118: Urban Climate – an experience from Hong Kong

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ABSTRACT: Over 50% of the world's population lives in cities. Designing zero, or low, energy buildings in cities must take into account not just the building itself, but the micro-climatic environment the building is located. If a city that can provide a conducive environment for the building and its occupant to begin with, designing for an energy efficient building is a lot easier. Finding ways to strategically plan a city environmentally requires urban climatic information that is human bio-meteorologically based. Using Geographic Information System (GIS), the study maps the urban fabric, topography, land use, greenery, and other parameters spatially. The parameters' contributions to thermal comfort were then calibrated and classified, either positively or negatively. Physiological Equivalent Temperature (PET) has been used as the basis of the classification. The GIS map establishes spatially the conditions of outdoor human comfort taking into account the urban morphologies of the location. Based on the map, the micro-climatic conditions of a building in the city could be better understood. This becomes the boundary conditions of the building for architects.

Keywords: planning, high density city, low energy architecture, urban climatic

1. Introduction

Figure 1: A typical cityscape of Hong Kong

High density living is increasing an issue that planners around the world have to deal with. Compact and high density city allows the practical design and implementation of an efficient public transport system. In addition, it allows mixed use, closer amenities and a more convenient pedestrian movement based living pattern.

Hong Kong is a high density city with a population of 8 millions living on a piece of land of around 1,000 square kilometres (Figure 1). The urban (city) density of Hong Kong is around 60,000 to 100,000 persons per square kilometre. For residential developments, the estate (site) development density of a piece of land in the city can be up to 3000 to 4000 persons per hectare. In a nutshell, it means that there are a lot of activities happening per square metre of land and its air space. Urban Hong Kong is multi-zoned; commercial, amenity, residential, and sometimes industrial buildings are mixed and co-exist in close proximity (Figure 2).

Figure 2: A typical street scene in metro Hong Kong.

Immediately beyond the territory of Hong Kong, the wider surroundings of the Pearl River Delta is also rapidly changing. The changing urban structure and coverage has an impact towards the meso-micro scale thermal and wind environment (Figure 3). For example, in weak background wind conditions, the meso-micro scale thermally developed air circulation between the water body and the land around it can greatly modify the wind patterns of coastal areas of the city.

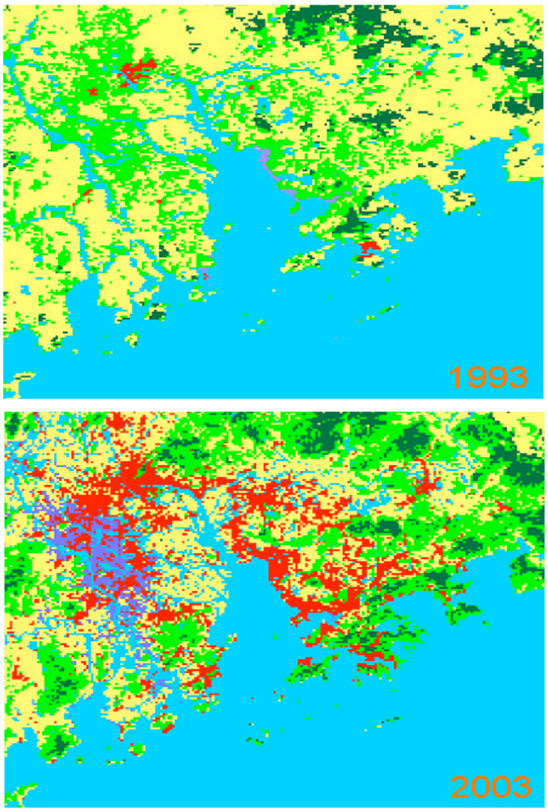

Figure 3: A map showing the rapid urbanisation of the Pearl River Delta. (Picture courtesy Professor Jimmy Fung of HKUST)

Furthermore, the intra-urban temperature rises as well as the wind and ventilation characteristics are greatly modified by the surroundings (Figure 4). Designing building is such a compact and high density context is challenging. Passive design techniques and simulations that do not take into account the micro-climatic conditions of the site are unlikely to be satisfactory. There is a need to have urban climatic information.

