Indian J. Met. Hydrol. Geophys. (1976), 27, 1, 37-41

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Temperature distribution over Bombay during a cold night

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(*Received 18 April 1975*)

ABSTRACT. A mobile temperature survey of Bombay and Greater Bombay was conducted in the early hours of 11 January 1975. The survey shows a 'heat island' over the Malabar Hill, Girgaum and Cuffee Parade area with a maximum temperature dfference of about 11° between the urban and the almost rural suburbs. The horizontal temperature distribution is found to be influenced by proximity to the sea, concentration of population, tall buildings and industry and the prevailing wind field. Vertical temperature profile measurements over the Worli Television tower indicate the top of presumably the first inversion layer in this area to be around 127 m on this day.

1. Introduction

Mapping of urban temperature fields has been undertaken in the recent past over Poona and Bombay by Daniel and Krishnamurthy (1973) and by Philip *et al.* (1973). Although in the latter study the seasonal variation of temperature distribution was dealt with, describing the results of mobile surveys conducted in the months of February, March, May and August, the coldest month of January was not covered. As the 'heat island' effect will attain its maximum intensity in the coldest season, a mobile temperature survey was planned for the early morning of 11 January 1975. This turned out to be the coldest morning of the month this year and, therefore, provides interesting results. The minimum temperature recorded at Colaba was 15° C and at Santacruz 11·4° C on this day.

2. Observation

2.1. *Horizontal temperature distribution*—The 'heat island' effect is most prominently noticed around the minimum temperature epoch. Temperature observations taken by mobile teams, during this period of time when the temperature tendency curve is generally 'flat' is considered to be the best substitute for a very close network of observing stations requiring considerable man-power and equipment. Two teams in vehicles started almost simultaneously from Colaba and Santacruz around 0230 IST after intercomparing their Assman psychrometers with the screen thermometers. The teams followed the routes shown in Fig. 1 stopping at the points marked for just enough time to take temperature observations. An additional feature introduced was the taking of temperature observations from the running suburban trains between stations on the Western Railway route from Dahisar to Churchgate and back, on the Central Railway route from Thana to Victoria Terminus and back and on the Central Railway Harbour Branch route from Mankhurd to Victoria Terminus and back. Thermographs giving the trend of temperature were already available at Colaba Observatory and at the radiosonde/rawin observatory at Santacruz. In addition, two more thermographs were installed for this purpose near Bombay Central station and at Shivaji Park (near Dadar). The temperature trend at Chembur was also obtained with the help of observations taken by a stationery observer in that area. These trends were used to reduce the observations to a single time, 0600 IST in this case.

2.2. *Vertical temperature distribution*—For more complete information regarding the temperature distribution over the city it is necessary to have temperature observations made with height. The routine radiosonde ascents taken at Santacruz in the early morning use balloons with a rate of ascent of atleast 18 km/hr *i.e.*, 300 m/min. This rate of ascent is too high to permit the fine structure of temperature variation just above the ground to be recorded. In the absence of any other facility it was decided to take observations on the platforms of the television tower at Worli. These platforms are open and constitute no significant obstruction to ventilation. The observations taken on the platforms could, therefore, be considered to be representative of the free atmosphere.

