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Isotherms and isohumes in Pune on clear winter nights : A mesometeorological study

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ABSTRACT. Results of two temperature mobile surveys conducted during clear, calm winter nights at Pune are presented. Warm pockets existed wherever agglomeration of buildings existed. Twin heat islands are noticed in Pune on either side of the river. Isohumes followed the same pattern of isotherms except *vice versa* in magnitudes. Isohumes and isotherms exhibited double peaks-one, four hours after sunset and another at the minimum temperature epoch.

1. Introduction

That the centre of a city is warmer than its environs forming a 'heat island' has been well known but yet continues to receive considerable attention in the literature. Landsberg (1962), Chandler (1965), Oke (1973), Padmanabhamurty and Hirt (1974) and several others documented heat island intensities under diverse meteorological conditions and geographical locations. Philip, Daniel and Krishnamurthy (1974) also showed the formation of heat islands in some Indian cities during clear months.

Heat island is not an instantaneous phenomenon but progressively develops following sunset. The growth and intensity of heat island depends upon the cooling rates of urban and rural environments (Oke *et al.* 1972). Because of the markedly different surfaces the rates of cooling of urban-rural environs differ widely and the growth of the heat island intensity varies with time of the night. In the present paper the results of two temperature mobile surveys pointing the growth of urban heat island in size, shape and intensity from sunset to sunrise on a clear, calm winter nights are presented. Greater Pune, a city of some 1.5 million located at the confluence of *mula-Mutha* rivers and encompassing an area of some 75-85 km^2 is used as the area source.

2. Methodology

Mobile temperature surveys were conducted employing calibrated whirling psychrometers. The period of survey (a few hours) was chosen near the time of the minimum temperature, when the temperature curve is flat. The survey was started from a suitable point in the city and successive values of temperatures at a number of predetermined points were obtained by moving in a vehicle. The survey was concluded by taking another observation at the first point thus completing the circuit. The observations were then interpolated to a common time by applying a small correction for trend obtained from thermograph records run at some locations in the experimental area. These temperatures reduced to minimum temperature epoch were analysed and the heat island intensity was determined.

3. Data collection

Bihourly dry and wet bulb temperatures were collected using calibrated whirling psychrometers from 2000 IST to 0400 IST and hourly observations subsequently till 0700 IST at 16 points evenly distributed and covering diverse localities and surfaces in Greater Pune. Minimum temperatures recorded at 7 urban climatological stations supplemented the above data. Seven thermographs operating at varying topographical locations from 2000 to 0700 IST served to correct the mobile survey temperature observations for trend. Mobile survey temperatures were obtained from 27 points. After applying appropriate correction, temperatures and humidities were plotted for 2000, 2200, 2400, 0200, 0400, 0500, 0600 and 0700 IST and for the minimum temperature epoch. The temperature network density at minimum temperature epoch is 55 but at other times it

