Distribution of Temperature over the National Capital Territory of Delhi - A Preliminary Report

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ABSTRACT

The study of distribution of maximum and minimum temperatures over Delhi and neighbourhood from a dense network of 19 fixed weather stations found that during most of the months, the zones of warmest temperatures over the region were located in the thickly populated northeast and north districts of the territory. A secondary maxima was found over southern parts of the city. Lowest temperatures were found towards west and northwest of the city with a belt of low temperatures extending up to agricultural research form of the Indian Agricultural Research Institute. The patterns of distribution of both the maximum and minimum temperatures were similar. The maximum intensity of Urban Heat Island at maximum temperature epoch was found in the month of January (3°C) and that at minimum temperature epoch in the transition months of March (5.5°C) and October (4°C). The intensity was low during the monsoon months. Population density and prevailing winds seem to determine the temperature distributions over the area.

Keywords: *Urban heat island, maximum and minimum temperatures, gradient of temperature.*

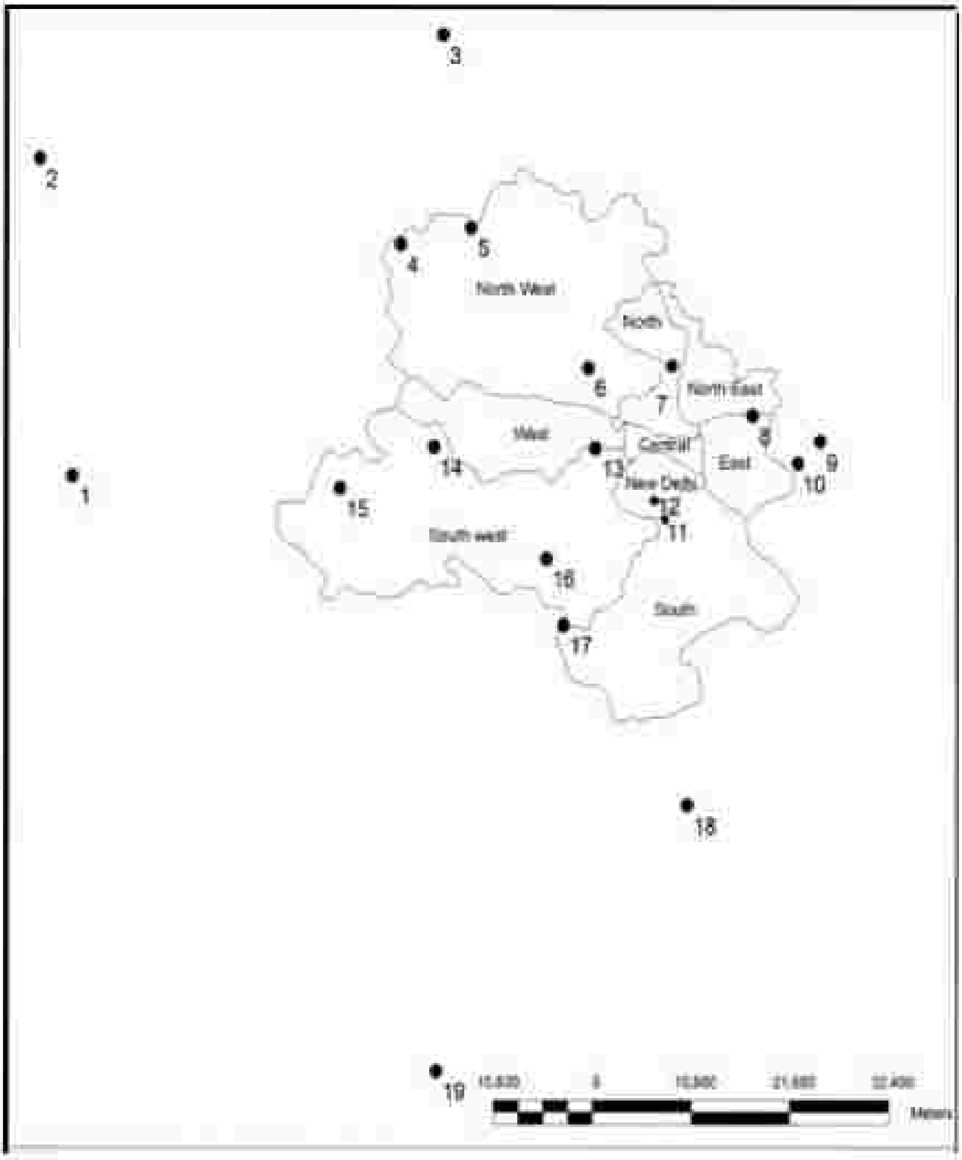
1. Introduction

The metropolitan areas are significantly warmer than their surrounding rural areas. Even within metropolitan areas, certain areas are warmer than others. These areas are called urban heat islands (UHI). The phenomenon was first investigated and described by Luke Howard in early 19th century (Howard, 1820). The temperature difference usually is larger at night than during the day, and is most apparent when winds are weak. Seasonally, UHI is seen during both summer and winter. The main cause of the urban heat island is modification of the land surface by urban development which uses materials which effectively retain heat. Waste heat generated by energy usage is a secondary contributor. As population centers grow they tend to modify a greater and greater area of land and have a corresponding increase in average temperature.

Not all cities have a distinct urban heat island. Mitigation of the urban heat island effect can be accomplished through the use of green roofs and the use of lighter-colored surfaces in urban areas, which reflect more sunlight and absorb less heat. Despite concerns raised about its possible contribution to global warming, comparisons between urban and rural areas show that the urban heat island effects have little influence on global mean temperature trends [Peterson et al., 1999].

