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Microclimate Variation of Urban Heat in a Small Community

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Abstract

Urbanization is known to disrupt the surface energy balance of an urban area. The phenomenon of higher temperatures and thermal discomforts within a local urban setting is broadly known as the Urban Heat Island (UHI) effect. This research employed roadside temperature measurements to examine microclimate UHI variation in Mongkok, a small urban community of Hong Kong. Results of the spatio-temporal examination indicated diurnal and seasonal variations in the microclimate. A five-level index named the "UHI Threat Rating" was devised to offer easy interpretation of the microclimate UHI variations and facilitate identification of temperature hotspots within a small urban community.

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Keywords: Urban heat island; Microclimate; Spatial analysis; GIS

1. Introduction

Rapid industrialization and urbanization are known to incur modification of natural surfaces into human-made structures. A typical urban environment features a setting with little vegetation amongst high rise buildings and transport infrastructures. These man-made alterations will exert impacts on local climatic variables and bring about changes in urban temperatures commonly known as the urban heat island (UHI). Urban microclimate is the most complex forms of microclimates and also one of the most heavily studied topics by geographers and meteorologists [1]. A fair amount of urban climate studies have examined microclimate conditions influenced by environmental

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settings within an urban area. However, the potential environmental impacts of various microclimate factors have remained uncertain [2]. Thus far, much of the highly-cited microclimate studies was established on experimental modeling or mathematical simulations [3,4]. The majority of these studies reported simulation results over a short time period, notably during the hottest periods or under ideal weather conditions. Therefore, a field study collecting empirical data to quantify microclimate variations at the street level is vital to further understanding of the impacts of environmental and human activities on longer-term and seasonal temperature changes.

This paper aims to explore the spatio-temporal microclimate variations by carrying out a series of detailed measurements of weather variables (including temperature, relative humidity, and wind speed) within a small urban community of Hong Kong for both hot and cool periods. With the aid of a geographic information system (GIS), the study will devise a rating scale for better appreciation of temperature hotspots and visualization of the microclimate UHI variations in two-dimensional (2D) and three-dimensional (3D) representations.

2. Data and Method

2.1. Study Area

Hong Kong, situated along the coast of southeast China, has a humid subtropical climate characterized by hot and humid summers but mild winters. The morphology of Hong Kong is a combination of mountainous terrain mixed with densely built high-rise buildings in the lowlands. Mongkok (MK) is a typical small urban community located in the Kowloon peninsula of Hong Kong. It is one of the most densely populated urban communities in the world [5]. MK has a mix of commercial and residential buildings and is one of the most popular shopping districts of Hong Kong. It is an area facing critical urban issues such as crowded settlement, lack of open space and heavy traffic. These issues have fostered the development of UHI microclimate within MK.

2.2. Microclimate Data

Most research has indicated traffic emission as one of the significant causative factors to UHI [6]. However, all but three of official weather stations of the Hong Kong Observatory (HKO) are located in non-built areas away from urban roadsides. The non-roadside locations of weather stations have prevented detailed examination of UHI variations within urban communities of Hong Kong. This study made use of portable weather sensors to sample street-level microclimate data for 17 days in the summer (Sept 2012) and repeated again in winter (Jan 2013). All portable sensors [7] have been calibrated and corrected to within ± 0.5 ºC accuracy and installed at strategic roadside locations.

Meteorological conditions measured at official urban and rural weather stations, HKO Headquarter (HKO) and Tsak Yue Wu (TYW) respectively, were obtained for the duration of study [8]. These data were compared against sampled street-level measurements to examine microclimate variations.

2.3. Methods of Analysis

The study firstly validated sampled air temperature readings against official urban readings from the HKO [9]. UHI values at Mongkok (UHI_{MK}) were estimated by comparing onsite measurement data against those at the official rural station (TYW). GIS technology was used to interpolate UHI_{MK} geographically using the inverse distance weighted method. Repeated applications of the procedure yielded a series of hourly UHI maps for different time periods (sunrise, midday, sunset and midnight) and seasons (summer and winter). Finally, a five-level rating scale grouped UHI_{MK} values into five quintiles for visual displays of UHI in 2D spatial representation and 3D building models.

