SAPIENZA UNIVERSITÀ DI ROMA

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ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA

Experimental and numerical study of pollutant dispersion from traffic sources in a real urban neighbourhood

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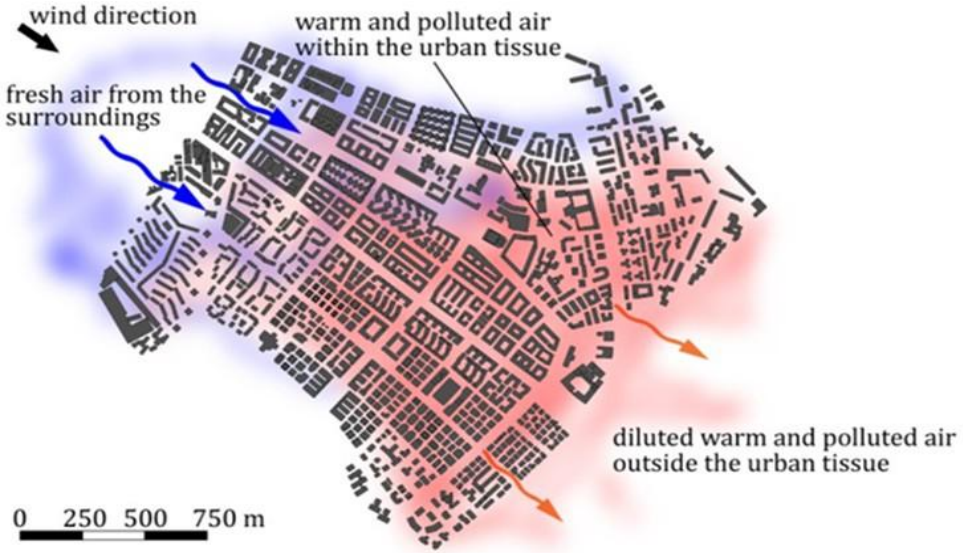
PROBLEM DESCRIPTION

- Urban air pollution from traffic sources poses significant public **health risks**, particularly if it accumulates at pedestrian level.
- The complexity of the urban fabric plays a role in influencing airflow dynamics, which can lead to unexpected outcomes in **pollutant dispersion** characteristics.
- Good **urban ventilation** can reduce smog, heat and the concentration of pollutants

Aim: investigate ventilation for a complex urban fabric, realistically reproducing the **interaction** between the urban morphological elements and the atmospheric wind.



Source: Palusci O. *Urban Ventilation and the Compact Mediterranean city. Numerical Analysis of the Dynamic relationships between Density, morphology and Wind Flow*. PhD thesis, Eindhoven University of Technology Sapienza University of Rome, 2023

GREEN-POLIS

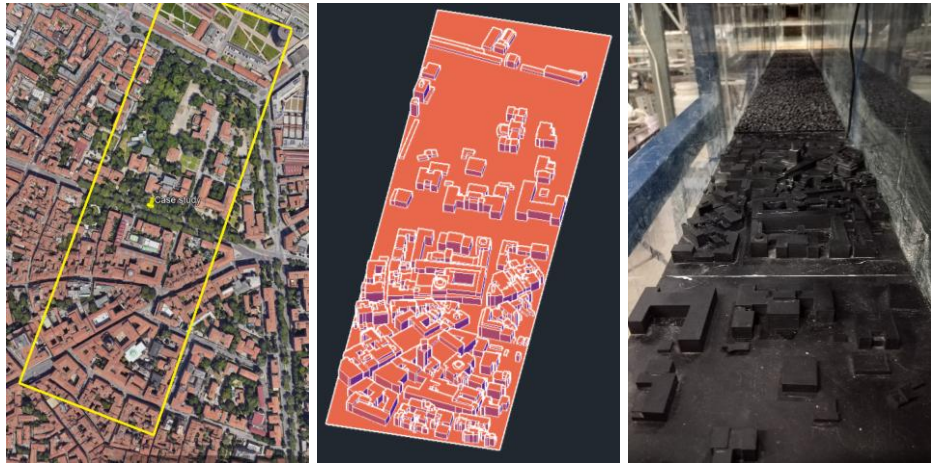
Multi-scale investiGation of natuRe-basEd solutions for thE mitigatioN of urban heat and POLlution ISland

CASE STUDY

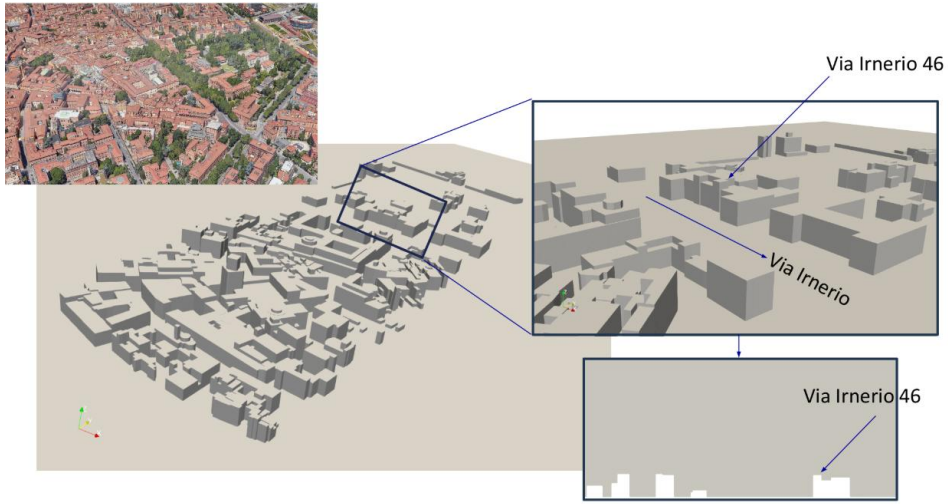
- The university areas surrounding **via Irnerio** in the north-east sector of the city of Bologna has been selected for the study as it experiences heavy traffic and a frequent presence of university students and staff.
- A **scale model 1:1000** has been used to reproduce the area of interest

Airflow dynamics and pollutant dispersion are studied through both:

laboratory-scale experiments

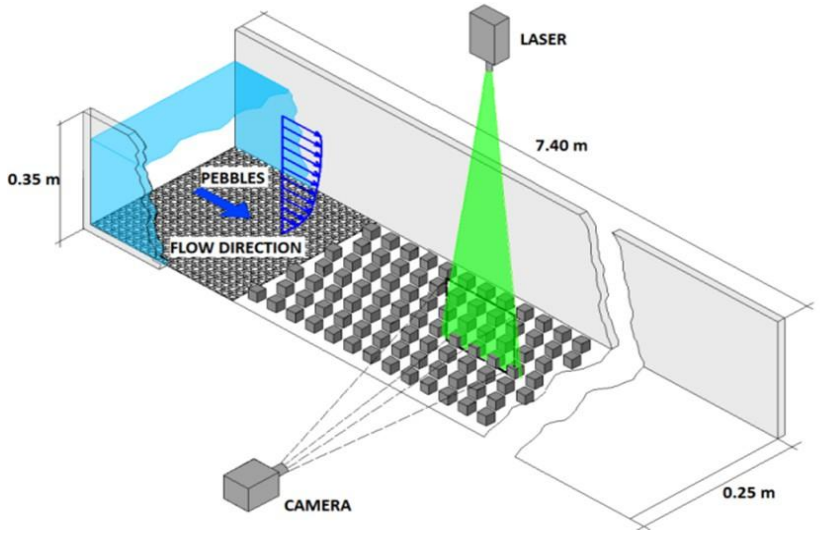


high-resolved numerical simulations



METHODOLOGY

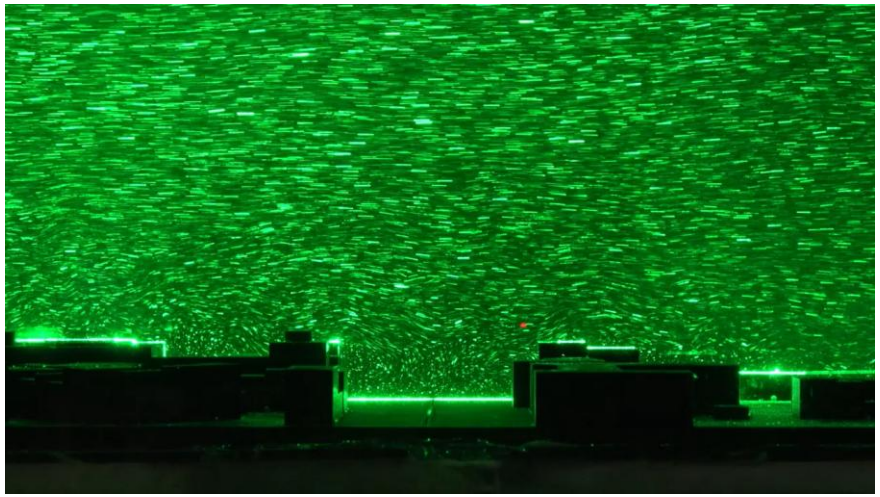
Experiments



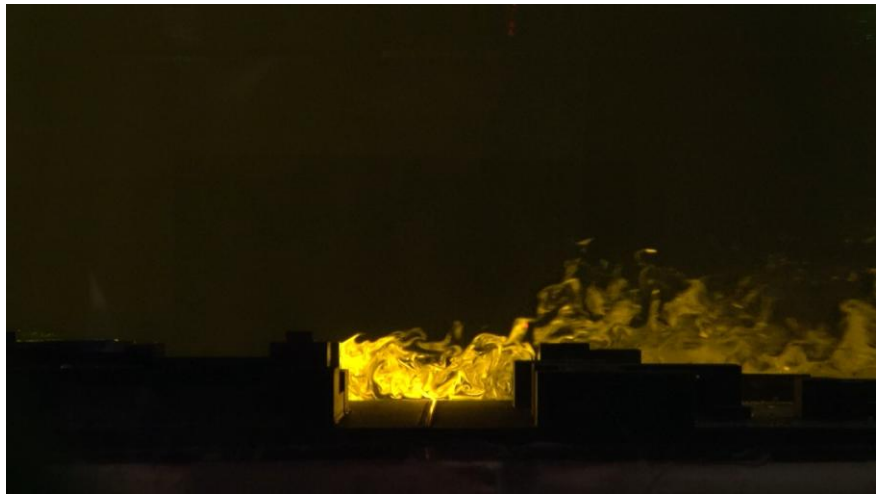
- Airflow and pollutant dispersion are reproduced taking advantage of the water-channel facility of the “Department of Civil, Building and Environmental Engineering of Sapienza University of Rome”
- The acquisition system consists of a green laser and a high-speed camera.

Techniques:

Feature Tracking

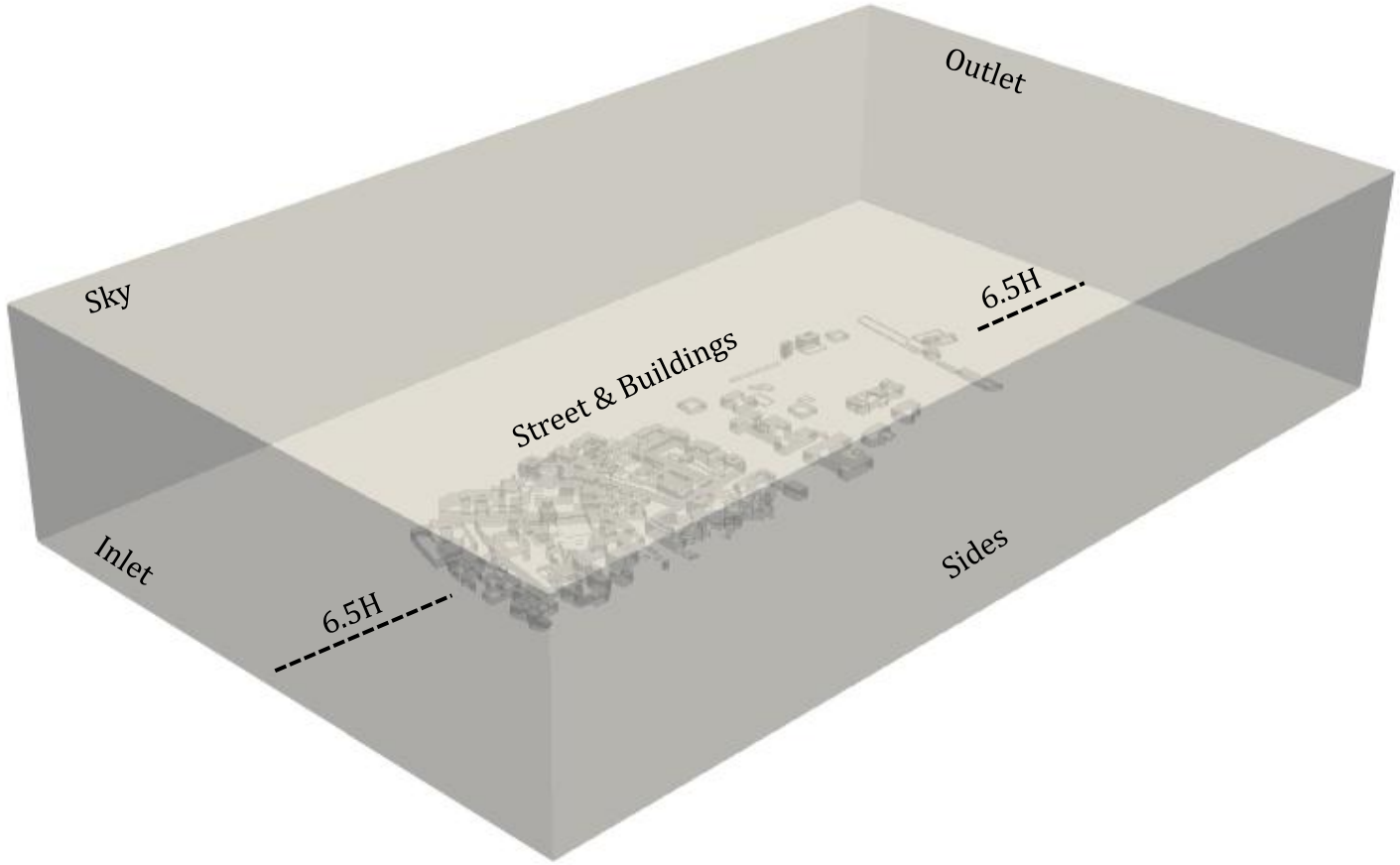


Planar Laser-Induced Fluorescence



METHODOLOGY

High-resolved numerical simulations

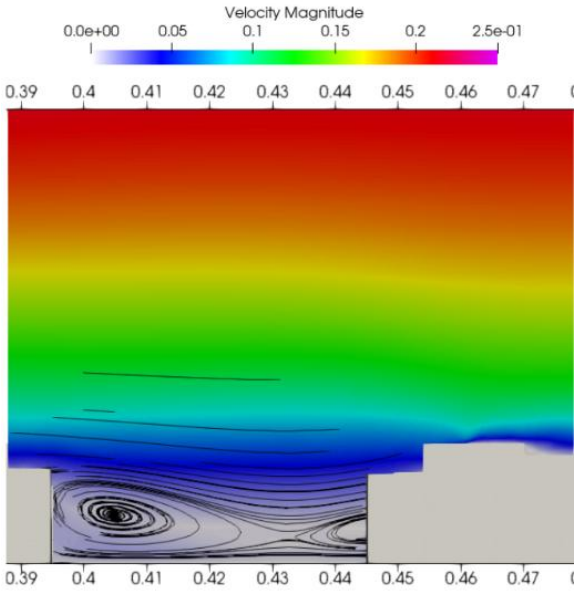


Characteristic length is the height of the Physics Dept Building, H = 1.9

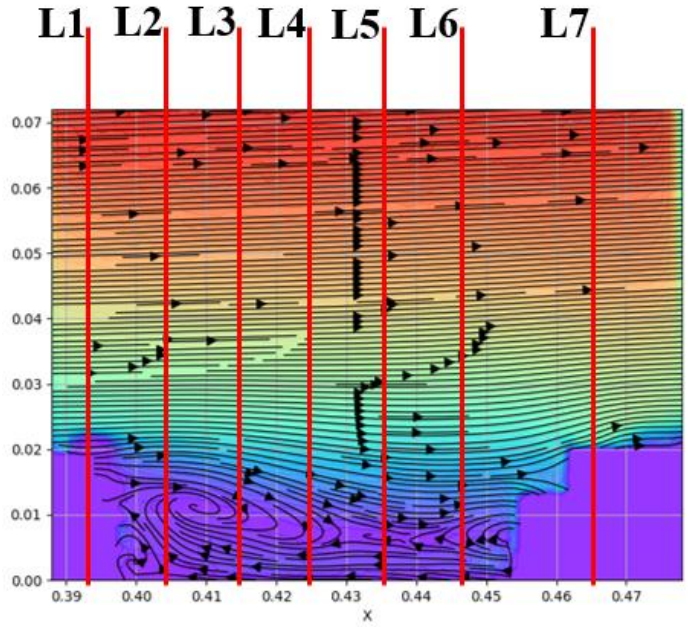
- The use of a Reynolds-Averaged Navier–Stokes (RANS) simulations, using a k-ε turbulent model, reproduce the laboratory experiment, providing a three-dimensional, full picture of the airflow dynamics and the pollutant dispersion mechanisms.
- **Domain Geometry**: following the COST ACTION 732 Best Practices
- **Computational Grid**: hexahedral unstructured mesh, refined near building for a direct resolution of the wall boundary layer (y+<5). Final grid of 16 million cells.
- **Inlet condition**: synthetic turbulent atmospheric boundary layer model to reproduce the laboratory inlet

VALIDATION

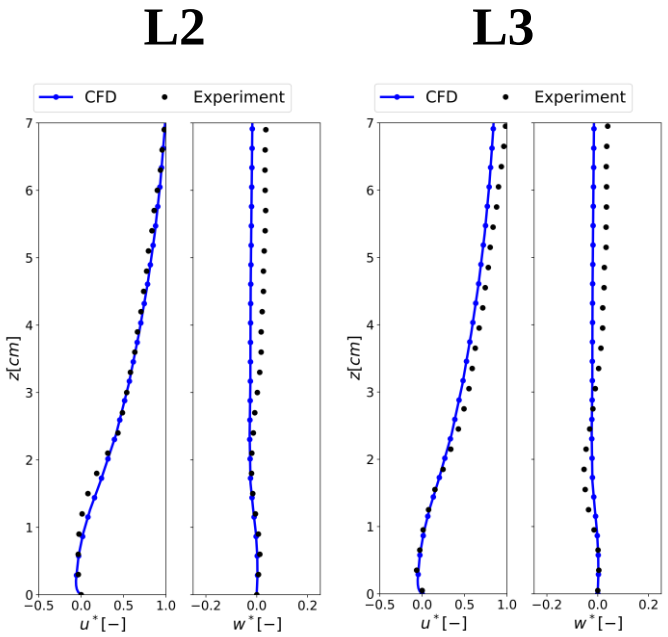
- The comparison between the measured and simulated streamwise and vertical velocity components averaged in time. Overall, the agreement between the two is satisfactory, both qualitatively and quantitatively.



