Urban Climate 17 (2016) 89–101

Contents lists available at ScienceDirect

Urban Climate

journal homepage: http://www.elsevier.com/locate/uclim

Urban Heat Island traverses in the City of Adelaide, South Australia

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ARTICLE INFO

Article history:
Received 21 October 2015
Received in revised form 27 April 2016
Accepted 6 June 2016
Available online xxxx

Keywords:
Urban Heat Island
Wind
Infra-red
Traverse measurements

ABSTRACT

Spatial temperature structure within the Urban Heat Island (UHI) phenomenon of the City of Adelaide, South Australia has been studied through early morning vehicular traverses over a fixed route in the central business district (CBD) and its surroundings. Recordings were made of local temperatures, both of the air and the infra-red long-wave sky. The UHI temperature structure has been studied under both clear and cloudy skies and with a number of wind speeds. It is most prominent under clear skies and low wind conditions with the phenomenon being lost at wind speeds above approximately 3 ms^{-1}. The air (screen) temperature variation is greatly exceeded in magnitude by the sky temperature variation although, at fixed locations, the magnitude of the temporal variation of sky temperature is similar to, or less than, that of the screen temperature. This suggests the possibility that UHI spatial structure is associated with local greenhouse gases and that infra-red measurements from ground level are a useful tool for UHI studies.

1. Introduction

The Urban Heat Island (UHI) phenomenon is well known to exist in central urban areas. Factors associated with human settlement and activity determine a local climate in urban areas, for which the main parameter usually identified as different from surrounding areas is an increase in temperature, hence the idea that a localized heat island is associated with the local urban environment. Many factors have been observed to be related to the strength of the UHI. These might be wind (Unger et al., 2001 who noted that, for 500 m cells, the

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http://dx.doi.org/10.1016/j.uclim.2016.06.001
2212-0955

magnitude of the UHI intensity decreased with increasing cloudiness and wind speed; Park, 1986, who showed that the UHI on kilometer scales was lost for wind speeds above the order of a few ms^{-1}), pollution in its various forms (Stanhill and Kalma, 1995; Járegui and Luyando, 1999; Hänel et al., 1990), architectural structures and city canyons (Oke, 1973; Nunez and Oke, 1977; Oke, 1981; Elnahas and Williamson, 1997; Zhu et al., 2013), and anthropogenic heat release (Grimmond and Oke, 1999; Ryu and Baik, 2012). The overall topic has been reviewed by Arnfield (2003).

Studies of UHI have been carried out through satellite observations (Kim, 1992; Weng, 2009), networks of ground stations (Katsoulis and Theoharatos, 1985; Guan et al., 2015; Zhu et al., 2013), and traverses (Ewenz et al., 2012; Unger et al., 2001). We report here results from a number of traverse observations through the central region of the City of Adelaide, South Australia (34.93° S, 138.6° E) in which the variations of the screen air temperature and the long-wave (10 μm) infra-red sky 'temperature' were studied as the traverses progressed. In this way, the spatial temperature variation (its spatial structure) within the heat island could be studied under a number of different wind and cloud conditions.

The Adelaide metropolitan area has been instrumented since 2010 with a static temperature monitoring network of 40 measurement points, 4 m above the ground (Guan et al., 2015). That network is concentrated mainly around the central business district (CBD) and its surrounding parklands. The network is extremely useful in studies of UHI effects over scales of tens of kilometers with a resolution of the order of hundred meters, depending on the network density. Work in this location has emphasized the importance of the sky view factor to the UHI phenomenon and has studied the effective sky view factor, which incorporates both the geometric view of the sky from urban canyons and the variation of the infra-red long-wave sky temperature with angle from the zenith (Zhu et al., 2013).

Traverse measurements offer the opportunity to examine finer spatial temperature structure in UHI studies, and to test that structure against other environmental parameters. The ability to make stable long-term studies is, however, reduced. Traverses provide spatially continuous data, with flexibility to incorporated simultaneous measurements of different variables, at times to fit specific research purposes. Satellite data may contain spatially continuous data but only a limited number of fixed variables are measured, at a fixed times.

In the present study, we primarily wished to measure the magnitude of the small-scale spatial variation in screen temperatures with location within the urban heat island phenomenon. We hoped that adding information on wind speed would enable us to increase our understanding of the overall UHI phenomenon. Further, our previous experience (Maghrabi and Clay, 2011) had led us to believe that simultaneous measurement of the infra-red sky temperature could add a useful extra dimension to the understanding of that air temperature structure, and the more general UHI phenomenon. We therefore added infra-red measurements to the traverse data set. We knew that the relationship between the air temperature and the infra-red sky temperature was related to greenhouse gas levels, water vapor in particular (Maghrabi and Clay, 2011). It seemed to be possible that a knowledge of infra-red temperatures might also lead to clues as to the detailed origin of the UHI phenomenon.

We present here simultaneous measurements of the air temperature and the infra-red sky temperature over UHI traverses. Such data, at scales of tens of meters, are not available in satellite data. Studies using traverse data to study spatial variability in urban heat island studies have already proved useful in studying spatial scales in UHI (e.g. Nichol and Wong, 2008) and the influence of complex urban topography (e.g. Acero et al., 2013). In the case of this work, long-wave infra-red observations were made together with screen temperature observations. This allowed a study to be made of the relationship between the air and sky temperatures, particularly at interesting specific locations such as central regions of the CBD, the open surrounding parkland areas, and the transition regions between those two. Additionally, the spatial structure of the variations of those temperatures over rather small distances could be studied.

2. Methods

Over 60 traverses have been carried out from time to time in the Adelaide metropolitan area over the period 2011 to 2015. These observations were made in the early morning, typically 2 h before local dawn, mainly at times when the skies were clear. For the study reported here, data were taken on weekday mornings. A fixed route was selected through the Adelaide urban heat island to ensure that a variety of built conditions were sampled, plus the parkland area which surrounds the central business district. Data were taken within