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HEAT ISLAND DEVELOPMENT IN MEXICO CITY

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Abstract—The present paper describes the climatology of the near surface urban heat island of Mexico City, using hourly data from two recently installed automatic stations at a rural and an urban site. The results show that the nocturnal heat island was more frequent (75% of the time for the period examined) than daytime cases (25%). The maximum nocturnal heat island intensity, 7.8°C was observed in a dry month (February) characterized by calm clear nights. Although less frequent, the daytime heat islands did occur and may have been caused by differences in evaporative cooling from wet surface during the wet season. Midday heat islands had a frequency of 13% and an intensity of 3–5°C during the wet season. The afternoon/evening heat islands had an intensity of 4–5°C. They occurred during both dry and wet season with a frequency of 12% of the time in a year. The average urban/rural thermal contrasts are positive throughout the year varying from 5°C at day break in the middle of the dry season to 1–3°C around noon during the wet months. © 1997 Elsevier Science Ltd.

Key word index: Urban heat island, tropical urban climatology, Mexico City.

1. INTRODUCTION

The presence of warmer air over cities has been documented first in mid-latitude urban areas and later in the tropical environment. The nocturnal heat island results from diverging rates of cooling between the urban and the rural environments which in temperate climate cities produce a sharp increase in intensity soon after sunset to a maximum of about 4 h later (Oke, 1982). Thereafter, slightly greater urban cooling reduces the intensity until the early daytime rural heating virtually erases the heat island (Oke, 1982).

Most mid-latitude studies have been undertaken during summer, when prevailing cloudless skies and calm or light winds allow full development of the phenomenon. Since the above conditions are not often present during winter, with some exceptions (e.g. Chandler, 1962; Eriksen, 1964; Munn *et al.*, 1969; Unwin, 1980) rather few studies were attempted to describe the seasonal behaviour of the heat island during an annual cycle in mid-latitude cities.

In vast regions of the tropics where all year round wet or wet–dry seasons prevail, some studies have attempted to derive overall climatologies of heat islands (e.g. Sham, 1973; Jauregui, 1973; Padmanabhamurty, 1986). In recent times an increasing number of works on various aspects of the heat island phenomenon have appeared in the literature. Yamashita (1988) examined geographical aspects of heat islands and their relation to city size and some causative factors such as roughness, sky view fraction and, soil moisture and temperature for several Japanese cities.

Using infra-red satellite data to display the surface radiant temperature heat islands of several mid-latitude cities Roth *et al.* (1989) have found that while heat island intensities are largest in the daytime, nocturnal heat island intensities are weaker and less correlated with land use. This is the reverse of what has been observed for near-surface air heat islands.

More recently, the use of satellite data has been attempted for the detection and assessment of the urban heat island by means of urban–rural differences of a normalized vegetation index and radiative surface temperatures (Gallo *et al.*, 1994). They conclude that data from DMSP satellite may provide a useful quantitative measure of urban heat islands. Satellite-derived surface temperature patterns are a good indicator of the daytime urban heat island in Singapore according to Nichol (1996) who has compared those patterns with field measurements of surface and adjacent air temperature in urban canyons at different orientations in that equatorial city.

In the desert cities of the United States the demand for cooling uses 3–8% of electric power to compensate for the urban heat island effect (McPherson, 1992). Daytime heat island in large cities with seasonally abundant sunshine are likely to contribute to the enhancement of some gaseous urban pollutants.

This could be the case of Mexico City where, as will be seen here, daytime urban/rural thermal positive contrasts are usually observed in conjunction with high ozone levels.

From the climatological perspective, knowledge of urban effects in tropical urban areas is still sparse and, as noted by Oke *et al.*, 1990/91, there is as yet little knowledge regarding the transferability of results from mid-latitude studies. Results from the first field survey of the physical climatology made in a tropical city (Mexico City) show that whilst there are some differences, the overall response of the system is essentially similar to that of temperate cities (Oke *et al.*, 1992). This paper intends to contribute with additional insights on the descriptive aspects of the heat island phenomenon characterizing a tropical urban environment as revealed by one year of hourly temperature data. The new set of observations aims to provide a clearer picture of the influence of forcing factors such as cloud cover and rain, particularly, in the development of daytime heat islands. It is well recognized that the warm air mass over cities has implications that include among others human discomfort, city water demand and episodes of unhealthy air pollution levels.

2. DESCRIPTION OF SITES AND INSTRUMENTATION

Two automatic weather stations have been set up by the Department of Atmospheric Sciences of the National University in Mexico City since 1994. One station is located in a typical urban area (School of Mines hereinafter termed SM) while the rural control station, Plan Texcoco, PT, is located 6 km upwind ENE from the city airport on the valley plains (see location in Fig. 1). In addition to these stations, simultaneous hourly temperature data from the Tacubaya Observatory (TO) (mercury temperature sensor at 1.5 m above roof level in a standard screen) were also available in order to compare readings with the SM station. Instruments at the Observatory are located on the flat roof of an old two-storey building (see Oke *et al.*, 1992 for description of the site). While