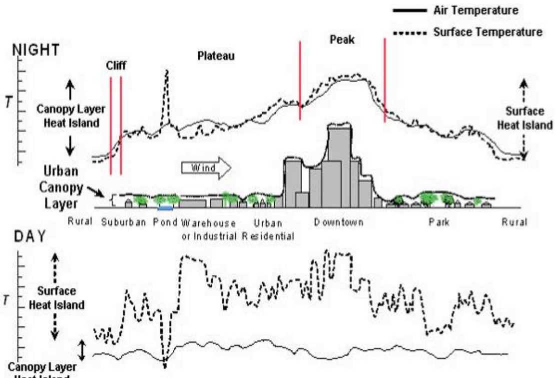

Figure 4: An understanding of urban Heat Islands. (Picture courtesy Professor James A Voogt)

Refer more closely to Figure 4, The daytime canyon layer heat island is of most interest to urban designers. The intra-urban temperature variations inside the city are largely due to design and hence are within the scope of control of the planners. .

2. Reviews

GIS based urban climatic information maps have been available since the 80s [1] [2]. Germany has been a leading country in conducting urban climate analysis (Figure 5). After the re-unification of Germany, several cities in the former German Democratic Republic were analyzed in terms of urban climate using remote sensing (especially thermal imaging) and synthetic climate function maps were constructed. By introducing the concept of Urban Climatic Map, key urban climatic factors including meteorological data for climate assessment are mapped on to the base map of land use, topography and urban geometry. Guidelines VDI 3787 (Part 1), regarding the urban climate mapping details have been published by the German Engineering Society in 1997 [3]. The Urban Climatic Map makes available the necessary climatic information to planners.

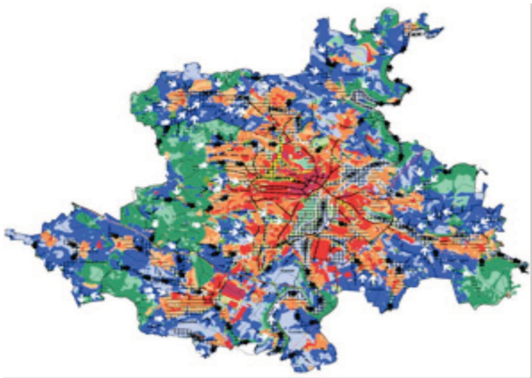

Figure 5: Urban Climatic Map of Kassel, Germany.

Apart from Germany, researchers in Japan have also produced urban climatic maps [4]. The Thermal Environmental Map for Tokyo promulgated by the Tokyo Metropolitan Government (TMG) (Figure 6).

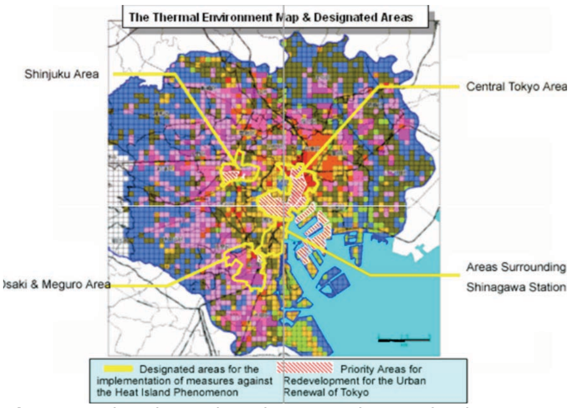

Figure 6: The Thermal Environmental Map of Tokyo.

Researchers have also produced urban climatic maps for Kobe [5]. In this particular case, the information has been used to guide better urban planning of a neighbourhood (Figure 7).

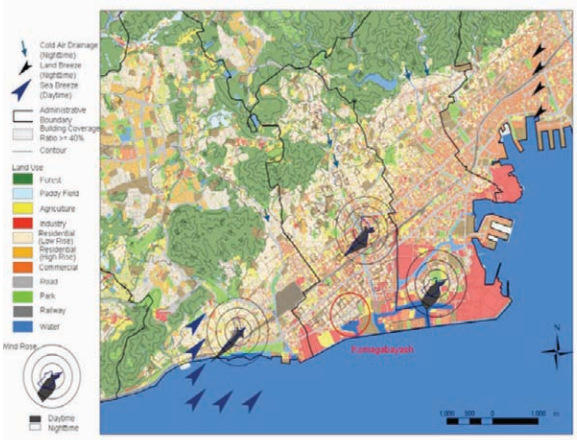

Figure 7: GIS based urban climatic map for Kobe, Japan. (Courtesy Professor M Moriyama)

