ASSESSMENT OF URBAN HEAT ISLAND INTENSITIES OVER DELHI

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Abstract

A field campaign was undertaken during summer, May 2008 named DELHI-I (**D**elhi **E**xperiments to **L**earn **H**eat Island **I**ntensity –I) to understand the latest intensity and dynamics of heat-island phenomena in Delhi, Surface meteorological observations were performed using multisite ground based mini weather stations and meteorological towers. Urban heat island effects were found to be most dominant in areas of dense built up infrastructure and intense human activity. Higher magnitude of UHI observed during day hours in summer is expected to increase cooling energy requirements in tropical cities such as Delhi and further strengthen the UHI leading to vicious cycle problem.

Key words: Urban Heat Island, micrometeorological experiments, land-use land-cover, anthropogenic emissions, energy demand

1. INTRODUCTION

Delhi, the capital city of India, has witnessed a consistent decennial population growth at the rate of over 45 % for last six decades. The corresponding urban infrastructure development is steadily increasing the resource dependency and anthropogenic heat emissions. Excessive urbanization has a possibility to induce regional-scale climate change well known as urban heat island (UHI) phenomena Most of the studies on UHI in Delhi were conducted in 1980's (Bahl and Padmanabhamurty, 1979; Krishnanand and Maske, 1981; Padmanabhamurthy and Bahl, 1982, 1984; Mohan, 1985). These studies assessed mean heat island intensities ranging from 0.8 °C to 6 °C on a monthly to seasonal scale. However, there exists a dearth of recent studies regarding urban climatological assessment in Delhi. The present study considers varying land use/land cover in the grid network also helps in outlining many of the features with UHI in greater details.

2. ABOUT THE STUDY AREA DELHI

Delhi is one of the largest metropolitan cities in the world. It is located at 28.61 °N and 77.23 °E at mean sea level of 216 m. The climate is mainly influenced by its inland position and the prevalence of continental air during a major part of the year and has extreme climatic conditions. Summer months are characterised by intense heat and strong convection with light winds. However, occasional dust storms and rains may also prevail. The area of National Capital Territory of Delhi was divided into a grid network of 32 x 32 km constituting of 16 major grid cells of 8 x 8 km. Each grid was allotted at least one site for surface temperature measurements. In all, 30 sites were chosen throughout the city including 3 weather stations (WS) and 27 micrometeorological stations. The micrometeorological stations were chosen so as to represent a wide variety of land use/land cover categories. Broadly the stations can be classified into Urban Built Up areas, Green Areas, Open Areas and Riverside Areas.

3. EXPERIMENT DESCRIPTION AND WEATHER CONDITIONS

Temperature and humidity measurements were undertaken from 25 May 2008 (morning) – 28 May, 2008 (night extending to 29th May). The weather stations installed on roof tops of the buildings, gave information about various other meteorological parameters such as wind speed and direction, dry bulb temperature, atmospheric pressure, and global solar radiation. The first two days of the experiment were marked by intermittent rainfall and comparatively lower temperatures which are unusual for summer conditions. The minimum temperatures ranged from about 20°C to 22°C while the maximum temperatures ranged from 33°C to 37°C. During day time the solar radiation peaked up to 936 W m^{-2} (Figure 1). The major wind directions were observed to be North-West, West and South-West. The wind speeds during the experimental days ranged up to 3.6 m/s but usually conditions

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were calm. The rainfall conditions were envisaged to be useful in understanding the development of heat islands progressively from humid conditions at the beginning to the dry conditions towards the end days of the experiments.

4. URBAN HEAT ISLAND INTENSITY (UHI) ACROSS DELHI

To study the temperature distribution over the entire temperature monitoring network grid, temperature isopleths were constructed for all four days of the experimental phase for the specific times of 0300, 0900, 1500, and 2100 hours. The major UHI zones were observed in commercial centers and densely populated residential areas such as Sitaram Bazar, Connaught Place (CP), Bhikaji Cama and Noida. The UHI intensity is significant both during daytime as well as night and the rainfall has shown reduced UHI effects during rainfall hours.

4.1 UHI at Different Times of Day

Figure 2 represent isopleths for 0300 hour on 26th (B), 27th (C), 28th (D) and 29th May (E) respectively. The heat island intensity at this temperature epoch varies from 4.1°C to 5.2 °C. All the days depicted the lowest temperatures in the green areas. Also, it can be noted that the area under warmer regions as well as the difference between the lowest and highest temperature observed progressively increases from 26 May to 29 May at this hour. This can be attributed to rainfall on 25th and 26th May which lowered overall temperatures and as summer conditions were restored on 27th and 28th May, more and more urban canopies came under warmer zones. The high UHI pocket around Bhikaji Cama [Station No. 7] is localized only encompassing small area as the surroundings are not densely populated and there are green areas also in this zone. Moving towards the northeast from Bhikaji Cama, we have the warmest pocket in the entire study area i.e. the Cannaught Place-Sitaram Bazar zone [Station Nos. 14, 30]. This pocket not only has the highest UHI but also covers the largest area in comparison to other pockets on all days. The dense urban canopy of Sitaram Bazar and surrounding localities with major commercial complexes, densely populated residences and some of the busiest traffic intersections is the major cause behind building up of this heat island. The lower skyview factor in dense built up areas emitting less longwave radiation and trapping of heat at late night hours may result into higher temperatures in these areas. In addition to this, anthropogenic heat generated in commercial and densely populated areas may also result into higher temperatures in these localities in comparison to their surroundings. The riverside areas experience higher temperatures than green areas but lower than those of urban canopies in vicinity.