There are several causes of an UHI. The principal reason for the nighttime warming is that buildings block surface heat from radiating into the relatively cold night sky. Two other reasons are changes in the thermal properties of surface materials and lack of evapotranspiration (through lack of vegetation) in urban areas. Materials commonly used in urban areas for pavement and roofs, such as concrete and asphalt, have significantly different thermal bulk properties (including heat capacity and thermal conductivity) and surface radiative properties (albedo and emissivity) than the surrounding rural areas. This causes a change in the energy balance of the urban area, often leading to higher temperatures than surrounding rural areas. (Oke, 1982). Other causes of a UHI are due to geometric effects. The tall buildings within many urban areas provide multiple surfaces for the reflection and absorption of sunlight, increasing the efficiency with which urban areas are heated. This is called the "urban canyon effect". Another effect of buildings is the blocking of wind, which also inhibits cooling by convection. Waste heat from automobiles, air conditioning, industry, and other sources also contributes to the UHI. High levels of pollution in urban areas can also increase the UHI, as many forms of pollution change the radiative properties of the atmosphere (Oke, 1982).

UHI studies have been carried out in India for a few cities. Bahl and Padmanabhamurty (1979) in a survey conducted over Delhi found warm packets over north and northeast Delhi and cold zones over west Delhi. Jayanthi (1991) in a study of heat island over Madras (now Chennai) found three distinct heat islands over thickly populated and industrial areas; and a relatively cool pool over the ventilated and vegetative areas of the city. The intensity of heat island on a cold night was found to be 2.2 degree C for Thiruvananthapuram by Gangadharan et al. (1999). Kumar et al. (2001) found that the heat islands in the city of Mumbai are located in the interior of the city. The maximum intensity was found to be as high as 12 degree C in winters. All these studies in India referred to above were carried out through mobile survey of the cities and the time of observations at all the observation points was not the same. Necessary corrections, however, were applied. Also the results were for individual days which might have been different from the mean conditions. Presently National Capital Territory of Delhi and its neighbourhood have a network of 19 fixed weather stations - both manual and automatic (Fig. 1). The data from which have been used with an objective of delineating warm and cold zones of the city averaged over the whole months.



1. Jhajjar (AWS)
2. Rohtak (AWS)
3. Sonepat (AWS)
4. Mungeshpur (AWS)
5. Narela (AWS)
6. Pitampura (AWS)
7. Delhi Ridge (Obsy)
8. Yamuna Sports Complex (AWS)
9. Indirapuram (AWS)
10. NOIDA (AWS)
11. Lodhi Road (Obsy)
12. Safdarjung (Obsy)
13. IARI (AWS)
14. Nazafgarh (AWS)
15. Jafarpur (AWS)
16. Palam (Obsy)
17. Ayanagar (Obsy)
18. Faridabad (AWS)
19. Nuh (AWS)

AWS - Automatic Weather Station

Obsy- Manned Observatory

Fig.1 District map of Delhi and observation network in the region.

2. Geographical Location of New Delhi

New Delhi, the capital of India, is located in northern India between the latitudes of 28°-24'-17" and 28°-53'-00" North and longitudes of 76°-50'-24" and 77°-20'-37" East (Fig. 2). Delhi shares borders with the States of Uttar Pradesh and Haryana. It has an area of 1,483 sq. kms. Its maximum length is 51.90 kms and greatest width is 48.48 kms. The Yamuna River and terminal part of the Aravali hill range are the two main physiographic features of the city. The Aravali hill ranges are covered with forest and are called the Ridges, they are the city's lungs and help maintain its environment. The Yamuna River flows through the eastern parts of Delhi. Delhi is bounded by the Indo-Gangetic alluvial plains in the north and east, by Thar Desert in the west and by Aravalli hill ranges in the south. The terrain of Delhi is flat in general except for a low NNE-SSW trending ridge which is considered and extention of the Aravalli hills of Rajasthan. The ridge may be said to enter Delhi from the SW. The eastern part of the ridge disappears below Yamuna alluvium in the NE on the right bank of the river. Ecologically, the Ridge acts a barrier between the Thar Desert and the plains and slows down the movement of dust and wind from the desert. This green belt, a natural forest, has a moderating influence on temperature, besides bestowing other known benefits on the people. Delhi is administratively divided into nine districts as given in Fig. 1.

3. Data and Methodology

Recently, a meso-network of automatic weather stations has been established in and around Delhi (Fig. 1). Daily observations from these stations are available for full one year (2010) now. Daily maximum and minimum temperatures from these stations were used to find the monthly averages of maximum and minimum temperatures which have been used in the present study. The results are presented for individual months categorized into four seasons - winter (January-February), summer (March-May), monsoon (June-September) and post-monsoon (October-December). The figures given in results section were prepared using Arc GIS 10 trial version. Temperature data of 19 weather stations distributed over and around Delhi were processed in spreadsheets as input for GIS analysis. These spreadsheets were then converted into feature class in defined spatial reference. Using the Topotoraster Geoprocessing tool, a surface was created by raster interpolation. This surface was then used as input for contour analysis. All the Geoprocessing tools were converted in to python script and edited to export the final output as temperature profiles.

4. Winter Season (January- February)

The lowest mean minimum temperatures in the city were recorded in West Central Delhi in the observatory situated in the Indian Agricultural Research Observatory (Pusa) for both the months. As this observatory is situated in the large agricultural research farm of the observatory close to the Central Ridge, it represents the typical rural settings. A tounge of low temperatures also extends towards Delhi from the southwest. Warmest temperatures are found in the east and northeast of the city. A belt of high temperature extends from northeast into North and northwest district (Fig. 2a and 2b).

