PhD position
Start: September/October 2023

Title : Data-driven reduced-order modelling of urban canopy flow

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General context

For health, safety and environmental reasons, good prediction of air ventilation in urban areas are increasingly important to guide policy makers, urban planners and environmental engineers. Urban areas are critical places where critical physical processes such as heat absorption and production, pollution emission, alteration of the water cycle, among others, take place. All these processes are driven by chemical and dynamical interactions with the atmosphere above. In most cases, it is indeed the wind field that drives the exchanges between the urban canopy (*i.e.* the region ranging between the ground and the top of the buildings) and the atmosphere, enhancing the dissemination of scalars (such as chemicals, particles or heat) and by acting aerodynamically on urban structures. Our ability to develop well-adapted management strategies, modelling and forecasting tools is therefore of crucial importance.

Difficulties arise due to the fact that the urban canopy is a highly heterogeneous and multi-scale terrain. As a consequence, the wind flow in the lower part of the atmosphere over such a surface is highly turbulent and is composed of various eddies of different scales in space and time (see Figure 1). Modelling and prediction of such flows are challenging for this type of configuration [*2*]. Classical numerical simulation approaches, such as Large-Eddy Simulation (LES) or Direct Numerical Simulation (DNS), still have a prohibitive computational cost as they involve solving nonlinear partial differential equations with a huge number of degrees of freedom (*e.g.*, $10^7 - 10^{10}$). In accidental hazards with short-range dispersion, it is essential to have precise and rapid models to reproduce the intermittent and unsteady dynamics of the flow responsible for the dispersion processes to minimise the impacts in terms of health and pollution. To produce such rapid models, the present project aims at developing reduced-order models (ROMs) of the urban canopy flow both derived from and driven by data.

To achieve this goal, data-driven model identification techniques and data-assimilation methods will be combined. Development and validation tests will be performed on canonical and realistic urban canopy configurations, ranging from small-scale laboratory experiments, up to full-scale street canyons. Our ambition is to demonstrate that scattered and potentially noisy observations in space and time can offer much more by (*i*) enriching physically-based models, (*ii)* combining at best different sources of information (data assimilation), and even (*iii)* discovering nonlinear models. This project will address challenges posed by this data revolution with the aim to obtain a simplified dynamical model of the turbulent flow within the urban canopy, at the scale of the street or neighbourhood including local buoyancy effects and scalar dispersion.

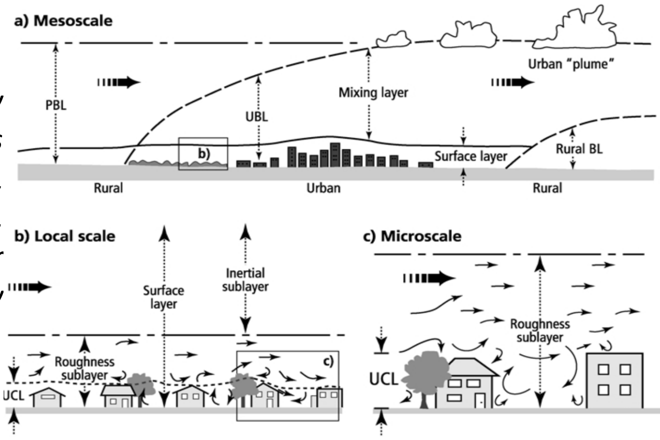

Figure 1: *Sketch of the urban boundary layer structure indicating the various (sub)layers and their names; PBL stands for planetary boundary layer, UBL for urban boundary layer, UCL for urban canopy layer and SVF for sky view factor [7].*

Objectives

The candidate will take part of the joint ANR research program MUFDD (Modelling Urban Flows using Data-Driven methods) between IMFT, LHEEA (Ecole centrale of Nantes) and PPRIME (Poitiers), to support the experimental activities carried out at IMFT, interacting with PhD, PostDocs and experienced researchers from all of the three laboratories. The work will focus on isothermal street canyon urban canopy configuration. Experiments will be performed in the large, 26 m long and 1.1 m wide, hydraulic flume of IMFT with optical access for laser optical measurements [*3*, *4*]. Several optical measurement techniques will be deployed, such as *Laser Doppler Velocimetry* (LDV), *time-resolved volumetric tomographic Particles Image Velocimetry* (Tr-3D3C PIV) and *Planar Laser Induced Fluorescence* (PLIF). The main objectives of the PhD are *(i)* to validate the urban canopy geometry model with LDV (common to all three laboratories), *(ii)* enrich the available databases [*1, 5, 6, 7*] with time-resolve volumetric measurements (Tr-3D3C PIV) which will constitute a new step in complexity compared to existing databases required to build ROMs, and *(iii)* to further test the robustness of the proposed approaches (buoyancy-driven flows, pollutant dispersion, …) by performing dispersion measurements using combined PLIF and PIV 2D2C. The candidate will be also in charge of the database organisation and sharing with other research groups. Though a great part of the PhD will be dedicated to experiments realisation, post-processing and analysis of the turbulent boundary layer structure, the candidate will also work in collaboration with other PhD and Postdocs of the project on the development of ROMs methodology, testing and validation.

Profile

The candidate must have a Master's degree or an engineering degree with skills in fluid mechanics. Knowledge in turbulence, turbulent boundary layers and/or atmospheric surface layer are also welcome. A particular interest in experimental fluid mechanics, optical diagnostics in fluids and signal processing will be appreciated. As a great part will be mainly experimental with generation of large databases, good practical sense and organisation are required, as well as autonomy, curiosity and creativity. An advanced level of scientific and technical English and good written and oral communication skills are required.

Funding

The financing of the PhD student is provided by the MUFFD project, through the French *Agence National de la Recherche* (ANR).

References

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