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Identifying seasonal heat islands in urban settings of Delhi (India) using remotely sensed data – An anomaly based approach

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A B S T R A C T

Delhi, the capital city of India is a rapidly urbanizing agglomeration. The city thus experiences various environmental challenges that are true for all the global cities. urban heat island (UHI) is one such issue that the city is facing. Being a tropical city, Delhi's UHI behaves differentially in comparison to developed cold country cities. This paper analyzes seasonal variation in spatial patterns of UHI in the semi-arid environmental settings of Delhi. Temporal variation in distribution and magnitude of UHI was also studied and analyzed with respect to land use land cover practices using Landsat TM data of all the five seasons (winter, spring, summer, monsoon and post-monsoon) for year 2010–11. An anomaly based approach was attempted to quantify seasonal and annual UHI intensities. Maximum and minimum seasonal UHI intensities were observed in summer (intensity = 16.7 °C) and winter (intensity = 7.4 °C), respectively. Mean annual LST anomaly map aided in identifying UHI vulnerable locations in the city. Major commercial and industrial sites across the city, and the airport area in south experienced higher UHI effects and were found to be the most vulnerable locations.

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1. Introduction

In recent years urban heat island (UHI) has become a topic of great interest both among the academicians and the governing bodies. Researchers are interested in understanding the various aspects of this phenomenon including its causes (Huang et al., 2011), impacts (Imhoff et al., 2010) and complexity (Mirzaei and Haghighat, 2010). UHI is increasingly gaining interest as it directly affects both environmental (Ferguson and Woodburry, 2007; Sharma et al., 2012) as well as human health (Lo and Quattrochi, 2003; Tomilson et al., 2011). UHI affects the environment through heat pollution (Papanastasiou and Kittas, 2012), it increases the number of smog events (Sham et al., 2012), higher energy consumptions (Kolokotroni et al., 2012), while from human health perspectives it causes larger number of heat-related health problems (Harlan and Ruddell, 2011) and adversely impacts human comfort (Steeneveld et al., 2011). Additionally UHI has the tendency to elevate heat wave intensities as observed in case of Chicago in 1995, Russia in 2003 (Sailor and Lu, 2004) and recently in Shanghai, China (Tan et al., 2010).

UHI manifests itself in two basic forms (Table 1); (i) the Surface UHI (SUHI) and (ii) the Atmospheric UHI (AUHI). SUHI is the phenomenon of temperature difference between surfaces of urban and surrounding rural areas. The phenomenon exhibits high spatial and temporal variability (Stathopoulou and Cartalis, 2009). SUHI is studied using land surface temperature (LST) retrieved from thermal satellite sensors (Schwarz et al., 2011). AUHI encompasses difference in pattern of air temperature between urban and rural settings. AUHI further falls in one of the two categories viz., Canopy layer or Boundary layer. *Canopy layer UHI* influence the atmosphere extending from surface to mean building height or tree canopy, while the *Boundary layer UHI* accounts for air beyond canopy layer (Weng, 2003).

AUHI is studied using meteorological data (Saaroni et al., 2000). Such data have often been explored to study monthly or seasonal variations in atmospheric UHI (Jongtanom et al., 2011; Cayan and Douglas, 1984; Fujibe, 2009; Jauregui, 1997; Liu et al., 2007; Gaffin et al., 2008; Hua et al., 2008). Gallo and Owen (1999) for instance, analyzed urban–rural temperature (using observation stations) and Normalized Difference Vegetation Index (NDVI) (using NOAA-AVHRR, National Oceanic and Atmospheric Administration–Advanced Very High Resolution Radiometer) of 28 cities on monthly and seasonal basis to study UHI. UHI intensity in Bangkok, Chiang Mai and Songkhla cities were investigated using urban and rural meteorological station data (Jongtanom et al., 2011). Cayan and Douglas (1984), Fujibe (2009), Jauregui (1997), Liu et al. (2007), Gaffin et al. (2008), and Hua

Table 1
Summary of forms of UHIs.

Atmospheric UHI		Surface UHI	Authors
Prominent during night		Prominent both during day and night	Yuan and Bauer (2007)
More intense during winters		More intense during summers	Imhoff et al. (2010), Papanastasiou and Kittas (2012)
UHI intensity is low		UHI intensity is very high	Grimmond (2007)
Studied using ground-based air temperature measurements taken from standard meteorological stations		Observed using airborne or satellite thermal remote sensors	Hung et al. (2006), Voogt and Oke (2003)
Best to study under calm and clear conditions at night		Satellite or aircraft thermal data of acquired at daytime when heat island intensities are greatest	Roth et al. (1989)
Boundary layer	*Canopy layer*		
Prominent at mesoscale	Prominent at local and microscale		Schwarz et al. (2012)
Observed using tower sodar (fixed) and aircraft, tetroon (mobile)	Observed using screen (fixed) and automobiles (mobile)		Cermak et al. (1994)