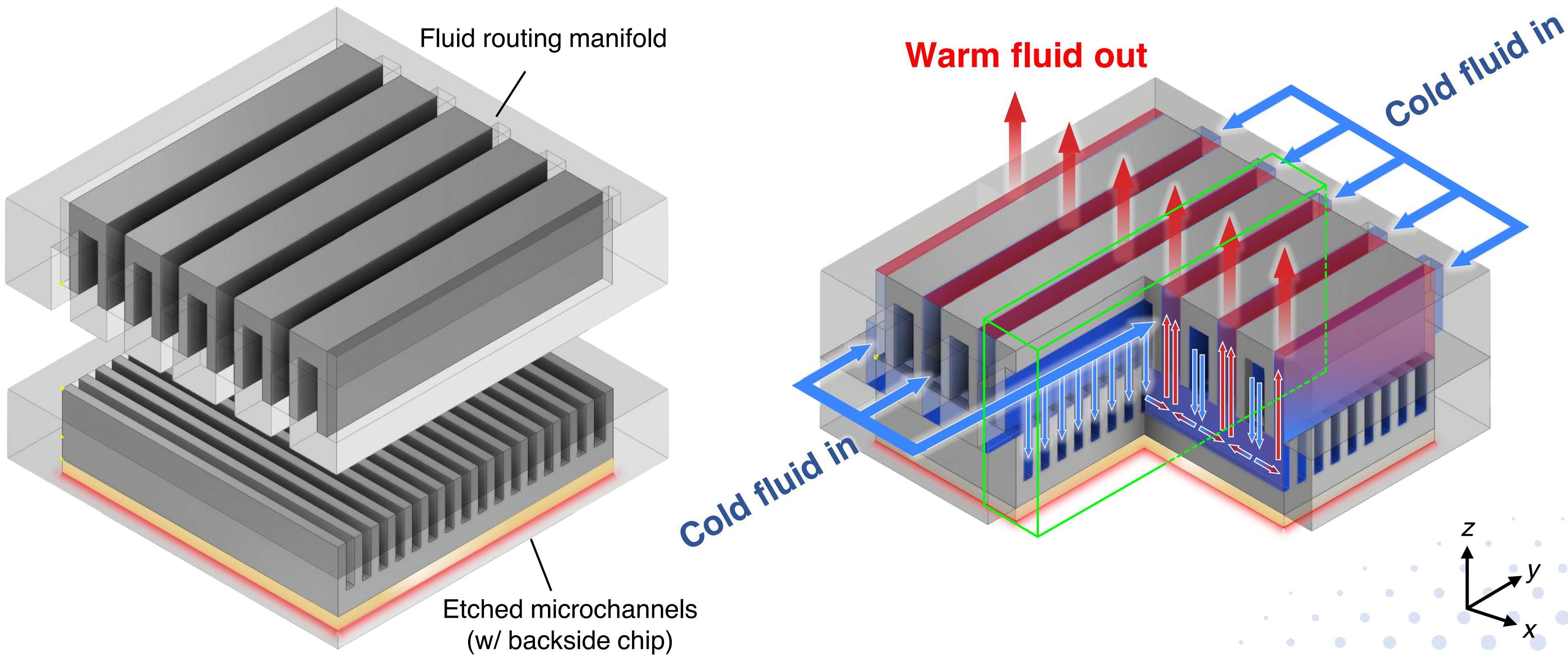
Thermal-hydraulic modeling of silicon-embedded manifold microchannels (MMC) for thermal management of advanced electronics

01. Silicon-based embedded cooling

Silicon-based embedded cooling using manifold microchannels (MMCs)

- **<u>An MMC heat sink is an effective embedded cooling device for high-performance electronics</u>**, consisitng of an overlying fluid-distributing manifold and a silicon substrate with microchannels.

