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Heat island studies at Delhi

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ABSTRACT. Mobile temperature surveys were conducted in Delhi during the winter months in the early hours of 18 December 1976, 29 January 1977, 26 February 1977 and 26 March 1977. The surveys show the formation of heat island within the thickly populated walled city encompassing areas from Delhi Gate, Chandni Chowk to Ajmeri Gate. Secondary, 'heat islands' in the trans-Yamuna area and near Yusaf Sarai area in South Delhi are also found. The maximum temperature difference between the warmest part of the city and the coldest area of the suburb was nearly 5°C during December which increased to nearly 7°C in the months January to March.

1. Introduction

Urban agglomerations, because of the buildings and topography, are capable of creating their own climate, different from that of surrounding rural areas. Of the many meteorological parameters that are affected by urbanization, temperature anomalies are widely reported (Landsberg 1962, Chandler 1965, Padmanabhamurty and Hirt 1974, Vukovich *et al.* 1976, Nkemderim 1976). It is a common experience that central parts of cities are warmer than the rural areas particularly at night which is often referred to as the "urban heat island". The main factors that contribute to this warmer temperature in cities are (*i*) heat storage by buildings and pavements, (*ii*) heat generated artificially by combustion processes such as from industrial, domestic, transportation and human resources, (*iii*) increased turbulence due to increased roughness of the built-up area and due to automobile traffic and (*iv*) pollution over the city. These factor sare of varying importance in different cities. Their combined effect, however, results in the formation of the "heat island" which varies in intensity from city to city and from season to season. A detailed study of the temperature field over cities and its rural environs will facilitate a better understanding of the imbalances in dispersion of atmospheric pollutants in the lower atmosphere.

Mapping of urban temperature fields have been conducted in the recent past to show the formation of "heat island" in some Indian cities, *viz.*, Pune and Bombay by Daniel and Krishnamurthy (1972) and Philip *et al.* (1974). The conclusions of the study appear to be interesting in relation to urban pollution distribution. In an attempt to locate the warm pockets and cold pools to identify the meso-scale circulations that are responsible to transport pollutants from high pollution zones to low pollution areas, mobile surveys of temperature were conducted at Delhi during the last winter months. In this paper are presented temperature fields in and around Delhi at the minimum temperature epoch during four months (December 1976-March 1977). During the surveys the skies were mainly clear and winds light.

2. Meteorological features of Delhi

Delhi city with a population of 60 lakhs and encompassing an area of 1485 sq. km is the source of the study. Mainly located on the right bank of *Yamuna* river, it consists of two towns (*i*) Old Delhi at the centre with densely populated built-up area and congested market centres and (*ii*) New Delhi with its broad shady avenues and spacious parks and planned construction around old Delhi. Delhi with a semi-arid type of climate, is mainly characterised by its inland posi'ion and prevalence of air of continental origin during the major part of the year except in the rainy season when maritime air holds sway. During winter, the most predominant direction of surface wind is W to NW with speed 4-8 knots. In the wake of western disturbance during winter, temperatures drop low, sometimes causing cold waves.

3. Data collection

The heat island effect is most prominently noticed around the minimum temperature epoch. Generally the time between 0100 IST and sunrise will indicate very little variation in temperature. Temperature observations taken by mobile teams during this period of time when the temperature curve is generally flat is considered to be the best substitute for a very close network of observing stations requiring considerable manpower and equipment. Mobile temperature surveys at Delhi were, therefore, conducted by two teams simultaneously on each occasion on 18 December 1976, 29 January 1977, 26 February 1977 and 26 March