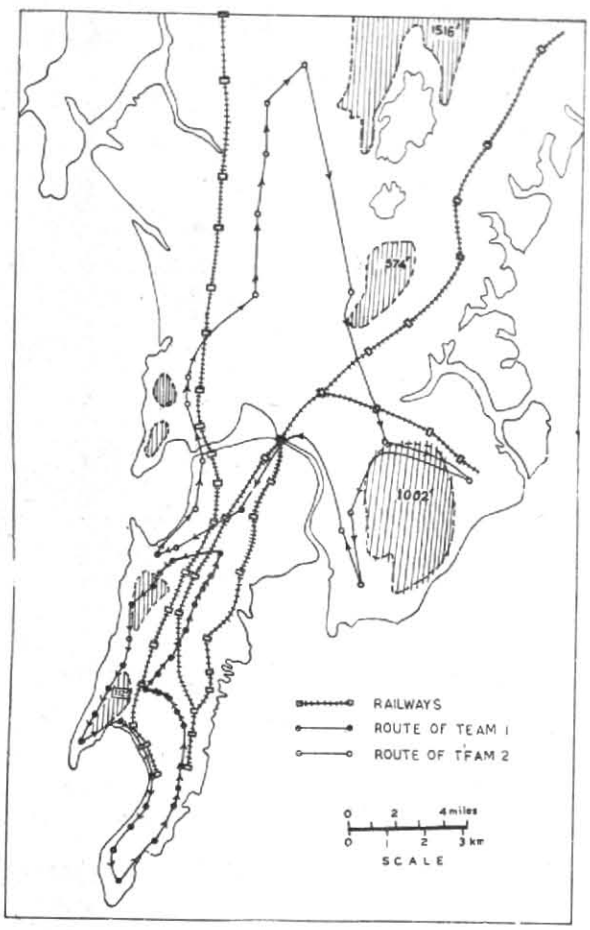

Fig. 1. Routes followed by the survey team

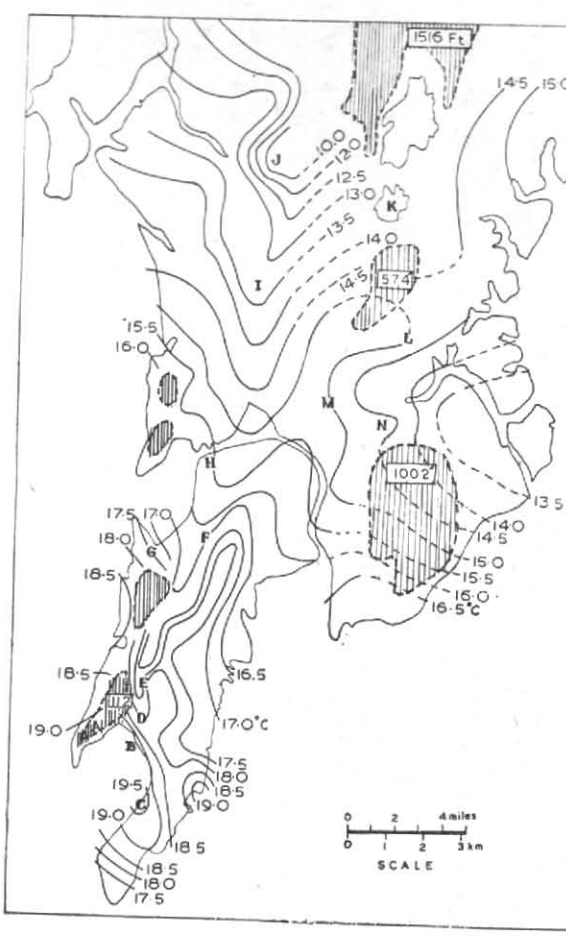

Fig. 2. Surface temperature distribution over Greater Bombay Isotherms (°C) on 11 January 1975 at 0600 IST

A Malabar hill, B Marine lines,
C Cuffe parade-Nariman point,
D Girgam, E Bombay Central,
F Dadar, G Worli, H Mahim,
I Bombay airport (Santacruz RS/RW station)
J Jogeshwari, K Powai Lake,
L Ghat Kopar, M Kurla, N Chembur

The observations were taken with Assman psychrometers. The first six platforms are at heights of 32, 86, 127, 171, 230 and 257 m above ground and are accessible by an open lift. The observations recorded on the tower were timed to be as close as possible to the morning radiosonde ascent at Santacruz.

3. Discussion

3.1. *Horizontal temperature distribution*

Heat Island— The results of the survey may be seen at Fig. 2. It may be noticed that the 'heat island' is over the Malabar Hill, Girgaum and Cuffe Parade area. This agrees with the position located by Daniel and Krishnamurthy (1973) and Philip *et al.* (1973) in earlier surveys. This is the area that is highly populated and studded with tall concrete buildings. The 'concrete jungle', it is easy to understand, would have contributed to the higher temperature to a great extent by the trapping of heat within it. The coldest area observed was close to Jogeshwari where the reduced temperature at 0600 IST was only 8·8°C. This area happens to be comparatively open and in line with the slope of the hills to the east and northeast and the lowering of temperature could well have been caused by katabatic flow from these hills. The highest contrast between the urban and this almost rural suburban area is about 11°C. During the surveys conducted earlier, the maximum difference noticed was 6°C in the month of March 1972. The 11°C difference in January is understandable considering the fact that raditaion cooling during this coldest month could bring out the temperature contrasts to the maximum extent. The average wind during this survey on 11 January 1975 was NW to NE/4-5 kt at Colaba and NE/4-8 kt at Santacruz. It is conceivable that

