PROPOSITION DE SUJET DE THESE

Intitulé : Atmospheric flow study around hospital center in urban environment for drones operation

Référence : **MFE-DAAA-2025-12**
(à rappeler dans toute correspondance)

Starting date : 10/2025	**Application deadline :** 30/05/2025

Mots clés

Atmospheric Boundary Layer, Wind engineering, Unmanned Aerial Vehicles, Turbulence, Wind Tunnel

Expected profiles and skills

Fluid dynamics master, « Grandes écoles » engineering school.

A good knowledge in fluid dynamics and turbulence is expected, with a strong interest in undertaking experimental studies. Proficiency in Python or an equivalent programming language is expected.

The doctoral project, its context and objectives

Context :

The improvement of Unmanned Aerial Vehicle (UAV) technologies make them increasingly useful for 3D mapping, disaster relief, and parcel delivery in urban areas (*Barrado et al., 2020*). This sector is experiencing constant development, leading to an ever-expanding range of drone usage zones, particularly in urban environments (*Nithya et al. 2024*). The latter requires planning and construction of new hosting structures, such as vertiports. Nevertheless, operating drones in urban settings during takeoff, landing, or transit phases poses a challenge for these types of aircraft, characterized by relatively low inertia and wingspan.

Indeed, the Atmospheric Boundary Layer (ABL), i.e., the region of the atmosphere directly influenced by the Earth's surface, is a highly complex environment characterized by exchanges of momentum, heat, and moisture, with atmospheric turbulence being the primary vector (*Stull, 1988*). The turbulent intensity in this atmospheric region (approximately spanning from 0 to 1 km in altitude) is remarkably high (on the order of 30% in the immediate vicinity of the surface) due to friction with the surface and potentially various thermal and hydric forcings it undergoes (dependent on the nature of the terrain and the instant considered) (Fig. 1).

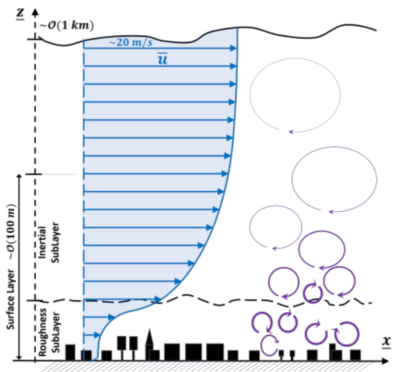

Fig. 1 – Diagram of a neutral atmospheric boundary layer structure (inspired from *Monin & Obukhov, 1954* ; *Kaimal & Finnigan, 1994*)

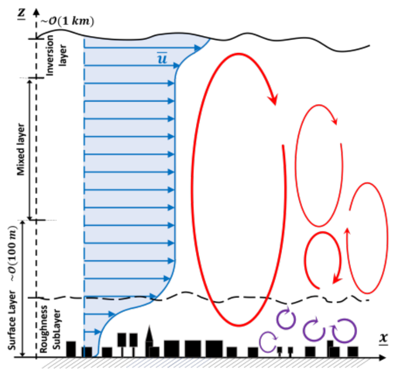

Fig. 2 – Diagram of a convective atmospheric boundary layer structure (inspired from *Monin & Obukhov, 1954*, *Kaimal & Finnigan, 1994*)

Within the atmospheric boundary layer (ABL), several sublayers can be distinguished (*Monin & Obukhov, 1954; Stull, 1988; Kaimal & Finnigan, 1994*). Closest to the ground, the “roughness sublayer” conforms to the specific geometry of terrain roughness elements. At heights corresponding to these roughness features (buildings, streets, trees, etc.), the flow, referred to as the “canopy layer”, exhibits significant temporal and spatial variations, highly sensitive to the specific configuration being studied. This is partly due to interactions between large turbulent structures from the upper parts of the ABL (notably the inertial sublayer) and smaller structures formed within the roughness sublayer (*Perret et al. 2019*). Notably, it is within this sublayer that a drone is intended to operate for urban environment applications.

