An Initial Investigation on Microclimatic Environment in High Density City — Spot Field Measurement Study in Hong Kong

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ABSTRACT: The paper focuses on the study of microclimatic environment in Hong Kong according to the result of spot field measurement, which is a part of Hong Kong Government Project named as "Urban Climatic Map and Standards for Wind Environment- Feasibility Study". Its study result aims to understand the microclimatic environment of high density urban areas of Hong Kong and to calibrate the Urban Climatic Map (UCMap).

Key words: Microclimatic Environment, spot field measurement, air temperature distribution, Urban Climatic Map

1. INTRODUCTION

Recently urban climate as one of important environmental issues in the process of designing has been received high attention. There are many urban climatic studies by researchers mainly from Europe and North America(Katzschner, 2003; Mayer, 1993; Oke, 1987). Among them, there is a lack of research concerning the microclimatic environment of high density city, e.g. Hong Kong, which has a population of 6.9 million on an area of 1,100 km² and 70% of land is characterized by hilly terrain. Its urban population density ranges from 60 000 to 100 000 persons/ km² (WHO, 2005). It is situated at 22°22' Latitude N and 114°11' longitude E. It has subtropical climate. In 2006, Planning Department of Hong Kong Government commissioned a consultancy on the **Urban Climatic Map and Standards for Wind Environment – Feasibility Study** for enhanced and long-term improvement of the living environment of Hong Kong. In this study, the spot field measurement aims to understand the microclimatic environment in high density urban areas. Its results could be used for calibration and verification of the UCMap.

The paper firstly analyzed the general wind condition of Hong Kong based on the metrological data from Hong Kong Observatory (HKO) Stations and MM5 simulation result provided by HKUST. Secondly two highly built-up areas with various land uses and built forms are selected to conduct the spot field measurement for collecting microclimatic data at the pedestrian level. Then, based on the initial analysis, the air temperature distribution, local wind pattern and bioclimatic situation have been carefully examined and drafted. Finally according to the study result, it offers some urban design strategies to help planners, architects and developers to produce good quality urban spaces. Its ultimate is to aid better town planning in Hong Kong and to contribute to the current knowledge gap on microclimatic environment of high density cities.

2. METHODOLOGY

2.1 Wind Environment of Hong Kong

According to the summer wind data from HKO and MM5 simulation, wind roses were generated in GIS platform by using the software of WindRose Pro. Then, two maps with terrain and spatial information illustrate general wind condition of Urban Canopy Layer (UCL) of Hong Kong (Figure 1a & 1b). Due to the complex terrain of Hong Kong (with the highest peak of 975m, complex coastline and numerous islands), the wind environment is very complex and the wind characteristics (mainly the prevailing wind directions) of the various urban areas are largely different. From the collected wind data, it could be found that under the weak regional wind condition in summer, three kinds of winds dominantly work, such as Background Wind, Land and Sea Breezes, and Topographically-generated Wind (e.g. Channelling Wind, Downhill Air Movement).

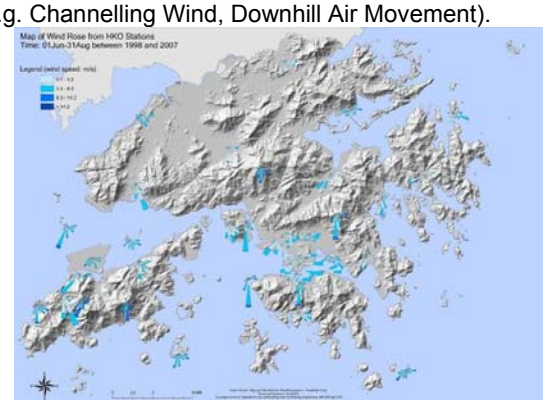
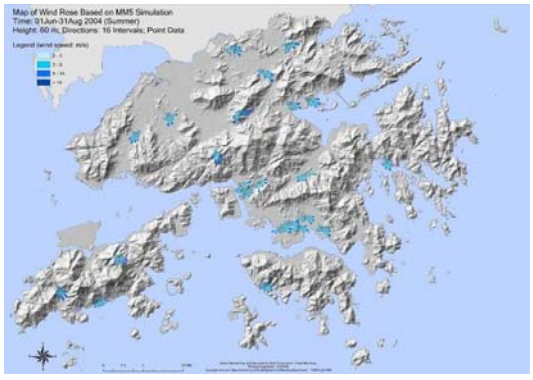


