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Investigating the relationship between local climate zone and land surface temperature using an improved WUDAPT methodology – A case study of Yangtze River Delta, China

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ABSTRACT

The concept of Local Climate Zone (LCZ) was developed to quantify the relationship between urban morphology and urban heat island (UHI) phenomenon. Each LCZ is supposed to represent homogeneous air temperature. However, there is inadequate data for verifying the air temperature differences between LCZ classes. Therefore, it is necessary to utilize alternative temperature data which allow more comprehensive assessment of the effect of LCZ on local climatic conditions. Land surface temperature (LST) acquired from satellite images can be used to establish the relationship between LST and LCZ by providing continuous data on surface temperature. This paper aims to investigate how LST represents the UHI intensity determined by using an improved method of the World Urban Database and Portal Tool (WUDAPT) to develop the LCZ map of the Yangtze River Delta (YRD) megaregion. The results show that LST in different YRD cities is generally consistent with the LCZ classes with higher LST observed in built-up LCZ classes. The diverse urban morphology and temporal vegetation variation are likely the reasons to inconsistencies in LCZ 9, and LCZ A to D. Findings of this paper provide a better understanding of how urban morphology affects local climate and more accurate delineation of LCZ classes.

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1. Introduction

Urbanization in China has reached an unprecedented level with 54.77% of the population living in cities in 2014 (National Bureau of Statistics of China, 2014). With continuous urbanization and the increasing communications between different metropolitan cities, the idea of megaregions was introduced as a new framework for national policy of spatial development (The state council of People's Republic of China, 2016). There are ten megaregions in China with the Pearl River Delta, the Yangtze River Delta (YRD), and the Capital Region as three leading megaregions. Although these three megaregions occupy 1.6% of the total area of China, 10.6% of the total population in China reside in these three megaregions (Amekudzi et al., 2012). Such a high population density results in enormous pressure on the urban systems and challenges to the sustainable urban development of the urban agglomerations.

Urban development converts natural landscape into artificial constructions and pavements, resulting in altered climatic conditions in urban areas and the formation of urban heat island (UHI) phenomenon (Oke, 1982, 1987). The concept of Local Climate Zone (LCZ) was developed to quantify the relationship between urban morphology and UHI phenomenon (Stewart and Oke, 2012). It provides a standardized framework to characterize cities according to the surface properties. Each LCZ class is assumed to be homogeneous in terms of surface properties and the effect on air temperature. One of the major advantages of the LCZ classification system is the new perspective of defining UHI by using the temperature differences among LCZ classes rather than the traditional urban-rural difference. It therefore emphasizes the importance of intra-urban temperature comparison to analyze the influence of heterogeneous urban morphology on the formation of local climate.

For the nature of LCZ classification, air temperature is the most suitable meteorological parameter for analyzing the temperature differences among LCZ classes. However, the coverage of ground-level, observational meteorological stations is generally limited, resulting in poor spatial resolution for verifying the differences in air temperature between LCZ classes. As such, alternative temperature data is necessary for more comprehensive assessment of the effect of urban morphology on local climatic conditions. Satellite images provide continuous coverage, high integrity and real-time data acquisition over large areas (Voogt and Oke, 2003). In addition, satellite images acquired during night-time were found to have stronger relationship between land surface and the adjacent air (Stoll and Brazel, 1992) so they provide a representation of air temperature sufficient for UHI studies at city scale (The state council of People's Republic of China, 2016). As night-time temperature increases at a higher rate than daytime temperature in urban areas due to UHI phenomenon (Schrijvers et al., 2015), LST derived from night-time satellite imagery is a suitable alternative as an indicator of urban heat island.

This paper aims to determine the relationship between LST and LCZ classes with the YRD megaregion selected as a case study. Night-time Aster satellite images of Shanghai and Hangzhou were used to investigate LST from the YRD megaregion, which were subsequently classified to show the surface UHI intensity. An improved method of the World Urban Database and Portal Tool (WUDAPT) was also used to develop the LCZ map of the YRD megaregion. Air temperature data from weather observational stations was used to test against the LST pattern of LCZ classes. LST of different LCZ classes can therefore be characterized in order to inform urban climate researchers and urban planners about the influence of LCZ on local climate, leading to more sustainable urban planning in megaregions in China.

2. Materials and methodology

2.1. Study area: Yangtze River Delta

The YRD region is composed of the territory of Shanghai, southern Jiangsu Province and northern Zhejiang Province (Fig. 1). The terrain of this region is generally flat and low-lying floodplain with some hilly areas located in the south of Hangzhou. The YRD region has a subtropical monsoon climate with annual mean temperature of 15–16 °C and annual precipitation of 1000–1400 mm. Rapid urbanization in this region has given rise to one of the largest megalopolis in the world, covering an area of 99,600 km^2 and home to over the 83-million urban population (National Development and Reform Commission, 2016). This region is selected in the present paper due to the similar geographic characteristics and urban morphology of the YRD cities.

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