Schematic of MMC heat sink



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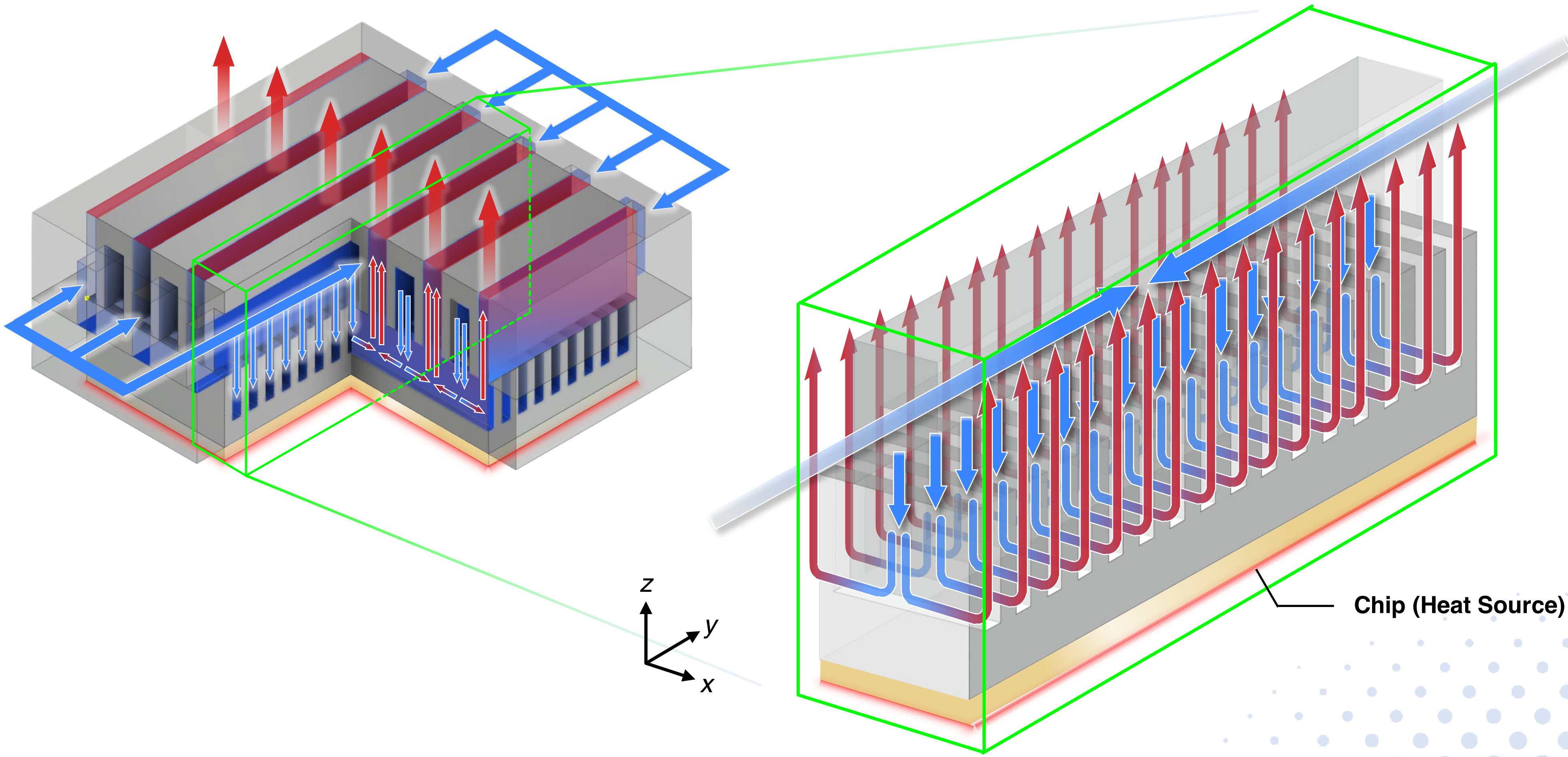
Flow characteristics within the embedded MMC heat sink

- **<u>The main fluid stream within the manifold is distributed to the microchannels,</u>** resulting in the non-uniform temperature distribution at the chip side.