The distribution of maximum temperatures was also similar to that of the minimum temperature with the lowest temperatures in the Pusa- Central Ridge zone with a tounge of low temperatures extending from southwest. Highest temperatures were found in the east and northeast of the city (Fig. 2c and 2d).

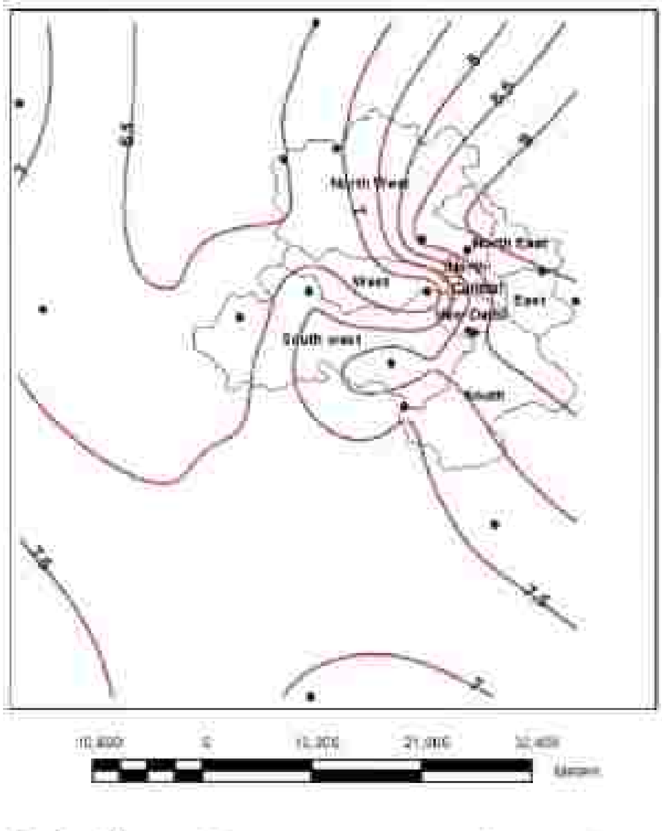


Fig.2a Mean minimum temperature (January).

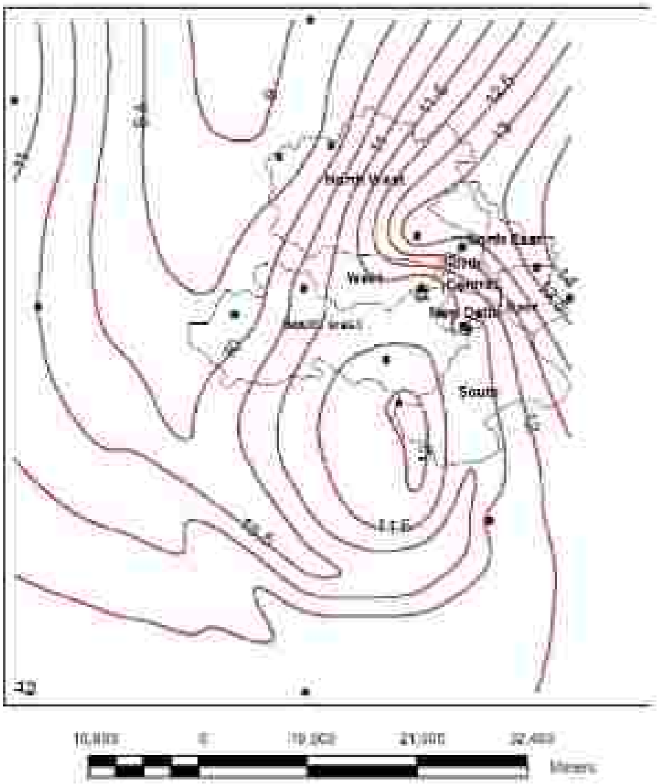


Fig.2b Mean minimum temperature (February).

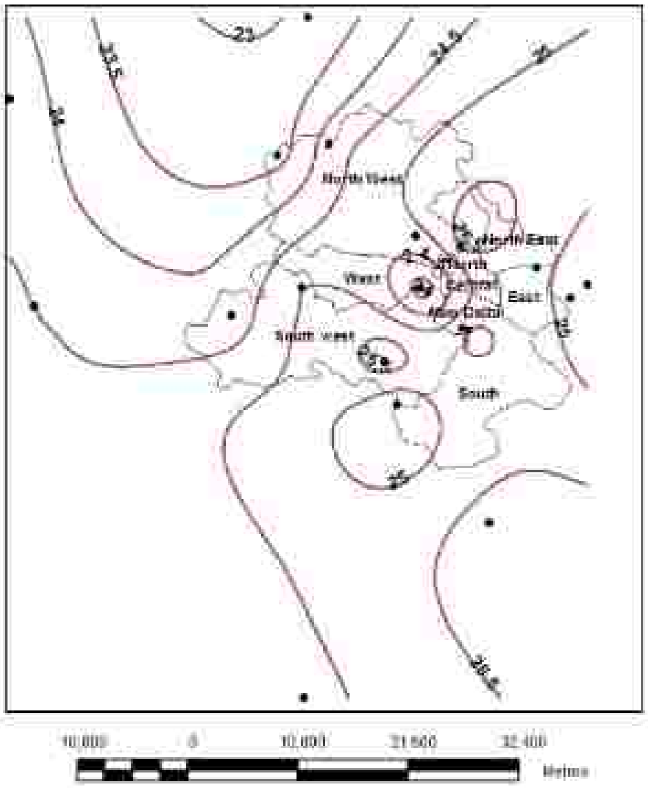


Fig.2d Mean maximum temperature (February).