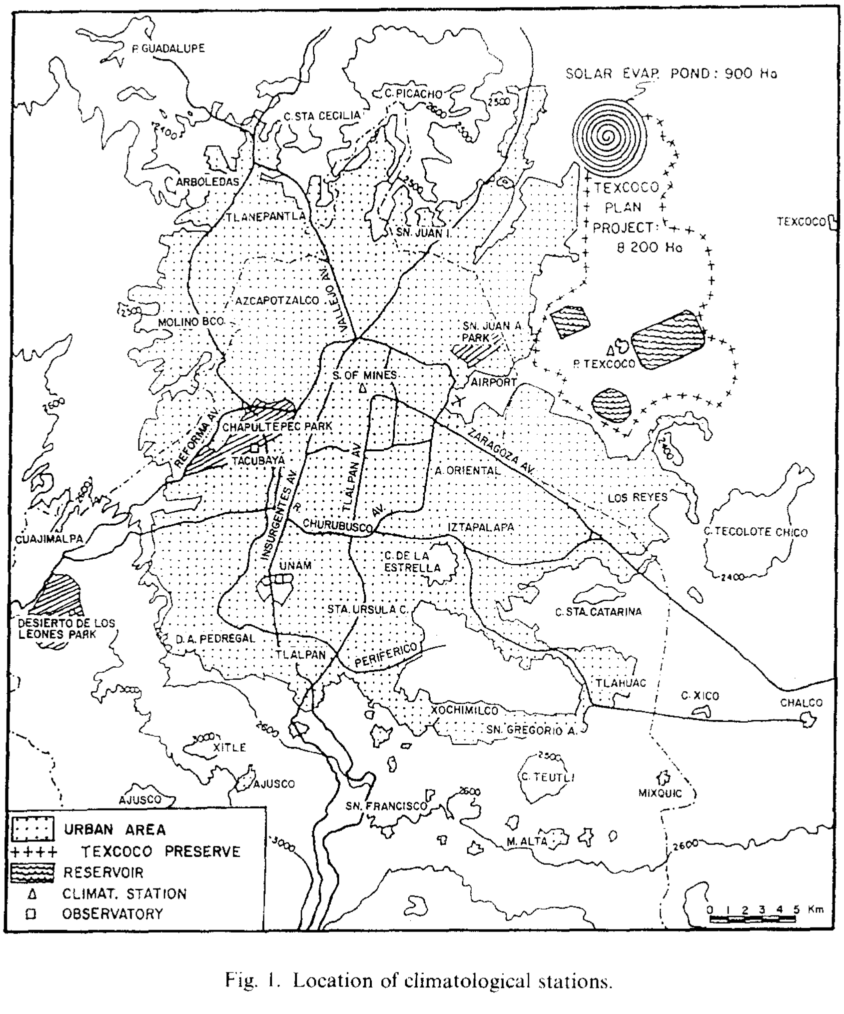

Fig. 1. Location of climatological stations.

the two automatic stations are at about the same height (2250 m m.s.l. at the rural station and 2270 m m.s.l. for SM), the Observatory lies on a slope 60 m higher (Fig. 1).

The instruments at the urban station (located at the SM building) are mounted on a mast on the roof of a 18th century two-storey building in the old sector of town (the temperature sensor was placed at 6 m above the roof). Most constructions in this area are very similar and closely packed.

The measurements at SM and PT were made using an automated data acquisition system that was programmed to generate 1 h averages. The data were recorded using a Campbell (R21) Micrologger. The following instruments were used for the urban site; for temperature a Vaisala HMP31 UT hygrothermometer, precipitation was measured with a tipping bucket raingage (Texas Electronics, 525) and the wind speed with a Teledyne WS-2015 anemometer. For the rural site (PT) the sensors mounted on a tower to measure temperature (at 6 m above the ground), precipitation and wind were Climatronics models 102,090, 100,097 and 100,075 respectively. The temperature sensor was not ventilated.

The rural site (on grounds of Plan Texcoco Project, PT) is characterized by flat partly swampy land covered by patches of native (salt resistant) grass and bushes during the rainy season. The temperature sensor is probably subject, under nighttime stable conditions, to the influence of two upwind sources of moisture: a small (~16 ha, 4 m deep) reservoir, and a larger (~900 ha, 6 m deep) artificial, rectangular all-year lake (Fig. 1). Since their construction in the late 1970s, advection of moisture from these lakes has increased the frequency of morning ground fog (lasting several hours) during the dry season at the nearby airport which is located about 4 km downwind (Jauregui, 1990/1991; Mendoza, 1992). Fog formation at this time would tend to prevent any further cooling at the time of minimum temperatures. The site is often subject to wind erosion of the dried out salty clay soils of ex-Lake Texcoco during the dry season generating dust storms that usually follow a NE to SW trajectory (Jauregui, 1989). Thus, the physical properties (e.g. the thermal admittance and albedo) of the soil in this large ~8000 ha) ecological preserve (see Fig. 1) are subject to considerable seasonal change. It is responsible in reducing the thermal admittance, and therefore is likely to produce the large (nocturnal) heat islands as suggested by the results from simulations of the thermal regime of urban and rural surfaces at night by Oke *et al.* (1991). This paper attempts to provide observational support for such findings for a tropical city.

3. THE CLIMATE

Located at latitude 19°N and at an elevation of 2250 m, the basin of Mexico City enjoys a tropical mountain climate with a relatively small annual temperature range. During the cool period (November–April) modified polar air masses cause most of the country to have scarce rainfall and anticyclonic weather (e.g. clear skies, calm conditions). This causes frequent surface radiation inversions. During the wet season (May–October) the trade winds bring unstable air and moist conditions that produce intense convective rains. These showers usually occur very regularly in the afternoon and early evening hours (Jauregui and Romales, 1996). Evaporational cooling linked to precipitation mainly at the rural site is thought to be one of the causes of the short lived (1–2 h) daytime heat islands in the city as will be illustrated further on.