Figure 1: a) map of wind rose based on HKO data (1998-2007);



b) map of wind rose based on MM5 simulated data (2004);

2.2 Site Selection

For understanding the microclimate of the high densely urban area, Tsim Sha Tsui (TST) and Tsuen Wan (TW) which have a wide variety of urban layouts, land uses and built forms are selected for the study

- Tsim Sha Tsui Areas including Kimberley Road – Carnarvon Road – Cameron Road Areas and Granville Road – Chatham Road South – Mody Square Areas.
- Tsuen Wan Areas including Chung An Street – Sha Tsui Road – Yeung Uk Road Areas and Ma Tau Pa Road – Texaco Road – Wang Lung Street Areas.

Figure 2: a) Location of two sites in Hong Kong; b) Tsim Sha Tsui Areas; c) Tsuen Wan Areas;

2.3 Method of Spot Field Measurement

Ground measurements are done using handheld equipments along pre-selected measuring paths (Figure 3a). Before conducting the field measurements, the measuring paths and the fixed measuring points are chosen and drawn into the map according to the characteristics of urban structures of each of the study areas; the criteria of consideration include topographic characteristics (seafront/inner city), built forms (open/dense), street widths (wide/narrow), and street orientations (parallel/perpendicular to prevailing wind). Generally, the routes of the field measurement start from the seafront to the inner area of the study area. Measurements are made along the paths at fixed measuring points. Trained researchers were employed to conduct the field measurement; they were supervised by a staff of the research team. Before the field work, the researchers were briefed on the purpose of the study and taught how to properly handle the measuring equipments. On the day of the measurement, researchers were arranged in teams and were allocated to a measuring path. To conduct the measurement, they were given a set of measuring equipment (Figure 3b), a street map showing the measuring paths and a log sheet for recording the data. All teams started the measurements at Point 1 of the corresponding path at the same time. During the measurements, measuring sensors are located at 2m above ground and logged the data. When the measuring time was up, the researchers recorded the results of the measurement on the log sheet provided and moved on to the next measurement at the designated time.

Apart from the measurements along the measuring paths, the prevailing wind condition at the UCL level was tracked; this was done by continuing monitoring of the wind conditions at a fixed observatory station during the period of the measurements (Figure 3c). The reference point was chosen so as to best capture the prevailing wind conditions without the immediate effects of nearby buildings or structures.

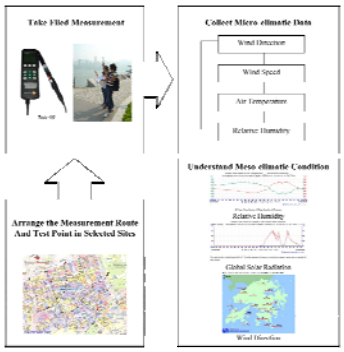
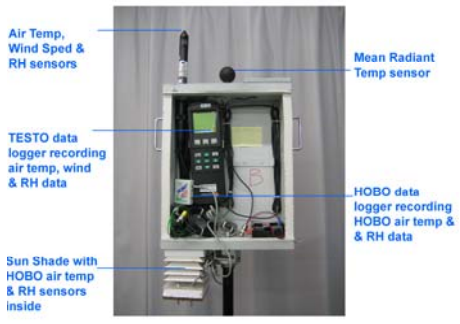


Figure 3: a) working process



b) Handled equipments

c) Fixed Observatory station on top roof

In addition to the field measured data, climatic data at some of the Hong Kong Observatory (HKO) stations was also downloaded for background reference. The climatic data acquired included (i) air temperature and relative humidity

at Hong Kong Observatory; (ii) wind at Waglan Island (WGL), King's Park and the HKO station and CPH station, which are closer to the measured areas; and (iii) solar radiation intensity at King's Park. This data is publicly accessible at the Hong Kong Observatory website (www.hko.gov.hk).