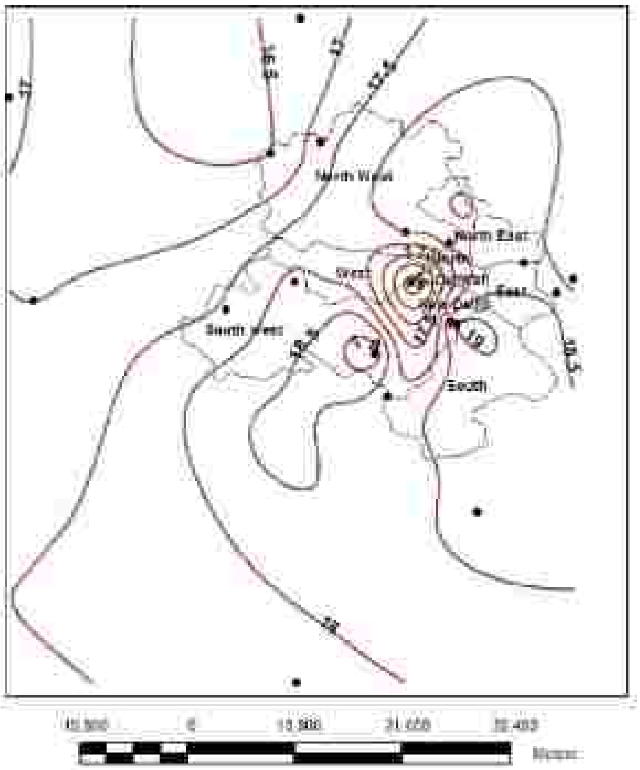


Fig.2c Mean maximum temperature (January).

5. Pre-Monsoon Season (March- May)

Generally, the temperatures start rising over entire northwest India from the month of March. Meso-analysis of temperatures over Delhi and neighbourhood shows that the lowest maximum temperatures in the month of March are to the north and northwest of Delhi. A narrow tongue of low temperatures extends from east into central parts of the city. The maximum temperatures are highest over northeastern and southwestern parts of the city. The pattern of maximum temperature distribution remains the same during April and May. There is a general increase of about 7-8°C from March to April. Further increase from April to May was not found to be only about 1-2°C. The gradient of temperature in and around the city is the steepest in March; and it generally slackens as the season progresses into April and May (Figures 3a, 3b and 3c).

The minimum temperatures are again the lowest in north and northwestern and highest in northeastern parts of the city. The belt of warmest temperatures extends from northeastern parts into the northern parts of Central Delhi. The area of lowest temperatures is found in the northwest corner of the city. It extends through the western parts into west- central Delhi where the observatory located in the research farm of the Indian Agricultural Research Institute (IARI). As the observatory is situated in middle of large agricultural research farm it records lower temperatures. A belt of relatively higher temperatures is also found in the south- southwestern parts of the city. The pattern of minimum temperatures during the months of April and May is similar to that of March with northeastern parts of the city being the warmest and northwestern parts of the coldest. The gradient of minimum temperature also slakens with progress of the season as is the case for maximum temperature. The general increase is 7-8oc from March to April and 3-4oc from April to May (Fig. 3d, 3e and 3f).

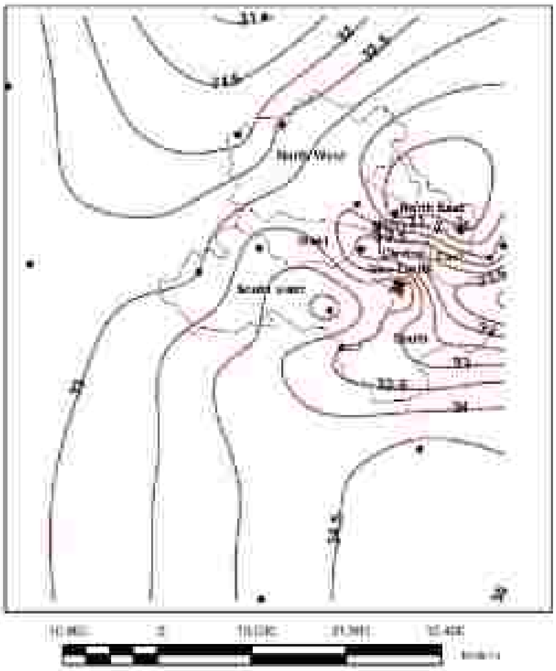


Fig.3a Mean maximum temperature (March)

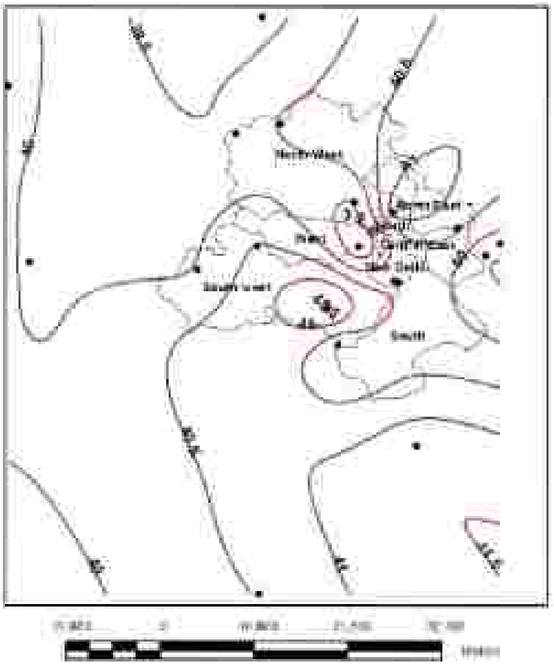


Fig.3b Mean maximum temperature (April).