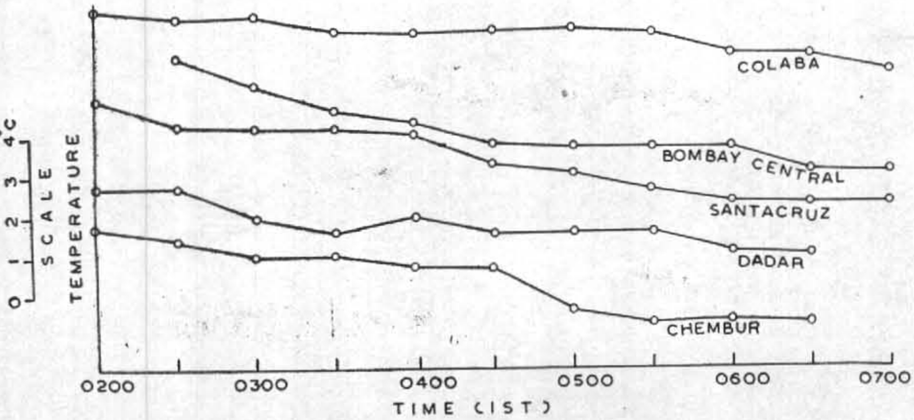

Fig. 3. Temperature tendency curves at different locations over Greater Bombay

if it was calm throughout the period the contrast would have enhanced further.

Maritime influence—It is seen from the temperature distribution that the coastal portions of Bombay are generally warmer than the interior. This is due, presumably, to the maritime influence. The only exception seems to be the east coast of the island where the docks are situated. This pattern has also been noticed in earlier surveys and seems to be caused by the advection of colder air from the mainland across the harbour during the night when easterly flow is a normal feature. The maritime influence might have accentuated the 'heat island' near the Marine Drive-Cuffe Parade area.

Other contributory factors— Temperature has always been an index of the density of population, human activity and concentration of buildings. It is, therefore, interesting to note that the survey has brought out the lower temperatures adjoining the well-ventilated and comparatively open areas of Mahalakshmi and the stretch from Worli to Jogeshwari across the Mahim creek and Santacruz Airport. By contrast, a warm tongue extends from the 'heat island' through the congested central areas of Bombay island upto Dadar. The katabatic effect has been most pronounced near Jogeshwari where a sharp temperature gradient has been introduced by the flow of cold air from the hills.

Trends in variation of surface temperature in various sectors—The variation of surface temperature between 0200 and 0700 IST on 11 January 1975 was as already mentioned, recorded at five places which were chosen to represent topographically homogeneous sectors of Greater Bombay. Continuous records of temperature at Colaba, Bombay Central, Shivaji Park and Santacruz were obtained during this period by exposing thermographs, while at Chembur half-hourly temperatures were arranged for through an observer. The results are shown in Fig.3. It is seen from the trend of temperature variation at the suburban areas of Santacruz and Chembur that there is a steady fall throughout the period and a larger rate of fall compared to the urban areas. In the case of the urban areas of Colaba, Shivaji Park and Bombay Central the rate of fall has been low over a larger part of the period. Another interesting feature exhibited by the trends at Colaba, Shivaji Park and Bombay Central is the steady temperature recorded between about 0400 and 0530 IST. This period seems to coincide very well with the period when the wind recorded at Colaba showed a shift to the NE from a generally NNW'ly direction. When the trends at these places showed a fall before 0400 IST and after 0530 IST the wind at Colaba was NW'ly. The shift in wind direction to the NE could have brought the air from over the polluted areas of the city to the south thereby lowering the rate of radiation cooling in the southern portions of the island. At Santacruz, however, the wind was generally from the NE except between 0500 and 0700 IST when it was calm.

3.2. *Vertical temperature distribution*

The vertical temperature observations taken almost at the same time at the television tower at Worli and at the RS/RW observatory near the airport may be seen in Fig.3. As explained earlier the radiosonde ascent could provide temperature information only at intervals of roughly 100 m, the observations on this occasion commencing only from near about 250 m above sea level. The TV tower at Worli, however, provided information from 32 to 257 m at closer intervals. It was, therefore, possible to have an idea of the fine structure of temperature variation close to the ground. It is significant that the top of the inversion layer closest to the ground at Worli was near 127m. If the radiosonde data alone was available it would have been concluded that the

