UNIVERSITAT POLITÈCNICA DE VALÈNCIA

ESCUELA TÉCNICA SUPERIOR DE INGENIERÍA DEL DISEÑO

KTH ROYAL INSTITUTE OF TECHNOLOGY

DEPARTMENT OF MECHANICS

High-order spectral simulations of the flow in a simplified urban environment

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FINAL DEGREE PROJECT IN AEROSPACE ENGINEERING

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Introduction

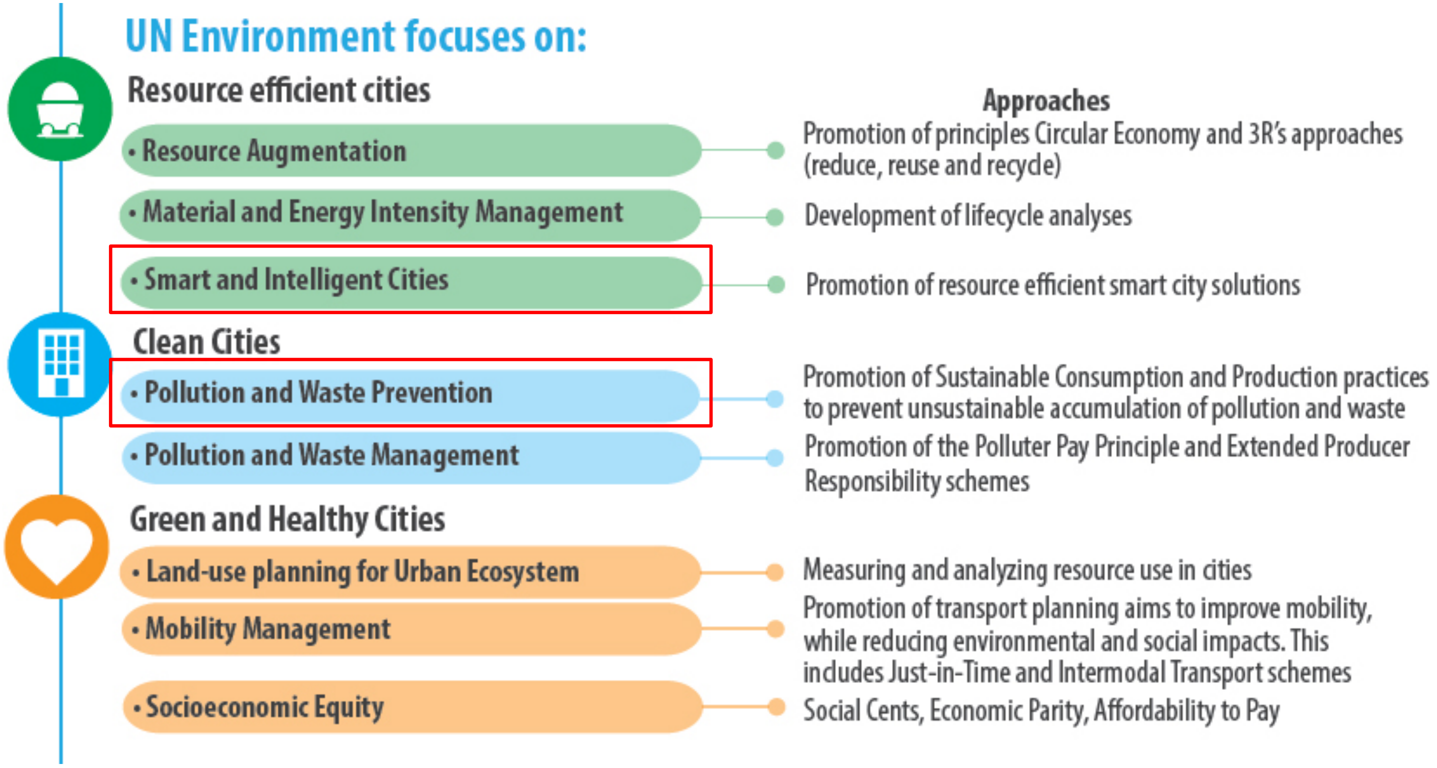

Fig. 1 . Sustainable cities. United Nations Environment Program. Retrieved from UN Regional Initiatives.

Fig. 2 . SDG 11. United Sustainable development program. Retrieved from UN Sustainable Development Communications materials.