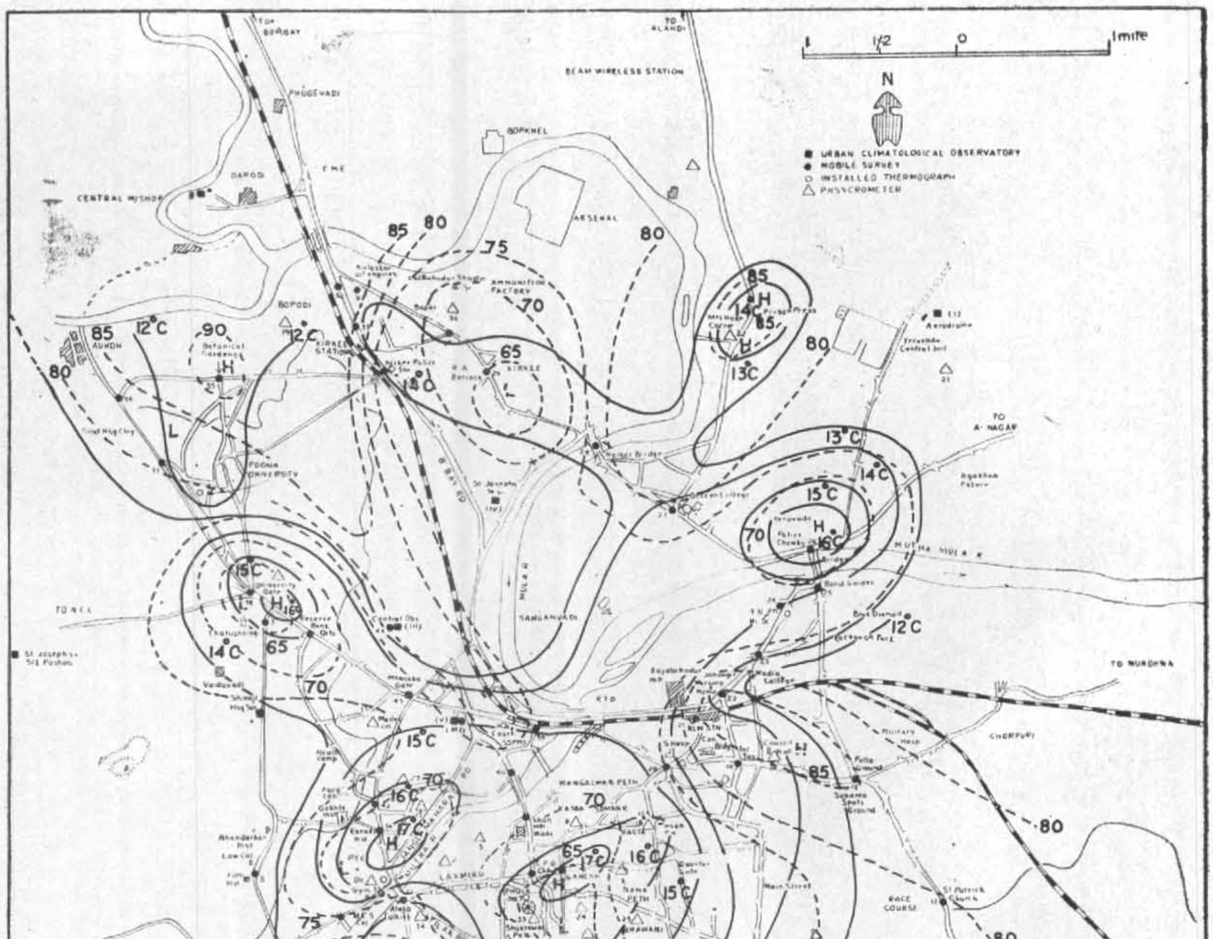

Fig. 1. Isohumes and isotherms at minimum temperature epoch 0600 hr on 8 Dec 1974 at Pune city, Pune Cantonment, Kirkee and Kirkee cantonment

limited to 23, *viz.*, psychrometer and thermograph values. While trend correction for temperatures was applied from thermographs, humidity trend was applied utilising the variation of relative humidity at sixteen psychrometers locations. The relative humidity network was sixteen at all times except at minimum temperature epoch when it was 43. While drawing isopleths of either temperature or relative humidity extreme care has been taken so that continuity in shape and size is maintained in respect of both islands.

4. Results

Development of heat islands — Two heat islands are noticed on either side of the river from 2000 IST