Schematic of unit cell of MMCs



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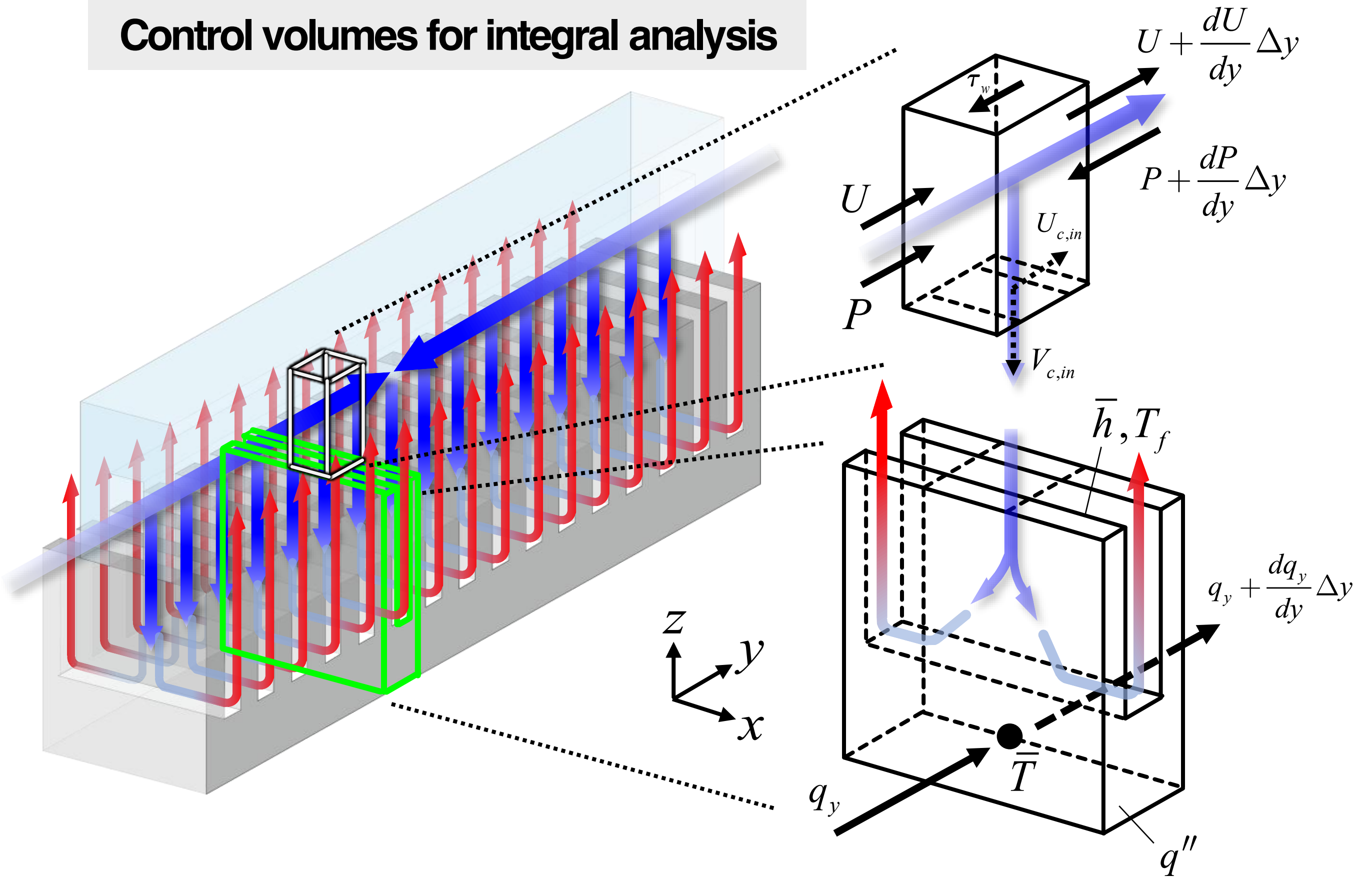
Approach

- The governing **3-D partial differential equations** are transformed into **the 1-D ordinary differential equations** using integral analysis.

