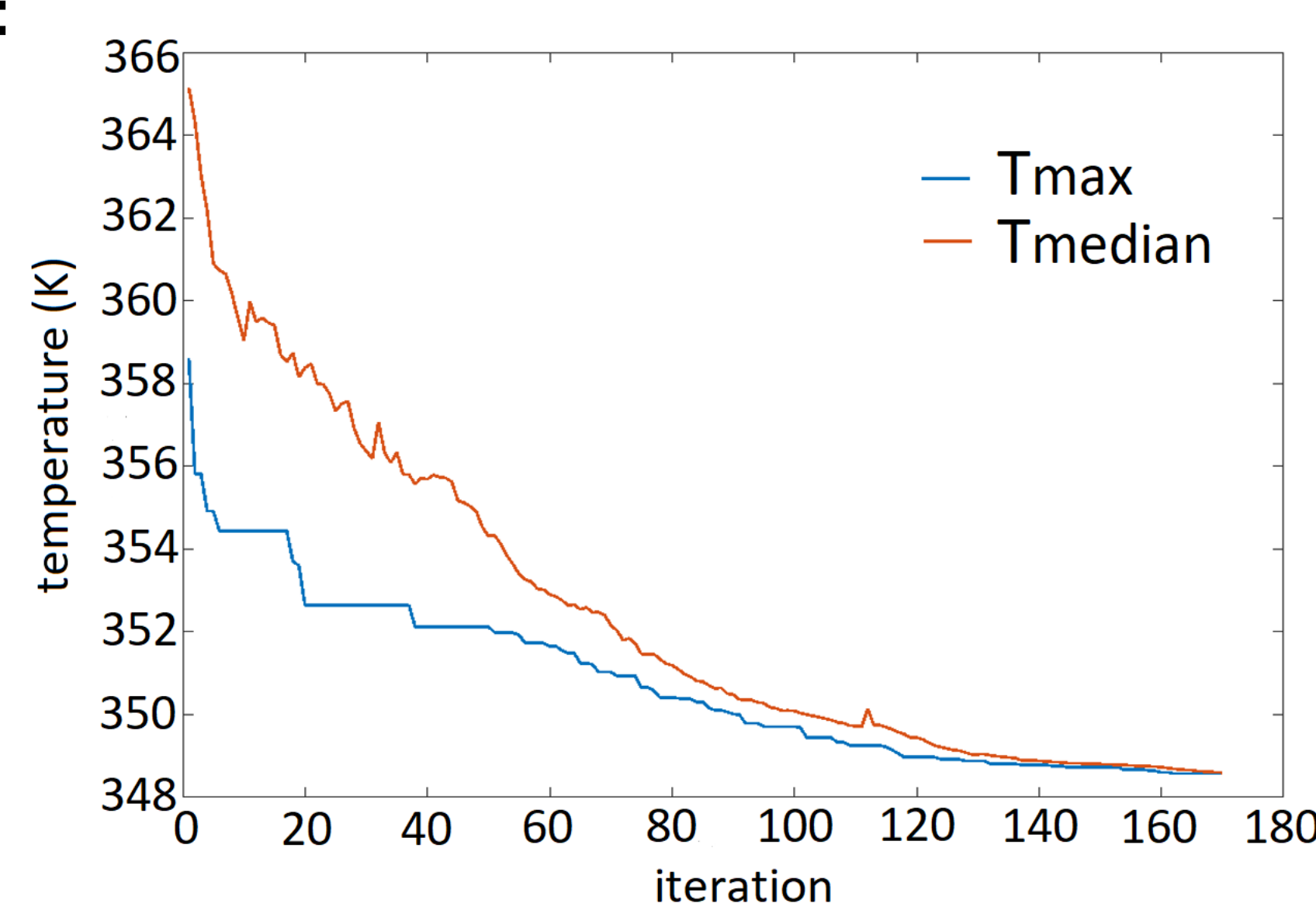


Results and Discussion

