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Numerical simulation and modelling of extreme events in the urban boundary layer for a UAV flight application

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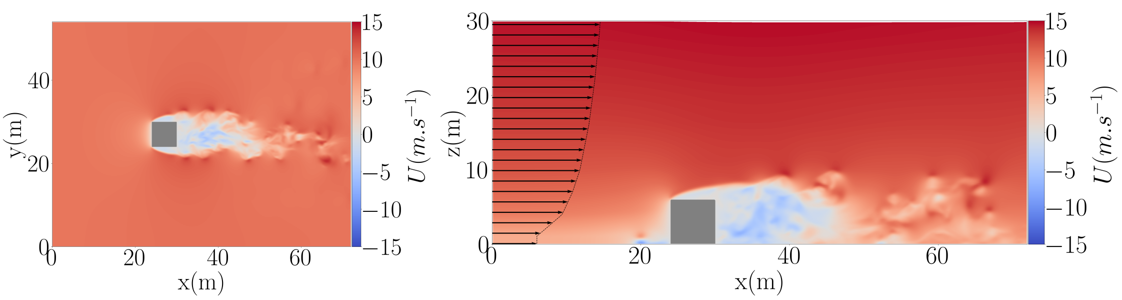
Advances in drone technology mean they can be used in urban environments for applications such as delivery and 3D mapping. Due to their low inertia, Unmanned Aerial Vehicles (UAV) or drones are highly sensitive to flight conditions. They operate primarily within the urban atmospheric boundary layer, a complex environment directly influenced by the local building configuration. Although turbulence in this layer has been studied, extreme events that create important risks to UAV stability remain partially understood.

This work aims to address these gaps by performing high-fidelity simulations of the atmospheric boundary layer for urban configurations by identifying extreme events for drone flight and analyzing them by adapted methods. This presentation focuses on results for a cubical building configuration. This configuration has been chosen due to the large amount of bibliography available[1 2], which therefore validates the tools used. Large-Eddy Simulations (LES) are performed with Meso-NH, a meteorological code with advantages such as surface thermal forcing and water cycle processes modules. LES methods are used to resolve large-scale events and therefore capture the detailed dynamics of turbulent flows in urban configurations. The Meso-NH [3] code employs Immersed Boundary Methods (IBM) to model urban configuration and grid nesting to simulate a representative turbulent atmospheric boundary layer.

Here, the flow is studied around a 6 meter height cube ($H = 6$ m) and the simulation conducted within a domain measuring $12H * 9H * 5H$ with a cell size $\Delta = 0.2$ m. A logarithmic turbulent atmospheric boundary layer profile is provided at the inlet. A first look of the simulation results is shown in figure 1, highlighting the formation of a recirculation bubble downstream of the cube, a characteristic phenomenon of flows of this type, and the creation of an unsteady wake. These unsteadiness poses a significant risk to drone flight as turbulent flows can destabilize them. A validation of the tools and methods used for the simulation is provided. A study of the wake is performed in order to identify extreme events and a first statistical analysis will be presented.



(a) Horizontal view at height = 5 m

(b) Longitudinal view at latitude = 27 m (middle of the cube)

Figure 1: Plan view of a Simulation around a cubical building immersed in an atmospheric boundary layer. The instantaneous longitudinal wind speed is shown in color with the cubical building represented in gray. A mean wind speed profile is added in subfigure 1b

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[1] Köse and Dick, *Journal of Wind Engineering and Industrial Aerodynamics* **98**, 628-649 2010

[2] Martinuzzi and Tropea, *Journal of Fluids Engineering* **115**, 85-92 1993

[3] Auguste et al., *Atmosphere* **11**, 2020