3. Results and Discussion

3.1. Spatial Analyses of UHI

Figure 1 illustrates hourly UHI maps on the day with the highest UHI values based on daily averages over the 17-day measurement period for four time periods (sunrise, midday, sunset and midnight) and two seasons (summer and winter). The colour spectrum at the bottom right progressing from Blue (-3 ºC) to red (12 ºC) indicates varying degrees of UHI intensity. The spatial pattern of diurnal variations (from sunrise to midnight) of UHI appeared consistent between the seasons. UHI was most evident at midnight (7.5 ºC to 11.0 ºC) whereas urban cooling was observed at midday for both seasons. The average microclimate variations were 2.2 ºC and 2.8 ºC respectively for summer and winter. The maps in Figure 1 clearly reveal spatial (geographic) and temporal (daily and seasonal) variations of UHI. An understanding of the local situations can help explain the variation patterns. For example, UHI intensities were higher along major arterial roads (shown by thicker lines) at all times due to anthropogenic heat from traffic and public activities, as well as nocturnal heat released from built structures.

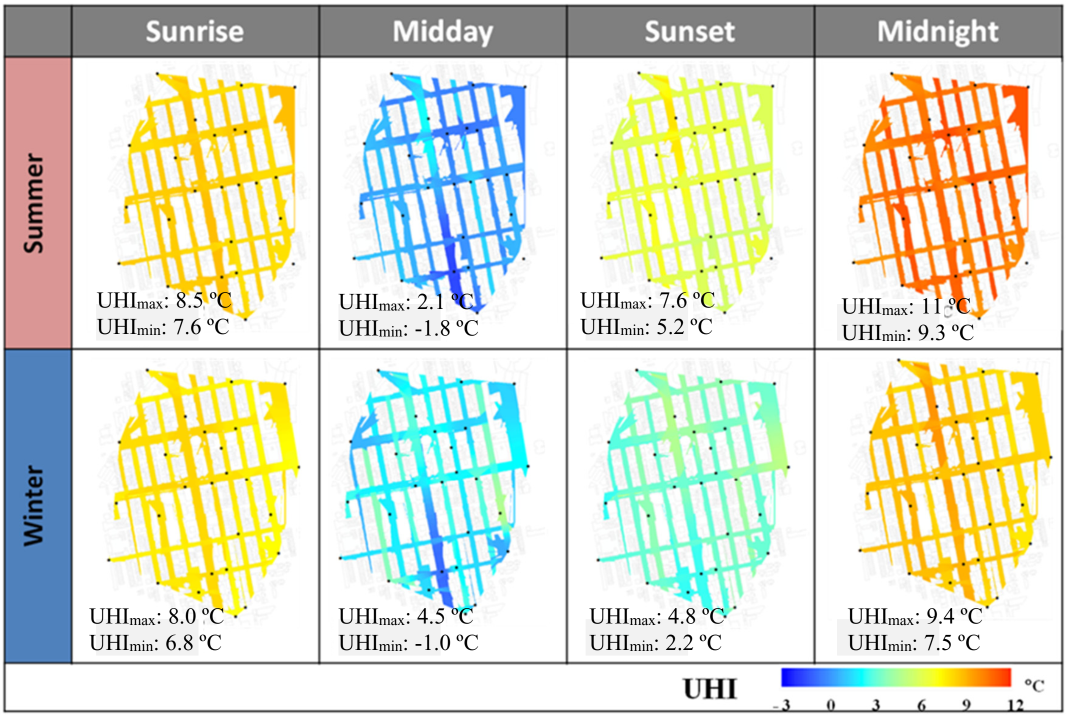

Figure 1: UHI surfaces of Mongkok (MK) in different time periods and seasons.

