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# The role of one large greenspace in mitigating London's nocturnal urban heat island

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## HIGHLIGHTS

- Trees help regulate urban air temperatures and combat the urban heat island effect.
- We describe cooling of London's heat island by one large greenspace over 5 months
- Cooling of up to 4 °C over 440 m distance from the park was observed on single nights.
- The park cooled London when cooling was most needed, on warm still nights.

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## ABSTRACT

The term urban heat island (UHI) describes a phenomenon where cities are on average warmer than the surrounding rural area. Trees and greenspaces are recognised for their strong potential to regulate urban air temperatures and combat the UHI. Empirical data is required in the UK to inform predictions on cooling by urban greenspaces and guide planning to maximise cooling of urban populations. We describe a 5-month study to measure the temperature profile of one of central London's large greenspaces and also in an adjacent street to determine the extent to which the greenspace reduced night-time UHI intensity. Statistical modelling displayed an exponential decay in the extent of cooling with increased distance from the greenspace. The extent of cooling ranged from an estimated 20 m on some nights to 440 m on other nights. The mean temperature reduction over these distances was 1.1 °C in the summer months, with a maximum of 4 °C cooling observed on some nights. Results suggest that calculation of London's UHI using Met Stations close to urban greenspace can underestimate 'urban' heat island intensity due to the cooling effect of the greenspace and values could be in the region of 45% higher. Our results lend support to claims that urban greenspace is an important component of UHI mitigation strategies. Lack of certainty over the variables that govern the extent of the greenspace cooling influence indicates that the multifaceted roles of trees and greenspaces in the UK's urban environment merit further consideration.



## 1. Introduction

Cities frequently demonstrate higher mean average air temperatures than surrounding rural areas, a phenomenon termed the 'urban heat island' (UHI) (Oke, 1987). The UHI is a result of the process of urbanisation, which alters the energy balance of a city in comparison to that of the countryside. More energy from the sun is used for raising air temperature than in evapo-transpiration as vegetated surfaces are replaced by engineered surfaces (Greater London Authority, 2006). The intensity of the UHI, defined as the difference in air temperature between the city and the surrounding rural area, varies diurnally and seasonally (Watkins et al., 2002), and is reported to be up to 9 °C on some nights in London, England (Greater London Authority, 2006). Concentrated human activities in more built-up areas support the formation of a more intense UHI than in less densely grouped centres, although small urban centres do demonstrate the phenomenon (Watkins et al., 2002).

Global temperatures are set to rise during the foreseeable future as a consequence of anthropogenic activities (Stern, 2006). Current climate change projections are for south-eastern England to warm by 2.5–4 °C by the 2080s (Davies et al., 2008; Department for Environment Food and Rural Affairs, 2012). There is a direct impact of heat on human health and the Department of Health has identified threshold temperatures for each region within the UK that, when exceeded, give rise to heat-related stress and excess summer deaths (Department of Health, 2008). The frequency of days with temperatures above these regional thresholds and UHI induced heat stress are set to increase under the changing climate predicted for the UK, with major implications on the thermal comfort and health of city dwellers. Heat-related mortality already accounts for around 2000 premature deaths in the UK and is

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forecast to increase to around 3400 premature deaths in the 2020s and to around 10,800 premature deaths in the 2080s (Health Protection Agency, 2012). The risks are greatest in large metropolitan areas that suffer from the UHI, such as London, Manchester and Birmingham (Department for Environment Food and Rural Affairs, 2012).

Trees and greenspaces are recognised for their strong potential to regulate urban air temperatures and combat the UHI. Delivering several mechanisms of cooling simultaneously and in a complementary manner vegetation gives rise to air temperatures within a greenspace that are as much as 8 °C cooler than the surrounding urban area (Oke, 1987) and a cooling effect that extends out beyond the boundaries of the greenspace (Taha et al., 1988; Saito et al., 1990). The neighbourhood cooling effect of greenspaces has been demonstrated in highland subtropical (Jauregui, 1991), humid sub-tropical (Saito et al., 1990; Chang et al., 2007), moderate oceanic (Spronken-Smith and Oke, 2010), Mediterranean (Givoni, 1998; Spronken-Smith and Oke, 2010) and continental climates (Mayer, 1988). There are comparatively few published data for a temperate oceanic climate, as experienced in the UK (Chandler, 1965; Watkins, 2002; Smith et al., 2011).

Studies investigating the cooling effect of greenspace typically compare the air temperature within the greenspace with a reference point located just beyond the range of the greenspace influence (Chang et al., 2007); often assumed to be equivalent to the width of the greenspace (Honjo and Takakura, 1991; Jauregui, 1991; Spronken-Smith and Oke, 2010). The extent of cooling is reported to be affected by the size, structure and design of the greenspace, the design and structure of the surrounding urban environment, and the prevailing weather patterns (Yu and Hien, 2006). To what extent cooling changes with increased distance from a greenspace and if and how this varies with time is less clear, however. Following systematic review of urban cooling by greenspaces, Bowler et al. (2010) concluded that future research must explicitly investigate the distance effect to efficiently guide the planning of urban greenspace and to investigate the importance of the abundance and distribution of greenspaces in providing cooling benefit to urban dwellers. In addition to these specific research needs, UK empirical data is required to:

- Demonstrate the cooling potential of trees and greenspaces in the UK, and
- Support modelling of the role of trees and greenspaces in mitigating the UHI and its effects under a changing climate.