Control volumes for integral analysis



3-D partial differential equations

1-D ordinary differential equations

$$\frac{dP}{dy} = -f_{man}\left(\frac{1}{2}\rho U^2\right)\left(\frac{L_{c,man,in}}{A_{man,in}}\right) + \rho(2-\gamma)U\left(-\frac{dU}{dy}\right)$$

$$\frac{d^2\bar{T}}{dy^2} - \frac{\eta_o}{kt_{base}}\alpha\bar{h}(y)\left(\bar{T}_b - \bar{T}_f\right) + \frac{q''}{kt_{base}} = 0$$

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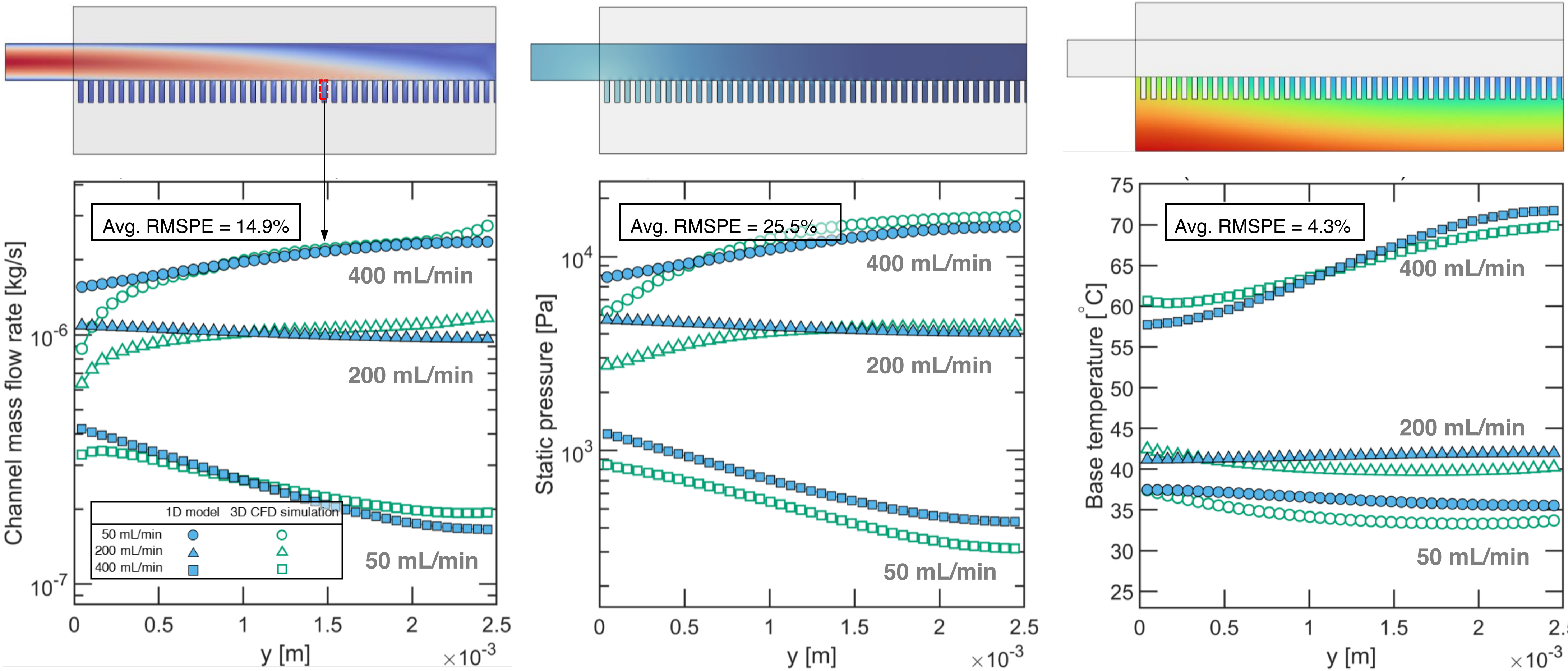
Results

- **<u>The developed 1-D model accurately predicts the static pressure variation within the manifold, flow distribution among the microchannels, and resulting base temperature distribution.</u>**



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Results

- **<u>The present 1-D model shows an excellent accuracy for predicting the thermal performance ($R''_{tot,max}$), pressure drop (ΔP), flow non-uniformity (CV</u>**) of MMC heat sinks across various geometries.