4. RESULTS AND DISCUSSION

Simulations of urban surface heat islands at night by Oke *et al.* (1991) reveal that amongst the various possible causes mentioned in the literature, the combined effects of geometry (e.g. sky view factor) and thermal properties (e.g. urban/rural admittance contrasts) can produce the most intense heat island development after sunset. From a network of existing regular climatological stations (both urban/rural) the mean position of the nocturnal heat island core has been found to be in the vicinity of the SM site. This has been done by drawing 10 yr-mean monthly values of minimum temperature (Jauregui, 1993). With a similar procedure (by drawing maximum temperature isotherms) the core of the day time heat island appears to lie somewhat to the east of SM. The displacement is likely to be originated by the different main causes giving rise to the phenomenon: during the night, the critical properties governing the thermal contrasts are the radiation geometry and the surface thermal properties (e.g. thermal admittance) (Oke, 1982) while during the day the dominant processes are turbulent sensible heat flux from increased absorption of shortwave radiation and anthropogenic heat sources (industrial and vehicular, mainly). As pointed out by Unwin (1980), the time of occurrence of these temperatures is not necessarily contemporaneous and therefore some error is implicit. However, a glance at the mean hourly variations of temperature at both urban and rural sites (Figs 4 and 6) shows that at least in this case, the extreme values occur at about the same time and therefore, the error in estimating thermal contrasts is likely to be generally small.

Figure 2 shows that on a day during the rainy season heat island intensity as estimated by the SM minus rural PT is generally greater than that obtained from the TO minus PT where TO is located some 6 km away from the heat island core near the western outskirts of the city. Thermal contrasts between the two urban sites (SM minus TO) are positive (around 2–3°C) indicating that air at SM is most of the time warmer than at TO, especially during the nocturnal

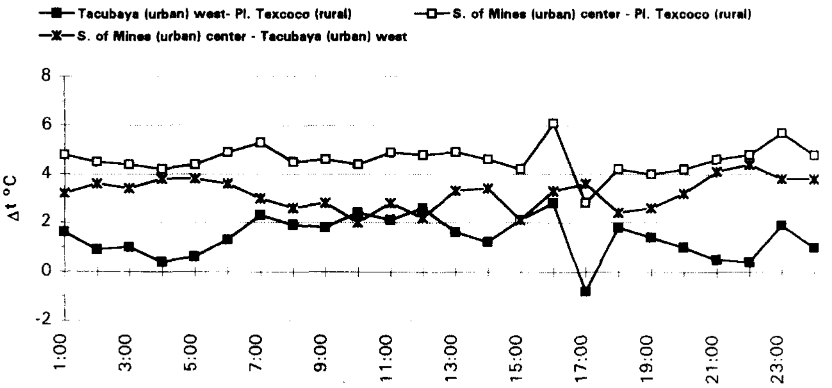

Fig. 2. Temperature differences; Tacubaya (urban) – Plan Texcoco (rural); SM (urban) – Plan Texcoco (rural) and SM – Tacubaya. July 7, 1994 (local time).

period. It is worth noting that urban/rural temperature contrasts observed at the three sites although different in absolute value, show variations that are very much in agreement with one another. This is also true for wind speed variations at the two sites, as will be illustrated further on. This fact gives more confidence to the results presented here.

Table 1 shows the frequency of days when a well-marked urban temperature excedance (of more than 1°C maintained over several hours, except for the 1 h maximum HI described in Section 4.4) was observed at different times of the day for Mexico City during the year from May 1994 to April 1995. Data were available for 343 of the 365 days. It is evident that the nocturnal (9 pm to 10 am) heat island is the most dominant case covering three fourths of the time of the year and prevailing mostly during the dry season. Daytime heat islands were classified by their time of occurrence at around noon (11–15 h) and afternoon (16–20 h) heat islands. They are mostly observed during the rainy season. The average and extreme values of the heat island along the 1 yr period of observations are illustrated in Fig. 3. While the mean heat island intensity for nocturnal events (about 5°C) is nearly constant throughout the year, the midday phenomenon occurs mainly during the wet months, and has somewhat lower intensities (3–5°C) and less variability of extremes. When they occur, the afternoon heat islands have about the same intensities as the night-time, but narrower range of variation probably due to the result of fewer cases. That is, except for one case that occurred on the afternoon 19 October 1994 when the largest urban/rural thermal contrast for the available period of observation occurred. This event will be examined in detail further on.

It is readily seen from Fig. 3 that no midday/evening heat islands were observed during the cool season (December–February) suggesting that the phenomenon is mainly linked to cloud cover and evaporational cooling from rainfall events at both sites during the wet season.

Table 1. Frequency (%) and number of heat island events occurring durng three periods of the day as estimated from thermal contrasts observed between an urban (School of Mines, SM) and a rural (Plan Texcoco, PT) site in Mexico City from May 1994 to April 1995. For missing data refer to Section 2

	21–10 h	11–15 h	16–20 h
May 1994	80.6	9.7	9.7
June 1994	52.4	19.0	28.6
July 1994	36.7	26.7	36.7
August 1994	10.3	41.4	48.3
September 1994	52.2	34.8	13.0
October 1994	59.3	22.2	18.5
November 1994	96.7	0.0	3.3
December 1994	100.0	0.0	0.0
January 1995	100.0	0.0	0.0
February 1995	96.6	3.4	0.0
March 1995	96.8	0.0	3.2
April 1995	96.7	0.0	3.3
No. of events	256	42	45
Freq/yr (%)	74.6	12.2	13.1