CFD



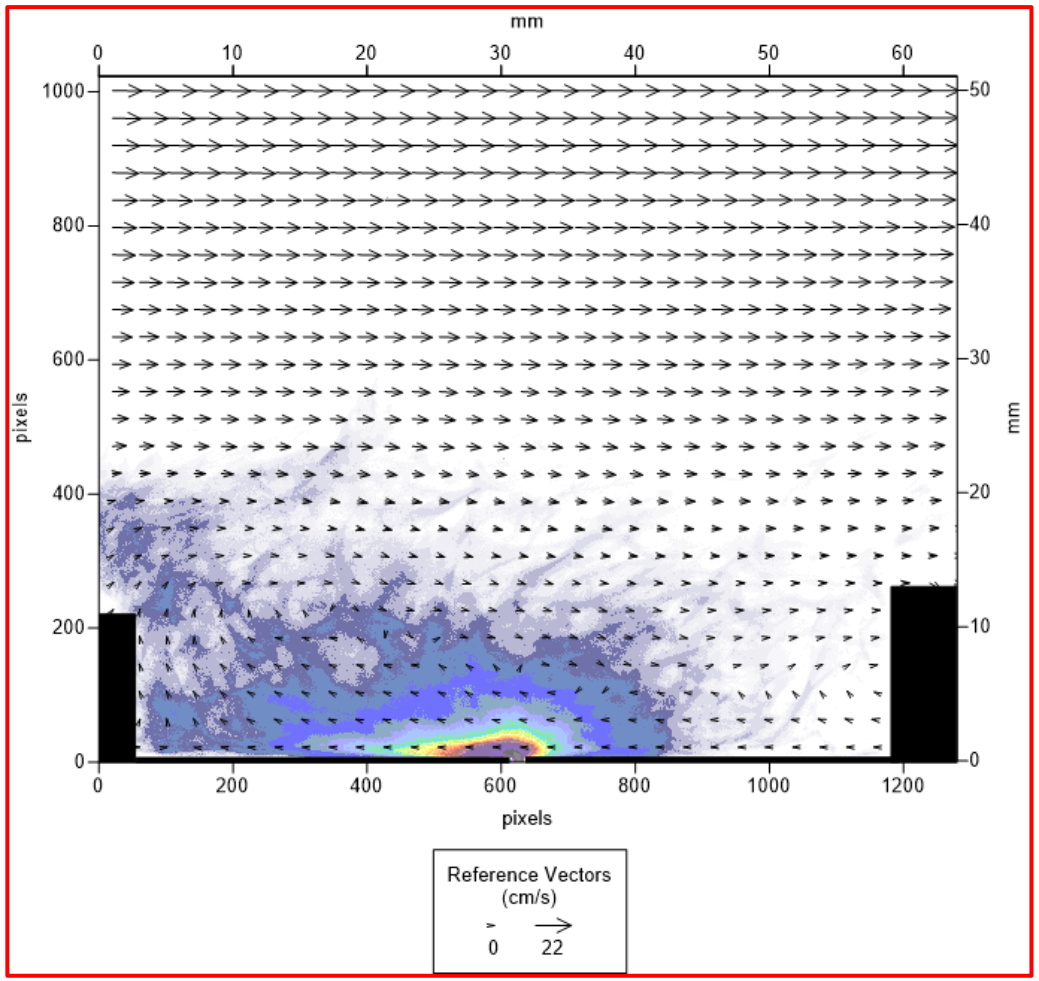
Experiment

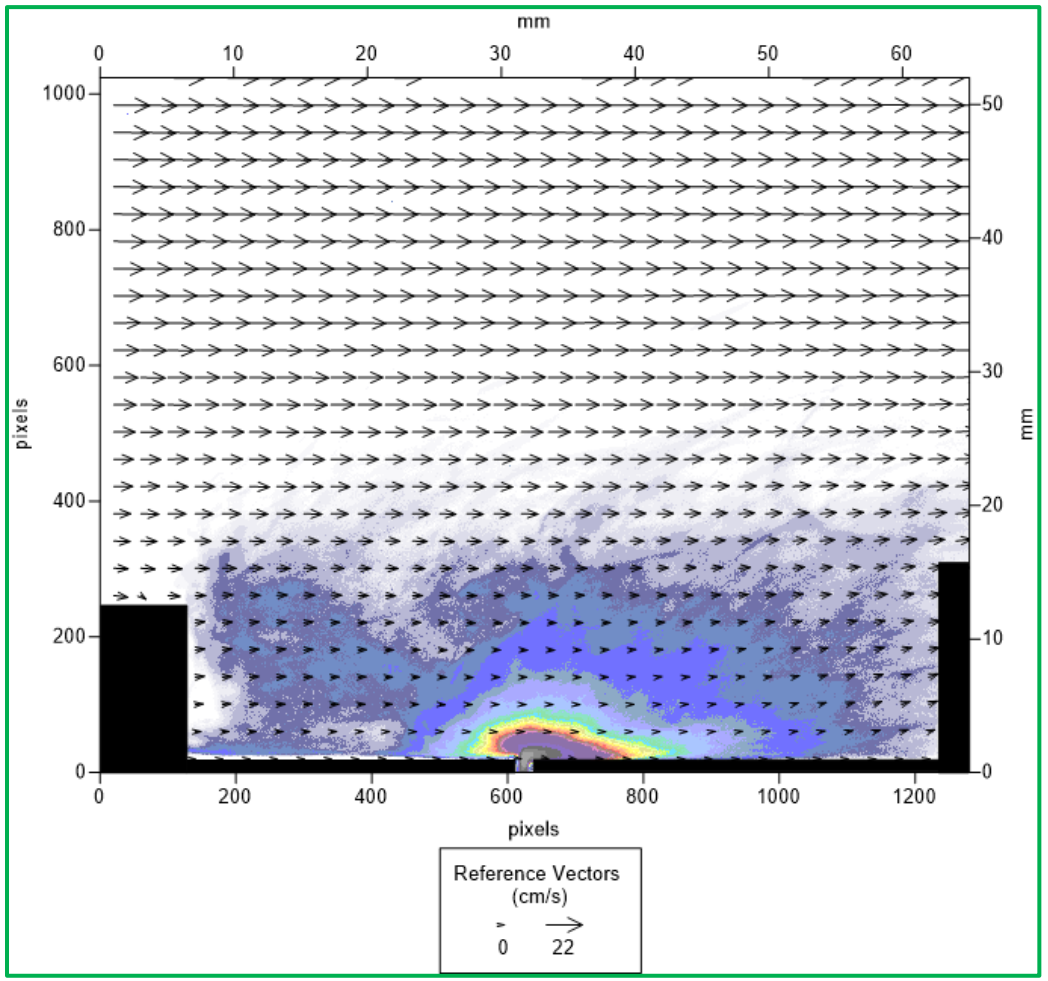


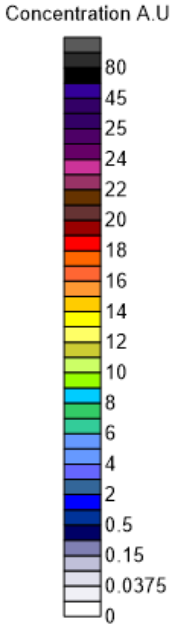
PRELIMINARY RESULTS

From Experiments

Vertical planes parallel to the streamwise direction



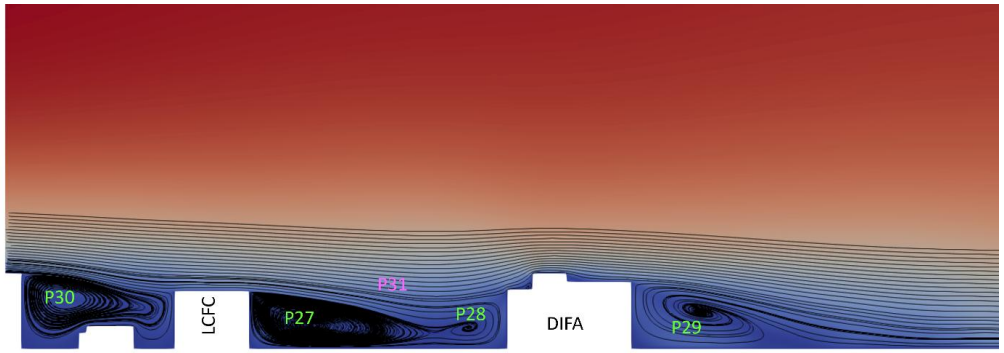




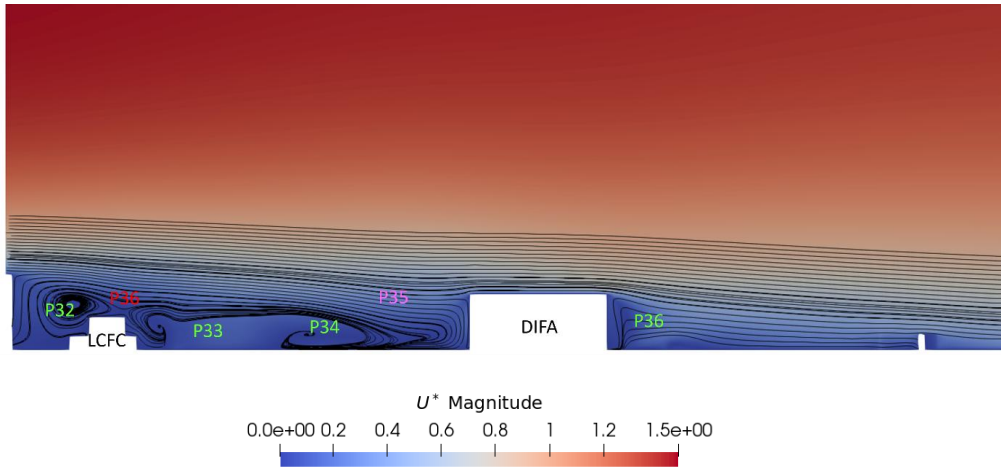
PRELIMINARY RESULTS

From CFD

Vertical cross-section extracted along the spanwise direction at the central axis of the DIFA



