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PROPOSITION DE SUJET DE THESE

Intitulé : Numerical simulations of urban turbulent wind flow for UAV flight

Référence : **SNA-DAAA-2026-04**
(à rappeler dans toute correspondance)

Début de la thèse : October 2026	**Date limite de candidature :**

Mots clés

Unmanned Aerial Vehicles, Urban canopy, Atmospheric boundary layer, Thermal stratification, Computational Fluid Dynamics, Rare-events theory

Profil et compétences recherchées

Master II in Fluid Dynamics, Engineering « Grandes Ecoles »

Présentation du projet doctoral, contexte et objectif

Context:

Ongoing advancements in Unmanned Aerial Vehicle (UAV) technology are rapidly expanding their potential applications, ranging from high-resolution 3D mapping and disaster response to urban package delivery highlighting their transformative impact across multiple sectors (*Barrado et al. 2020*),. As the UAV sector continues to expand, operational zones for drones are rapidly increasing, particularly in urban areas (*Garcia-Gutierrez et al. 2022*). This growth underscores the need for new infrastructures, including Vertiports, to support urban drone operations. At the same time, navigating the complexities of urban airspace presents significant challenges for these lightweight, compact aircraft with low inertia, especially during takeoff and landing phases.

The Atmospheric Boundary Layer (ABL), extending roughly from the surface up to 1 km, is a highly dynamic region where momentum, heat, and moisture exchanges are dominated by turbulence (Stull, 1988). Near the surface, turbulence intensity can reach around 30%, driven by surface friction and variable thermal and moisture forcings depending on terrain and time (Figs. 1 and 2).

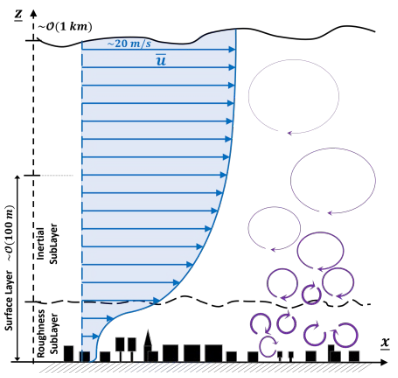

Fig. 1 – Schematic visualization of the neutral ABL (inspired from *Monin & Obukhov, 1954; Kaimal & Finnigan, 1994*)

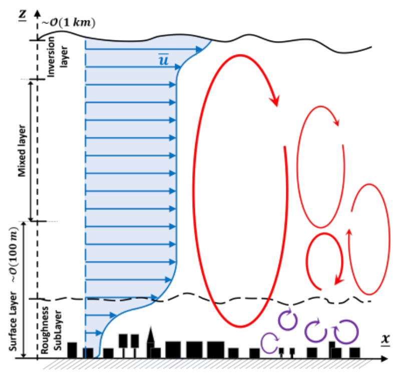

Fig. 2 – Schematic visualization of the convective ABL (inspired from *Monin & Obukhov, 1954, Kaimal & Finnigan, 1994*)

Studies on the impact of environmental conditions on UAV flight highlight the critical role of wind and turbulence, specifically during take-off and landing (*Ranquist et al. 2017*; *Sytsma, 2013*). A major challenge for the operational deployment of UAVs in urban areas lies in accurately characterizing these conditions within complex urban configurations. This need is underscored by several projects around the world of UAV-based medical sample delivery system between hospitals, such as the projects AirSHAB and AirGHT in the «Hauts-de-France» region (e.g. Figure 3). A detailed understanding of urban turbulent flow is therefore essential for optimizing flight paths, ensuring navigation safety, and guiding vertiport placement.