3. GIS based Urban Climatic Map

The methodology of creating a GIS based urban climatic map can be summarised in Figure 8. Details of the structuring and layering of the GIS based map has been earlier reported. [6]

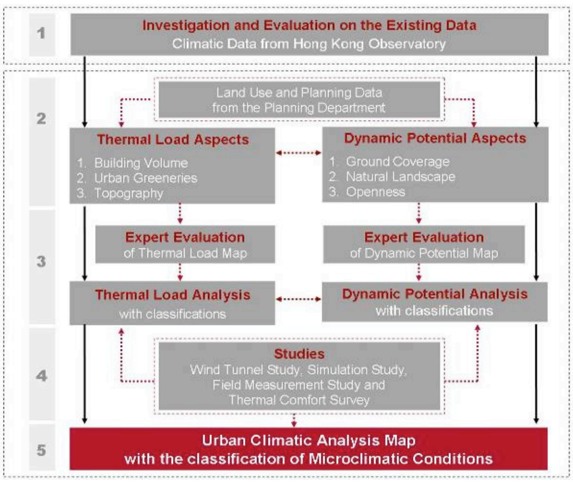

Figure 8: Schema of the GIS based urban climatic map process.

The concepts of urban heat island are well rehearsed [7]. Figure 4 above demonstrates its various understanding graphically. For Hong Kong's hot and humid sub-tropical climatic conditions, urban heat island adds to human thermal stress in the summer months [8] [9] [10]. However, instead of trying note the air temperature difference between urban and rural sites, for city designers, a key issue of design is to deal with the intra urban air temperature variation micro climatically [11] [12] [13] [14] [15] [16]. The air space pedestrian traverse is where people can feel the urban environment.

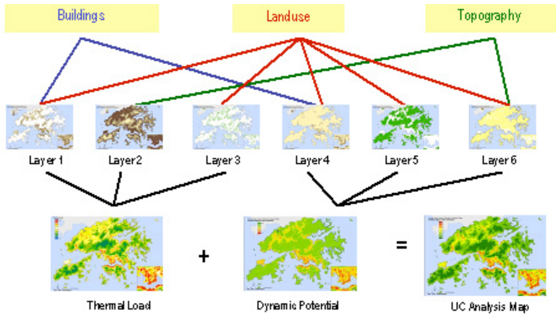

Figure 9: Layer structure of the GIS based urban climatic map of Hong Kong.

The urban climate of the city could be characterized with a balanced consideration of "negative" Thermal Load effects due to building bulks and building layouts and "positive" dynamic and mitigate effects. For the positive effects, two aspects are considered: Mitigation Potential (e.g. green open spaces) and Dynamic Potential (e.g. air ventilation). Figure 9 shows how the GIS layers of information are collated. Results of the thermal load and dynamic potential characteristics of Hong Kong are as shown in Figure 10 and Figure 11.

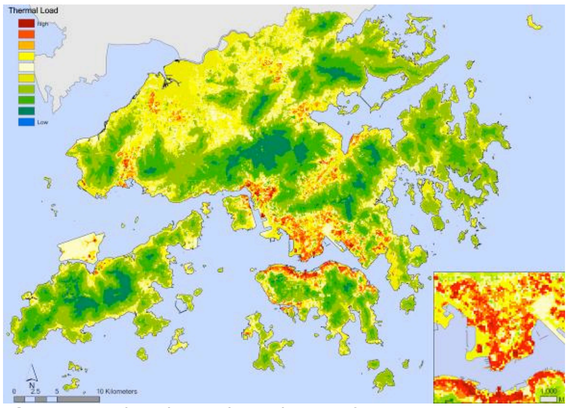

Figure 10: The Thermal Load map of Hong Kong.

