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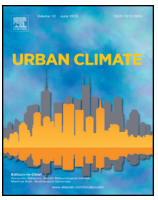

Impact of future urbanization on temperature and thermal comfort index in a developing tropical city: Ho Chi Minh City

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ABSTRACT

This study examines the climate impact of future urbanization on the urban heat island effect over one of the developing megacities in tropical Southeast Asia, the greater Ho Chi Minh City area, using a dynamical downscaling approach with a high-resolution regional climate model coupled to urban canopy model. Simulations incorporate different land use/cover and anthropogenic heat release data sets for the current and future periods, while the boundary condition was fixed in the current time to detect only the impact of urbanization. Furthermore, human thermal comfort due to changes in the thermal environment was examined by analyzing the temperature-humidity index. Simulated results show that the increase in the surface air temperature is approximately 0.22 °C in the preexisting urbanized area and approximately 0.41 °C in new highly urbanized areas. The main factor in these changes is conversion from agricultural or grassland to urban structures, which results in increased sensible heating and decreased latent heating. Simulated results also show that despite the increase in air temperature, there is no significant change in thermal comfort. This is because human comfort is not only determined by temperature alone, but also by relative humidity. Urbanization increases temperatures, but decreases evaporation, which then decreases the relative humidity.

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1. Introduction

Urban heat island (UHI) has been garnering substantial attention in recent decades. Extensive studies have been carried out to explore the impact of past urbanization on the UHI effect in cities with unique urban landscapes and histories using numerical models, e.g. Tokyo, Paris, New York City, Beijing, Houston, Singapore (Kusaka and Kimura, 2000; Lemonsu and Masson, 2002; Holt and Pullen, 2007; Miao et al., 2009; Chen et al., 2011a; Li et al., 2013).

Regarding future urban climate, Kusaka et al. (2012) and Adachi et al. (2012) have conducted numerical experiments with a regional climate model and showed that, in the case of Tokyo, the effect of greenhouse gas-induced global warming, rather than urbanization, will play a dominant role in the future urban warming. This contrasts to that urbanization had contributed more to the rise of Tokyo air temperature during the last century (Kusaka and Kimura, 2000). This is because Tokyo is an already developed city, and urbanization is not expected to be a considerable contributor to urban warming in the future. Argüeso et al. (2014) and Hamdi et al. (2014) reported similar results for Sydney, Australia, and Brussels, Belgium, respectively.

However, it is unclear whether these conclusions can be applied for cities still evolving. Georgescu et al. (2014) have conducted regional climate simulations incorporating several distinct urban expansion futures for the United States in 2100 and showed that in the absence of any adaptive urban design, urban expansion, alone and separate from the global warming effect, can be expected to increase near-surface temperature 1–2 °C over the large regional swaths of the country. The study highlights the importance of urbanization-impact investigation on the still-evolving cities. Indeed, the next decades will witness the emergence of mega cities, especially in developing countries in Asia and Africa. However, so far, there have been a very few studies focused on cities in these countries.

Greater Ho Chi Minh City (GHCM), Vietnam's largest metropolis, has been rapidly urbanized since the late 1980s, when the country conducted a series of comprehensive economic reforms called the Doi Moi policy. The region's total population has grown from 11.2 million in 1989 to 17.3 million in 2009. Rapid urbanization has induced regional climate change, especially the increase of UHI over urban areas (Tran et al., 2006; Luong, 2008a, 2008b; Doan and Kusaka, 2015).

It is well known that there is a strong relationship between the increase of temperature and the emergence of heat-related illnesses, e.g., heat stress and mortalities, in cities (Patz et al., 2005; Wong et al., 2013). Although there is no any investigation addressing this issue for Ho Chi Minh City, another study on Da Nang, another major city in Vietnam, showed that hot air temperature causes heat stress and other health issues, especially in the outdoor environment (Dao et al., 2013). This implies that, owing to the tropical climate, residents in Vietnam are likely to tolerate warming through acclimatization as well as variations in food habits, clothing, etc.; however, the temperature increase still causes issues for the human living environment, increasing discomfort, heat-related illnesses, and mortality.

According to the master plan released by the Ministry of Construction of Vietnam in 2008, the GHMC is expected to keep urbanizing with a population of 28–30 million by 2050. Studying future urbanization impacts on regional climate is urgent, especially, on the changes in the UHI effect, as well as its impact on the human living environment.

The present study has two parts. First, we numerically examine the impacts of future urbanization on the UHI effect over the GHCM using dynamical downscaling with a high-resolution regional climate model (RCM) coupled with an urban canopy model (UCM). Second, we assess the impact of urbanization-induced regional warming on human comfort.

2. Data and methodology

2.1. Study area

The Greater Ho Chi Minh City metropolitan area is located in the southeastern region of Vietnam. It comprises Ho Chi Minh City and a number of satellite cities and towns, e.g. Bien Hoa, Vung Tau, Binh Duong, Tay Ninh, My Tho. By 2009, the region had a total area of 30,404 km^2 and a population of 17.3 million. According to the master plan released by Ministry of Construction of Vietnam in 2008, the GHMC is expected to keep urbanizing in the next several decades. By 2050, the region's population will be 28–30 million, and at the same time, urban built-up area will increase to 2500 km^2 (from 1500 km^2 at the present time).