4.1. *The nocturnal heat island*

Figure 4 illustrates the mean hourly development of the heat island for six non-contiguous days with clear skies and light winds in January 1994 which was characteristic of a dry month. The average nocturnal heat island reaches its maximum value (5°C) at the end of the cooling period at about sunrise. This development differs from what is observed in mid-latitude cities where the urban/rural diverging rates of cooling lead to a maximum heat island intensity before midnight (Oke, 1982). For the case of Mexico City the divergence of both cooling rates leads first to a slight increase in heat island intensity beginning early in the evening to a mean maximum of 1.2°C at around 7 or 8 pm and reaching a plateau thereafter declining to about midnight. It is likely that this evening peak in heat island intensity, albeit small on the average,

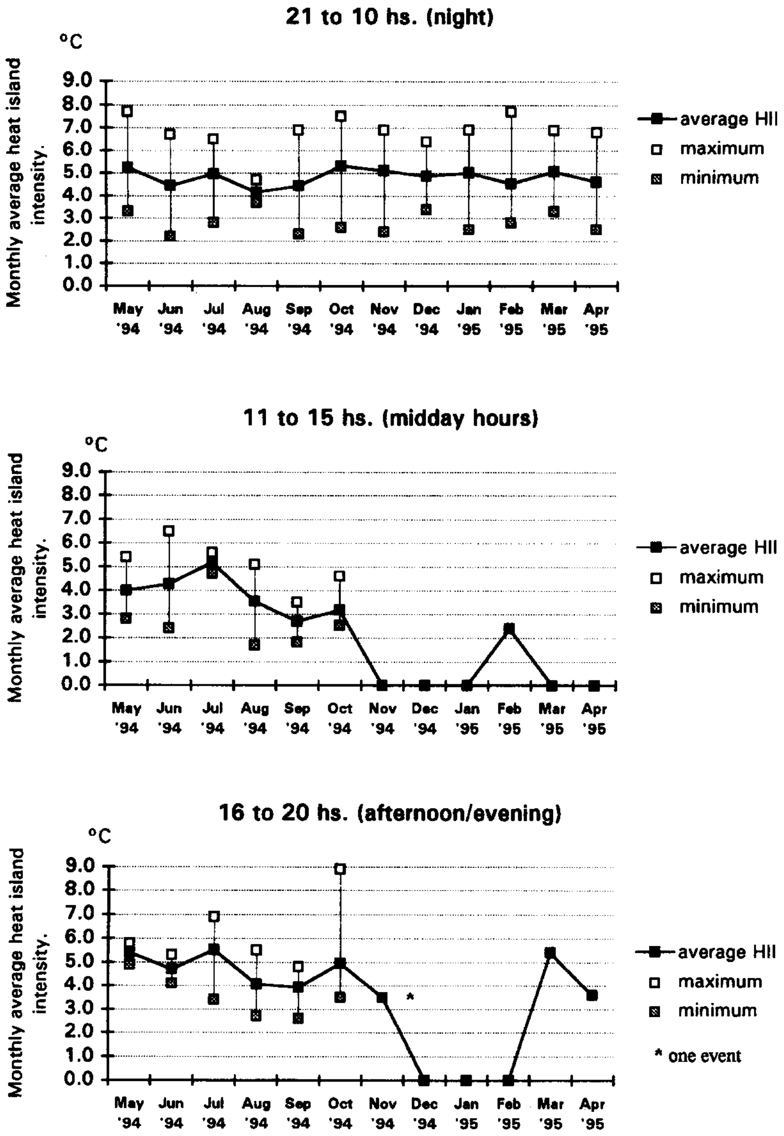

Fig. 3. Average and extreme values of heat island intensity (HII) for three periods of the day in Mexico City for May 1994–April 1995.

might be linked to the release of sensible heat from "rush hour traffic" occurring from about 6–9 pm. Thereafter, the heat island continues to develop through the early morning hours due mainly to the rural net radiative energy loss to an unobstructed sky and less polluted atmosphere prior to sunrise. After this time solar heating generates a turbulent mixed layer over both the urban surfaces and the city environs, so thermal contrasts decline until around the end of the afternoon as seen in Fig. 4.

Heat island intensity has been noted to be related to the strength of the rural inversion (e.g. Ludwig, 1970). In the case of Mexico City the heat island intensity is not significantly correlated either with the rate of change of temperature with height (°C/100 m) or the thermal contrast between bottom and top of the surface inversion layer observed at the airport. However, as shown in the correlation matrix in Table 2 constructed with data for November 1994 to April 1995, there is a highly inverse relationship of the heat island intensity with the surface inversion thickness. This would suggest that shallow surface inversion layers (characterized by a marked rate of increase of temperature with height) tend to be associated to the formation of intense urban/rural thermal contrasts.

4.2. *The noon heat island*

Daytime features of mid-latitude heat islands have been little studied. Nkemdirim and Truch (1978) have reported mid-morning urban/rural mean maximum thermal contrasts varying from 5° (in summer) to 10°C in winter for the city of Calgary (latitude 51°N).