Objectives

1. Identify and study the relevant processes and factors in urban turbulent flows
2. Develop and integrate the meshing and solution processes
3. Design the geometry and mesh
4. Set the simulation strategy and parameters
5. Obtain the time-averaged quantities
6. Analyse and appraise resolution and boundary-layer quantities
7. Analyse and discuss the obtained flow behaviour

Historical perspective

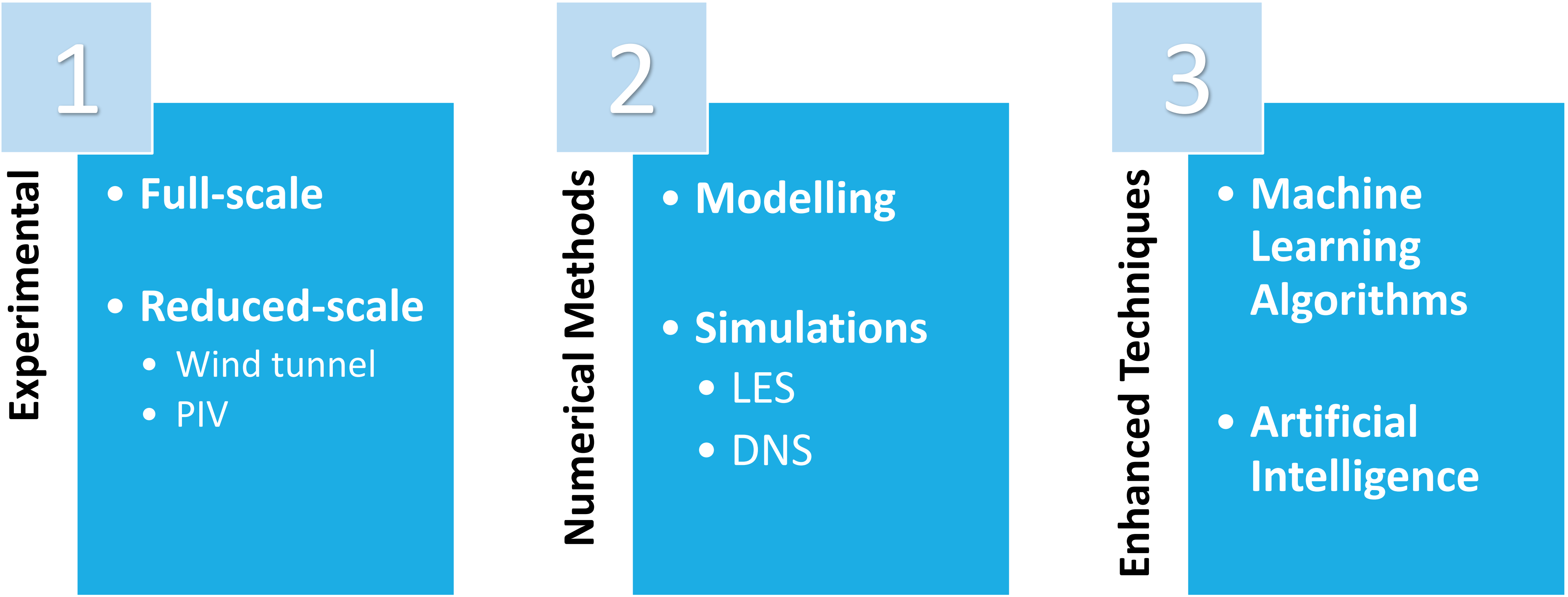

Fig. 3. Historical perspective classification

Tools and setups

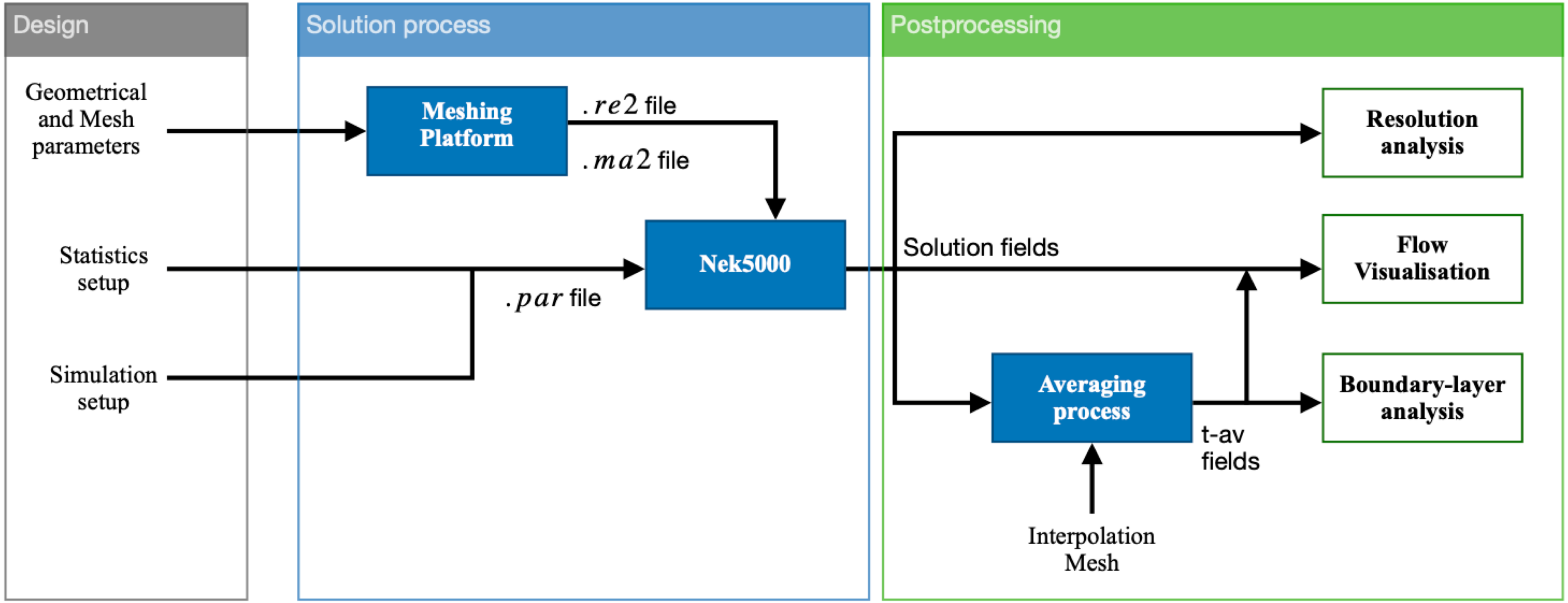

Fig. 4. Design, solution and postprocessing scheme

Final simulation setup

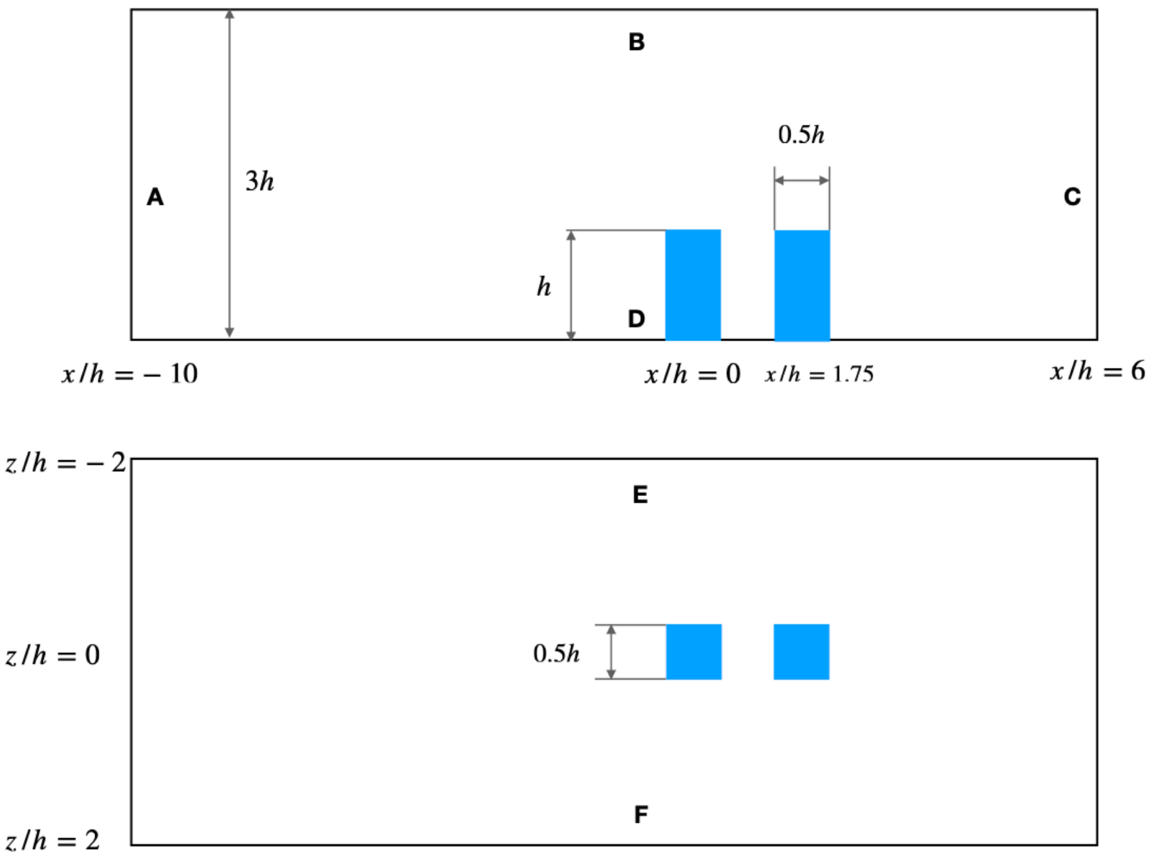

Fig. 5. Diagram showing the final geometry design

Key Figures

- 205 605 elements
- N = 7 GLL distribution