The afternoon hour of 3:00 pm represented conditions for maximum temperature. The difference between the lowest and highest temperatures in this hour ranged from 3.8 to 7.6°C. The zone of Cannaught Place-Sitaram Bazar observes higher temperatures on all experiment days except 26 May. On 26th may the rainfall resulted in lowering of temperatures and homogenization of the ambient temperature. All green areas like IIT [Station No. 2], Hauz Khas District Park [Station No. 28], forest of Sanjay Van [Station No. 25] and Buddha Jayanti Park [Station No. 8] fell under cooler pockets on all the days. Relatively higher temperatures during afternoon hours in comparison to the night hours in busy commercial and densely populated areas of the city could be due to higher anthropogenic heat emissions due to greater cooling and other energy requirements apart from the different surface radiative characteristics across the city.

The average UHI at transition hours of 0900 and 2100 hours was 5.4°C and 5.1°C respectively which is also comparable to UHI obtained at minimum and maximum temperature epoch. Again, Sitaram Bazar-Connaught Place zone formed a prominent heat island on all four days at these hours while the coolest pockets were usually observed in Sanjay Van-Hauz Khas Distt Park zone and Buddha Jayanti Park-Moti Nagar zone.

4.2. Relation with Atmospheric Stability, Rainfall Events and Wind Direction

Even though unstable and convective atmosphere during daytime is expected to facilitate temperature uniformity, the canopy structure of intense human activity with localized anthropogenic heat emissions in urban areas dominates the convective mixing thereby resulting in high magnitudes of many pockets of urban heat island intensity even during day time.
The morning hours of 26th May experienced rainfall for duration of roughly two hours from 9:00 am to 11:00 am. The maximum heat island intensity decreased from 8:00 am (3.7°C) to 10:00 am (2.2°C) and again increased at 12:00 pm (2.5°C) and continued later at 3:00 pm (3.8°C). The rainfall was observed to reduce the magnitude of heat island intensity. However, conspicuous pockets of varying UHI still existed that may be attributed perhaps to the uneven spatial and temporal distribution of rainfall across the city.

It was observed that for hours with comparatively higher wind speeds (2.5 - 3.8 ms^{-1}), the heat island zones roughly corresponded to the wind direction. Thus localized UHI pockets are influenced by the prevailing wind direction also. However the effect of wind direction could not be studied in detail due to prevalence of mostly calm conditions.

Table 1: Site Classification

Classification	Station No.
i). Urban Built Up Areas	
Dense Canopy	30
Medium Dense Urban Canopy -1	6, 7, 9, 10, 12, 14, 16, 17, 19, 20
Medium Dense Urban Canopy -2	4, 13, 24, 26, 29
Less Dense Urban Canopy	1, 2
Industrial Area	22
ii). Green Areas	8, 25, 28
iii). Open Areas	23, 27
iv). Riverside areas	11, 21

