

## Chapter 18

# Studying Surface and Canopy Layer Urban Heat Island at Micro-Scale Using Multi-Sensor Data in Geographic Information Systems

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### ABSTRACT

*Variations of Urban Heat Island (UHI) effect within urban areas cannot be studied in detail using traditional combination of satellite images with thermal infrared (IR) bands and local weather station data due to their limited spatio-temporal scale. In this article, a system has been built to supplement the current infrastructure and enhance the high spatio-temporal scale. The article progresses from initially traversing through the city of Greater Noida to continuous manual data collection on an academic campus and later by automating it with integrated sensors on a microcontroller while achieving the objective of the collection of continuous high spatio-temporal scale data. Geographic information systems (GISs) were used to integrate and visualize these data with land surface temperature (LST) and air temperature data. The system provided the diurnal cycle of urban materials and insights into nighttime UHI at micro-scale. Overall the low-cost sensing technology presented has the potential to monitor citywide UHI.*

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## INTRODUCTION

When rural areas are transformed into urban areas, they experience higher surface temperature and air temperature, which is known as Urban Heat Island (UHI) phenomenon (Environment Protection Agency, 2008). UHI is a matter of concern because of the more intense the UHI effect, it has a direct impact on indoor energy demands for thermal comfort. UHI also affects human health by causing heat stroke, and other conditions. Raised temperatures are closely linked with urban air pollution as well, which is catalyzed by this effect (Stone, 2005).

The report by International Panel for Climate Change (IPCC) indicates that average surface temperatures are going to increase by nearly 1.5° C by the end of 21st century (Pachauri et al., 2014). In addition, the number of extreme heat events has been on a rise as per climate change studies. This leaves the cities more vulnerable as a combined effect of UHI and climate change extremes (Easterling et al., 2000). Overheated cities face climate change costs at least twice as big as the rest of the world, due to urban heat island effect (Estrada, Botzen, & Tol, 2017). Thus, cities are gaining attention from climatologist and economist, as interdependency between cities UHI and climate change is complex and still under study. In general, understanding of city's UHI becomes of prime importance to make them resilient rather than more vulnerable to heat extremes.

Traditionally, satellite data having thermal infrared bands provide land surface temperature (Weng, 2009), which are used to study urban climate with various limitations (Voogt and Oke, 2003). Along with satellite-based observations, air temperature details by weather stations in urban areas provide more details about UHI. The relationship between the satellites based temperature and air temperature is weak, as the coupling is not yet fully understood in the urban environment (Roth, Oke, & Emery, 1989).

Satellite data is highly useful in delineating land surface characteristics, city morphology, and land use patterns, which are responsible factors for UHI (Emmanuel, Rohinton, & Erik, 2006). Satellite data, however, are limited by its spatial resolution (especially thermal bands have low spatial resolution than other bands) and temporal resolution. These limitations are serious ones when one wants to study spatial variations of UHI within urban areas by going beyond the mere difference between rural and urban temperature. Moreover, a variation of UHI throughout the day and night cycle, which is important for energy demand and health, cannot be captured using satellite data alone.

Urban areas usually have limited number of weather stations, which does not provide a reliable estimate of air temperature for microclimatic zones within the cities. For experimental purposes, some studies have realized this limitation and installed hundreds of automatic weather stations within their urban setup. This, however, proves to be a very expensive method (Muller et al., 2013).

Given that the detailed UHI studies are bounded by limitations of current technologies, this study attempts to overcome them and enhance the results in terms of capturing variations of surface and air temperatures at a finer scale. Here, it has been demonstrated that the handheld sensors could be used to obtain data about ambient air temperature (Samsung Galaxy S4 smartphone has ambient air temperature sensor – SHTC1 and DHT22 sensor used with Arduino microcontroller has air temperature and humidity sensor) and surface temperature (using Thermal infrared (IR) gun – Fluke 59 Max and thermal probe used with Arduino microcontroller). The study is being continued in the region of our university, Shiv Nadar University, which is located in Greater Noida, India. It is a rapidly urbanizing satellite city of Delhi. In the study area, representative surfaces for urban and rural setups are selected based on the configuration

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