- 105 M points in total
- Resolution in the near-obstacle region:
  - $\Delta x^+_{n.o.} \approx 15$
  - $\Delta y^+_{n.o.} \approx 0.25$
  - $\Delta z^+_{n.o.,max} \approx 10$
  - $\Delta z^+_{n.o.,min} \approx 4$

Boundary-layer & Resolution analysis

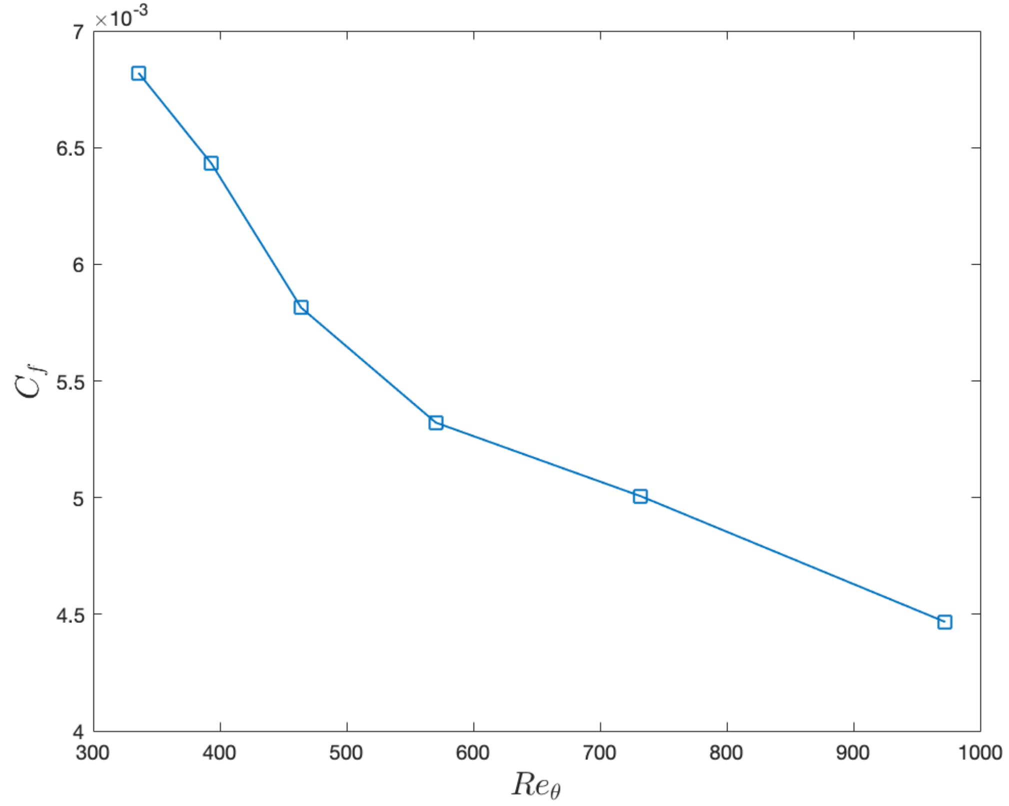

Fig. 6. z-averaged friction coefficient evolution with the Reynolds number evaluated using the momentum thickness

