A Distributed Approach to Monitoring Microclimate Urban Heat Island Effects

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Introduction

Urbanization is known to disrupt the surface energy balance of a city. These modifications to the energy balance of a city, that bring higher temperatures and undesirable thermal impacts to the local urban living environment, is broadly known as the Urban Heat Island (UHI) effect.

This empirical study establishes the methodological feasibility and reliability of employing small and inexpensive logging sensors (on the right) to take "Road-side" and "Vertical" temperature and relative humidity measurements at strategic sites over continuous time in summer and winter.

Road-side Measurement

Study Area

Mongkok (MK) and Causeway Bay (CWB) are two urban communities located in the Kowloon Peninsula and Hong Kong Island respectively. Both areas are popular residential districts that are also known to have high levels of commercial and retail activities in Hong Kong. These conditions typify microclimate of an urban area affected by UHI.

Data and Method

Road-side Microclimate Data
58 calibrated sensors, each housed in a solar radiation shield, were mounted on road-side street sign posts at 2.3m above ground throughout MK and CWB for 17 consecutive days in summer and winter.

Method of Analysis
The road-side air temperature readings were compared against the official rural readings to obtain UHIs (UHIMK, UHICWB, and UHIDF) at 15-minute intervals over 17 days each for summer and winter.

Vertical Measurement

Study Area
In this study, two typical street configurations: a narrow street canyon (HW ratio = 7.3) and an open street, were selected. Both sites are located in urban Kowloon (see map below) with high levels of population and traffic flow. The general wind directions are from the south-east (summer) and north-east (winter).

Data and Method

Vertical Microclimate Data
20 small logging sensors were deployed to measure vertical air temperature changes for 7 days in summer and winter. Each sensor was calibrated and mounted on buildings at vertical distances of every 2 storeys apart up to 17-20 storeys (>60 meters) above the street level.

Method of Analysis
Air temperature measured by sensors in summer and winter are averaged daily for 6 days and plotted against storey level as line graphs to exhibit a vertical profile of temperature behavior.

Vertical Analysis

The UHI line graphs (right) display similar fluctuation patterns for all locations (MK, CWB, and Official), with higher values at night than during the day. It was observed that UHICWB > UHIFs > UHICWB most of the time. The highest summer (top) and winter (bottom) UHIs were 10.4 °C and 9.5 °C respectively. Moreover, a bimodal peak was observed in some nights for both summer and winter.

Accuracy Discussion

All road-side measurements at MK and CWB were validated against local control and official measurements. The validation outcome indicated that road-side and control measurements were strongly correlated (r > 0.81) and their average difference was well within the manufacturer claimed ± 0.5 °C measurement accuracy (with software correction).

Conclusion

- Our study has effectively validated and confirmed the methodological feasibility of deploying a large number of small, durable and inexpensive sensors for widespread measurement of "road-side" and "vertical" temperature and relative humidity in urban neighbourhood.
- The observational studies and its distributed methodology have set a sound foundation and provide essential framework for future studies on microclimate variation of UHI. Given that modern cities have mixed landuses and are increasingly vertical, our microclimate study can benefit urban design and policy making concerning thermal comfort and quality of life in urban areas that are expected to be homes to more than two thirds of the world population by 2025.

Acknowledgements

The authors thank the following government departments for data access and permission to install sensors: Hong Kong Observatory, Transport, Highways, Leisure and Cultural Services and Environmental Protection. Acknowledgement of funding support is also due to the Hong Kong Research Grants Council [Project: HKU744113] and the Health Effects Institute [Project RFA13-1: The Hong Kong D3D Study: A Dynamic Three Dimensional Exposure Model for Hong Kong].

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