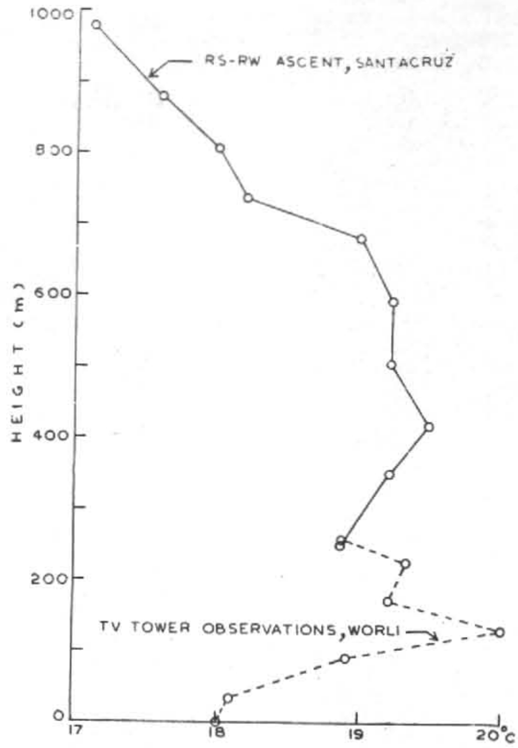

Fig. 4. Upper air temperature profile on the morning of 11 January 1975

top of the first inversion layer was at 450 m. The observations on the television tower clearly show the need for routine low-level soundings of the atmosphere at significant points over the city for making a correct assessment of the temperature structure in the vertical. The mixing depths calculated over cities based only on routine radiosonde data may not, therefore, indicate the correct picture.

It may be seen from Fig. 4 that the temperature at a height of about 250 m recorded at Santacruz through the radiosonde ascent and that observed by direct measurement on the television tower at Worli agree very well. It may not be unreasonable to presume that the prevailing NE'ly wind had brought about a similar temperature structure at Worli and Santacruz above this level, the temperatures below 250 m, where the free flow of air would have been modified by topography, buildings etc., being different between these two places. The steep lapse rate of about 1·1°C in 125 m between 125 and 250 m at Worli suggests this cold advection.

Clarke and McElroy (1970) making experimental studies of the nocturnal urban boundary layer over the city of Cincinnati, Ohio found that with a wind of about 6 mph blowing over the city from the rural and suburban areas, there is a down-wind propagation of the rural characteristics of temperature profile which establish themselves over the 'urban boundary layer'. The urban boundary layer itself depends, on topography and the degree of urbanisation.

It is not uncommon for observers, approaching the Worli television tower in the mornings of this season just after sunrise to see only about a half of the television tower being covered by the haze layer, the upper part being clearly visible. This would corroborate the observations made on the tower and support the existence of the lowest inversion layer with top between 100 to 200 m.

Another interesting visual observation was made from the highest accessible platform of the television tower. At the time the highest platform was reached (0530 IST) there was only a small area with haze coverage and this more or less coincided with the 'heat island' area of Girgaum. The rest of the city was clear and the lights stood out prominently in the background. Even the coast line could be faintly made out. The haze coverage would have naturally extended later around the sunrise time.

4. Conclusions

(1) The urban excess of temperature over the rural in the case of Bombay could be as much as 11°C in the coldest month of the year.

(2) There is a marked maritime influence particularly along the west coast of the island. Valley inversion due to katabatic (fall wind) effects are also noticeable in Greater Bombay.

(3) The wind shifts influence the trend of surface temperature variation depending upon geographic location and local topography.

(4) For pollution studies it is very important to measure the vertical temperature distribution at closer intervals over significant points of the city. The measurements on the television tower show the top of presumably the first inversion layer to be around 127 m on 11 January 1975.

Acknowledgements

The authors are grateful to the team of Officers and staff of the Regional Meteorological Centre, Bombay (S/Shri M.T. Bhatia, P.A. Kale, S.N. Kalambi, M. Koteswara Rao, G. Krishnamurthy, V. A. Venkataraman, S.V. Dahotre, R. D. Kulkarni, K.D. Lipare, P.B. Vishwkar and Kum. P. Lakshmi) who willingly spared the time and undertook the survey with enthusiasm. Thanks are also due to the authorities of the Television Centre at Bombay for very kindly permitting the use of the lift and taking observations at the platforms of the Television Tower at Worli.

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Page	*For*	*Read*
p. 335 Eq. (2)	$\cos \omega \, [t - \epsilon_1 (z)$	$\cos \omega \, [t - \epsilon_1 (z)]$
p. 339 Eq. (11)	$W = V - Ge^{ift} + G$	$W = (V - G)e^{ift} + G$
p. 340 Eq. (19)	$W_1 = \ldots \phi \left(T - \frac{z^2}{4K_0\mu} \right) \ldots$	$W_1 = \ldots \phi \left(T - \frac{z^2}{4K_0\mu^2} \right) \ldots$