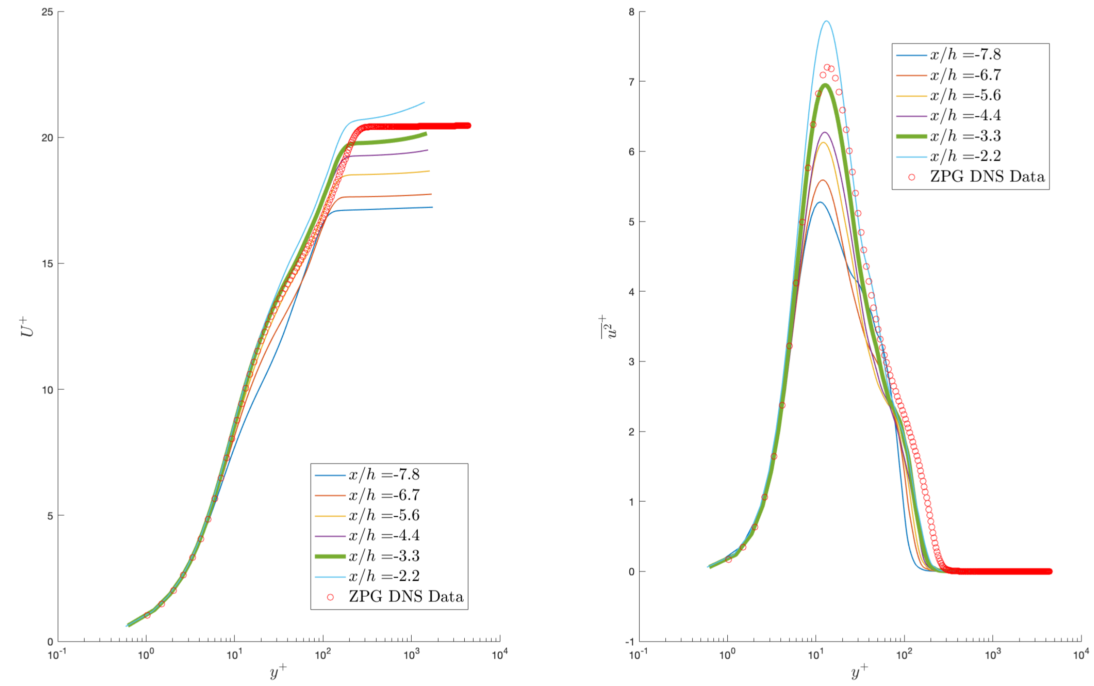

Fig. 7. Normalised z-averaged streamwise velocity (left) and Reynolds-stress tensor component (right).

Results

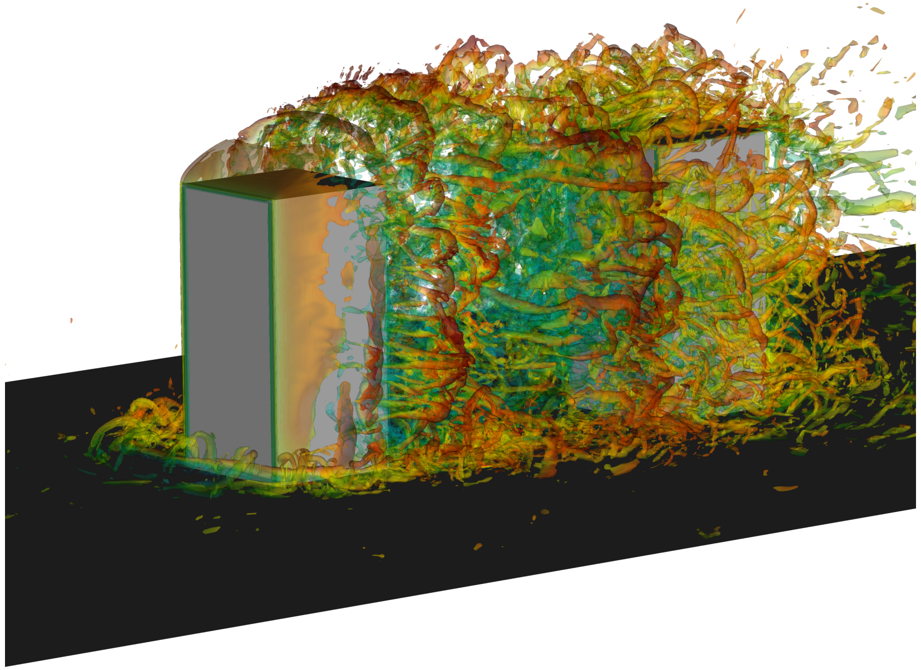

Fig. 8. Instantaneous capture of the vortical structures.