The aim of this research was to provide empirical evidence for the extent of cooling of London's UHI by one large greenspace. To achieve this aim, the following objectives were set:

- Measure and describe the temperature profile of one of central London's large greenspaces and in an adjacent street
- Determine UHI intensity across the study area
- Determine reduction in UHI intensity with increasing distance from the greenspace
- Assess the impact of weather on UHI reduction by greenspaces.

## 2. Methodology

### *2.1. Study area*

The study area was centred on Kensington Gardens in London, England. A Royal Park, Kensington Gardens covers an area of 111 ha. It lays immediately to the west of Hyde Park (142 ha) and abuts Green Park (19 ha) and St. James' Park (23 ha). Kensington Gardens contain two large stretches of water: the Long Water (4.9 ha) and the Round Pond (2.8 ha), mixed grass land and treed landscapes, and formal avenues and gardens including the sunken Dutch garden and the Italian Garden (containing four water fountains).

### *2.2. Survey methods*

Air temperature was monitored using Temperature Data Loggers (model: EL-USB-1) purchased from Lascar Electronics (Whiteparish, UK). The sensors have a stated accuracy of ±1 °C over the operating range of −35 to 80 °C. Sensors were set to monitor continuously (50 Hz) and average over 5 min. Surface and globe temperature measurements where not taken during the study. While surface temperature measurements are useful in understanding the regional effects of particular surfaces (e.g. within the street canyon) on air temperatures and globe temperature is a better measure of thermal comfort than air temperature, the case study location and the transect design were not conducive to their continuous in-situ measurement. The methodology is considered appropriate to the study's focus: the impact of greenspace on air temperature and UHI intensity.

Radiative warming of sensors is a known issue with these types of monitoring campaigns (Holden et al., 2013). Thus, following the method of Yu and Hien (2006), data loggers were housed in plastic boxes. Each sensor housing unit had 14 ventilation holes and was coated in self-adhesive reflective foil (Scotch™ Pressure Sensitive Tape by 3M) for protection from the effects of direct solar radiation. The accuracy of the sensors mounted in their housing units was tested at the Met Office's synoptic weather station at Alice Holt, Surrey prior to the field monitoring campaign in London. Five sensors in their housing units were used to monitor air temperatures over an 8-week period and the data collected was compared to the dry-bulb air temperature recorded in the Met Office's Stevenson screen. Within the range investigated (0.5 to 26 °C), the 24 h average error was found to be −0.01 °C to 1.5 °C (std. dev. ±0.5 °C). The linear regression correlating the data is: $T_{logger} = 1.05^{*}T_{Met\ Station} + 0.16$ ($R^2 = 0.98$).

A field study was conducted from August 1st to December 28th 2011. Air temperatures were recorded by mounting a sensor within its housing unit at eight locations across the Kensington Gardens. Four were mounted South-facing in an area of open grassland, two on immature trees and two on the bandstand. The other four were mounted on mature London planes (*Platanus × acerifolia*, diameter at breast height (dbh) > 60 cm) situated along the approximately north-south orientated glade known as Lancaster Walk. All were mounted using cable ties at ca. 2.5 m above ground level (after Yu and Hien, 2006 and Upmanis et al., 1998). This height allowed the sensors to be readily accessed for data collection while remaining unobtrusive, reducing the risk of theft or vandalism.

The temperature profile outside of Kensington Gardens was monitored along a street transect positioned in Gloucester Terrace. This street is situated to the north of Kensington Gardens and runs from Lancaster Gate on the boundary of the Gardens in a north-west orientation away from the park. Twelve sensors were positioned at distances ranging from 70 to 340 m, eight on lamp posts and four on street trees (*Ginkgo biloba*, dbh < 15 cm) (Fig. 1). Gloucester Terrace is an 'unclassified' road (residential street). Every 6 weeks, data was downloaded, the battery replaced and the sensor's memory cleared.

Gloucester Terrace was selected as it most closely met the selection criteria for the street transect, namely it is not a major arterial route, it has few street trees and those that are present are small, it is one of the longest straight streets in the vicinity that is not intersected by a major arterial route, the width of the street and the height of the buildings lining the street are approximately equal throughout, there are no other greenspaces adjoining the street or within 1 block. The aspect ratio (building height to street width ratio) along Gloucester Terrace ranges 0.8–1.1 (average 0.9). Sky-view factor is the proportion of the sky visible in a 180° field of view. While not determined for this study, sky-view factor is dependant on the aspect ratio (Shashua-Bar and Hoffman 2003) and can therefore be considered to vary little along the street canyon, only opening up at the intersections. There are no areas of grass/vegetation and, therefore, surface sealing is considered to be constant along the road.