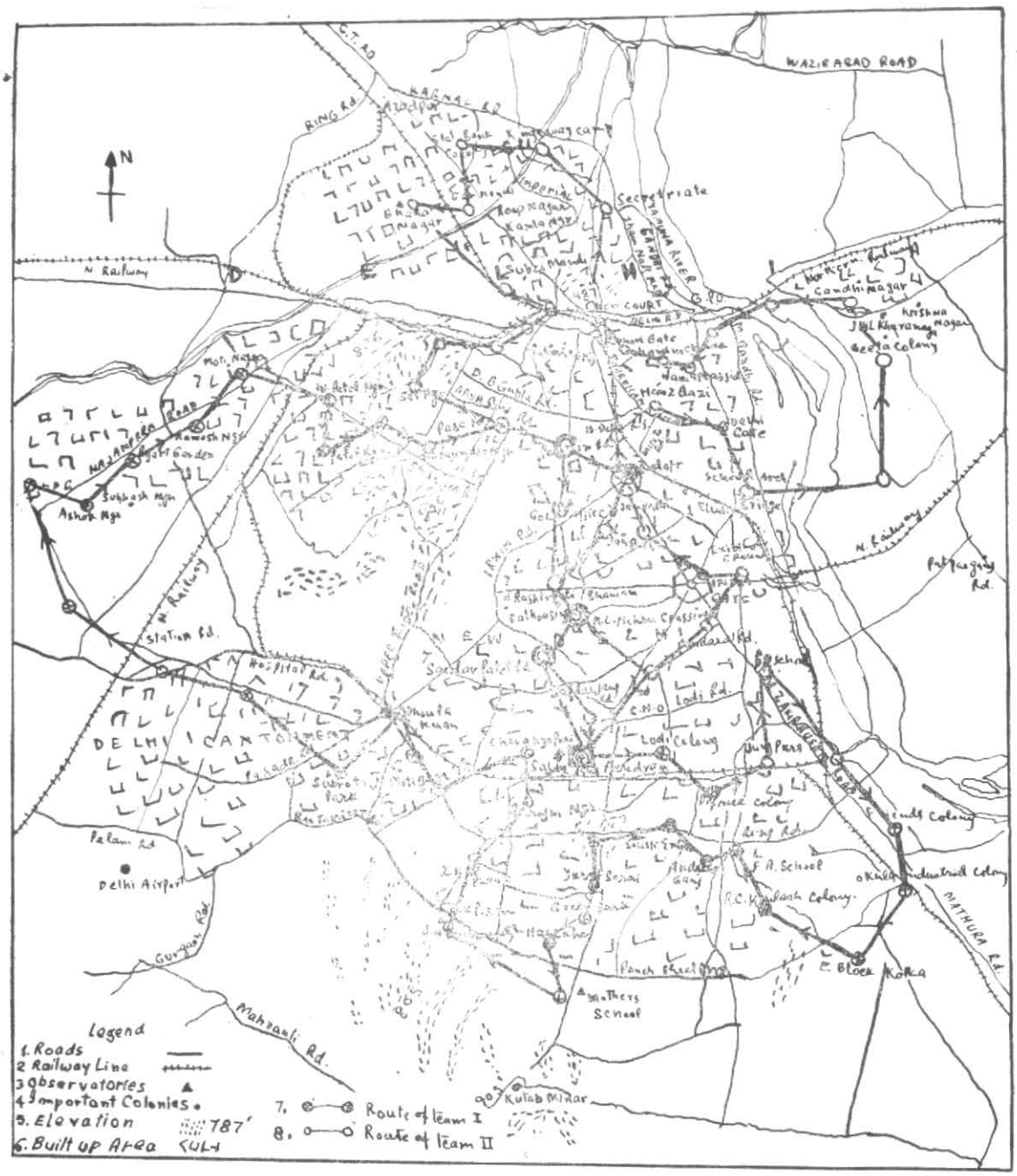

Fig. 1. Topography and survey routes

1977 by starting and ending the circuit at Safdarjung Airport Observatory where the pre and post comparison of psychrometers with the screen thermometers were carried out. The total number of points of observations were about 85 on each of these surveys, covering the whole of Delhi including the trans-Yamuna colonies as the experimental area. The points were predetermined and chosen in such a way as to ensure adequate coverage of the main urban area and portions of the suburbs. At each point of observation, temperatures were taken with calibrated and inter-compared whirling psychrometers and time of observations noted with the help of synchronised watches. The wind speed and direction were also estimated at each observation point. The psychrometers were exposed for about 2 to 3 minutes at each point on the survey route. In order to make corrections for the small temperature trend during the period of survey, thermographs were installed at representative locations. The observations taken at each of the points were reduced to