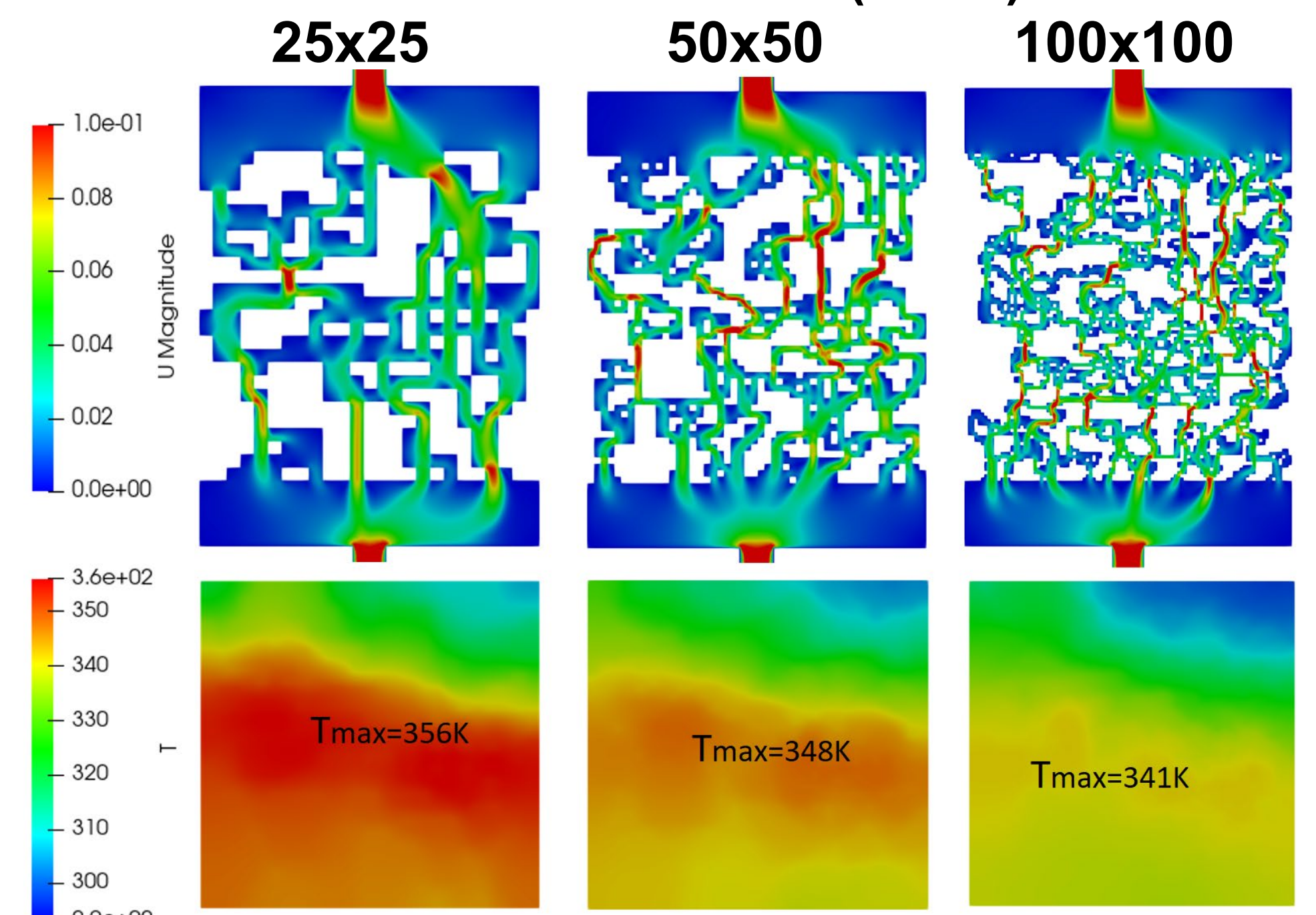
Boundary conditions (benchmark case):