Vertical cross-section taken at the spanwise plane located to the left of the DIFA



- P27 and P28 are two distinct recirculation zones. The first is dominant clockwise-rotating vortex, the second is a secondary, smaller one. These two vortices are separated by a critical saddle point, characterized by a local stagnation of flow .
- P30 and P29 are recirculation zones formed due to the interaction between the incoming atmospheric boundary layer and the buildings.
- P33 and P34 denote recirculation zones.

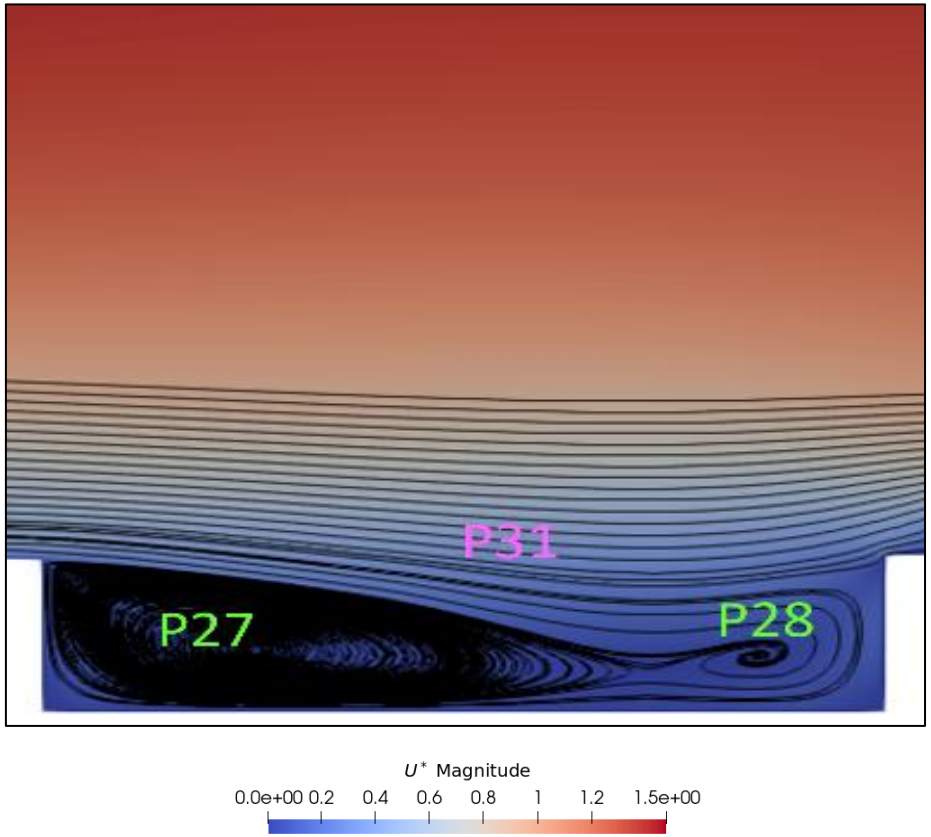
Legend of labels

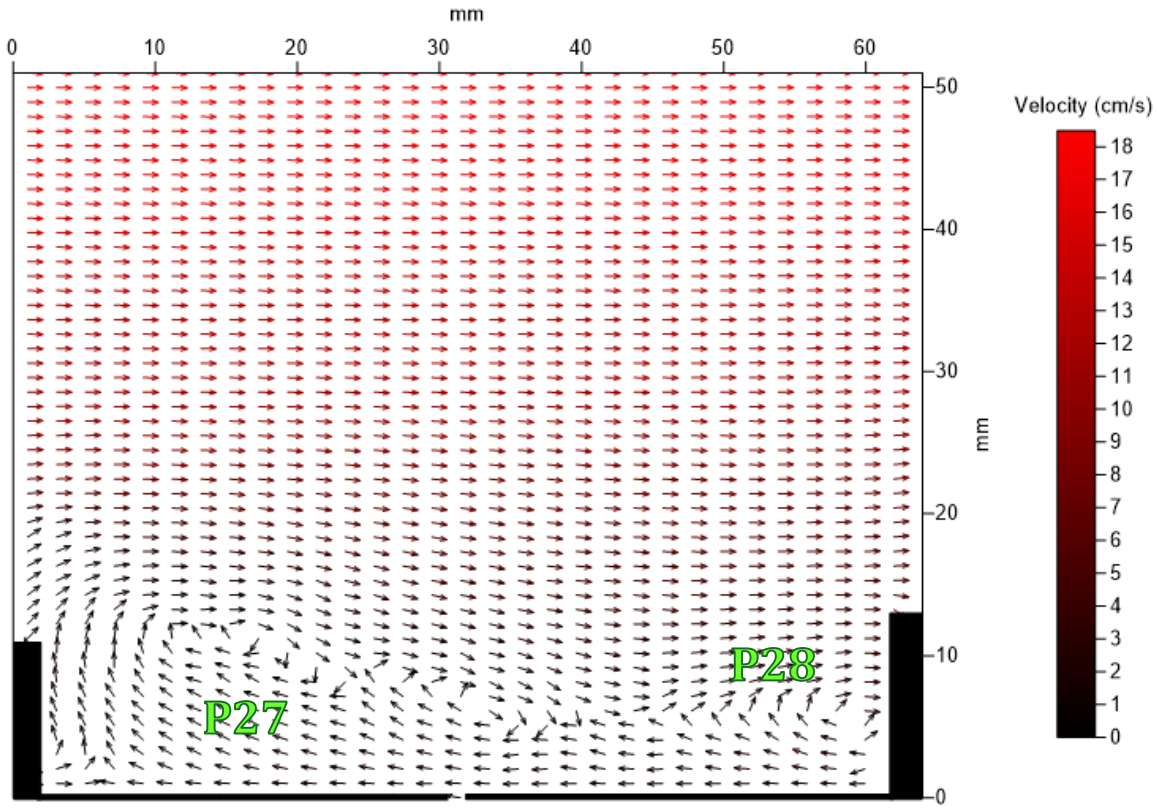
Black: Building
Yellow: corner vortices
Red: saddle points
Cyan: channeling zones
Green: recirculation zones