4. RESULTS AND ANALYSIS

4.1 Data Collection

For both measurements on 19 Sept 2006, the prevailing winds recorded at WGL were mainly from the east. Based on the measured microclimatic data (Figure 4b), the air temperature distribution map (Figure 4c) is developed. Furthermore, through examining the measured wind data and analyzing the urban morphology, air flow pattern of TST areas is drafted in Figure 4d.

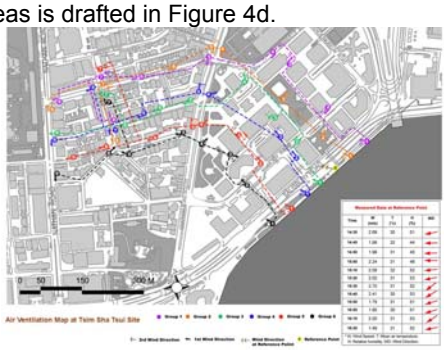


Figure 4: a) map of measuring points in TST

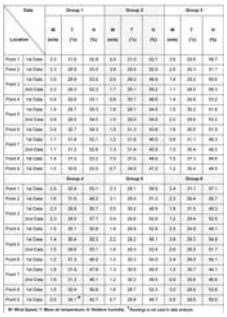


Figure 4: b) Measured microclimatic data

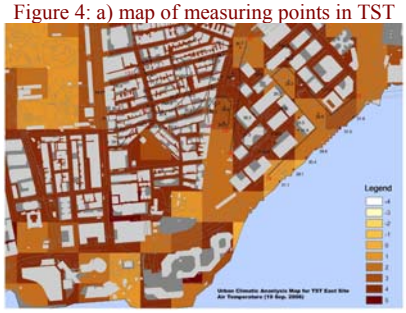


Figure 4: c) map of measured air temperature distribution;

Figure 4: d) evaluation map of air flow pattern in TST

Another spot field measurement was conducted in Tsuen Wan areas on 9 May 2008. The prevailing wind recorded at WGL was from the southwest. From the wind mast station record, it shows that the wind speed is very low and the wind condition of Tsuen Wan area belongs to the calm wind. All measured microclimatic data and relevant information are presented in Figure 5.