Studies on the impact of external conditions on UAV flight have shown that wind and turbulence conditions play a crucial role (*Ranquist et al., 2017*). A major challenge for operational UAV use in urban environments lies in characterizing these conditions within specific urban geometric and meteorological configurations. Several experimental investigations have already been undertaken recently across the world (e.g. *Frey et al. 2022, Al Labbad et al. 2024*)

This need is particularly pressing today for the upcoming operation of medical sample transport UAVs between three hospitals in the Hauts-de-France region. In collaboration with stakeholders from this project, wind tunnel studies are being considered to be undertaken in the large subsonic wind tunnel L2 at the ONERA Lille center, in order to investigate the aerology of one of these hospital complexes, thereby examining the operational conditions for the UAVs in question.

Fig. 3 – Hospital Center (Hauts-de-France Region)

Fig. 4 – Example of wind tunnel testing for Urban Flow Studies. Credits : Shimizu Corporation, Japon

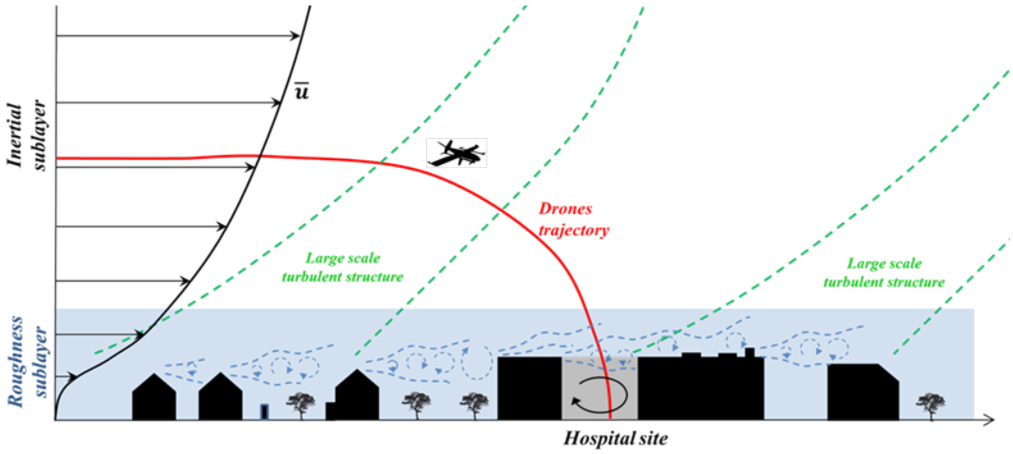

Fig. 5 – Schematic visualization of characteristic flow elements of interest for drone operations in a Hospital Complex (adapted from *Perret et al., 2019*)

Research project and objective :

This PhD project has the following objectives :

- Conduct a large wind tunnel experimental campaign to characterize the aerological environment of a hospital complex in the Hauts-de-France region, with a focus on mapping turbulence statistics in UAV operational zones as a function of wind conditions;
- More specifically, we aim to spatially and temporally characterize the flow within regions where UAV operations are considered critical, especially within an inner courtyard (representative of cavity flows), with an emphasis on quantifying rare events and their probability. It will involve setting up measurements using stereo-particle image velocimetry (S-PIV), hot-wire anemometry (HWA), or laser doppler velocimetry as needed (LDV);
- Experimentally study simpler generic urban configurations (“benchmark”) to isolate and characterize extreme phenomena hazardous to drones;
- Compare these experimental measurements to numerical simulations (large eddy simulations (LES)) to bolster our capabilities for numerically predicting urban flows and their effects on UAV flights;

- Develop UAV trajectory optimization algorithms and apply them to the experimentally and numerically studied environments to propose improvements for drone operator;
- Explore the compatibility of the experimental setup with the study of diffusion coefficients of different passive and active scalars.

The orientation of this thesis project will also be influenced by the interests and choices of the doctoral student.

Skills that will be developed by the PhD student:

This project will enable the candidate to:

- Become an expert in turbulent flow, its characteristics in both the atmosphere and wind tunnels and its effects on UAVs;
- Undertake an ambitious experimental work in a large wind tunnel, within a multi-disciplinary team of researchers and technicians;
- Implement several wind tunnel measurements technics, such as for instance Hot-Wire Anemometry and Particle Image Velocimetry;
- Communicate its scientific results in international conferences and peer-reviewed journals;

References:

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Collaborations envisagées

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