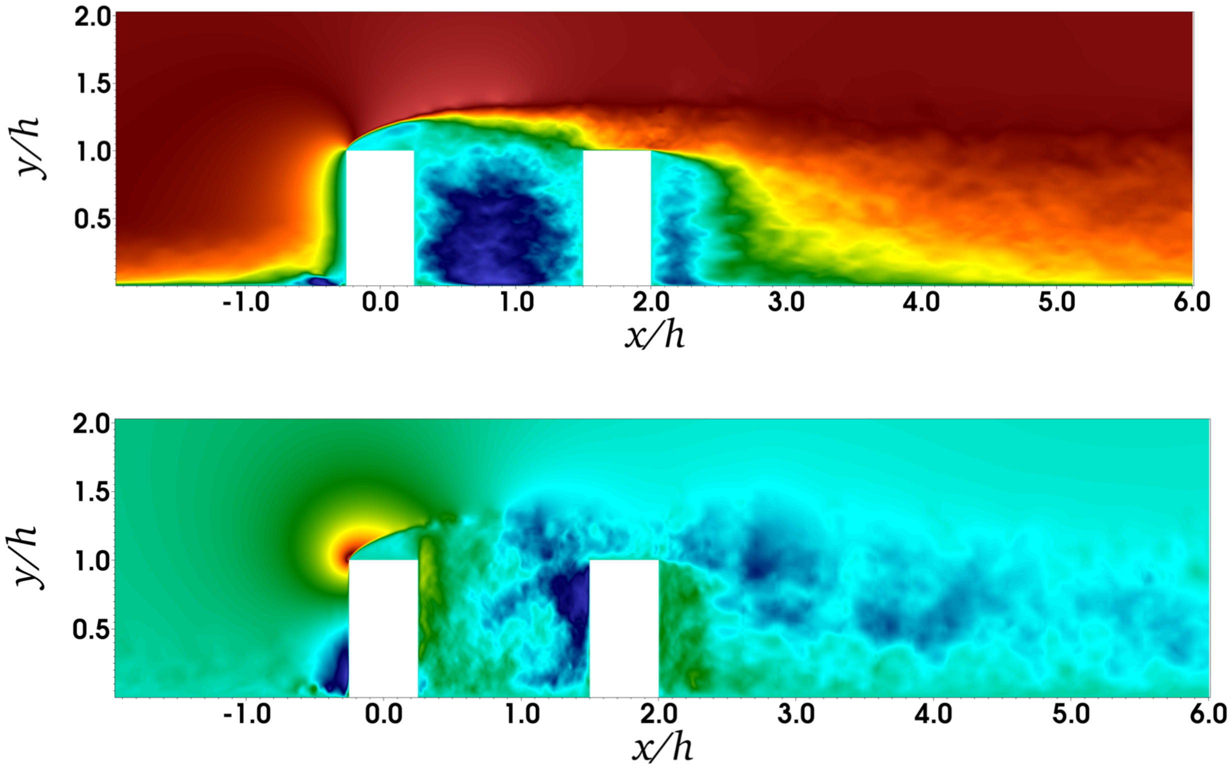

Fig. 9. (top) Time-averaged streamwise and heightwise (bottom) velocities at plane z = 0.