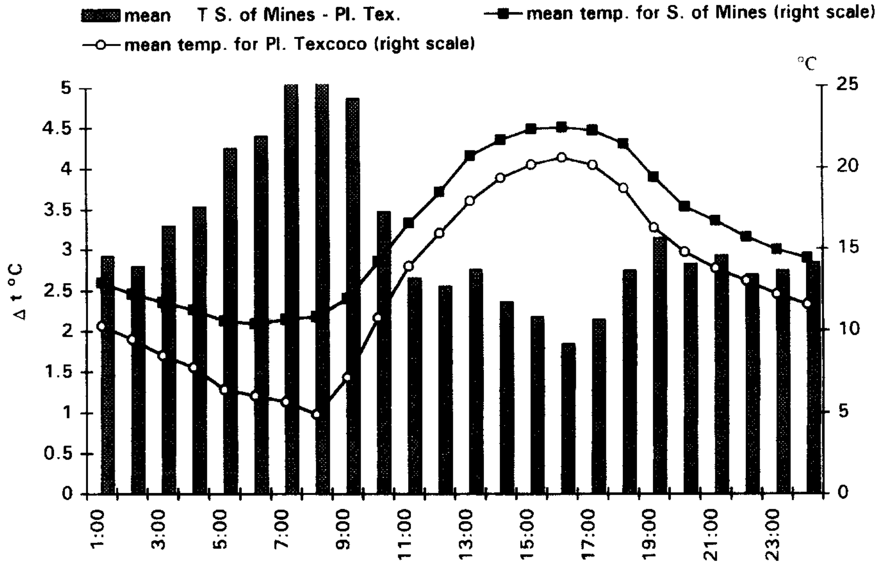

Fig. 4. Mean urban/rural temperature and temperature differences at SM (urban) – Plan Texcoco (rural) for six noncontiguous days with no rain (dry season) January 1994.

Table 2. Correlation matrix of the Mexico city urban heat island with the thermal contrast between the top and bottom of the surface inversion layer, the vertical gradient in the stable surface layer and the surface inversion thickness (m) at the airport for period November 1994 to April 1995 $N = 138$

	Heat island intensity (°C)	Vertical thermal contrast (°C)	Vertical gradient (°C/100 m)	Surface inversion thickness (m)
Heat island intensity (°C)	1	0.12	0.01	−0.51
Vertical thermal contrast °C		1	0.51	0
Vertical gradient °C/100 m			1	0.28
Surface inversion thickness (m)				1

They attribute the genesis of the phenomenon to anthropogenic heat releases and to geographical factors. On the other hand, other mid-latitude and less continental cities have been found to be cooler at certain daytime hours in summer (Chandler, 1962; Unwin, 1980). Oke (1982) mentions that the existence of a cool island in the middle of the day is generally attributed to canyon shading in the city center. Ludwig (1970) concludes that air temperatures in downtown Dallas with its closely spaced, very tall buildings were somewhat cooler (~1°C) than the surrounding countryside during the day. Comparing mean hourly temperatures between the Tacubaya Observatory (TO) and the airport (suburban), Jauregui (1986) found that for this pair of stations the city air was cooler during the afternoon hours. However, this result cannot be extended to the main downtown area since the Tacubaya Observatory while being urban in nature, lies on the western suburbs of the city (Jauregui, 1993). Since the SM urban station is, as mentioned in Section 2, under the direct influence of the heat island core, temperatures there, are rarely lower than at the rural site, even during the afternoon hours.

Figure 5 illustrates a case of wet-season daytime mean heat island for 15 non-contiguous days in August–September 1994. It is possible that the light nocturnal precipitation occurring at both the urban and rural sites was instrumental in reducing the magnitude of radiational cooling (and thermal contrast).

With humidity levels remaining higher at the rural site during the day it is likely that a considerable portion of solar heating was spent at the rural site for evaporation of near-saturated soil, while the opposite was true at the urban site where net radiation was mainly used to heat the urban surfaces that dry fast. The result was a weak daytime heat island of 2.5°C intensity.

Daytime heat islands can also occur during the cool season when there is no rain at either of the two sites, as illustrated in Fig. 6. Urban/rural contrasts of 4–5°C persisted from sunrise to 1 pm because urban

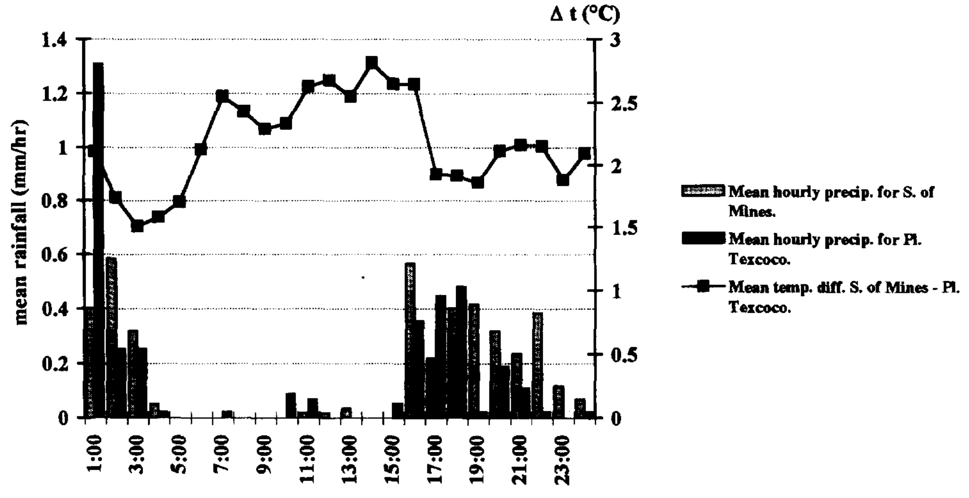

Fig. 5. Mean urban/rural temperature contrasts; SM (urban) – Plan Texcoco for 15 noncontiguous days when rainfall occurred at both sites (wet season) August and September 1994.

