Coupled time-resolved measurements of scalar dispersion and velocity fields in a turbulent urban street canyon

Maxime Sicat, Sébastien Cazin, Jean-Dominique Barron, Yara Abidine, Frédéric Moulin, and Romain Mathis*

Whether in small streets or large boulevards, traffic congestion in urban settings can lead to pollutant accumulation and public health hazards. Understanding and predicting pollutant dispersion in street canyon configurations has therefore been topic of numerous studies, both experimental and numerical[1 2 3]. The present work aims to better the knowledge of these flows through the acquisition of high-quality experimental data.

Two street canyon configurations are investigated : (1) a large one with an aspect ratio of h/W = 0.28 (where h = 40 mm and W = 1050 mm are the height and width of the canyon) and (2) a narrow one with h/W = 0.78, covering respectively the wake interference and skimming flow regimes[4]. Both canyons are immersed in a fully rough turbulent boundary layer ($Re_\delta = \delta u_* / \nu = 8400$ where δ is the boundary layer thickness, u_* the friction velocity and ν the kinematic viscosity) developed over aligned cubic roughness elements immersed in a large water channel flume 20 m long and 1.1 m wide. The aspect ratio between the water depth H and the canyon height h is H/h = 9, ensuring that the canyon is sufficiently submerged and free surface effects can be neglected.

The quantities of interest in this study are the turbulent statistics of the canyon flow, its spectral content, as well as the investigation of pollutant ventilation mechanisms within the street canyon. To acquire this information, measurements consist of synchronized 2D2C particle image velocimetry (PIV) and planar laser-induced fluorescence (PLIF), respectively yielding the velocity fields and the concentration fields of dispersed scalar. These measurements are performed in streamwise planes perpendicular to the canyon axis, both time-resolved at fs = 25 Hz = 12.5 / T and sampled over long durations of 1 hour = 7200 T, where T = 0.5 s is the integral timescale of the canyon flow. Both fields exhibit a high spatial resolution, with a streamwise/wall-normal resolution in wall units of $85\nu/u_*$ for the PIV and $21\nu/u_*$ for the PLIF. These high temporal and spatial resolution allow us to fully resolve spectral content of the flow, from large- to small-scale features. Fluorescein, serving as the PLIF scalar, is injected from the downstream bottom corner of the canyon. These measurements have been repeated for multiples streamwise/wall-normal planes, at several spanwise locations, enabling the use of double (temporal and spatial) averaging to assess the impact of the spatial inhomogeneity of the incoming roughness sublayer.

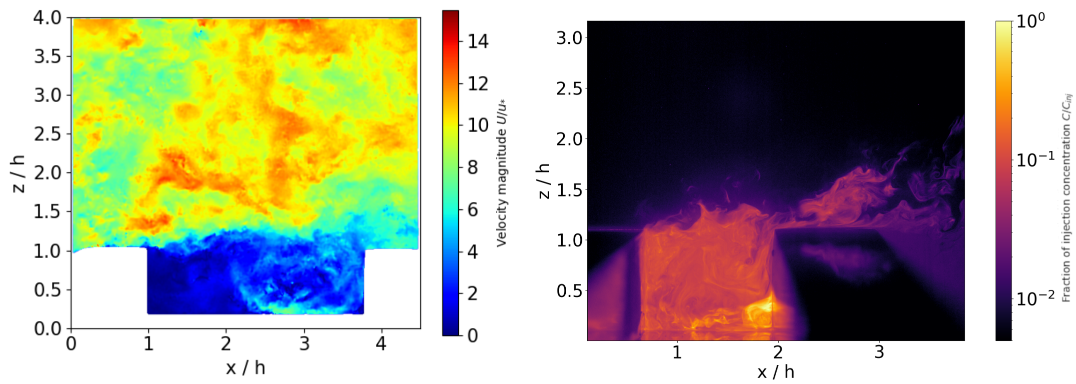

Figure 1: Example of instantaneous (a) PIV velocity field in the wake-interference flow configuration (large canyon), normalized by the friction velocity u_*, and (b) PLIF snapshot in the skimming flow regime (narrow canyon), normalized by the concentration of the injected fluorescein.

*Institut de Mécanique des Fluides de Toulouse (IMFT), Université de Toulouse, CNRS, INPT, Université Toulouse III - Paul Sabatier (UPS), Toulouse, France.

[1] Ahmad et al., *Journal of Wind Engineering and Industrial Aerodynamics* **93**, pages 697-717 (2005)
[2] Baik and Kim,, *Journal of Applied Meteorology* **38**, pages 1576-1589 (1998)
[3] Gonzalez Olivardia et. al, *Atmosphere MDPI* **10**, page 479 (2019)
[4] Oke, *Energy and Buildings* **11**, pages 103-113 (1988)