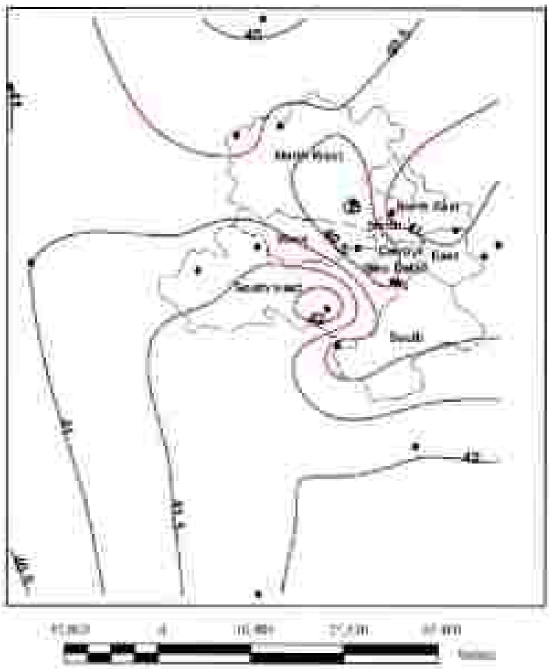


Fig.3c Mean maximum temperature (May).

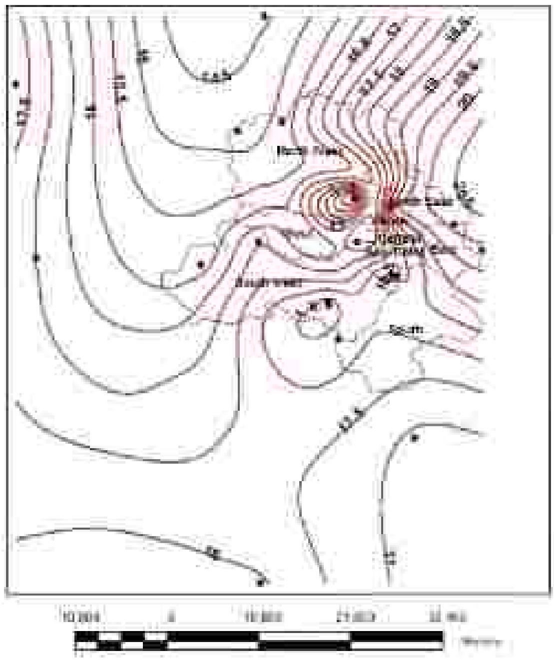


Fig.3d Mean minimum temperature (March).

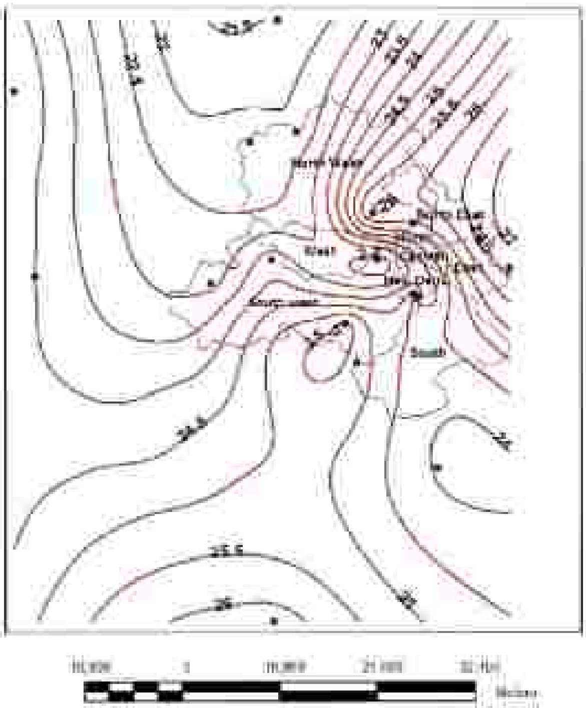


Fig.3e Mean minimum temperature (April).

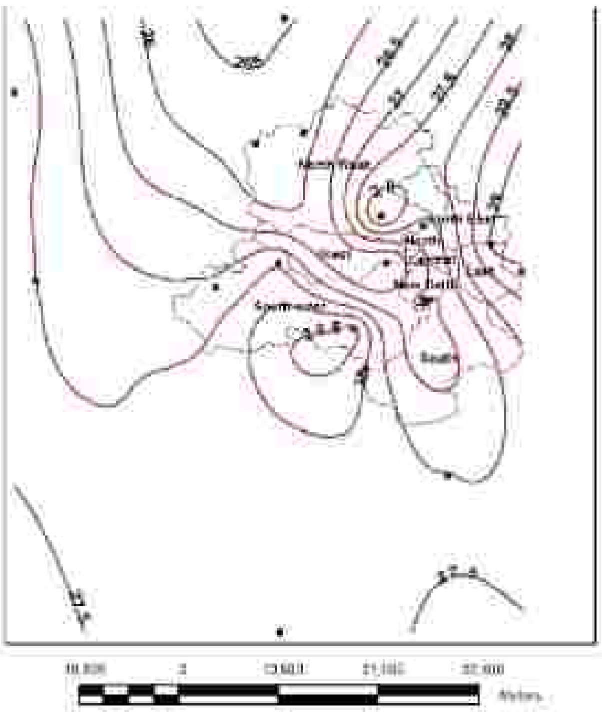


Fig.3f Mean minimum temperature (May).