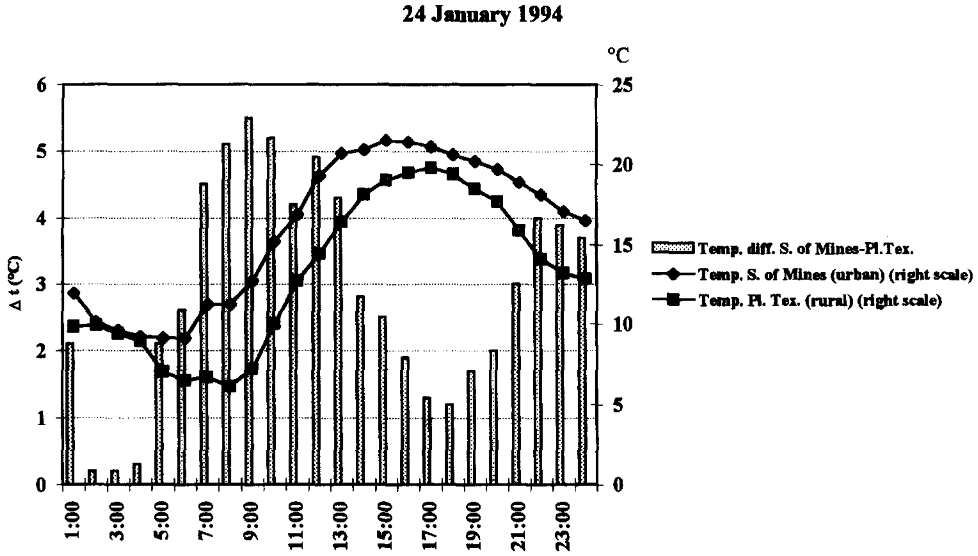

Fig. 6. Hourly temperature and temperature differences; SM (urban) – Plan Texcoco (rural), no precipitation at both sites during a dry season day.

and rural heating rates were similar during the morning hours of 24 January 1994. In this case, it is possible that the origin of the day time positive thermal anomaly was the increased absorption of shortwave radiation by urban surfaces with lower albedo than the dry soils at the rural site.

4.3. *The afternoon/evening heat island*

Effects of cloud cover or rain at either (or both urban/rural sites) can produce sudden changes in the daytime heat island development giving rise to one peak at around noon and another in the late evening. Figure 7 illustrates this case for a day in the rainy season when afternoon showers first at the urban site and then at both sites produced sudden changes that led first to a one hour 4°C positive thermal contrast and then to negative temperature differences immediately after the rain at both sites had stopped. This perhaps as a result of a more marked evaporational cooling rate both from falling rain drops and wet surfaces at the urban site. It is clear from Fig. 7 that the gradual decline of the heat island intensity after midday is caused by the shading effect from developing clouds before rain started. The characteristic evening peak before midnight observed in the dry season is here also present on a day of a wet month (August) suggesting that it is quite a persistent feature of heat island development throughout the year.

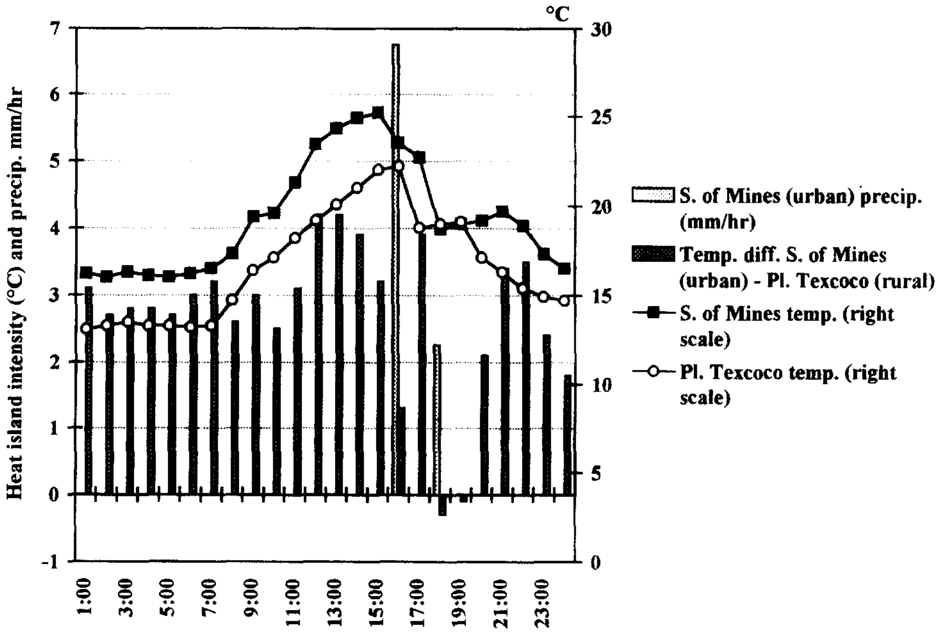

Fig. 7. Effect of rain at urban site on midday/evening heat island development on 7 August 1994 with no precipitation at rural site.

4.4. *The largest evening urban/rural thermal contrasts*

In mid-latitude cities the heat island phenomenon finds its best expression on calm clear summer nights (Oke, 1982). We have seen previously (Fig. 3) that except for a few months in the middle of the rainy season, the mean intensity (5°C) of the nocturnal heat island is maintained throughout the year. One would expect the highest values of this phenomenon to occur in Mexico City in the middle of the dry season and at the end of the cooling period of one long winter night. Surprisingly however, the largest urban/rural thermal contrast (8.7°C) for the 1 yr period was observed on a day with clear skies, around sunset and not at the end of the night but just before the end of the wet season, when rural thermal admittance is usually high. Figure 8a shows that on that day the nocturnal heat island declined after sunrise to a minimum (2°C) at 3 pm. On the subsequent two hours the arrival of cool gusty air at the rural site (Fig. 8b) produced a marked drop in the rural temperature giving origin to the brief absolute maximum value. Once the short burst of rather strong (6 m/s) winds subsided, so did the urban/rural thermal contrasts, suggesting a close link between the two phenomena.