Results

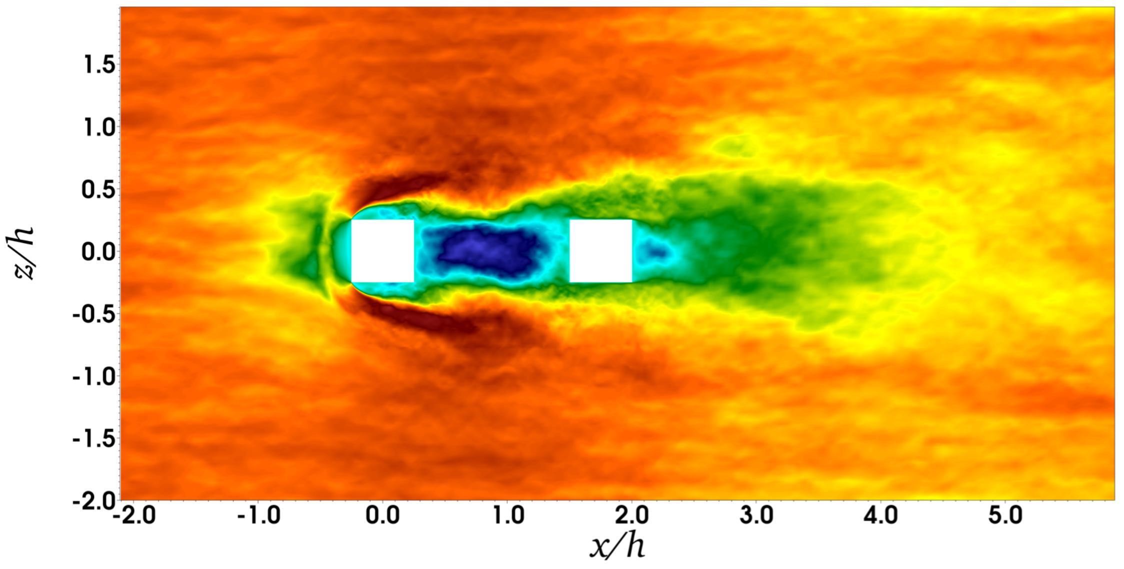

Fig. 10. Time-averaged streamwise velocity fields at y = 0.1

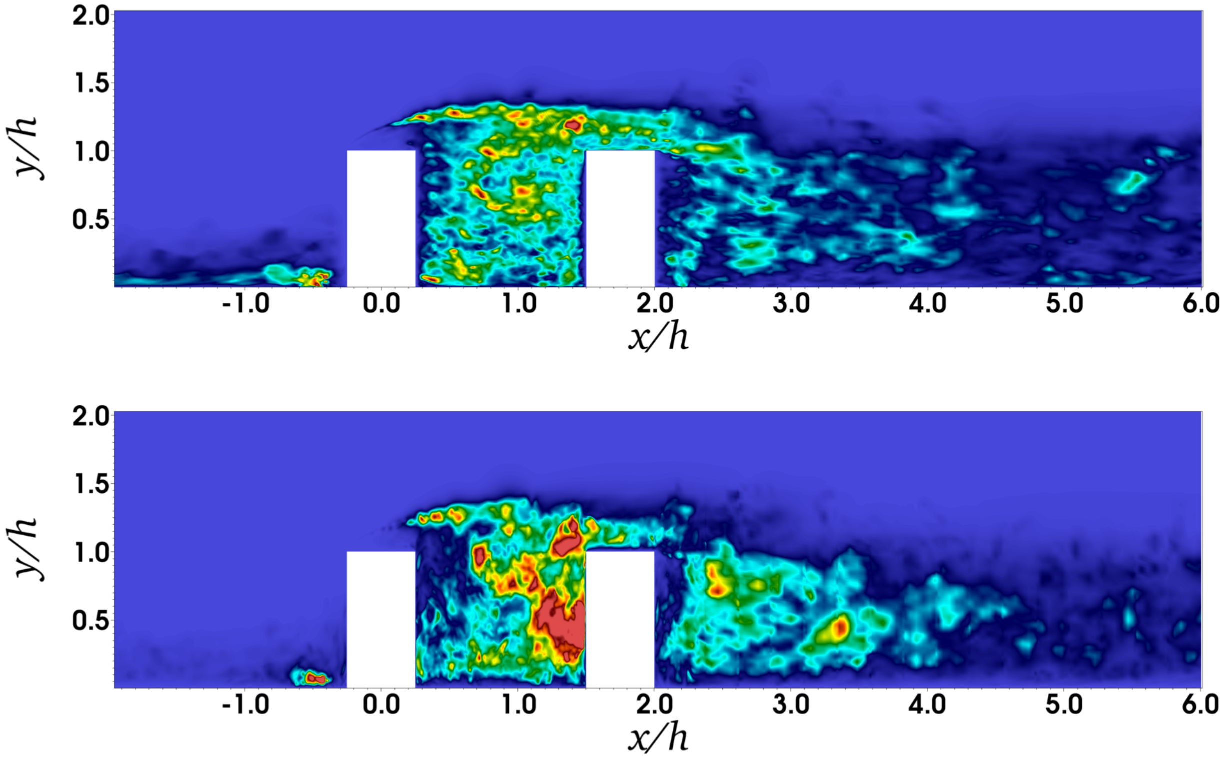

Fig. 11. Time-averaged Reynolds-stresses (top) u^2 and v^2 (bottom) components at plane z = 0.

