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Turbulent flow over street canyons with balconies

Huanhuan Wang[a,b,*], Keith Ngan[c]

[a] Department of Mechanical Engineering, The University of Hong Kong, Pokfulam, Hong Kong, China
[b] School of Energy and Environment, City University of Hong Kong, Kowloon, Hong Kong, China
[c] Institute of Ocean and Earth Sciences, University of Malaya, Kuala Lumpur, Malaysia

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ABSTRACT

Flow over a single street canyon with balconies located along the leeward and windward walls is studied using large-eddy simulation. The effect of different balcony configurations on the mean flow and turbulence statistics is assessed for height-to-width canyon aspect ratios of $AR = 0.25, 0.5, 1.0$ and a mean flow perpendicular to the canyon axis. For sufficiently small balconies, the flow continues to be well-described by the canyon aspect ratio; for more closely packed balconies, the applicability of alternative parameters, such as the effective aspect ratio for the interior (AR_e) and the balcony aspect ratio for the balcony regions (AR_b), is investigated. Over a wide range of balcony configurations, the mean flow, and to a lesser extent the turbulent kinetic energy (TKE), are described by AR_e and the normalised balcony separation distance (s'). It is argued that this is a consequence of the flow within the balconies being driven by a canyon-like flow within the interior.

1. Introduction

Urban flow, dispersion and climate are strongly affected by building geometry. Current understanding of urban flow is primarily based on geometries such as street canyons and building arrays (e.g. Britter and Hanna, 2003; Di Sabatino et al., 2013). These geometries have been widely studied numerically (Baik and Kim, 1999; Coceal et al., 2006) and experimentally (e.g. Brown et al., 2000; Eliasson et al., 2006) in order to elucidate the key physical mechanisms and characterise mean flow and turbulence statistics. Idealised geometries have also been used to study urban climate (e.g. Ali-Toudert and Mayer, 2006; Kwak et al., 2011; Nazarian and Kleissl, 2016).

Urban flows are often classified using some key dimensionless parameters. In the case of two-dimensional street canyons, there are isolated roughness (IR; $AR \lesssim 0.3$), wake interference (WI; $0.3 \lesssim AR \lesssim 0.7$) and skimming flow (SF; $AR \gtrsim 0.7$) regimes, where the aspect ratio, $AR \equiv H/W$, with H and W representing the building height and canyon width, respectively (Oke, 1988). In the case of building arrays, a similar classification exists for the frontal and plan area ratios (e.g. Hagishima et al., 2009).

Idealised geometries have two obvious limitations. On the one hand, real buildings are not identical. On the other hand, they are not specified completely by parameters such as the width, length and height of the building: the primary (e.g cuboidal) geometry may be perturbed by secondary features or auxiliary structures. In recent years, numerical and experimental studies based on digital elevation data have become commonplace as a means of characterising flow and dispersion in real urban areas (e.g. Gronemeier et al., 2017; Wang et al., 2021). Despite the improved realism, a limitation of such studies is the neglect of secondary features or roughness. In

* Corresponding author at: Department of Mechanical Engineering, The University of Hong Kong, Pokfulam, Hong Kong, China.
E-mail address: huanhwang3-c@my.cityu.edu.hk (H. Wang).

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