If the cause of these short-lived daytime heat islands is mainly either evaporational cooling from rural rainfall or advection of rural cool air, they are likely to have little impact on human comfort in the city since the urban air temperature instead of increasing shows a decrease once the rural cool wind reaches the urban site.

4.5. *Urban geometry and maximum heat island intensity*

Since the temperature sensor was positioned several meters above the canopy layer, it was to be expected that the observed urban/rural contrasts did not reach values as those anticipated given the size of the capital city. Moreover, advection of water vapour from the artificial lakes near the rural site helped reduce nocturnal radiational cooling, as discussed in Section 2.

4.6. *Seasonal variation of the heat island*

In the previous sections, the various types of heat island development on an hourly basis have been examined using a pair of urban/rural stations. In this section, the seasonal variation of the urban/rural thermal contrasts is presented at two critical hours of the day and along the year. Figure 9 shows the mean monthly values of thermal contrasts at maximum and minimum temperature time.

The displacement is likely to be originated by the different main causes giving rise to the phenomenon: during the night the critical properties governing the thermal contrasts are the radiation geometry and the surface thermal properties (e.g. thermal admittance) (Oke, 1982) while during the day the dominant processes are turbulent sensible heat flux from increased absorption of short-wave radiation and anthropogenic heat sources (industrial and vehicular, mainly).

A marked seasonal variation is evident in both the nocturnal and daytime phenomena. This is tied to the

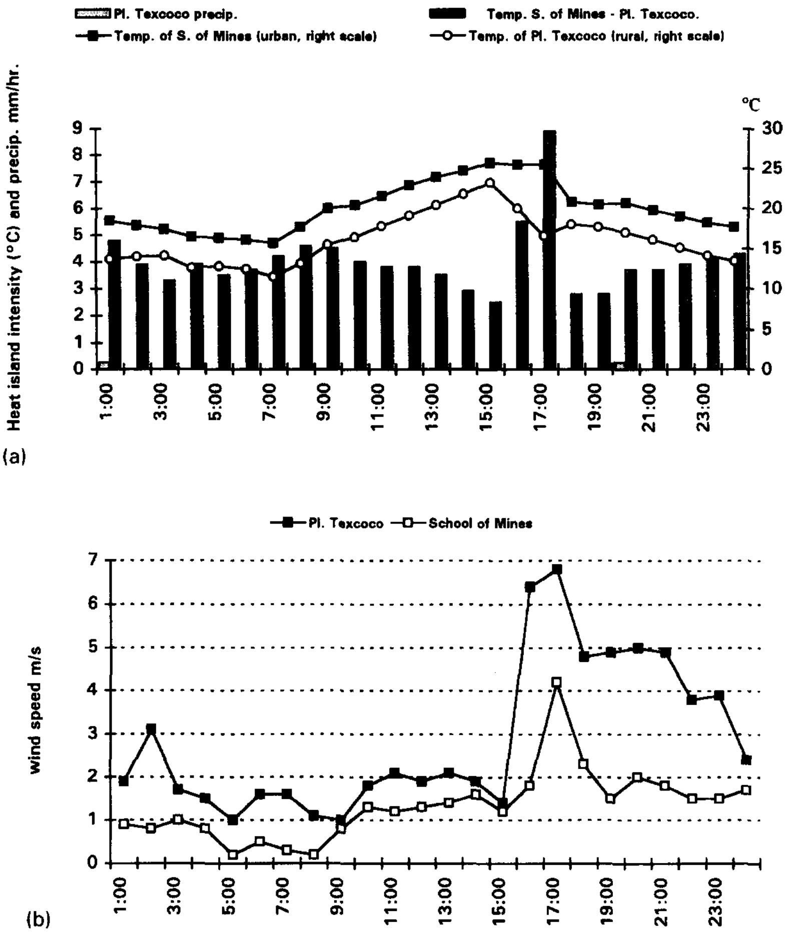

Fig. 8(a) Largest evening heat island 19 October 1994. (b) Diurnal variation of wind speed at SM (urban) and Plan Texcoco (rural) for the day of the largest evening heat island, 19 October 1994.

seasonality of weather controls: anticyclonic weather favouring clear, calm nights in the cool season and unstable weather conditions with clouds and rain in the May–October period. Therefore, as seen in Fig. 9, the largest mean nocturnal heat islands (5°C) occur in the dry season when differences in urban/rural thermal admittance are more marked, declining to a minimum (of 2°C) during the wet months of August–September when soil in the rural site is near saturation. Daytime heat island intensity is in the mean less intense reaching a maximum in July (3°C) (when the high sun favours rural evaporational cooling from rainshowers), declining to a minimum (1°C) in December. It is worth noting from Fig. 9 that at least in this 1 yr survery, the urban-rural thermal contrasts remain on the average always positive throughout the year and at all hours of the day.

