330: Daytime urban heat island intensity in London during the winter season

Giridharan Renganathan
Brunel University

Abstract

This paper will present results of the daytime urban heat island intensity (UHI) in London during the peak winter season. Usually UHI studies focus on the phenomenon during the summer as this is the period that temperature peaks are observed. However, for urban planning mitigation strategies, the heating season should be also considered, since proposed measures to alleviate the summer UHI might have a negative effect during the winter or intermediate seasons. This study will investigate the winter daytime UHI of London by carrying out trend analysis while controlling the climatic and geographical variations in the data set. The peak winter daytime UHI trends are not as regular as summer and this could be attributed to presence of frequent cyclonic conditions. But during this period, maximum daytime UHI is in the order of 9 º C when the wind velocity is less than 5 m/s.

Keywords: Urban heat island intensity, daytime, controlling variables, trend analysis.

1. Introduction

London falls in the temperate climate zone and it has a moderate summer and a reasonably cold winter. But, in London, most of the studies related to urban heat island are carried out during summer, especially in the last decade [1, 2, 3, 4]. In general, literature on UHI studies related to winter season of London is very weak. This phenomenon is true globally as well. The research work done in the recent past by Kawashima et al [5], Livada et al [6], Nichol [7] and Ferrari [8] suggest that the possible reasons for limited research work for winter period as following;

- Unlike summer UHI, the winter UHI does not cause any harmful effects or discomfort for the human beings
- Carrying out field experiments during winter is difficult.

With the advancement of satellite based studies, winter UHI studies could become a rigorously pursued research area. Further, drastic changes in global climate could lead to investigations on the impact of summer time UHI mitigating strategies during winter period. The winter UHI, especially at high latitude, is different from summer for the following reasons;

- It has long period of darkness
- Solar intensity during winter is negligible

Kolokotoroni and Giridharn [9] have already presented a detail discussion on summer time characterisation of UHI in London. This paper will attempt to investigate the peak winter period (December to February) UHI in London by carrying out trend analysis while controlling geographical and climatic variations.

2. Controlling variables

The seasonal and geographical changes influence the changes in outdoor air temperature of an environment [6, 10, 11, 12, 13]. In this paper, in order to investigate the location specific UHI, changes in seasonal and geographical factors are controlled. Similar approach was followed during summer period investigation as well [9]. Broadly seasonal control is brought about by focusing on peak winter. The heating season in temperate climate is from October to April. But the peak heating season or winter is from December to February [6, 10]. More specific seasonal control within the winter is considered in terms of sky condition and wind velocity. In summer solar radiation intensity is an important variable and it needs to be controlled due to its location specific impact [13]. But in winter solar radiation contribution is marginal [10]. Therefore, during winter, the focus will be on controlling cloud cover and wind velocity (Table 1).

Table 1: Heating period climate classifications for London

Description	Cloud Cover (Oktas)	Wind velocity (m/s)
Clear-sky periods (CSP)	< 4	Each of the category is divided into three wind spectrums (10, 5 and 2.5)
Partially cloudy periods (PCP)	4 to 6	
Cloudy periods (CP)	>7	

Note: The cloud cover data is from London Weather Station while the wind velocity is from Heathrow Weather Station.

The cloud cover classification for London follows the characterisation of sky condition for daylighting [9]. Three cloud cover classifications are clear sky, partially cloudy and cloudy periods (Table 1). The wind velocity classifications are below 10m/s, below 5m/s and below 2.5 m/s. This study considers wind velocity data from Heathrow meteorological station. Therefore, on most occasions, at any location under this study, one could expect lower wind velocity than what is specified above. Geographically, London is classified into core (zone-1), urban (zone-2) and

semi urban (zone-3) [9]. The summery of the classification is presented in Table 2.

Table 2: Geographical classification of London [9]

Description	Extent of the zone	Number of Locations
Core (zone-1) 	3.5 km from measurement focal point.	20
Urban (zone-2) 	3.5 to 10 km range from measurement focal point.	24
Semi-Urban (zone-3) 	10 to 27 km range from measurement focal point.	33

Note: The study considers British museum as focal point of London because this is the central point of the measurements network. In reality the thermal centre might be slightly different but this shifts during the day, season and weather conditions. Therefore, a convenient geographical centre in central London has been used as the focal point throughout the study [1]

Table 3: General climatic characteristic of London during the study period.

Description	London weather station			Heathrow weather station			Reference station
	Solar radiation intensity (W/m^2)	Cloud cover (Oktas)	Air temperature (º C)	Wind velocity (m/s)	Precipitation (mm)	Relative humidity (%)	Air temperature (º C)
Clear sky period (CSP)	166.7	2	5.8	3.2	1.6	72.0	5.1
Partially Cloudy period (PCP)	146.4	5	7.3	3.8	1.8	71.9	6.5
Cloudy period (CP)	55.4	7	8.5	4.5	48.4	81.6	7.3

Note: 1. Mean values for December to February are presented except precipitation which is cumulative for the period.

