Etude numérique de la ventilation urbaine à l'échelle d'un quartier avec une géométrie réelle complexe : la Part-Dieu

Porteur : Ariane Emmanuelli
(Le porteur s’engage à participer et présenter son projet aux journées de la GI-EIF)
Partenaires : (si applicable)
Laboratoire : Laboratoire de Mécanique des Fluides et d’Acoustique (LMFA)
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Résumé : (200 mots)

Plus de la moitié de la population mondiale vit en milieu urbain, et face au changement climatique, il devient crucial de mieux comprendre et prédire la ventilation urbaine pour améliorer la qualité de l’air et le confort thermique notamment. La littérature sur la ventilation urbaine s’est longtemps concentrée sur des géométries de rues, mettant en évidence l’impact de leur géométrie, des intersections, de la hauteur des bâtiments ou de la végétation. D’autres travaux ont exploré la couche limite urbaine avec des configurations simplifiées de quartiers ou de villes. Ces dernières années, des simulations de quartiers réalistes sont devenus possibles, mais elles se limitent souvent à démontrer leur faisabilité ou à des études de cas. Hors, l’écoulement à l’échelle du quartier ainsi que les petites échelles introduites par la prise en compte de géométries complexes réalistes vont affecter la ventilation au niveau des rues. Ainsi, ce stage vise à analyser les interactions entre les processus physiques à l’échelle du quartier et des rues, en utilisant des simulations aux grandes échelles appliquées au quartier lyonnais de la Part-Dieu. Celle-ci pourra être validée grâce à des données obtenues en soufflerie.

Sujet développé :

Societal context – Over half of the world's population is urban, and this number is expected to reach 68% by 2050 [1]. As such and in the context of climate change, there is a need to better understand and predict urban ventilation in order to improve quality of life in cities by dealing with thermal comfort, air pollution and pedestrian comfort issues.

Scientific context – Many studies of urban ventilation focus on idealised street canyons, in which the population lives. The significant effect of their geometry has been identified, as well as, looking at a collection of streets, the impact of intersections, main streets, tall buildings or vegetation. [2,3] Others have investigated the development of the urban boundary layer (UBL) with simplified neighbourhood or city configurations [4]. More recently, work has been led on real geometries to account for their complexity and various scales, at the street canyon level by accounting for roof-type or courtyards, and at neighbourhood scale using GIS data [5]. However, the latter have mainly been demonstration case-studies or earlier work lacking the computational resources to account for unsteadiness and turbulence. There is a need to better understand both how neighbourhood-scale phenomena affect street-canyon ventilation, and the physical implications of complex real geometries on the flow. In the future, this could help introduce more physics into operational models in an effort to improve them, and allow more accurate prediction of pollution or temperature peaks in urban settings.

Aim & objectives – to better understand the interaction between physical processes at play at neighbourhood scale and within street canyons and their impact on urban ventilation, by detailed physical analysis of the flow in a real urban geometry.
To do so, the Large Eddy Simulation (LES) code PALM is used. It is an open-source high-fidelity code developed at the University of Hannover for atmospheric boundary layer applications [5]. The chosen configuration is the Part-Dieu district of Lyon, a dynamic neighbourhood which includes various geometry types: open spaces and tall buildings, as well as compact-city-type street canyons.

Training period – After getting familiar with the literature and the PALM code though tutorials, the intern will start work on a preliminary case, prepared prior to the internship, which consists of a small portion of the Part-Dieu neighbourhood, made of compact-city-type street canyons and an open-space. The intern will start by post-processing this simulation to further familiarise themselves with the tools and physics, and to start investigating the singularities of such a neighbourhood. In parallel of this, the student will start setting up the full neighbourhood simulation. A preliminary wind-tunnel study has been led on this geometry, so that some validation data is available. Neighbourhood-scale effects will be analysed first by detailed phenomenological description of the flow in key areas, and secondly, by comparison with the flow around academic configurations of elementary urban geometries, which are analysed in an ongoing project. Depending on the advancement of the project, complementary simulations may be run either to further investigate a particular physical phenomena or configuration, or to look at their effects on pollution dispersion.

[1] United Nations, Department of Economic and Social Affairs, Population Division (2019). World Urbanization Prospects: The 2018 Revision (ST/ESA/SER.A/420). New York: United Nations.
[2] Badas, M. G., Ferrari, S., Garau, M., Seoni, A., & Querzoli, G. (2020). On the flow past an array of two-dimensional street canyons between slender buildings. Boundary-Layer Meteorology, 174, 251-273.
[3] Fellini, S., De Giovanni, A., Marro, M., Ridolfi, L., & Salizzoni, P. (2020). Effect of trees on street canyon ventilation (No. EGU2020-10661). Copernicus Meetings.
[4] Barlow, J. F. (2014). Progress in observing and modelling the urban boundary layer. Urban Climate, 10, 216-240.
[5] Gronemeier, T. et al. (2021). Evaluation of the dynamic core of the PALM model system 6.0 in a neutrally stratified urban environment: comparison between LES and wind-tunnel experiments. Geoscientific Model Development, 14(6), 3317-3333.