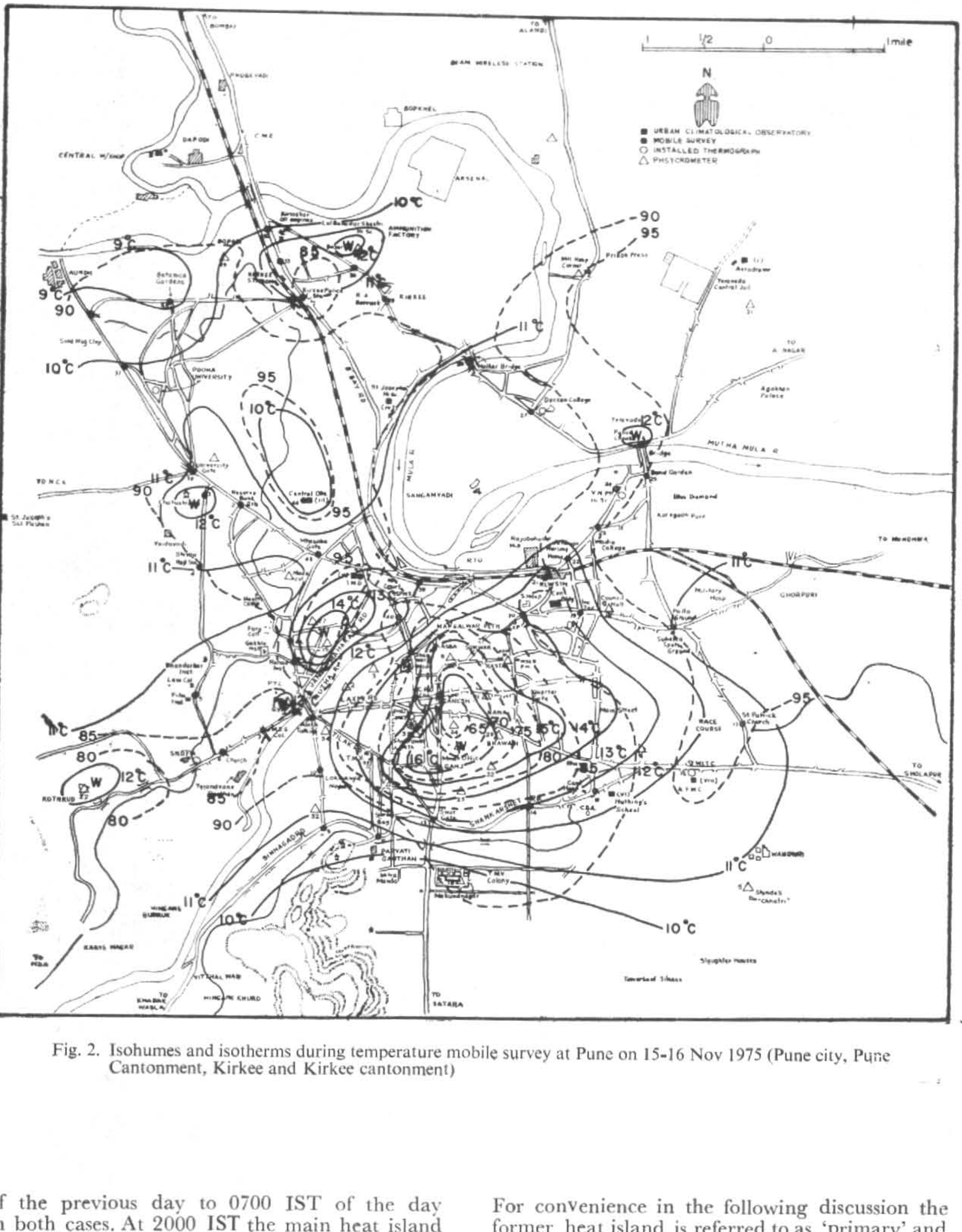

Fig. 2. Isohumes and isotherms during temperature mobile survey at Pune on 15-16 Nov 1975 (Pune city, Pune Cantonment, Kirkee and Kirkee cantonment)

of the previous day to 0700 IST of the day in both cases. At 2000 IST the main heat island in the city encompassed a large area, elliptically shaped and the major axis oriented along NW-SW. The second heat island on the other side of the river at Deccan Gymkhana too covered wide area, elliptically shaped with its major axis oriented parallel to river in NE-SW direction. For convenience in the following discussion the former heat island is referred to as 'primary' and latter as 'secondary'. At 2200 IST the 'primary' intensified and slightly shifted with major axis in E-W. The 'secondary' was confined to a small area. The isotherms became organised by this time of night. Isohumes continued to follow the isothermal pattern till the end of the survey

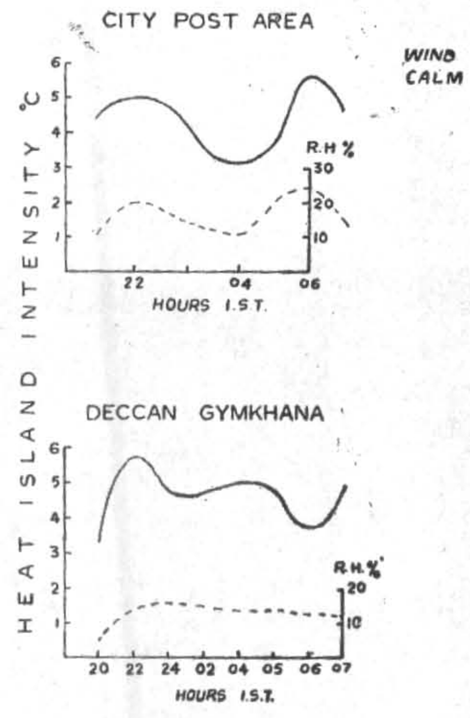

Fig. 3. Calm wind, 7-8 December 1974

Isohumes and isotherms at minimum temperature epoch — Figs. 1 and 2 show the pattern of isotherms and isohumes at the minimum temperature epoch on 8 Dec '74 and 16 Nov '75. There are several heat pockets and cold pools. The main heat island elliptically shaped covers a small area in the city with the major axis oriented NE-SW running parallel to the river. The twin heat island on the other side of the river is also elliptical with major axis parallel to the river in NE-SW direction. Isotherms encircling these twin heat islands bend inwards when cold air rushes from sub-urban/rural areas. The density of isotherms is low in the built-up area but high at transition points like land/water/green vegetation surfaces. Several heat pockets are noticed whenever a built-up area comes across rural open ground.