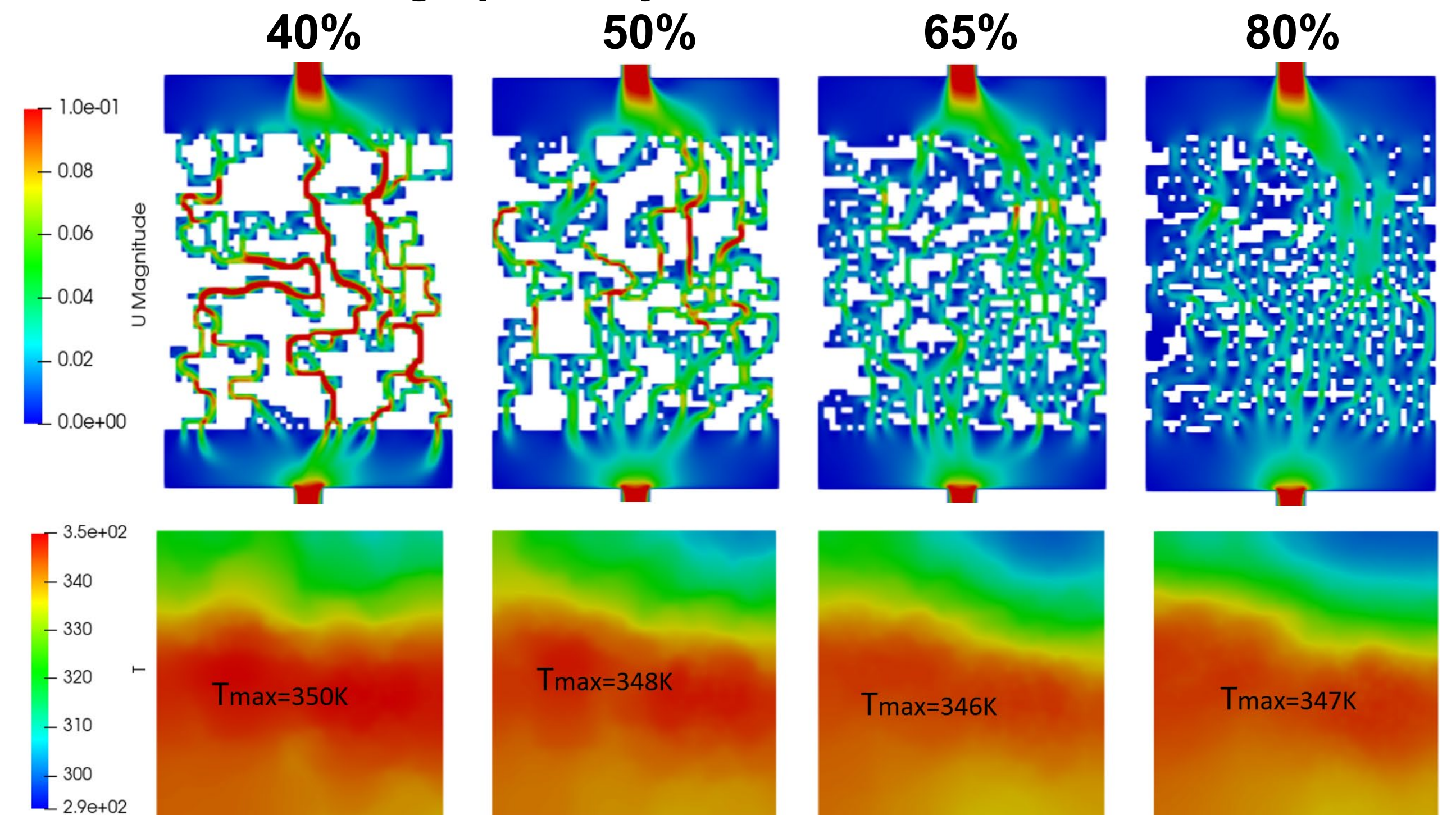
- Total power of 90 W;
- Steady-state, incompressible and laminar flow;
- Constant thermal-physical properties of solid (Aluminum) and fluid (Water);
- 50 × 50 Matrix resolution and 50% porosity



Influence of matrix resolution ($n \times n$):



Influence of design porosity:



Conclusion & Perspective

- A GATO method has been proposed and developed to optimize the heat sink for effective convective cooling of a heating surface with multiple-peak heat flux;
- The peak temperature of the heat sink optimized by GATO is significantly lower than that of a conventional straight channel heat sink;
- The developed GATO method is effective and robust to optimize the flow circuit configuration regarding different design parameters.

On-going work:

- Improvement of the current GATO by post-treatment and parameter study
- Experimental validation of the optimization method by testing different heat sinks;
- Extension of the algorithm to multi-objective optimization problems.