6. Monsoon Season (June-September)

There is not much difference in magnitude of maximum temperature from May to June. The distribution over and around the city is also broadly similar for the two months. A zone of highest maximum temperature is found in north and northeast of the country. There is another area of high temperatures in southwestern parts of the city. Like many previous months, the zone of lower maximum temperatures extends from northwest of the city upto the west- central parts (IARI). Another zone of low maximum temperatures is found in southeastern parts of the city.

As the monsoon sets in the average maximum temperatures fall to about 34oc in the month of July. The distribution also becomes flat with reduced gradient over the city. The areas of warmest temperatures of more than 35oc are located in southwestern parts with a small pocket in northern parts of the city. Small pockets of relatively lower temperatures are located in the northwest, west-central and southeastern parts. The distribution flattens further in August with most parts of the city having temperatures between 33 and 33.5oc. Small pockets of temperatures lower than 33oc are located in northwest; northeast and southeastern parts of the city. The maximum temperature distribution in September over the entire city is within half a degree C (31 and 31.5oc) (Fig. 4a, 4b, 4c and 4d).

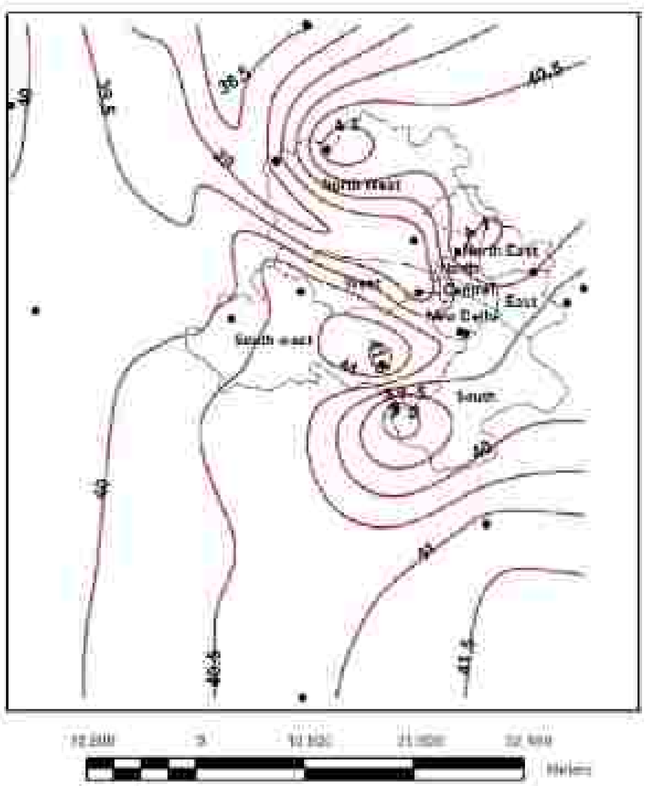


Fig.4a Mean maximum temperature (June).

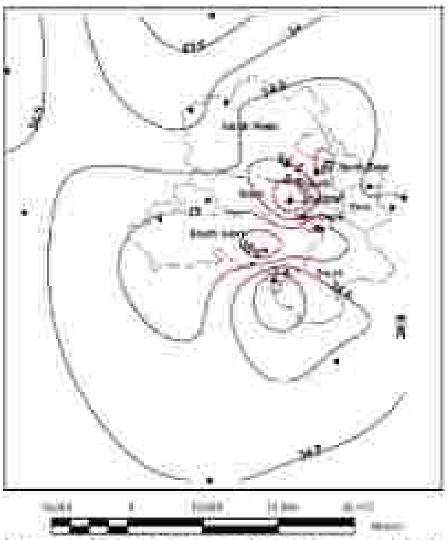


Fig.4b Mean maximum temperature (July).

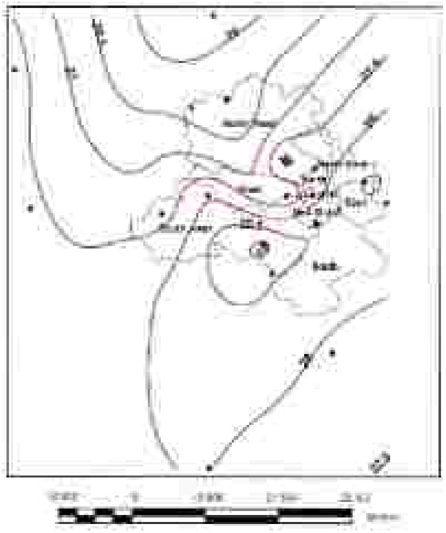


Fig.4e Mean minimum temperature (June).

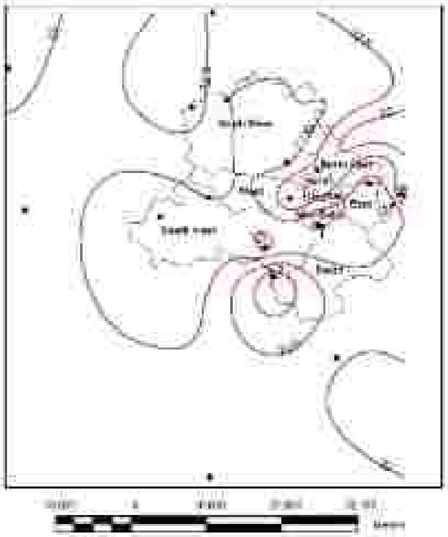


Fig.4c Mean maximum temperature (August).

