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Improving a pavement-watering method on the basis of pavement surface temperature measurements



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ABSTRACT

Pavement-watering has been studied since the 1990's and is currently considered a promising tool for urban heat island reduction and climate change adaptation. However, possible future water resource availability problems require that water consumption be optimized. Although pavement heat flux can be studied to improve pavement-watering methods (frequency and water consumption), these measurements are costly and require invasive construction work to install appropriate sensors in a dense urban environment. Therefore, we analyzed infrared camera measurements of pavement surface temperatures in search of alternative information relevant to this goal. Firstly, surface temperature reductions of up to 4 °C during shading and 13 °C during insolation were found. Secondly, the infrared camera successfully detected temperature spikes indicative of surface drying and can therefore be used to optimize the watering frequency. Measurements made every 5 min or less are recommended to minimize relevant data loss. Finally, if the water retaining capacity of the studied pavement is known, optimization of total water consumption is possible on the sole basis of surface temperature measurements.

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Nomenclature

APUR	Parisian urban planning agency
BMI_{Min}	Minimum biometeorological index, 3-day mean of daily minimum temperature, °C
BMI_{Max}	Maximum biometeorological index, 3-day mean of daily maximum temperature, °C
MRT	Mean radiant temperature, °C
UHI	Urban heat island

1. Introduction

Pavement-watering is only a recent topic in French cities such as Paris and Lyons (Météo-France and CSTB, 2012; Bouvier et al., 2013; Hendel et al., 2014; Maillard et al., 2014), while it has been studied as a method for cooling urban spaces in Japan since the 1990's (Kinouchi and Kanda, 1997, 1998; Takahashi et al., 2010; Yamagata et al., 2008; Nakayama and Fujita, 2010; Nakayama et al., 2012). This technique is viewed as a means of reducing urban heat island (UHI) intensity, with reported air temperature reductions ranging from 0.4 °C at 2-m (Bouvier et al., 2013) to 4 °C at 0.9-m (Takahashi et al., 2010). In France and especially Paris, the predicted increases in heat wave intensity and frequency due to climate change (Lemonsu et al., 2012) and the high sensitivity of dense cities to such episodes (Robine et al., 2008; Li and Bou-Zeid, 2013) have focused research efforts on the search for appropriate adaptation tools. In parallel to techniques such as developing green spaces and improving urban energy efficiency, pavement-watering is seen as one of these potential tools.

As climate change is also expected to change the region's seasonal precipitation distribution (Burton et al., 2010), water use optimization of this technique is crucial. The City of Paris has taken an interest in pavement-watering and numerical and experimental studies of the method have been conducted over the last few years (Météo-France and CSTB, 2012; Bouvier et al., 2013; Hendel et al., 2014). Previous work by the authors based on these experiments revealed that pavement heat flux and solar irradiance measurements could be used to optimize a pavement-watering technique applied to an approximately N–S street with a canyon aspect ratio equal to one ($H/W = 1$) (Hendel et al., 2014). It was found that the optimum watering method consisted in watering the exact water-holding capacity of the pavement at the lowest frequency which avoids surface drying between watering cycles. Therefore, if the water-holding capacity of a given surface is known, then the optimization of pavement-watering rests fully on determining the lowest watering frequency necessary for the surface to remain wet. In the case of the studied street configuration and pavement materials, sprinkling 0.16–0.20 mm (equivalent to L/m^2) every 60 min during shading and every 30 min during insolation was recommended. Conducted continuously from 06:30 until 18:30, this would result in the daily use of less than 3.2 mm/day. Generalized to all of Paris' 2,550 ha of street surfaces (Météo-France and CSTB, 2012), this would amount to approximately 82,000 m^3/day or 36 L per day per capita, i.e. equivalent to half of a shower per person.

Unfortunately, streets within the same city often have different configurations or use different materials, preventing the generalization of conclusions drawn from a single site. It is therefore recommended to study several characteristic streets before a city-wide strategy can be developed. However, installing a heat flux sensor in combination with solar instruments over long periods of time is an expensive and invasive procedure and requires close cooperation with the relevant city services. It is therefore difficult to install large numbers of these sensors in a dense urban environment for this purpose.

In order to overcome these issues, we propose an alternative measurement method consisting of a fixed infrared camera recording radiometric data from selected areas of pavement at regular intervals. These instruments require very little effort to install compared to pavement heat flux or solar instruments and can therefore be installed at several urban locations more easily. Infrared temperature data will be analyzed in a similar fashion to that conducted for pavement heat flux (Hendel et al., 2014) in the same hopes of minimizing the number of watering cycles while keeping the pavement surface

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