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Defining Building Archetypes for Urban Climate Simulations of the Complex High-Density Environment in Hong Kong

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ABSTRACT: Building data are required to initialise urban canopy parametrisations in atmospheric models. Improving the precision of such data enhances the accuracy of model outputs and enables us to better simulate the urban surface energy balance and the potential impacts of climate change on cities. This study aims to characterise buildings in Hong Kong using a locally-adapted approach, taking into consideration its subtropical climate, rapid urban development process, and complex high-density environment. We identify 18 building archetypes distinguished by their morphology and use. For these we define building architectural characteristics and human behaviour schedules. These parameters are intended for use in fine scale urban climate simulations with the Town Energy Balance (TEB). Subsequent findings may be applied for urban planning and climate change impact studies.
KEYWORDS: Building archetype, Construction materials, Urban canopy parametrisation, High-density city

1. INTRODUCTION

Atmospheric models are effective tools for understanding the potential impacts of climate change on cities. In particular, urban land-surface schemes, like urban canopy parametrisations (UCPs), are constantly being refined to accurately simulate the altered surface energy balance due to urban environments and anthropogenic activities [1]. Buildings form an important component in UCPs because their physical characteristics (e.g. albedo, thermal conductivity) and building energy consumption influence the city-atmosphere interactions. The WUDAPT [2] initiative aims to provide a standardised global database on urban tissue based on local climate zones (LCZs) [3] to facilitate urban climate, environmental, and energy use modelling studies. With a similar objective, the GENIUS database for building architecture has been developed for French cities. It assumes that building architecture is mainly shaped by urban morphology, building use, construction period, and geographic location [4]. A further step has been taken to incorporate human behaviour schedules, inferred from building use, in parametrisations to improve the modelling of spatio-temporal variabilities in anthropogenic heat flux [5].

In this study, we aim to characterise buildings in Hong Kong (HK) using a locally-adapted approach to define parameters on building architecture and human behaviour required for the initialisation of the UCP – Town Energy Balance (TEB) [6], coupled with the Meso-NH model [7]. The results can then be used to inform urban planning and climate change impact studies.

2. CHARACTERISTICS OF HONG KONG BUILDINGS

Urban tissue in HK are distinctly different from that of European or American cities owing to its subtropical climate, high population density, and short urban development history. Here are major reasons why previous approaches may not be suitable for describing the complex high-density urban environment in HK:

- The dominance of high-rise buildings is reflected by the large proportion of LCZ 1 (compact high-rise) and LCZ 4 (open high-rise) in the urban areas of HK [8]. However, within these two LCZ classes, the existence of large variabilities in building height and building use may cause significant differences in building physical properties and energy consumption patterns.
- The prevalence of mixed-use buildings, specifically with commercial use on the ground or podium floors of residential buildings, may pose challenges on defining schedules for occupancy and energy use.
- Geographic locations and thermal regulations on building insulation have largely influenced the choice of construction materials in French cities [4]. In HK, however, reinforced concrete, often in the form of prefabricated component blocks, is used as the structural material for over 90% of skyscrapers [9] and building codes focus on reducing cooling, instead of heating, energy demand [10]. Thus, cooling practices, such as the use of air-conditioners, would also need to be carefully characterised.
- Window design, including the glazing type, window-to-wall ratio (WWR), and shading elements, is another important factor for building performance in HK since building heat intake is found to be dominated by solar heat gain through windows [10]. Controls on “gross floor area” calculation and the preference for unobstructed window views also shaped designs of “bay windows” and curtain walls in HK [11].

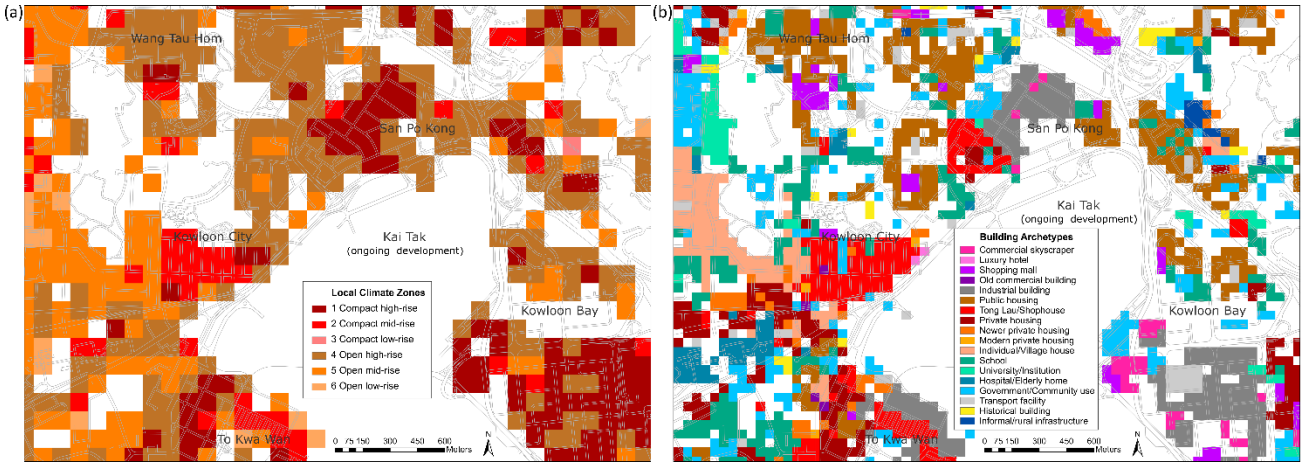

Figure 1: Comparison between the (a) LCZ [3,8] and (b) building archetype classifications of the pilot study area in Hong Kong.

Table 1: Morphological and window characteristics of selected residential building types.

Building type	LCZ	No. of storeys	Glazing type	WWR	Shading
Public housing	4	35-45	Single glazing	0.2	Building self-shading
"Tong Lau"/Shophouse	2	4-8	Single glazing	0.4	Metal overhangs
Newer private housing	1/4	40-60	Tinted single glazing	0.35	Bay windows, little shading
Individual/Village house	5/6	2-6	Tinted single glazing	0.4	Balconies common

3. BUILDING ARCHETYPES AND INITIAL RESULTS

A total of 18 building archetypes (Fig. 1b) are identified for HK based on a combination of building type and use. A relative dependency on the construction period is only found for commercial and residential buildings. We then define a detailed description on typical morphology, use, wall and roof materials, WWR, mechanical ventilation system etc. for every building archetype. A few examples are presented in Table 1, highlighting major differences in morphological and window characteristics for various residential buildings. Since no maps of building use and age with sufficient detail are available, mapping of building types is conducted with the aid of ArcGIS and Google Street View for a pilot study area covering parts of the Wong Tai Sin and Kowloon City districts, which is an inner-city area currently undergoing urban redevelopment. Compared to the LCZ classification [3], our initial results provide a much more detailed representation of the urban tissue in the area.

4. CONCLUSION AND FURTHER WORK

We define 18 building archetypes in HK which will be used for fine scale urban climate simulations. Further work includes sensitivity tests on the defined parameters and the validation of model results. Findings are expected to contribute to a more precise understanding of the urban surface energy balance and the evaluation of climate-responsive planning strategies in high-density cities.

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