For the purposes of identifying hotspots or areas of excessively high UHI in the study area, hourly UHI maps of MK for both seasons were combined and grouped into five-quintiles referred to as the "UHI Threat Ratings": 1=high (red); 2=above average (orange); 3=average (yellow); 4=below average (green); and 5 = low (blue). Figure 2a is a 2D map representation of "hot" and "cool" spots in MK. When compared with Figure 1, it clearly shows that "hot" spots are characteristically hot areas in space and time. These areas require further study to find out reasons contributing to the exceptionally high thermal conditions. Figure 2a offers a useful overview of the spatial distribution of UHI in a small urban community.

Given that MK has a compact urban morphology comprising of high-rise buildings, a 3D representation may highlight its urban constructs to better associate the UHI phenomenon. Figure 2b immerses UHI threat ratings in a 3D building model of MK for better representation of the "real world" environment and street landscape. The display is effective in highlighting street canyon effects and vulnerable areas within MK.

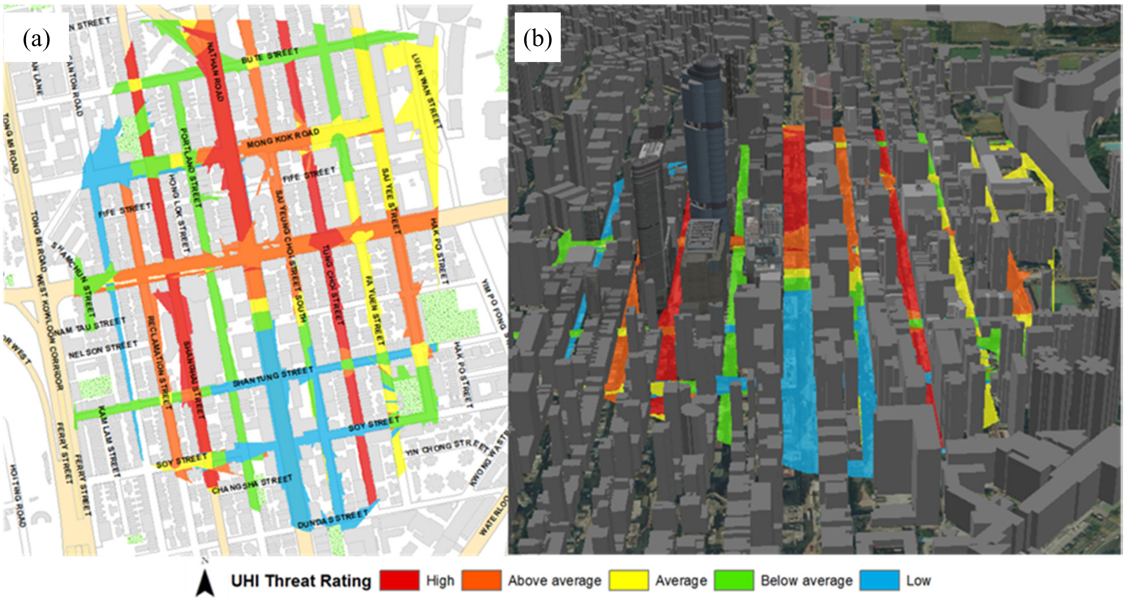

Figure 2: (a) A map of "UHI Threat Rating" showing hot and cool spots in Mongkok (MK): 1=high (red); 2=above average (orange); 3=average (yellow); 4=below average (green); and 5 = low (blue). (b) UHI Threat Ratings of MK displayed in a 3D building model.

4. Conclusion

This empirical study established the feasibility of widespread deployment of portable weather sensors to monitor microclimate temperature variation at the street level. Findings of spatial and temporal variations of UHI have contributed to local understanding of the microclimate UHI. The five-level UHI threat rating is easy to use and effective in displaying UHI hotspots. The study also demonstrated the use of GIS methodology in computing UHI ratings and enabling 2D and 3D data visualization. This methodological contribution has advanced the means of investigating and visualizing microclimate UHI variations that is adaptable for public consultation and urban planning.

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