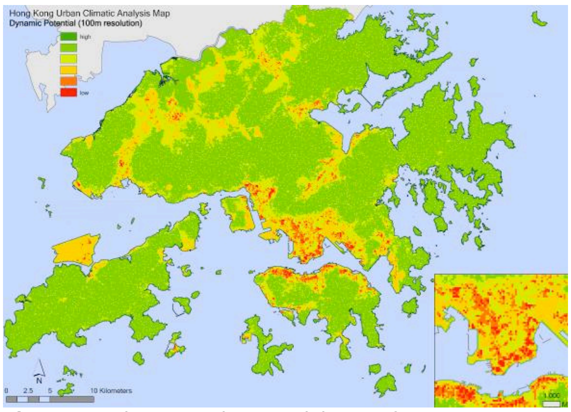

Figure 11: The Dynamic Potential map of Hong Kong.

According to the study on the relation between PET and its environmental factors – especially Air Temperature and Wind Speed – it is found that with an increase of air temperature by 1°C, the PET value would also increase by about 1 °C [17]. In addition, an increase of wind speed from 0.5 to 1.5 m/s has an effect of decreasing PET by 2 C.

The consideration of Thermal Load and Dynamic Potential need to be brought together to became the Urban Climatic Map (Figure 12). The use of a human urban thermal comfort indicator as a synergistic element seems appropriate; the study uses Physiological Equivalent Temperature (PET).

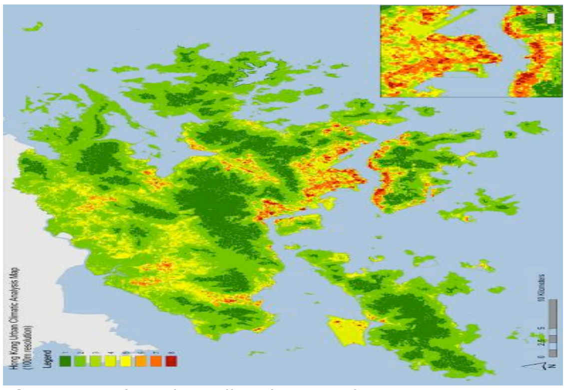

Figure 12: The urban climatic map of Hong Kong.

Based on the PET formulation, eight climatic classes of the urban climatic map can be defined based on thermal sensations (Table 1).

Table 1: An understanding of urban climatic classes and thermal sensation in a typical summer day of Hong Kong.

	Description	Approximate Δ PET	Thermal Sensation when Ta is 28 degree C
1	good ventilated areas no heat load, land sea breeze effects	-2	Comfortable
2	resonable ventilation pattern moderate land sea breeze	-1	Slightly comfortable
3	areas with minor ventilation combined with small heat load	0	Neutral
4	some ventilation capabilities; heat load	+1	Warm slight stress
5	reduced ventilation capabilities strong heat load	+2	Warm moderate stress
6	weak ventilation heat load	+3	Warm Strong stress
7	heat load and reduced ventilation	+4	Hot Strong stress
8	heat load (max.)weak ventilation	+5	Very Hot Extreme stress

Meteorological data of wind directions, speeds and frequencies are collated from the Hong Kong Observatory. An example of the summer conditions is shown in Figure 13.

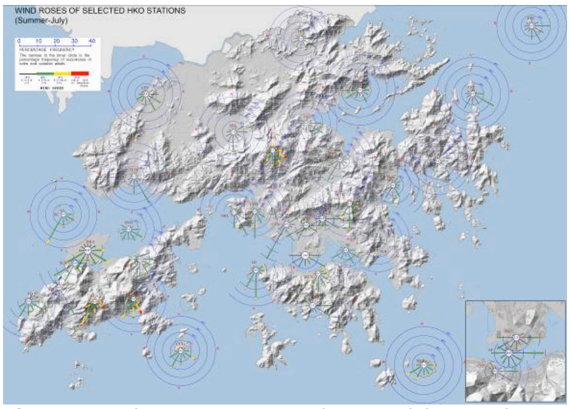

Figure 13: The summer Dynamic Potential map of Hong Kong based on Hong Kong Observatory data.