The urban heat island intensity (UHI) in this research is the air temperature difference between a specific station in London area and Langley measurement station (reference station) at a given time. North and Northeast directional winds create extreme whether conditions during winter, especially Northern part of UK. But, UK winter also experience frequent winds from West and Southwest directions [14]. During winter London is largely exposed to West and Southwest directional winds. Therefore, it is important to select a reference station in the predominant wind direction of winter [11, 15]. Langley is a large park located far west of

London (Fig. 1). Further, it is the reference station for summer period analysis carried by Kolokotroni and Giridharan [9]. Selecting a common station for both winter and summer will eliminate the geographical influence with respect to reference station in the event of comparing winter and summer results.

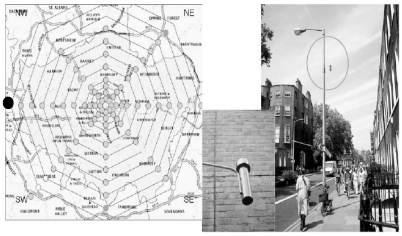

Figure 1: Map of Greater London with air temperature stations (rural location-Langley- marked black) and monitoring equipment mounted on a lamp post [9].

3. Data protocol

This paper is based on field experiment data collected at 77 stations in London area during December 1999 to February 2000. A detail description on measurement locations and procedures are presented in the research work done by Watkins et al [2], Kolokotroni and Giridharan [9] and Watkins16].

Table 3 presents the climate characteristics of London and the reference station during the study period. In general, 29%, 13% and 58% of study periods accounted for clear sky, partially cloudy and cloudy conditions respectively.

4. Analysis

This study considers 8:00hrs to 16:00hrs as daytime. Since the research is based on three months data, trend lines are plotted on seven days interval instead of monthly interval.

According to Hinkel et al [10], wind velocity less than 3.5 m/s is the critical spectrum to capture the UHI profile in places like Alaska during winter. This study assumes that wind velocity of 5 m/s at Heathrow meteorological station will lead to wind velocity less than 3.5 m/s in the urbanised areas (study areas) of london. Therefore this paper will limit its critical analysis to wind velocity less than 5 m/s on most occasions

In the absence of wind control, mean daytime UHI during clear sky, partially cloudy and cloudy period are 0.6, 0.6 and 0.5 ºC respectively (Fig. 2). Like summer daytime, in the absence of wind control, the winter UHI is under estimated. But in summer daytime, the climate trends lines follow a hierarchical order. In winter daytime, such hierarchical order is not visible. In general, temperature variations within the cloudy period are marginal compare to other two periods (Fig. 2).

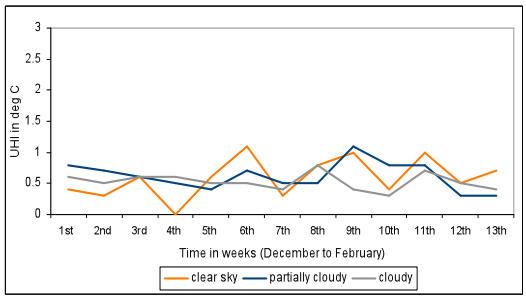

Fig. 2. Daytime UHI patter during 1999/200 winter in the absence of wind control.

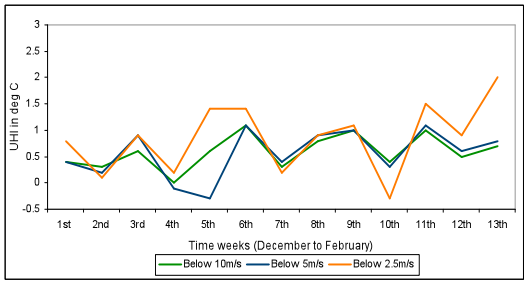

Fig. 3a. Mean daytime UHI during clear sky periods under 3 categories of wind velocity

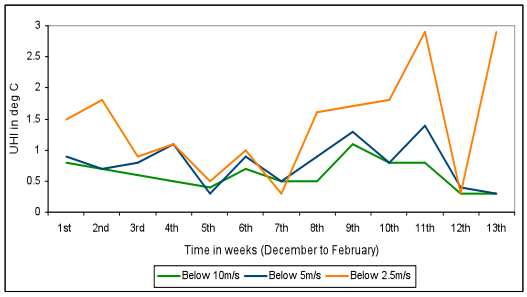

Fig. 3b. Mean daytime UHI during partially cloudy periods under 3 categories of wind velocity

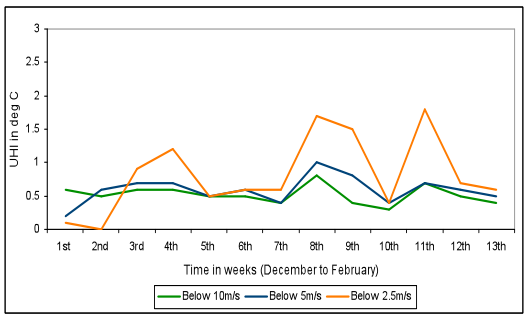

Fig. 3c. Mean daytime UHI during partially cloudy periods under 3 categories of wind velocity