Fig.4f Mean minimum temperature (July).

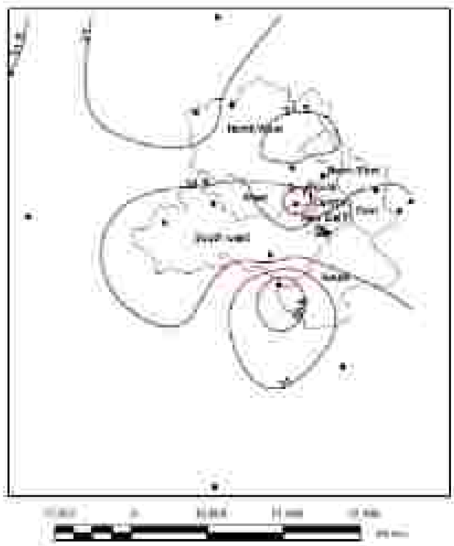


Fig.4d Mean maximum temperature (September).

Fig.4g Mean minimum temperature (August).

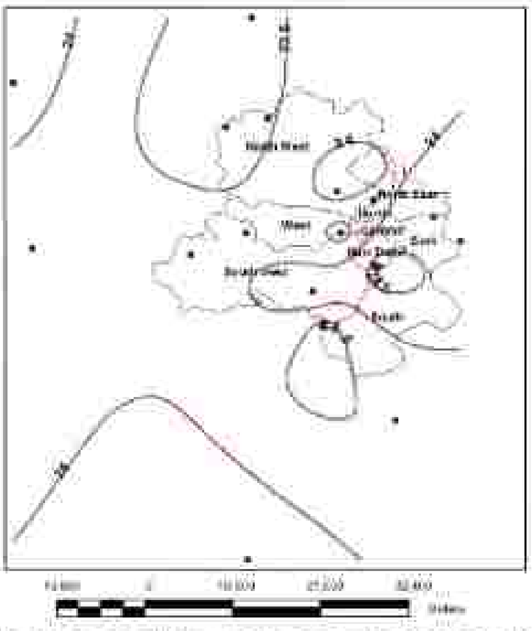


Fig.4h Mean minimum temperature (September).

7. Post-Monsoon Season (October-December)

During the post monsoon season also, the maximum temperatures increase from northwest to east of the city. The area of lowest temperatures in all the three months extends from northwest of the city upto IARI where a zone of lowest temperature exits. Another area of low temperatures is located to the south of city in all the months. The zone of warmest temperatures in October extends from southwest to central and then to northern parts of the city. The belt of high maximum temperatures during the months of November and December extends from southeast to central and then to northern parts of the city (Fig. 5a, b and c).

The distribution of minimum temperatures is also similar to that of maximum temperature with the belt of minimum temperatures extending upto west-central parts (IARI) from northwest of the city with a secondary zone of low minimum temperatures in south. The highest minimum temperatures in all the three months area found in north eastern parts of the city (Fig. 5d, e and f).

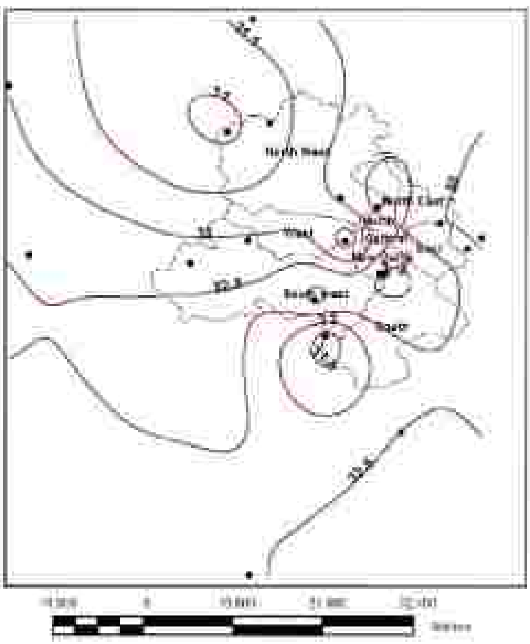


Fig.5a Mean maximum temperature (October).

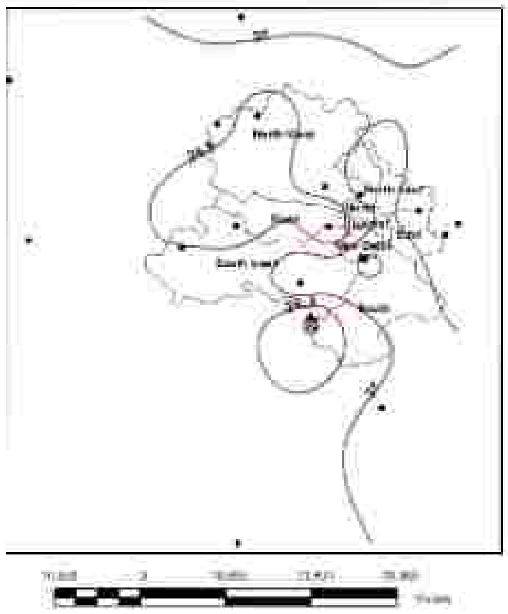


Fig.5b Mean maximum temperature (November).