5. CONCLUDING REMARKS

The hourly differences in temperature between two recently installed urban rural automatic stations have been used to measure heat island development in Mexico City. Results from 1 yr observations show:

(a) Nighttime heat islands are the most frequent and most intense. They are most frequent during the dry season when it is likely that low rural thermal admittance of dry soils combines with relatively low air moisture to cause rapid cooling rates at the rural site throughout the night. This contrasts with mid-latitude experience, where the diverging urban rural cooling rates produce a maximum thermal contrast before midnight.

(b) The most significant factors governing heat island development during the rainy season are the changes in wind speed, cloud cover and rain (particularly at the rural site), that are associated with unstable turbulent weather. Daytime heat islands during the wet season are generally less intense (3–5°C), of short duration, that at other times of the year.

(c) The afternoon/evening heat islands had a mean intensity of 4–5°C. Their frequency during the year was 12% of the days. They were about equally likely to occur during the dry or wet seasons.

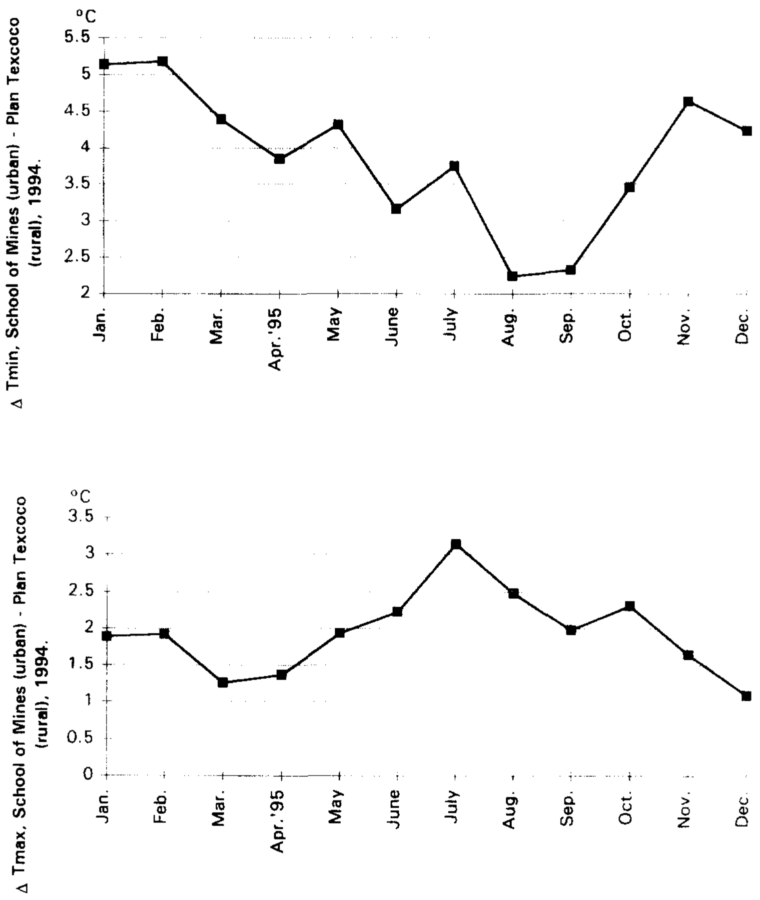

Fig. 9. Seasonal variation of urban heat island using mean monthly differences between maximum and minimum temperatures for 1994 (except April 1995).

(d) The development of those evening heat islands that occur during the rainy period, begins at around sunset, reaches a maximum near mid-evening and declines thereafter to a minimum around midnight. Their development is often modulated by rural rain events.

(e) It is possible that the position of the sensor at the urban site may play a role in increasing the daytime heating rates since, as is well established, roof tops act as elevated heat sources (see Ludwig, 1970). Recently, Sakaida and Suzuki (1994) have shown that afternoon air temperatures at 3 m above roof level are about 2°C higher than at 2 m above street level.

While Oke (1981) has shown that geometry and thermal admittance are capable of generating the largest (nocturnal) heat islands, field observations in this tropical city demonstrate that occasional daytime heat islands may emerge as a result of advected cool air or from downdrafts from rainshowers at the rural site. The sometimes short-lived daytime thermal contrasts may attain the highest value of the period. It is likely that these short temperature contrasts emerge because the selected pair of stations are sensibly aligned with the most frequent direction of cool gusts from the northeast first at the rural site and leaving the urban site temporarily unaffected. Even though these apparently rare events are not central to the heat island issue discussed here they cannot be completely discarded. They might be of help for future heat island studies when the decision of the sites location is made. Clearly, the shortness of the period examined here prevents determination of how representative the above results are. The fact that maximum heat island observed was not as large as would be anticipated given the size and population of the city could be attributed to:

(a) The city station (SM) does not represent thermal conditions in the urban canopy layer but rather the urban boundary layer, where nocturnal cooling rates are likely to be greater than at street level.

(b) The rural site being affected by water vapour advection from nearby reservoir for certain wind directions restricting nocturnal radiational cooling.

(c) Mean urban/rural thermal differences estimated from mean monthly minimum temperature maps for Mexico City have been shown to be as high as 9°C

(Jauregui, 1986) for a rural station located (to the SE of the city) away from moisture sources. Therefore, higher maximum values of the nocturnal heat island may be occurring relative to other rural sites.

The maximum heat island observed might be the result of the conjunction of critical controls being present only once during the observation period. Perhaps more amenable for generalization would be, to compare urban heat islands in the tropics by their mean maximum nocturnal thermal contrasts rather than to characterize them from an extreme case. Since in many parts of the humid tropics showers tend to begin frequently at a certain hour with clockwise regularity, it is likely that rainy-season daytime heat islands described in this paper for Mexico City be also a feature in other tropical cities.

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