4. Validation

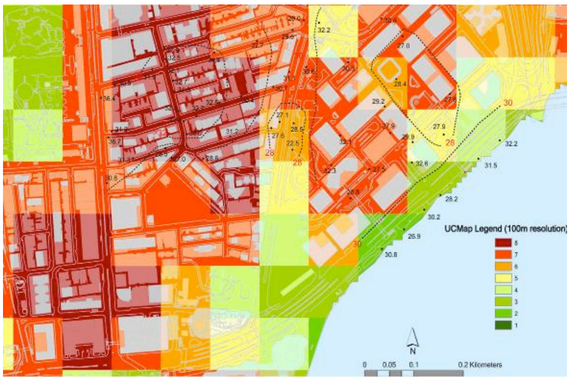

Figure 14: A colour coded PET value urban climatic map and the field measurement PET contours showing results in good agreement with each other.

Field measurements have been conducted. These scientific activities have already been reported and also presented in international conferences [18] [19] [20]. The validation results show that they are in good agreement (Figure 14).

5. Planning Interpretation

An example of how the Urban Climatic Map could be used at the district level is demonstrated in Figure 15, 16, 17 and 18.

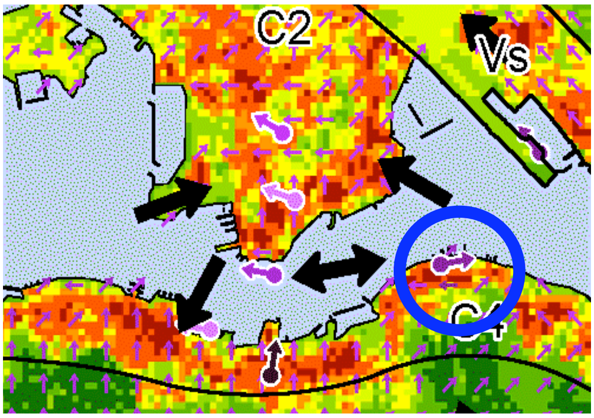

Figure 15: The urban climatic map of Hong Kong showing the Victoria Harbour areas, with the study district [North Point] circled.

Referring to Figure 15, one can see the combined effects of buildings, open spaces, the natural landscape and topography. The urban climatic map illustrates a strategic and holistic approach towards understanding the urban climate of Hong Kong.

When the urban climate Map is further examined at the 100x100m grid resolution, the wall like effects of buildings along the coastline is apparent. There are small gaps, and those might need some protection (Figure 16). The downhill katabatic wind from the south over the ridges of the hill on the Hong Kong Island can be detected. This, perhaps more important than the already diminished coastline sea breezes, contributes positively to the urban climate of the district.

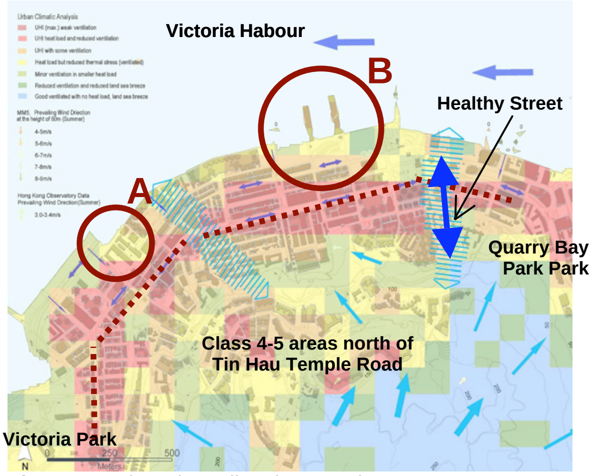

Figure 16: The urban climatic map of Hong Kong.

The district of North Point could be characterized with a Class 7-8 belt (areas colour coded RED in Figure 16 and highlighted with the dotted line; also refer to Table 1 for description of Class 7-8) between Electric Road-Java Road and King's Road. This belt extends from Victoria Park to Quarry Bay Park Phrase II with a small gap near Healthy Street (blue arrow, Figure 16). This Class 7-8belt is "effective" blocking a lot of the air ventilation coming down from the hills. The main reason of this belt is the high ground coverage and high building volume in the areas. This Class 7-8 belt is not too "thick"; penetrating it with strategic intervention may be possible. On the other hand, it is important not to "thicken" it by building another high density layer north or south to it.

The Class 7-8 belt along the coastline is between the Victoria Harbor and Class 2-3 green areas (colour coded BLUE and GREEN in Figure 16) of the hills. A Class 4-5 area (colour coded YELLOW and ORANGE in Figure 16) can be seen north of Tin Hau Temple Road.

