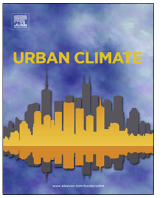
Urban Climate 9 (2014) 75–88

Contents lists available at ScienceDirect

Urban Climate

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



Impact of mid-high rise buildings on summer air temperatures in the coastal city of Takamatsu in southwestern Japan

Atsuko Nonomura [a,*], Yuki Uehara [a], Takuro Masuda [a], Takeo Tadono [b]

[a] *Department of Safety Systems Construction Engineering, Faculty of Engineering, Kagawa University, Hayashicho 2217-20, Takamatsu, Kagawa 761-0396, Japan*

[b] *Earth Observation Research Center, Japan Aerospace Exploration Agency, 1-1 Sengen 2chome, Tsukuba-shi, Ibaraki 305-8505, Japan*

ARTICLE INFO

Article history:
Received 17 September 2013
Revised 29 May 2014
Accepted 7 July 2014

Keywords:
Mid-high rise building
Air temperature
Land-use
Land-cover

ABSTRACT

During summers, particularly in low- and mid-latitudes, it is necessary to identify the influence of urban areas on the local climate to improve the urban thermal environment. Numerous studies have investigated the causes of the urban heat island, one of which is on land-use and land-cover. Lower air temperatures have been observed in areas with abundant vegetation, while higher air temperatures have been documented in urban areas. However, other studies have shown lower temperatures in urban areas during the day. To understand the influence of land-use and land-cover on the local climate in an urban area, the structure of buildings—mid-high rise or low-rise—needs to be considered during both daytime and nighttime. In this study, we investigated the influence of urban area on the local climate in the Japanese coastal city, Takamatsu using clear sky summer day. The impact of land-use and land-cover on the air temperature was analyzed by differentiating mid-high rise buildings from other impervious surfaces in the day and night using daily maximum and minimum air temperature data. It was found that the percentage cover of mid-high rise buildings was correlated with the air temperature negatively in the day and positively at night.

* Corresponding author. Tel.: +81 87 864 2146.
E-mail address: nonomura@eng.kagawa-u.ac.jp (A. Nonomura).

http://dx.doi.org/10.1016/j.uclim.2014.07.003

1. Introduction

Global air temperature has increased, on average, 0.13 °C per decade over the 50 years from 1956 to 2005, which is nearly twice the increase per decade for the 100 years from 1906 to 2005 (IPCC, 2007). It is well documented that the probable main contributing factor of global warming is an increase of greenhouse gases, which affect the absorption and emission of radiation within the atmosphere and alter the energy balance. In urban areas, the urban heat island effect, which causes urban areas to be significantly warmer than surrounding nonurban areas, is intensified by the warming trend. There are several causes of the urban heat island effect. In urban areas, upward longwave radiation flux is mostly higher than that measured over rural areas, and radiation trapping in street canyon affects upward longwave radiation flux, significantly (Christen and Vogt, 2004). Anthropogenic heat sources, such as traffic heat and waste heat from buildings, are also known to be among the causes of the urban heat island effect (Oke, 1987).

Urban heat island phenomena due to land modification in densely populated areas have also been demonstrated (Deosthali, 2000; Arnfield, 2003; Streutker, 2003; Weng and Yang, 2004; Emmanuel, 2005; Xiao and Weng, 2007). For example, in Houston, Texas, both the magnitude and extent of the heat island increased from 1987 to 1999 in rough correspondence with the increase in population (Streutker, 2003). In China, a significant temperature increase in densely populated cities since the mid-1980s and an increase in air temperature differences between urban and rural areas have been reported (Weng and Yang, 2004; Xiao and Weng, 2007; Zhang et al., 2010). In Colombo, Sri Lanka, and Pune, India, which have experienced rapid urbanization, air temperature has been increasing and nighttime temperatures have been reported as less comfortable because of increased humidity (Deosthali, 2000; Emmanuel, 2005). Hung et al. (2006) investigated the spatial pattern of urban heat island intensity in eight Asian megacities: Beijing, Seoul, Pyongyang, Shanghai, Tokyo, Bangkok, Ho Chi Minh, and Manila. They showed that the magnitude and extent of the urban heat island intensity is positively correlated with the population size of the cities. These studies investigated the thermal environment in large, densely populated cities. Lee et al. (2012) indicated that in Phoenix, US, the urban heat island intensity is related to city size; urban heat island intensity was extreme in large scale urban areas.

In contrast, Kim and Baik (2004) analyzed the thermal environment in the six largest cities in Korea, and the strongest urban heat island intensity was found in a city with a population four times smaller than Seoul. Nonomura et al. (2009) showed that the average air temperature has been increasing relative to an increase in unvegetated but low-population-density areas due to urban sprawl in mid-sized cities in southwestern Japan. These studies suggest that the urban heat island effect is not always related to the size of the city or the population density. To clarify the impact of urbanization on the local climate, many studies have demonstrated the impact of land-use and land-cover on the local climate using various approaches (Taesler, 1991; Saitoh et al., 1996; Shudo et al., 1997; Steinecke, 1999; Voogt and Grimmond, 2000; Eliasson and Svensson, 2003; Bourbia and Awbi, 2004; Pauleit et al., 2005; Kueppers et al., 2008; Susca et al., 2011).

Based on air temperature data, some studies have indicated that urban areas have higher air temperatures than green spaces, which have lower temperatures due to the cooling effect of vegetation from heat absorption and shade creation, and evapotranspiration of soil water (Sun et al., 2013; Wang et al., 2013; Giridharan et al., 2004; Giridharan et al., 2008; Oliveira et al., 2011). However, some studies have indicated that built-up areas are cooler than green spaces during the day (Sevensson and Eliasson, 2002; Yang et al., 2010). These studies imply that the energy balance between the atmosphere and the earth's surface at the boundary layer is governed by several factors, such as season, time, location, and land-use and land-cover. For urban planning with respect to climatic conditions, the thermal environment needs to be analyzed by specifically identifying the decisive cause of air temperature variation throughout the day and night.

In differentiating the weather conditions, statistically significant differences are rarely analyzed using air temperature observation data because of the limited amount of data (Eliasson and Svensson, 2003). On the other hand, remote-sensing techniques can collect data within a large coverage area. The amount of data is large enough to perform a spatial analysis between surface temperature and