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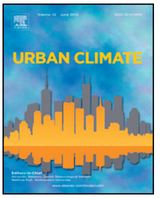

Remote sensing retrieval of urban land surface temperature in hot-humid region

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ABSTRACT

With the rapid urbanization and the global climate change, the urban climate problems become increasingly serious in the hot-humid region of China. This study established the satellite-based remote sensing retrieval methods for urban land surface temperature (LST) based on the mono-window algorithm and the estimation methods of ground emissivity and atmospheric transmittance. Through retrieving LST of Haizhu district in Guangzhou in a sunny summer day, it was found that the retrieval methods were able to distinguish the surface temperature variations for different underlying urban surfaces. By comparison with the field observations, it was found that the error of the retrieval methods was about 1.0 °C and the methods were applicable for LST retrieval in the cities in the hot-humid region. By applying the retrieval methods, it showed that the cooling effects of water and vegetation on surrounding urban lands were effective within distances of 250 m and 350 m, respectively. The water cooling effect correlated with its area and width positively, and the vegetation LST correlated with its canopy density negatively. The present study provides reliable techniques for observing and evaluating urban LST and useful guidance for planning and design of urban climate in the hot-humid region.

1. Introduction

With the rapid urbanization and the global climate change, the urban environment and climate problems become increasingly serious in China. In the hot-humid region of China, the summer is long, hot and humid,

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and the urban climate problem is severe. On one hand, mortality increases with urban warming. For instance, the mean daily count of non-accidental death reached 32.6 during 2006 to 2009 and the temperature-mortality relationship showed a U shape in Guangzhou, a big city in the hot-humid region of China (Wu et al., 2013). On the other hand, building energy consumptions increase with urban warming. For example, a 10% increase in air-conditioning demand was caused by the heat island in Hong Kong (Chan, 2011). The neighborhood microclimate, as the micro-scale of urban climate, relates to people's daily life very closely (Roth et al., 1989). It is thus important and necessary to study the urban climate and the neighborhood microclimate in the hot-humid region for improving living environmental quality, reducing building energy consumption and mitigating urban heat island.

Previous studies on urban climate and neighborhood microclimate are mainly focused on filed study of individual cases and hard to be generalized. On the other side, the advanced technologies of remote sensing are mainly applied to large-scale fields like agriculture and ocean. Only a few studies have been carried out in the cities of Singapore (Nichol, 1996), Tel-Aviv (Saaroni et al., 2000), Salt Lake Valley (Gluch et al., 2006) and China (He and Xu, 2012; Ye, 2009; Wang and Zhang, 2010). The primary work of utilizing remote sensing to urban climate and neighborhood microclimate studies is to acquire land characteristic parameters retrieved by remote sensing techniques. Land surface temperature (LST) has been proved to be an important factor controlling the physical, chemical and biological processes on Earth's surface (Qin and Karnieli, 1999). In the recent years, the remote sensing techniques that based on satellite and aircraft have been advanced greatly and applied extensively in urban climate, for instance, Voogt and Oke (1997, 1998) and Chen et al. (2014) have done many works on urban climate by remote sensing techniques. By using the remote sensing techniques, it can acquire the urban climatic information quickly and broadly and provide a large number of neighborhood microclimatic data by taking its advantages on macro, multiband and high resolution.

This paper aimed at establishing remote sensing retrieval methods for urban LST based on previous studies and testing performances of the retrieval methods through field observations in the city in the hot-humid region of China. Furthermore, the cooling effects of water and vegetation on urban LST will be quantitatively studied by using the validated methods. This study provides reliable methods for remote sensing retrieval of urban LST, and useful guidance for urban climate planning and design in the hot-humid region.

2. Retrieval methods

2.1. Mono-window algorithm

There are three methods, i.e., atmospheric correction method (also called radiative transfer equation), mono-window algorithm (Qin et al., 2001), and single channel algorithm (Jimenez-Munoz and Sobrino, 2003), appropriate for retrieving LST by using the satellite thermal band data. The atmospheric correction method needs to know the in situ atmospheric profile data. It is complicated and hard to acquire and huge error would be produced by its estimation. The mono-window algorithm and the single channel algorithm are both derived from the thermal radiance transfer equation, which are simple, needing few inputs and with relatively less error. Some studies compared the three methods with the field observations in the Chinese cities of Beijing (Bai et al., 2008) and Gansu (Meng et al., 2005), and concluded that the accuracy of the mono-window algorithm was highest for retrieving LST. Therefore, the mono-window algorithm was determined to be the method for retrieving urban LST in the present study.

The mono-window algorithm retrieves LST (T_s) by knowing ground emissivity, effective mean atmospheric temperature and atmospheric transmittance by Eqs. (1)–(3):

$$T_s = [a(1-C-D) + [b(1-C-D) + C + D]\,T_6 - DT_0]/C \quad (1)$$

$$C = \varepsilon\tau \quad (2)$$

$$D = (1-\tau)[1 + (1-\varepsilon)\tau] \quad (3)$$

where a and b are constants, $a = -67.355351$, and $b = 0.458606$; T_6 is the brightness temperature in K; T_0 is the effective mean atmospheric temperature in K; ε is ground emissivity; τ is atmospheric transmittance.