In the summer months, North Point benefits from two kinds of winds. On the one hand there is a southerly wind from over the hills; on the other hand, there is an easterly-westerly wind along the harbor front. North Point's slight protrusion into the harbor helps the easterly-westerly wind ventilating the area. East-west oriented streets are useful air paths. Strategically widening these air paths will help the area.

Wind from the hills down slope to North Point also provides useful air ventilation. To capitalize it, the Class 7-8 belt mentioned above must be perforated. There are two such existing perforations (near Healthy Street and near Power Street). They must be respected. More north-south air paths should be created to help the area. Strategically vary the building heights perpendicular to the belt described in (A) could create useful semi-air paths (air paths over lower buildings). Widening streets perpendicular to the belt would also help. It is useful that some of the smaller north-south orientated streets are to be pedestrianised. Relieving these streets from traffic pollution as well as greening them will greatly enhance the air ventilation quality of the area. Ideally, spacing these green air path at roughly 100-200m interval along the belt could be considered. The paths allow air ventilation to penetrate, as well as lowering the air temperature near the ground [21] [22] – around 1 to 3 degree C.

Buildings along the waterfront and south of King's Road must be carefully designed and spaced so as not to block both the easterly-westerly habour wind, and the downhill winds from the south. They could be set back from the boundary creating a wider east-west air path. They could also be spaced out adequately for the southerly winds from the hills.

Given that the belt areas described earlier is already Class 7-8, Thermal Load is high and air ventilation alone may not be enough to mitigate entirely. Greening is therefore recommended.

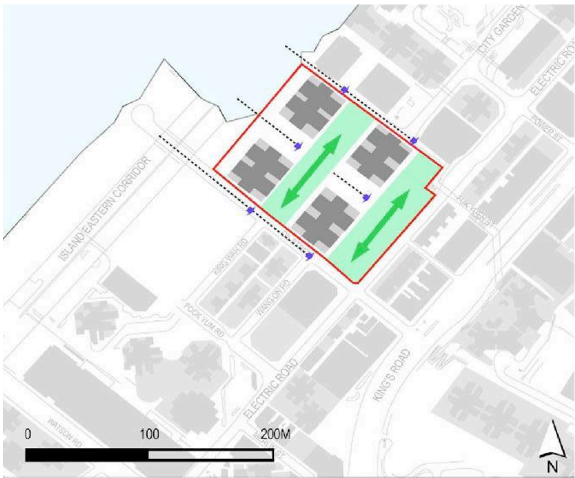
Figure 17: Planning recommendation of site A.

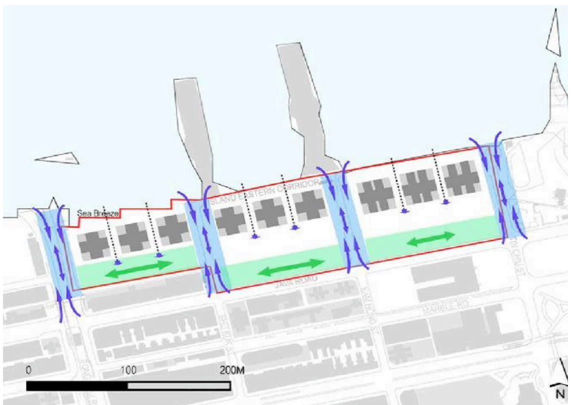
Figure 18: Planning recommendation of site B.

In addition to the district-wide urban climate understanding, planning recommendations are illustrated in terms of building mass and depositions, breezeway, air paths and setbacks of two sites in the district, site A and B (Figure 17 and 18). As such, the urban climatic issues related to the micro-climatic conditions of the site have been dealt with from the planning perspective. In addition, the boundary conditions of the buildings are now better understood.

6. Conclusion

The study demonstrates the usefulness and the necessities designing building from a meso-micro climatic and form a micro-site climatic perspective. The boundary conditions of a building must first be carefully understood. A GIS based urban climate information system providing territorial and district based information is therefore useful for building designers.

The work illustrated in this paper is still in its draft form of understanding. Further refinements are necessary. Hence the results reported here is academic and for further discussion only. However, the study illustrates an approach and methodology that will be of reference value to planners and building designers elsewhere in the world.

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