On most occasions, under control wind velocity daytime trend lines follow the accepted premises. But, under controlled wind velocity there is hardly any difference between mean daytime UHI for below 10 m/s and below 5 m/s during all three climates (Fig. 3a-c). Generally the difference is 0.1 to 0.2 ºC. In general, partially cloudy periods are warmer than clear sky and cloudy periods for all 3 wind controlled categories (Fig. 3a-c) But, maximum UHI during clear sky, partially cloudy and cloudy periods are 9.5, 6.5 and 7.3 ºC respectively when the wind velocity is less than 5 m/s. But, highest daytime mean air temperature

within the study period at both London weather station and reference station are found during cloudy periods even with high mean wind velocity (Table 3).

Table 4: Maximum daytime UHI (ºC) in 3 geographical zones during the 3 climate variations when the wind velocity is below 5m/s.

Description	Core (zone-1)	Urban (zone-2)	Semi-urban (zone-3)
Clear sky Period (CSP)	9.5	6.3	7.4
Partially cloudy period (PCP)	6.5	4.9	6.1
Cloudy period (CP)	7.3	5.5	7.0

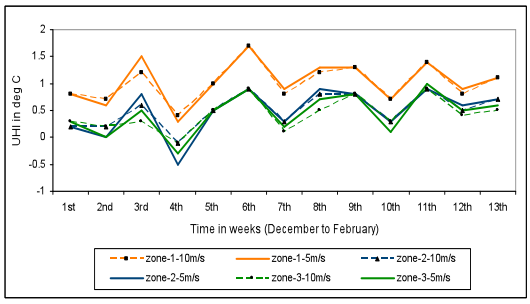

Fig. 4a. Mean daytime UHI pattern in 3 geographical zones during clear sky periods under 3 categories of wind velocity.

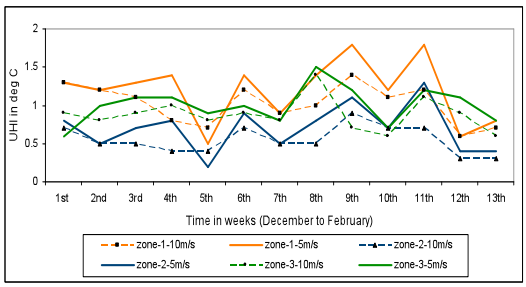

Fig. 4b. Mean daytime UHI pattern in 3 geographical zones during partially cloudy periods under 3 categories of wind velocity

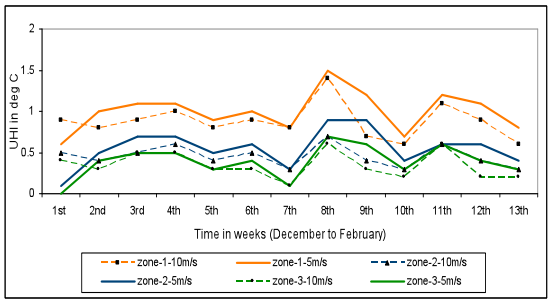

Fig. 4c. Mean daytime UHI pattern in 3 geographical zones during cloudy periods under 3 categories of wind velocity

The maximum UHI of 9.5 ºC was found in core area under clear sky periods when the wind velocity is below 5 m/s (Table 4). In general, during daytime, under all three climate periods core area remains the hottest place in London (Fig. 4a-b). The second maximum UHI is always found in semi urban area, especially when the wind velocity is below 5 m/s (Table 4). Mean daytime UHI in core area during clear sky, partially cloudy and cloudy periods are 1.0, 1.2 and 1.0 ºC respectively when the wind velocity is below 5 m/s. The trend lines of all three zones are fairly synchronized during clear sky and cloudy periods but not during partially cloudy periods. This is an indication that the seasonal influence is at maximum during partially cloudy periods i.e. fluctuation due cyclonic condition. On most occasions, the differences in UHI between urban and semi urban are marginal while the differences between any of these zones (semi urban or urban) and core area is substantial. Generally, urban area is warmer than semi urban area, but during partially cloudy periods, semi urban area is always warmer than urban area. This is an indication that the factors other than climate related variables are also influencing the changes outdoor air temperature during winter daytime.

5. Conclusion

In London, during winter daytime, maximum UHI is in the order of 9 ºC when the wind velocity is less than 5 m/s. Unlike summer, the winter daytime climate trend lines do not follow each other in a hierarchical order. During winter daytime, warmest is the partially cloudy periods. In London, during winter daytime, the hottest place is core area. The second hottest place is semi urban area. Mean daytime UHI in core area during clear sky, partially cloudy and cloudy periods are 1.0, 1.2 and 1.0 ºC respectively when the wind velocity is below 5 m/s. Most of the changes in winter could be attributed to frequent cyclonic conditions. But, further research needs to be done on on-site variables in order to capture the impact these variables in changing the outdoor air temperature. Such analysis may be able to answer cause for the semi-urban area to be warmer than urban area.

6. Acknowledgements

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7. References

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