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ScienceDirect
Solar Energy 83 (2009) 1668–1682
SOLAR ENERGY
www.elsevier.com/locate/solener

# Urban heat island characteristics in London during winter

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Received 4 January 2009; received in revised form 2 June 2009; accepted 6 June 2009
Available online 19 July 2009

Communicated by: Associate Editor Nicola Romeo

**Abstract**

This paper presents results characterising the urban heat island intensity (UHI) in London during the peak winter season. Most UHI studies focus on the phenomenon during the summer as this is the period when temperature peaks are observed. However, for urban planning mitigation strategies and building energy demand design, 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.

The study carries out trend and regression analysis by controlling climatic and geographical variations in the data set following a methodology developed for studying summer UHI [Kolokotroni, M., Giridharan, R., 2008. Urban heat island intensity in London: an investigation of the impact of physical characteristics on changes in outdoor air temperature during summer. Solar Energy 82, 986–998]. It was found that average nocturnal UHI of winter periods are of similar magnitude to the summer periods but the peak winter UHI trends are not as regular as summer giving a first indication that the effect of climate and urban parameters is different. The regression analysis in this research uses six on-site variables namely aspect ratio, surface albedo, plan density ratio, green density ratio, fabric density ratio and thermal mass to carry out impact investigation in six data sets, categorised by three geographical location within London and three sky conditions and regional wind velocity. The above variables do not explain the changes in outdoor temperature as much as they did during summer period models. However, unlike summer, the winter climate control models have the same $R^2$ indicating that most of changes in outdoor temperature are caused by climate factors and not the on-site variables.


*Keywords:* Urban heat island intensity (UHI); Winter; Climate control; Geographical zone control; On-site variables

## 1. Introduction

Literature on UHI studies related to winter season is not as well developed as for summer period. Recent research work by Kawashima et al. (2000), Livada et al. (2002), Nicol (2005) and Ferrari (2007) suggest that possible reasons for limited research work for the winter period as the 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 investigate the implications of summer time UHI mitigating strategies during winter period.

Kolokotroni and Giridharan (2008) have presented a detailed discussion on summer time characterisation of UHI in London. This paper attempts to characterise the peak winter period (December–February) UHI in London using the same methodology. In this context, it should be noted that winter UHI, especially in high latitude such as the city of London, is different from summer for the following reasons;

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

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0038-092X/$ - see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.solener.2009.06.007

Following the method described in Kolokotroni and Giridharan (2008), the analysis is broadly divided into trend and regression analysis of daytime and nocturnal data. As before, the regression analysis is limited to six on-site physical variables defined for the summer characterisation so that summer and winter implications could be assessed.

## 2. Controlling and selection of variables

Seasonal control is considered by focusing on peak winter. The heating season in temperate climate is from October to April. However, the peak heating season or winter is from December to February (Hinkel et al., 2003; Livada et al., 2002). More specific seasonal control within the winter is considered in terms of sky condition and wind velocity. During summer, solar radiation intensity is an important variable and it needs to be controlled due to its location specific impact (Giridharan et al., 2007). But in winter solar radiation contribution is marginal (Hinkel et al., 2003). Therefore, during winter, the focus will be on controlling *cloud cover* and *wind velocity* (Table 1).

The cloud cover classification for London follows the characterisation of sky condition for daylighting (Kolokotroni and Giridharan, 2008). Three cloud cover classifications are clear sky, partially cloudy and cloudy periods. The wind velocity classifications are below 10, below 5 and below 2.5 m/s. This study considers wind velocity data from Heathrow meteorological station. Therefore, theoretically, on most occasions, at any location under this study, one could expect lower wind velocity than what is specified above. But the practical implication of this assumption is discussed in the analysis section of this paper.

The geographically London is classified into core (zone-1), urban (zone-2) and semi-urban (zone-3) (Kolokotroni and Giridharan, 2008). The summary of the classification is presented in Table 2.

This study investigates impact of 6 on-site variables such as aspect ratio, plan density ratio, green density ratio, fabric density ratio, surface albedo and thermal mass (Table 3). Same set of variables were used for summer period analysis (Kolokotroni and Giridharan, 2008).

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) | 4–6 | |
| Cloudy periods (CP) | >7 | |

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

During summer, solar radiation is dominant factor in changing the outdoor air temperature (Oke, 1987; Givoni, 1998; Santamouris et al., 2001, 2007; Giridharan et al., 2007). Therefore, behaviour of variable is largely determined by their interaction with short wave and long wave radiations, especially focusing on shading. But in winter, the wind velocity, especially during cyclonic condition, is dominant factor in changing the outdoor air temperature (Hinkel et al., 2003; Kircsi and Szegedi, 2003; Wang, 2006). Therefore, behaviour of variables will be largely determined by their interaction with wind (wind breaks) and on some occasions in response to the solar angle. Above arguments suggest that unlike summer aspect ratio and green density ratio will produce positive coefficient for both day and night while plan density ratio will produce negative coefficient for both day and night (Table 3). For example, if a high aspect ratio canyon is perpendicular to wind direction, the temperature inside canyon will be high. This will result in positive coefficient for aspect ratio in the models. But this is not true for all the urban settings of London. Similar arguments could be established for other two variables as well. The models will be analysed under these premises and causes are discussed in detail in Section 5.

The dependent variable for the analysis is urban heat island intensity (UHI). The 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. But, UK winter also experience frequent winds from West and Southwest directions (Wang, 2006). Therefore, it is important to select a reference station in the predominant wind direction of winter (Oke, 1987; Voogt and Oke, 2003). 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 (2008). 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.

## 3. Data protocol

This paper is based on field experiment data collected at 77 stations in London area during December 1999–February 2000 (Fig. 1). A detail description on measurement locations and procedures are presented in the research work done by Watkins (2002), Watkins et al. (2002) and Kolokotroni et al. (2006).

The data for independent variables are sourced from literature and institutional information (Table 3) as presented in Kolokotroni and Giridharan (2008) for summer period.

Table 4a presents the climate characteristics of London and the reference station during the winter study period. In general, 29%, 13% and 58% of study periods accounted for clear sky, partially cloudy and cloudy conditions,