It can be seen that average relative humidity in the town is several per cent lower than that of surrounding rural areas confirming Landsberg (1962), Sasakura (1965) and Chandler (1965). The main reason for the difference in humidity of Pune urban-rural areas is that the evaporation, in the city is lower than that in the country because of the markedly different surfaces and lack of evaporation sources in the city.

Patterns of isohumes in Pune mostly resemble those of isotherms (Figs. 1 and 2) for the spatial temperature changes of the city are significantly greater than those of vapour pressure. Because of the heat island relative humidities in Pune are lower than the suburbs and outlying areas. The humidity differences are greatest at the time of greatest heat island intensity (Fig.3). Relative humidity variations in Pune are found to depend upon the shape of city's heat island which in turn depends upon the density of the built-up areas. Chandler (1962, 1967) working at London and Leicester (England) reported typical humidities of 90 to 100 per cent in rural areas during conditions favourable to heat islands formation, whereas in the heart of the city humidity values were approximately 70 to 80 per cent. In the present survey too sub-urban/rural relative humidities of 90 per cent or more and city relative humidity of 65 per cent a difference of 25 per cent are found. Because of the temperature difference, when the magnitude of heat island is small the urban-rural humidity differences would be small (Fig. 3.). Under meteorological conditions conducive to heat island formation, variation of humidity within the city often directly corresponds to building density (*see* 65 to 70 per cent isohumes in 'primary' and secondary' heat island areas).

March of heat and humidity island intensities — March of heat and humidity island intensities at the 'primary' and 'secondary' locations on 8 February 1974 are also shown in Fig. 3. The 'primary' heat island intensity grows and attains a peak at 2200 IST and decreases registering a minimum at 0400 IST and attains a maximum at minimum temperature epoch. The relative humidity island follows closely heat island. The 'secondary' heat island registers maximum intensity at 2000 IST but later the intensity remains more or less stationary attaining a minimum at 0600 IST. It rose again at 0700 IST. The relative humidity island intensity peak coincides with heat island intensity peak at 2200 IST but later it shows slight decline only till morning contrary to the variations at the 'primary' heat island probably due to its proximity to river.

The first peak is due to large differences between urban and rural temperatures. After the sunset, rural areas radiate faster than urban surfaces owing to nature of their surfaces. Thus rural areas cool more in the early night and by 2000 or 2200 IST the back radiations from both rural and urban surfaces becomes stable and result in maximum heat island intensity. This is in conformity with Oke *et al.* (1972), Ludwig (1970) and Hage (1972) who reported that the time of maximum heat island intensity occurs 3-5 hr after sunset in all seasons. The back radiations from both the surfaces are slow and steady till early morning and register a minimum in the early hours, *i.e.*, at about 0400-0600 IST.

The patterns of 'primary' and 'secondary' heat islands are unidentical. While the former is idealy influenced by built-up area and human acitivity, the latter is sandwiched between river on one side and open spaces and hills on the other. Both the heat islands are elliptical in shape with their major axis following the alignement of built-up areas. The 'secondary' is a consequence of intense transport and human acitivity till 2200-2300 IST at Deccan Gymkhana bus terminus compared to the immediate suburban areas. Influence of river on one side and the hilly open areas on the other restricted the development of this heat island hence confined mainly, to the bus terminus.

Heat island intensity at the surface is considered as the difference of temperature between the heat island in downtown and the lowest isotherm that could be drawn with observed temperature data.

The march of the heat island intensity of the 'primary' is sinusoidal with a peak at 2200 IST, *i.e.*, about 4 hours after sunset. Oke (1972) reported the occurrence of maximum urban-rural difference in temperature five hours after sunset. The second peak in the present study appears to be a novel feature. The author opines that the human activity and transport in the early hours of the day raise the urban temperature leaving the rural environment untouched rendering a secondary peak to attain.

Special features — One exception to the general observation is the occurrence of a heat pocket around Mental Hospital-Prison Press area (Fig. 1) together with high relative humidity of 85 per cent. The built-up area amidst open space created a heat pocket but the availability of moisture from the vegetation and nearby river rendered the humidity raise in proportion to the demand thus creating humidity island in association with a heat pocket.

Figs. 1 and 2 show cold country air pressing the hot city air wherever the built-up area is either sparse or absent. The isohumes and isotherms presented in Figs. 1 and 2 also point out the presence of cold tongues of air.

This isohume-isotherm study is first of its kind conducted at a tropical location, like Pune, on calm, clear winter nights. This is the first study in which the twin heat islands are noticed and their relative variations studied. The observational network was intensified to study the fine structure of isotherms and isohumes on 15-16 November 1975 (Fig. 2) which also confirmed the existence of two heat islands on either side of a river.

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