This growing interest in urban flow characteristics has driven an increase in research efforts aimed at simulating urban flow turbulence using experimental setup in wind tunnels and/or Computational Fluid Dynamics approaches (e.g. *Nithya et al 2024*). In particular, Large-Eddy Simulation (LES) is a crucial numerical simulation tool for capturing the complexity of urban wind conditions (*Garcia-Guttierez et al. 2022*, *Giersch et al. 2022*). Current numerical studies aimed at supporting UAV operations primarily focus on mapping the turbulent statistics of the flow under statistically stationary conditions, in order to identify hazardous flow regions that drones should avoid , such as the turbulent wake downstream of buildings (Figure 4)).

Fig. 3 – Hospital complex in Abbeville (Somme, France), a typical configuration for UAV-based medical delivery service

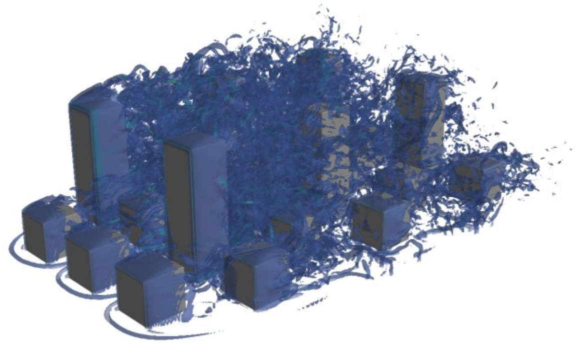

Fig. 4 – Turbulent flow around a generic urban configuration: isosurfaces of vorticity as computed by the code Meso-NH with IBC (credits: B. Caro)

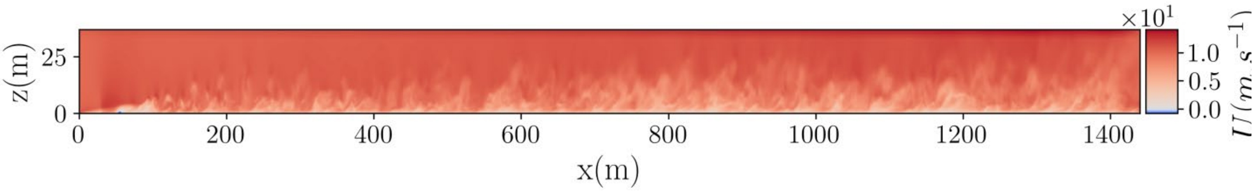

Fig. 5 – Generation of a neutral turbulent boundary layer, triggered by an upstream array of cubes, computed by the code Meso-NH (credits: B. Caro)

The current PhD project aims to extend this approach by numerically investigating unsteady turbulent rare events and their statistical properties. These intermittent, extreme turbulent events are expected to have a significant impact on the drone navigation safety. The analysis will provide estimates of the likelihood of such hazardous events and explore strategies to predict them based on unsteady inflow conditions.

The numerical simulations within this project will be held on the LES code Meso-NH, developed by Meteo France (*Auguste et al. 2020*). A previous PhD thesis undertaken at ONERA has developed methods for simulating the flow around buildings using Immersed Boundary Conditions (IBC) in Meso-NH (e.g. Figure 4), with a specific focus on the correct properties of the inlet conditions (Figure 5). A particular focus of the future work will be given to the representativeness of the code at scales close to typical drone sizes and the study of thermal forcing effects.

Research project and objectives:

The objectives of the PhD project are the following:

- Pursue the development of numerical simulations workflow based on Meso-NH (Météo France) in order to consider thermal forcing effect on the urban boundary layer;
- Generate a numerical database of the wind flows around several generic urban configurations, chosen to represent a broad range of building interactions;
- Characterize the effect of thermal forcing on the turbulent urban boundary layer in several generic urban configurations;
- Identify and characterize extreme turbulent events relevant for UAV navigation in urban environment;
- Develop tools for the optimization of UAV flight navigation and vertiport positioning;

– Investigate the need and the capacity to couple Meso-NH to engineering CFD codes more suited for studying smaller scale turbulence and considering finer details of the urban configuration, such as building roughness (e.g. the ONERA code SONICS or OpenFOAM);

Bibliographical references:

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Collaborations envisagées

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