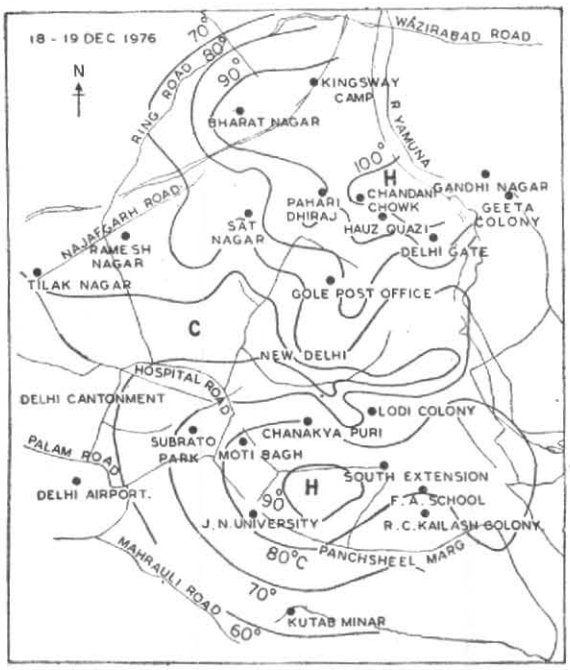

Fig. 2. Sky clear, wind calm

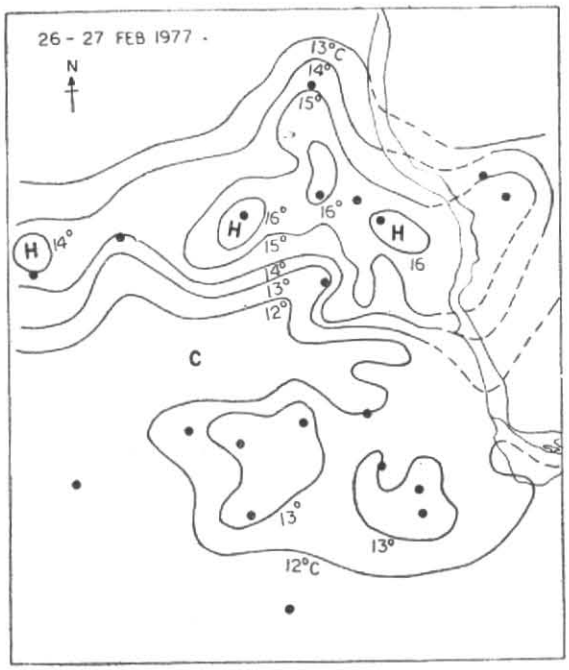

Fig. 4. Sky mainly clear, 5/8 *Ac*, wind variable 2-8 kmph.; calm in the morning

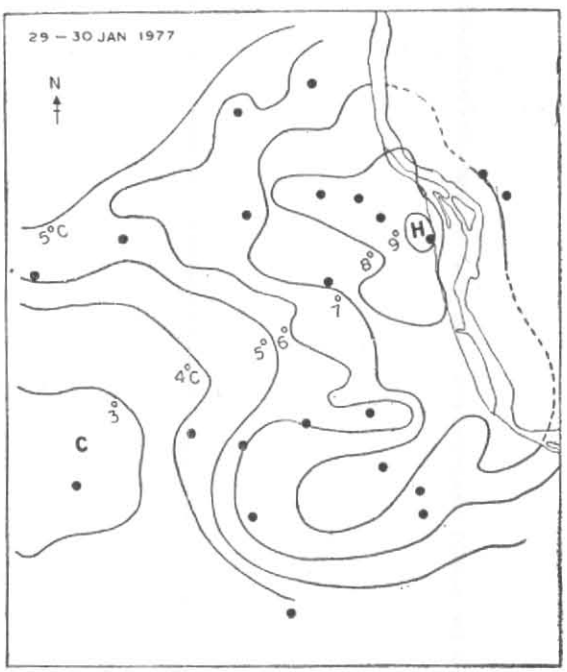

Fig. 3. Sky partly cloudy, wind NW/6-8 kmph

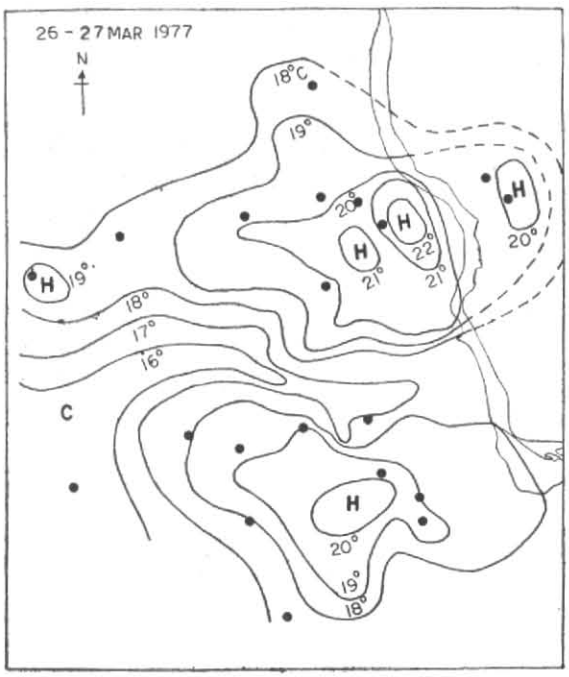

Fig. 5. Sky 1/8 high clouds; wind calm to NW/4-6 kmph

Figs. 2-5. Isothermal analysis at Delhi at minimum temperature epoch

minimum temperature epoch by applying the trend correction so as to render them quasi-simultaneous. The reduced temperatures were then plotted on maps and analysed taking the topography and wind into account. Fig. 1 is the topographic and locator map of Delhi. The routes followed by the survey parties are also indicated therein. Figs. 2 to 5 show the patterns of isotherms at the minimum temperature epoch on the nights of 4 surveys.

TABLE 1

Intensities of heat island and associated weather conditions

Date	Heat island intensity (°C)	Wind speed/ direction	Clouds	Synoptic feature
18-19 Dec 76	4·9	Calm	Clear sky	—
29-30 Jan 77	6·8	6-8 kmph NW	Sky partly cloudy with *Ci*	Western disturbance during 21-26 Jan
26-27 Feb 77	6·9	6 kmph/N to ENE & then southerly. Calm early morning	Sky more than half covered with *Ac*	—
26-27 Mar 77	6·9	Calm to 4-6 kmph/ NW	Sky partly cloudy with *Ci*	Dust haze

4. Discussion

The surveys made at Delhi on 4 dates, *viz.*, 18 December 1976, 29 January 1977, 26 Feburary 1977 and 26 March 1977 represent mainly the cold weather period and the surface 'heat island' intensity is most important as it provides the driving force for horizontal pollutant transport since vertical transport is inhibited by stable/inversion layers. The intensities of heat island obtained during the surveys along with the details of sky condition, average wind speed/direction and synoptic situation on every survey night are given in Table 1.

It will be noticed that during these surveys the 'heat island' is invariably within the thickly populated walled city extending from Delhi Gate, Chandni Chowk to Ajmeri Gate. The position of the main 'heat island' in this area was confirmed in the subsequent surveys. Secondary 'heat islands' have also been observed in the trans-Yamuna area and near Yusaf Sarai area in south Delhi wherever close groups of buildings