COMPARISON

Between numerical and experimental results

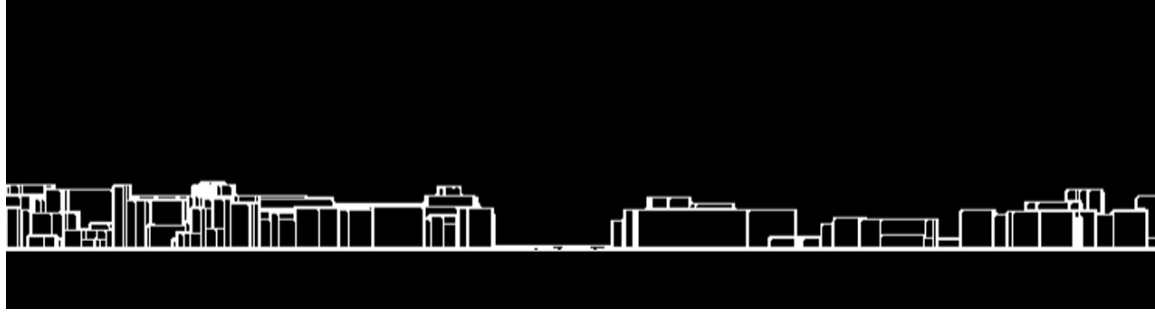
Vertical cross-section extracted along the spanwise direction at the central axis of the DIFA