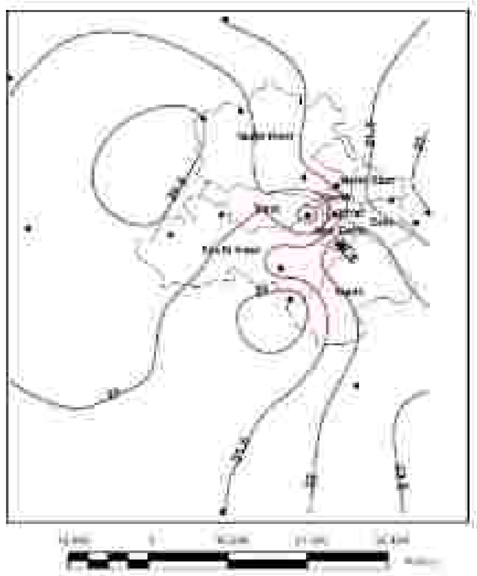


Fig.5c Mean maximum temperature (December).

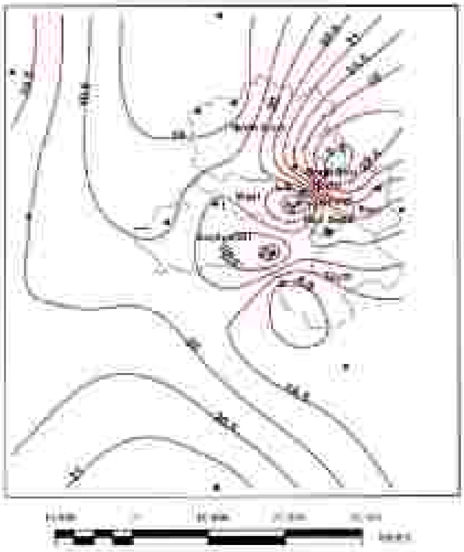


Fig.5d Mean minimum temperature (October).

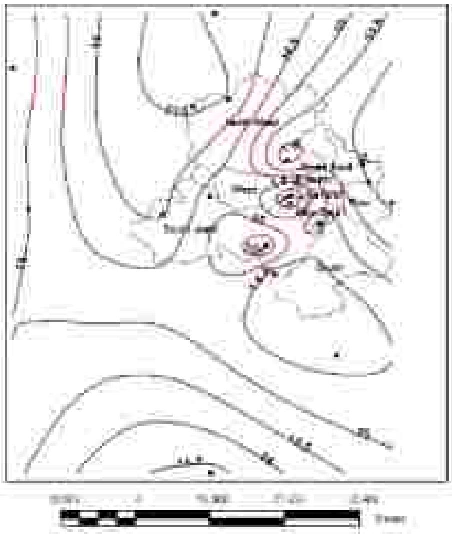


Fig.5e Mean minimum temperature (November).

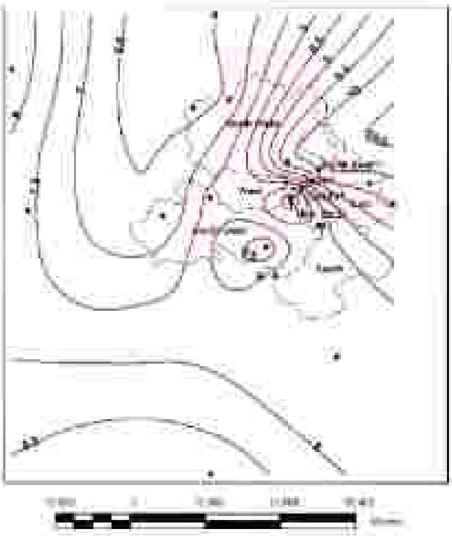


Fig.5f Mean minimum temperature (December).

8. Summary and Discussion

During most of the months, the pockets of highest maximum temperatures during the day were found in northeast, central and south eastern parts of the city and those of the lowest maximum temperatures over northwest parts of the city. The belt of lower maximum temperature extended to west central parts up to the IARI area. The pattern for the month of august was found to be different from other months as belt of lower maximum temperature extended from northeast in to central and up to west central parts of the city. The average monthly intensity of the UHI at the time of maximum temperature epoch (Table 1) was the highest during January (3°C). It was 2°C to 2.5°C from February to June .The intensity decreased to 1.5°C during the monsoon months of July to September. It was found to be the lowest (1°C) during November.

The pattern of minimum temperature distribution was also similar to that of the maximum temperature. The highest maximum temperatures were recorded in the northeast and northern parts of the city with secondary maxima over southwest. The lowest minimum temperatures were found over northwestern parts of the city with their belt extending up to IARI area where a secondary minima was observed. The intensity of the UHI at minimum temperature epoch was found to be highly variable between different months (Table 2). It was found to highest in the transition months of March (5.5°C) and October (4.0°C). The lowest intensity was in the monsoon month of July to September (1 to 1.5°C).

The pattern of mean monthly UHI found in the present study has been similar to that reported by Bahl and Padmanabhamurty (1979). They have also reported the highest temperatures over north and northeast of Delhi with secondary maxima over southwestern parts in the surveys conducted during four nights in the month of December, January February and March. The intensity of UHI reported by them was 4°C during the month of December and February; and 6°C during January and March. The intensity however, has been found to be the lowest during January in the present study. The different could be because of the reason that the result reported by Bahl and Padmanabhamurty (1979) are for individual nights whereas those in the present study are the means for each of the month.

One of the main reasons for consistently hotter temperatures over northeast and east districts could be the higher population density in these districts (http://www.censusindia.gov.in/2011-prov-results/data_files/delhi/3_PDFC-Paper-1-tables_60_81.pdf). The coldest temperatures to the northwest could be because of the reason that the prevailing winds during major part of the year (except monsoon season) are from the northwest. Also the large agricultural research farm of the IARI and the nearby location of the reserve forest of the central ridge provide the relatively greener and wetter microclimate, keeping the area cold.

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