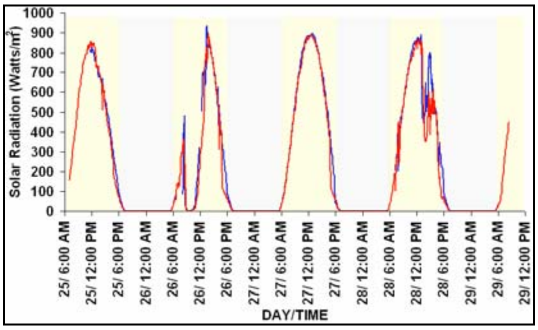

Figure 1: Solar Radiation at two Weather Stations during Experiment

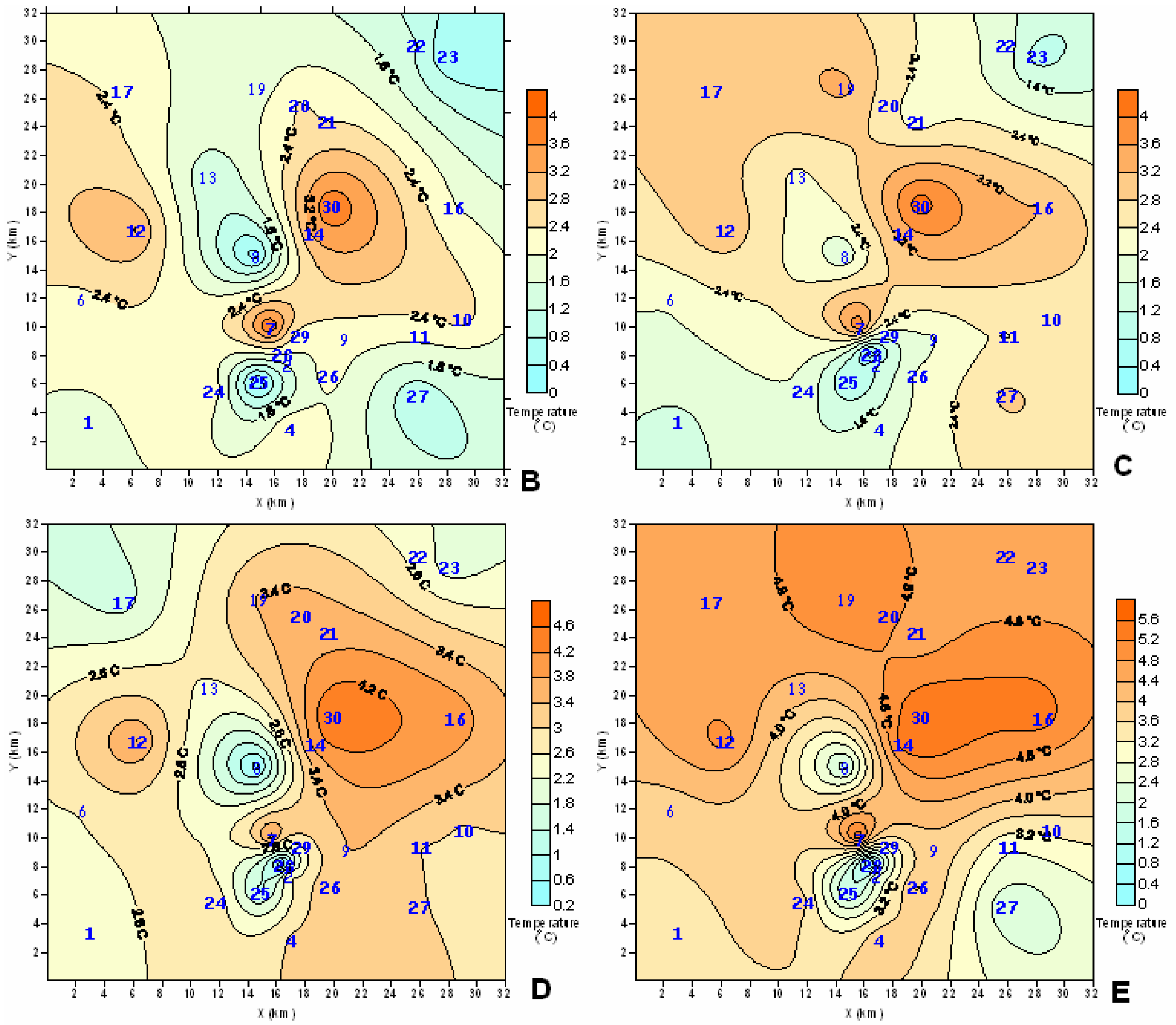

Figure 2: Isotherms for 0300 hours, B: 26th May, C: 27th May, D: 28th May, E: 29th May (Site Classification is given in Table 1)

5. DISCUSSIONS

The DELHI-I experiments were conducted for a span of few days only. The major part of the experiments were carried out in moderate summer conditions due to occurrence of rainfall, yet the heat island intensities obtained in the study were comparable to those observed in earlier studies. Moreover, very high UHI were observed in the later phase of the experiments when usual summer condition were restored. It seems plausible to assume that much higher UHI might have been obtained had the rainfall not occurred. Also the present study has showed that heat island effect need not be limited to a particular temperature epoch which signals towards the increasing dominance of anthropogenic heat emissions in rapidly developing cities such as Delhi. The results of the study undoubtedly call for implementation of mitigation measures along with the development of urban infrastructure to keep the heat island effect in check.

6. Conclusions

- The UHI intensity in Delhi is found to be more both in the night at 9 PM (2.8 °C to 8.3 °C) and afternoon hours at 3 PM (3.8 °C to 7.6 °C) respectively in comparison to early morning hours at the time of minimum temperature epoch (4.1°C to 5.6 °C). Considering that these were moderate summer conditions, the UHI obtained are reasonably high at various times of the day.
- During rainy conditions also city showed UHI in the range 2.2 °C to 3.7 °C
- The 3 top ranking UHI locations amongst the entire measurement network in the city are all commercial areas namely CP, Sitaram Bazar and Bhikaji Cama Place. Other pockets with reasonably high UHI are residential or mixed use namely Noida [Station No. 10], Dwarka [Station No. 6], Janakpuri [Station No. 12], Kaushambi [Station No. 16], Adarsh Nagar [Station No. 19] etc.
- Green and forest vegetation has a greater impact on lowering heat island effects as compared to a water body such as a river etc. in vicinity.
- The higher UHI around the time of peak temperatures in the city both in the afternoon hours and night hours increases the energy demand resulting into generation of more anthropogenic heat and thereby increasing the UHI. This would result into strengthening the vicious cycle problem which reinforces the need for urgent mitigation measures for urban heat centers.

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