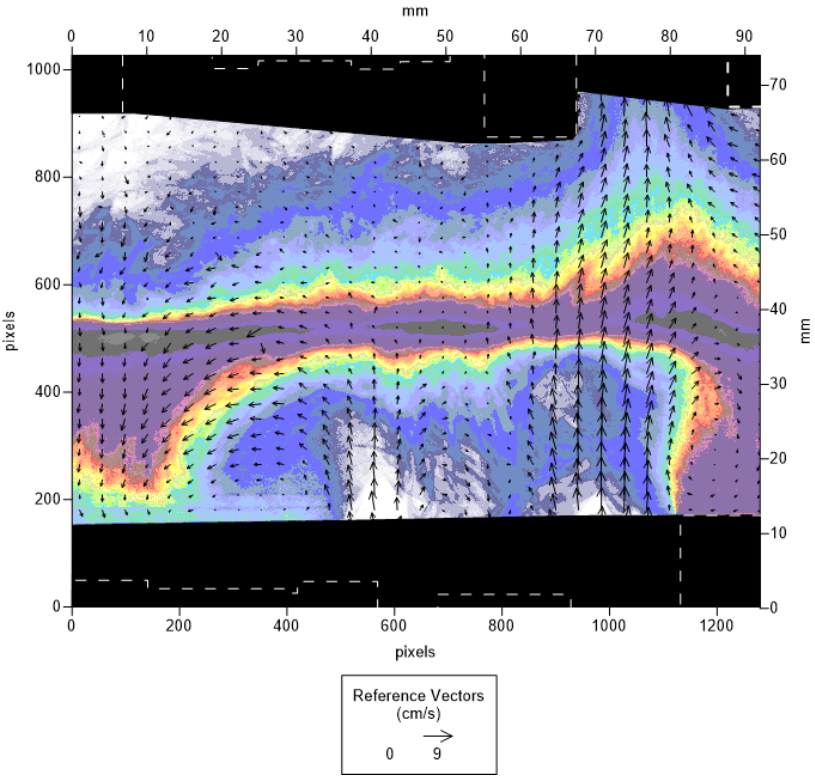


PRELIMINARY RESULTS

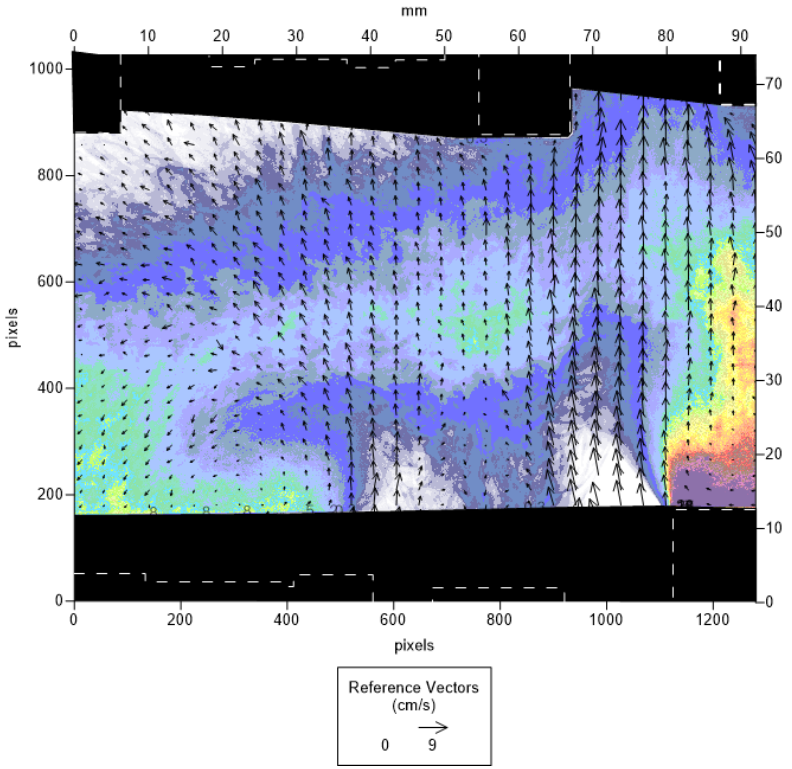
From Experiments



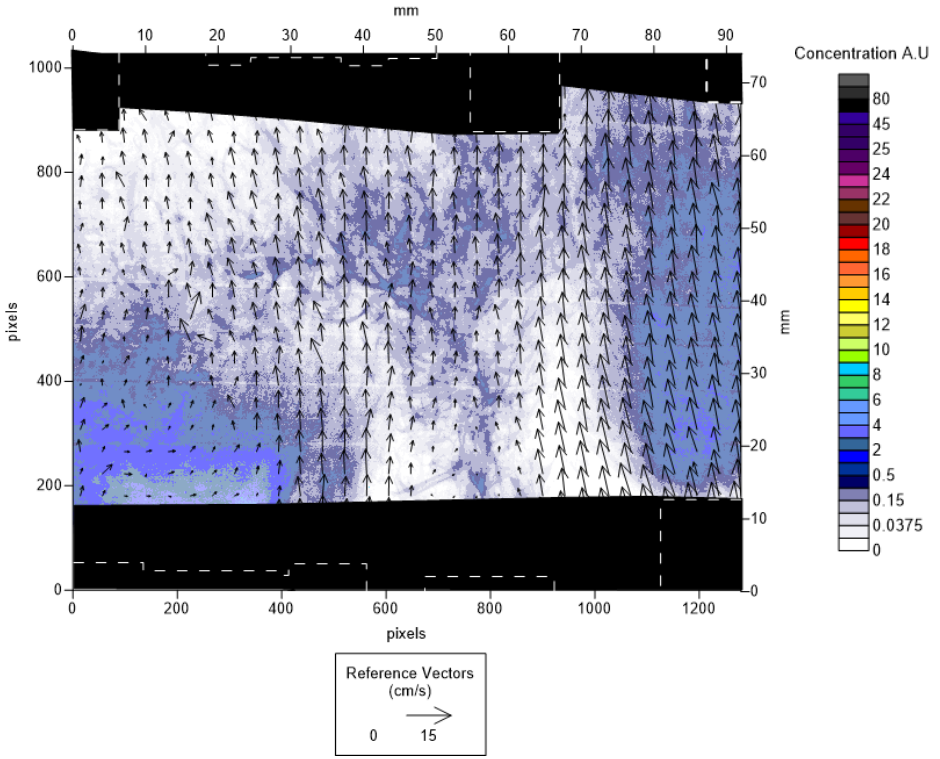
Horizontal plane located at z/H=0.05



Horizontal plane located at z/H=0.5



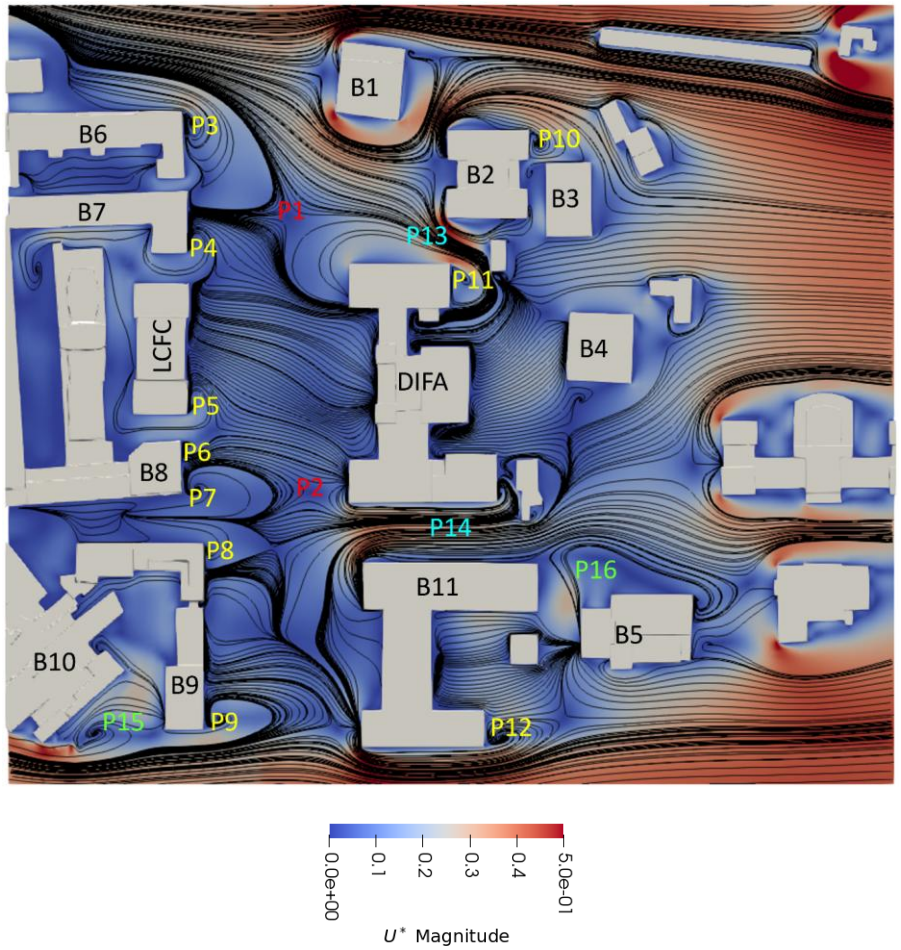
Horizontal plane located at z/H=0.85



PRELIMINARY RESULTS

From CFD

Horizontal plane located at z/H=0.05



- P1 and P2 are saddle points. These regions are characterized by local stagnation zones where the velocity vector vanishes (u=0).
- P3-P9 are corner vortices, arising primarily from flow separation at sharp building edges.
- P13 and P14 mark channeling effect. This effect manifests as localized acceleration of the flow between narrow urban corridors.
- Recirculation zones, marked at P15 and P16 behind buildings B10 and B5, respectively, are indicative of flow separation followed by reattachment.

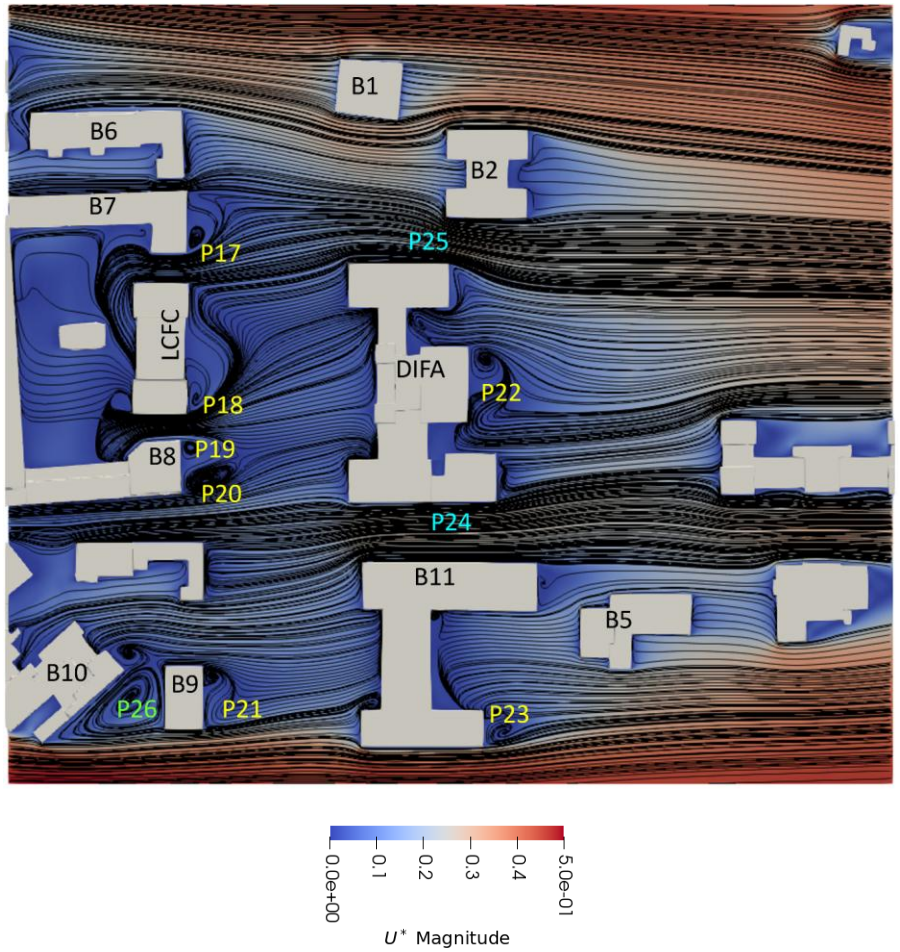
Legend of labels

Black: Building
Yellow: corner vortices
Red: saddle points
Cyan: channeling zones
Green: recirculation zones

PRELIMINARY RESULTS

From CFD

Horizontal plane located at mid-building height, z/H=0.5



- Saddle points, previously observed near the ground, are absent at this height, indicating reduced stagnation and splitting of flow at the mid-level.
- P17 and P18 denote corner vortices.
- P19 and P20 represent a pair of counter-rotating vortices that persist from the lower level but now exhibit increased size and coherence.
- The vortex in P21 has significantly enlarged. The recirculation zone in P26 has also grown in strength and extent
- In P24 and P25 the streamwise acceleration of the flow is substantially higher than that observed at z/H=0.05.