Results

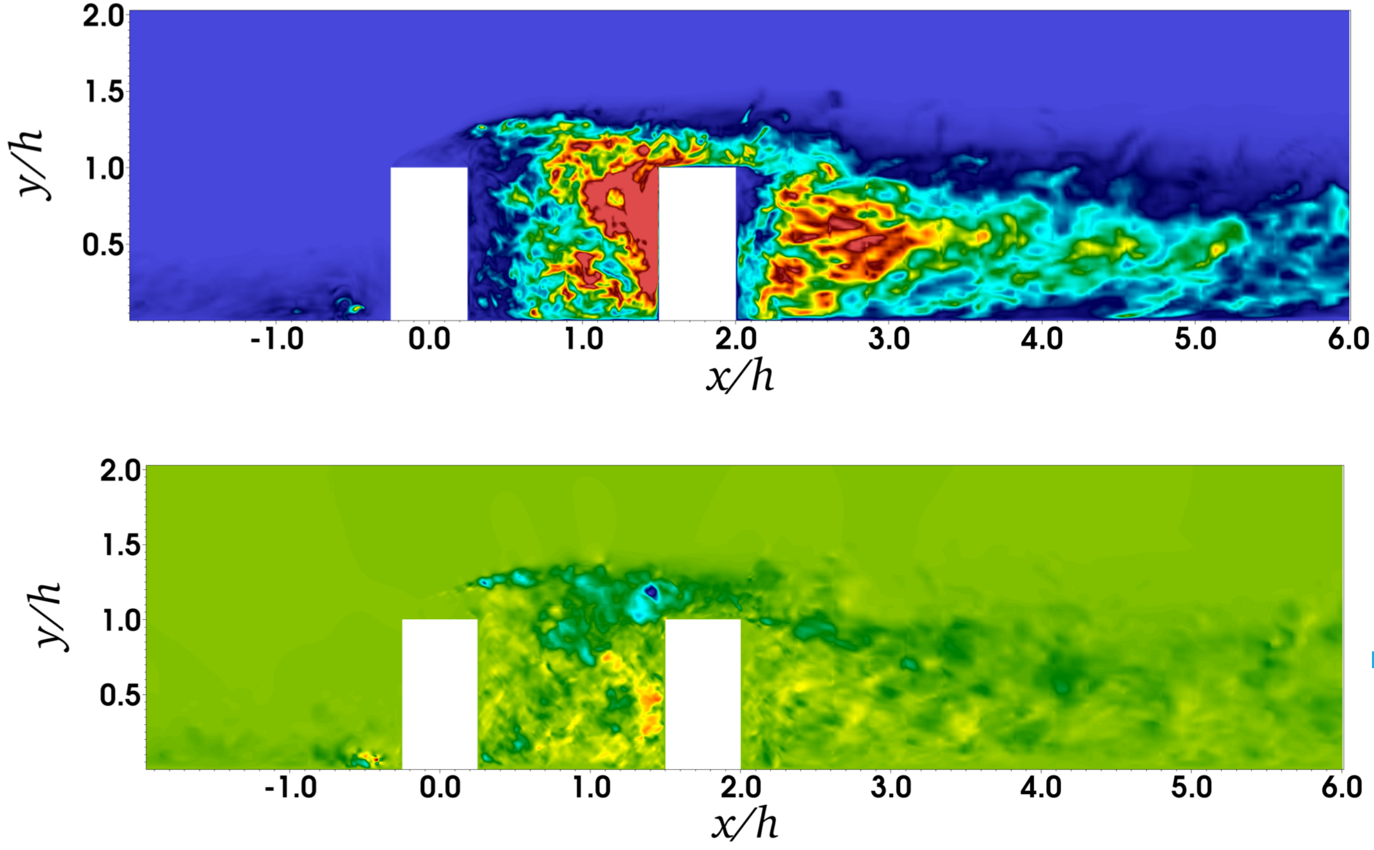

Fig. 12. Time-averaged Reynolds-stresses (top) w^2 and uv (bottom) components at plane z = 0.

Conclusions

1. A well-resolved LES was obtained
2. The mesh was able to properly represent flow and turbulent boundary-layer quantities
3. Flow behaviour matched theoretical expectations
4. Cost was constrained within the pre-established limits

Q & A