appear in vast open areas. The coldest area observed in these surveys was towards western Delhi between Delhi Cantonment and Palam. The isothermal patterns indicate the penetration of the cold air from west to east upto river bed. The difference in temperature between the warmest part of the city and coldest area of the suburbs was nearly 5°C during December and increased to nearly 7°C during the months of January to March.

Topography and river have their own share in modifying the urban climate of Delhi. Close network of observations in February and March showed several warm pockets extending from Geeta Colony to Tilak Nagar through Hauz Kazi, Pahari Dhiraj area and Sat Nagar which are closely skirting the *Yamuna* river flowing through eastern Delhi and the Najafgrarh Nalla towards northwest Delhi. This effect is even noticed in the surveys of December/January in a subdued form. The existance of main heat island at Delhi Gate and of warm pocket at Geeta Colony in the west and east of *Yamuna* river seem to be influenced due to the proximity to the river which tends to increase in surface humidity and consequent reduction in radiative cooling of the lower layers over this area.

The katabatic flow of air from the ridge is considered influencing the spreading of cold tongues around the ridge in the February/March surveys, particularly towards Gole Post Office, Ramesh Nagar and towards east and south. The formation of warm pockets at Sat Nagar (Fig. 4) and Yusaf Sarai also appear to be due to katabatic flow of air from Ridge and from high elevations in southsouthwest Delhi respectively.

5. Conclusions

(*i*) The temperature excess of the urban area over the rural surrounding in the case of Delhi in the early mornings during cold weather period is of the order of 5°C in December and 7°C in the months of January to March.

(*ii*) The 'heat island' is generally found over the congested and closely built-up Old Delhi area extending from Delhi Gate-Chandni Chowk to Ajmeri Gate in the heart of the city and having the maximum human activity. The exact shape and the location of the 'heat island' varied slightly from month to month in cold weather period depending upon prevailing wind, local influences and terrain conditions.

Acknowledgement

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