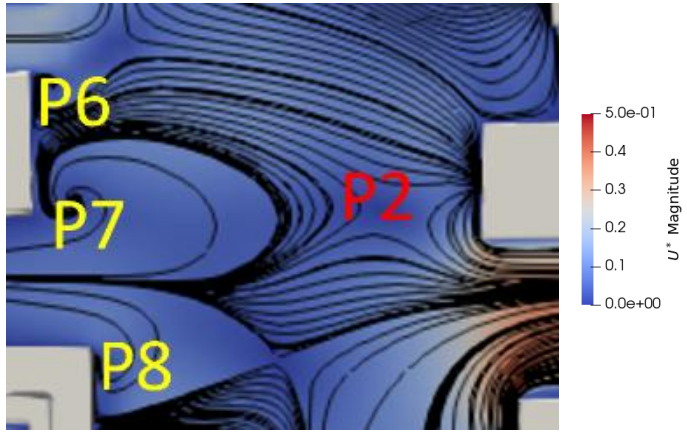
Legend of labels

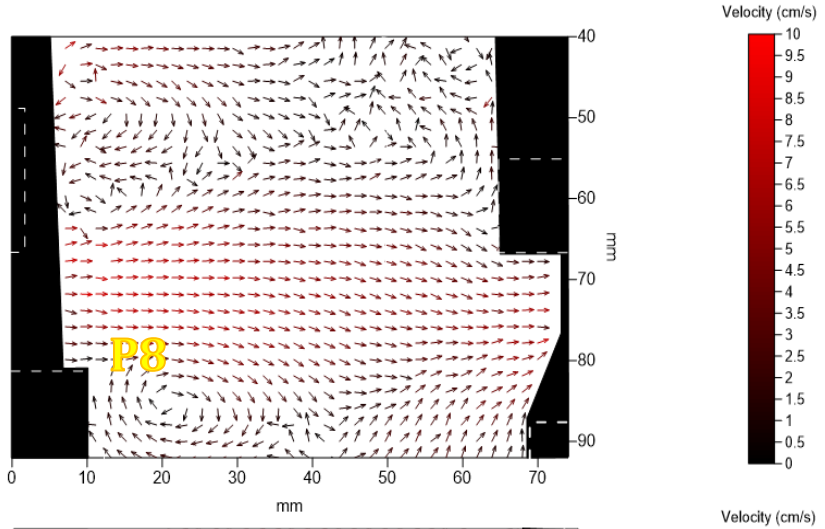
Black: Building
Yellow: corner vortices
Red: saddle points
Cyan: channeling zones
Green: recirculation zones

COMPARISON

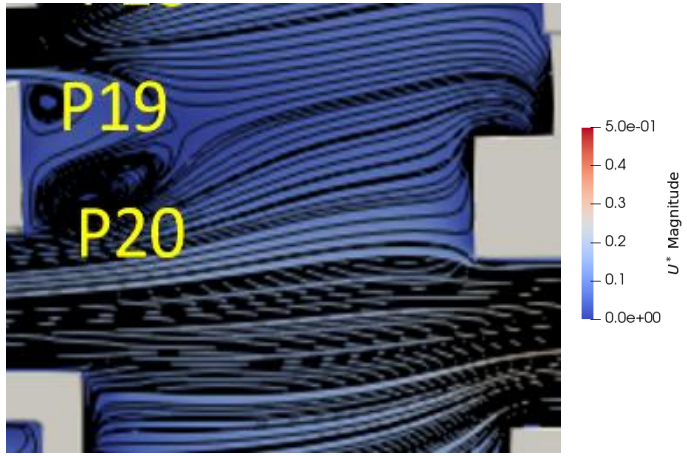
Between numerical and experimental results

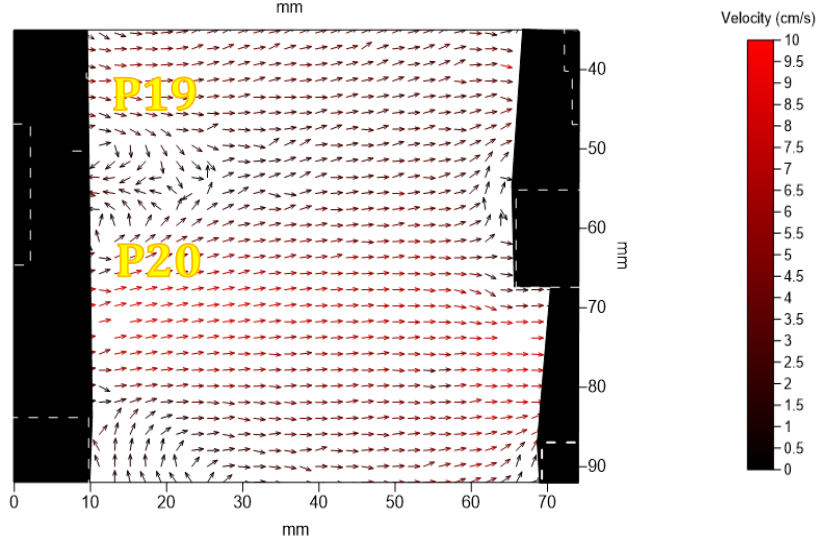
Horizontal plane located at z/H=0.05





Horizontal plane located at mid-building height, z/H=0.5

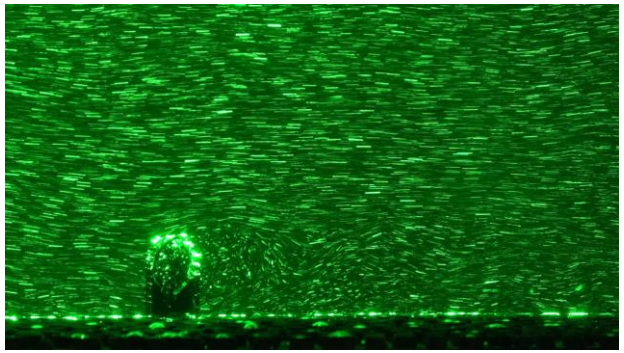




CONCLUSIONS & NEXT STEPS

- ✓ Good agreement between the two applied approaches
- ✓ Identification of flow features specific to the case study
- ○ Completion of numerical simulations including the presence of pollutants
- ○ Identification of the best method to represent vegetative elements at laboratory scale
- ○ Integration of vegetative elements into the model for both laboratory experiments and numerical simulations
- ○ Repetition of the previously described analyses with vegetative elements and comparison of results, assessing their impact on ventilation and pollutant dispersion

Porosity: 20 ppi
Total height: 1.8 cm
Crown width: 1 cm



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Thank you for your attention

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