Figure 5: a) map of Measuring point in TW

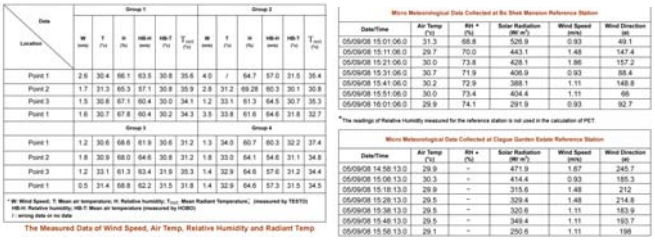


Figure 5: b) Measured microclimatic data in TW

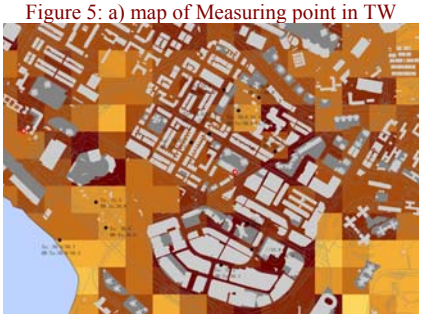


Figure 5: c) map of measured air temperature distribution

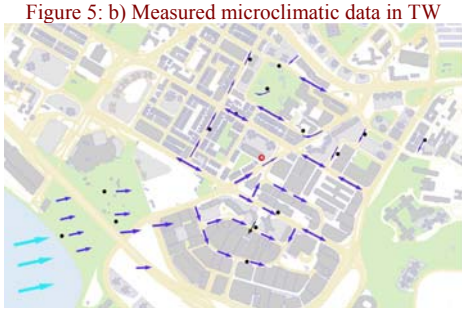


Figure 5: d) evaluation map of air flow pattern in TW

4.2 Analysis and Discussion

Since the UCMap for Hong Kong employs PET as a thermal index to balance and classify the evaluation on the living environment of Hong Kong, two maps of calculated PET based on the field measurement results are developed (Figure 6a and Figure 7a). Furthermore, the relationship between PET values and classes of UC-AnMap is plotted (Figure 6b and Figure 7b). Based on the initial analysis, it could be found that for both of two areas, the distribution of PET values roughly matches the pattern of classes of UC-AnMap and the R^2 of their linear trend is 0.79 (TST) and 0.62 (TW). That means the 1 ΔUC-Map Class equals to 1 C deg of PET value due to their strong relationship. At the same time it demonstrates that the classification of UCMap and the predicted human comfort pattern in UCMap are reasonable and in a good agreement with the real climate condition on site.

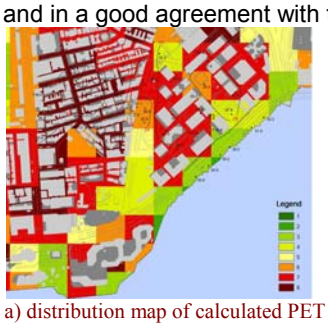
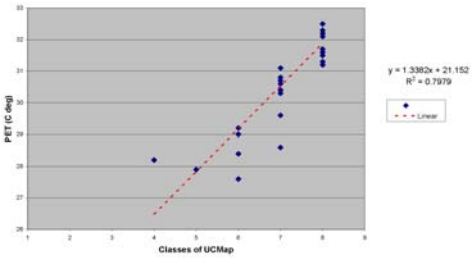
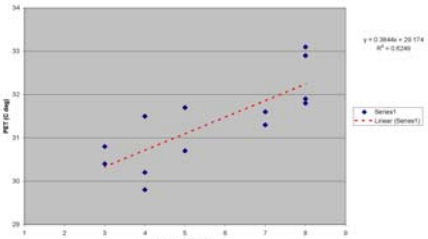


Figure 6: a) distribution map of calculated PET values ;



b) relationship between PET and classes of UCMap

Figure 7: a) distribution map of calculated PET values ;



b) relationship between PET and classes of UCMap

According to the measured temperature distribution, it showed that the vegetated urban park with size of 100m by 100m is cooler than its surroundings, such as Tak Wah Park in TW; the green belt along the street also could decrease air temperature by 1 to 2 °C. Thus, in the urban design, the vegetated urban park should not smaller than 100m by 100m and green belt along the street is recommended. From the evaluation map of air flow pattern, it found that the air flow at the centre of Tsim Sha Tsui areas is not only coming from the seafront but also along Chatham Road South being re-directed by the buildings. Hence, the major streets should be widen as the main air path and followed the prevailing wind direction for improving the air ventilation.

5. CONCLUSION

The field measurements provide limited but useful microclimatic data. Given Hong Kong's unique urban morphology, the results of the measurements are largely predictable expertly, which assisted researchers to have a better understanding on the outdoor living environment of highly built-up urban areas in Hong Kong. In addition, some understanding of the air flow patterns at ground level in Hong Kong's highly dense urban built environment has been gained. Through the further analysis, it found that PET could be used as thermal index to balance and classify the thermal environment of Hong Kong under the scenario of typical summer condition. the classification of UCMap and the predicted human comfort pattern in UCMap are reasonable and in a good agreement with the real climate condition on site.

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