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Summertime Urban Heat Island study for Guwahati City, India

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ABSTRACT

Summertime Urban Heat Island (UHI) effect in Guwahati, a small but rapidly growing city of India, is studied, by using half hourly temperature data measured at four fixed observation sites – two in the urban core and the others at the periphery, away from the city. The in situ measurements were conducted using stationary loggers from the months of May to October 2009 to study the temporal variation. Also, mobile measurements were carried out during the months of June, July and August 2013 to bring out the intra-city temperature variation. The results show existence of UHI above 2 °C. The highest magnitude of daytime Urban Heat Island Intensity (UHII) for the entire period of study was found to be 2.12 °C while highest nighttime UHII was 2.29 °C. Diurnal ranges of temperature (DTR) showed wide variation in each of months included in this study. Higher DTR were experienced in the month of May for all the stations – rural as well as the urban. As the summer progressed, the DTR showed declining trend through the months of June to August and started rising again in September showing the influence of monsoon in air temperature regime. Variation in the average monthly DTR within the season is low in urban stations compared to rural ones. The temperature difference, recorded in the mobile runs, between the urban pockets and the suburban areas, ranged from 1.23 to 0.78 °C.

1. Introduction

Urban Heat Island (UHI) is a phenomenon where surface and atmospheric modifications due to urbanization generally lead to modified thermal climate that is warmer than the surrounding non-urbanized areas (Voogt & Oke, 2003). The UHI effect has been extensively studied for several cities of the world like London (Kolokotrani & Giridharan, 2008), Osaka (Huanga, Taniguchib, Yamanoc, & Wangd, 2009), Johannesburg (Tyson, Toit, & Fuggle, 1972), Hongkong (Giridharan, Ganesan, & Lau, 2004), Nanjing (Huang, Li, Zhao, & Zhu, 2008; Zeng, Qiu, Gu, He, & Wang, 2009), Singapore (Jusuf, Wong, Hagen, Anggoro, & Hong, 2007; Wong et al., 2007), etc. Long-term temperature record have revealed that the influence of urbanization on thermal environment is not only confined to large cities but also have been detected in cities with population less than 10,000 (Karl, Diaz, & Kulka, 1988). India, being a growing economy, has undergone rapid urbanization in the last few decades. The phenomenon of UHI which is associated with urbanization has not drawn much attention of the scientific fraternity within the Indian subcontinent. Only a few studies have come up over a large span of time (Deosthali, 2000; Emmanuel, 2000, 2005; Sundersingh, 1990/91). Reduction in land area, in terms of total area available for residential purposes, coupled with projected doubling of the global urban population by 2030 and resultant increase in the levels of air pollution, call for greater attention to this field in order that effective strategies for managing microclimate in the cities can be devised. Studies in the field of UHI also become imperative due its effect on energy demand, human health and environmental conditions related to pollution dispersion (Crutzen, 2004; Harlan, Brazel, Prasad, Stefanov, & Larsen, 2006).

Guwahati (26°10′ N, 92°49′ E) is the largest city in the state of Assam, India. The urban area is around 262 km^2 and has a population of about 12 lakh (Census of India, 2011). It has a starfish like urban form with a core in the central areas and tentacles extending in the form of growth corridors towards south, east and west. River Brahmaputra intersects the Guwahati into two parts with southern part comprising the urbanized core and extensions, while the northern part representing the rural areas. The general climate of the city as well as the entire region is of warm humid type. Being the gateway to the entire northeastern region of the country, the city has undergone rapid urbanizational changes in the past decade. There has been considerable increase in the density of the population in the past and is projected to grow up to 21.74 lakh by 2025 (GMDA, 2009). Rapid population growth has pushed the expansion of the urban areas in the southern Guwahati into the suburban extents. Most of these expansions are unplanned. Replacement of natural vegetated areas with dry impervious surfaces, use of building materials having high heat capacity and low surface reflectivity and increased anthropogenic heat emission into the urban atmosphere are likely to modify the thermal regime of this city.

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So far no study analyzing the thermal environment of Guwahati city using actual ground data has been reported. Therefore, this study has been undertaken with the main objective of studying the UHI of Urban Canopy Layer (UCL) of Guwahati city.

2. Material and methods

Three methods are usually employed to measure UHII; urban–rural difference method, city traverse method or remote sensing (Goldreich, 1995). Though comparison between the urban and the rural climates is the most common approach towards analyzing UHI effect, researchers have also studied the phenomenon based on the comparative temperature measurements of vegetated and non-vegetated surfaces (Wong & Yu, 2005; Wong et al., 2007).

Most of the works in this field make use of either in-depth field measurements (Wong & Yu, 2005; Wong et al., 2007) or meso-scale measurements with the help of remote-sensing satellites (Chen, Zhao, Li, & Yin, 2006; Streutke, 2005). The results are generally expressed in terms of Urban Heat Island Intensity (UHII), which, in turn, has also established itself as an important indicator for evaluating the severity of the urbanization of an area (Memon, Lung, & Chunho, 2008).

In this study, the summertime UHI of Guwahati City is analyzed using half hourly temperature and humidity data measured at four fixed stations. HOBO Pro V2 Temperature and RH data loggers were used for the purpose. The data loggers have temperature measuring range of −40 to 70 °C with an accuracy of ±0.21 °C from 0 to 50 °C. The humidity measurement range is from 0 to 100% RH with accuracy of ±2.5% from 10% to 90% RH. This instrument is used because of its weatherproof housing for outdoor usage or condensing environments and highly accurate temperature and RH sensors.

The data loggers were stationed at the height of 1.5 m and covered with hollow wooden cuboids to avoid direct sunlight. The sites for data logger stations were selected in such a manner that they could give faithful representations of both urban and rural surroundings. Local knowledge of the area as well as the settlement pattern of the city based on satellite imagery was used for locating the observation sites. Bhangagarh and Ganeshguri areas are situated in highly urbanized G.S. Road corridor in the southern part of Guwahati. The G.S. Road corridor is an important commercial area with retail, wholesale and offices developed along the main road, and it is also a densely built residential area in the inner parts. North-Guwahati on the other hand represents rural areas of Guwahati with proximity to water body due to its location in the north bank of Brahmaputra. Basistha, with abundant vegetation and considerable distance from Brahmaputra represents rural area from another perspective. The temperature and humidity readings from Bhangagarh and Ganeshguri areas are averaged for having a true representation of an urban area (URB) while North-Guwahati (RUL1) and Basistha (RUL2) are selected for representing the rural surrounding with proximity and remoteness to a larger water body respectively (Figs. 1 and 2). In situ field measurements were conducted for 170 days from 1 May to 17 October 2009. The mobile measurements which were carried out, in the months of June, July and August to analyze the intra-urban air temperature variation, were conducted by mounting the temperature–humidity sensor over a vehicle and running the same at a constant speed. The experiments were conducted during nights between 1.00 and 3.30 AM.

3. Results and discussion

3.1. Urban Heat Island

Temperature differences were taken into account for finding the Urban Heat Island Intensity. Half hourly data recording between 6.00 h and 17.59 h was considered for daytime temperature and

Fig. 1. Google image showing the study area.