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BERICHTE UND MITTEILUNGEN

URBAN HEAT ISLAND DEVELOPMENT IN MEDIUM AND LARGE URBAN AREAS IN MEXICO

With 4 figures and 1 table

ERNESTO JAUREGUI

1. *Introduction*

A typical example of man-made modifications on the city climate due to the urbanization process is the so-called heat island effect. The phenomenon of air temperature often being higher in the city than in its surrounding country side, has long been recognized and documented for mid-latitude cities. Studies on heat island effects are so numerous for the temperate zone that it seems possible now to draw some generalizations regarding its morphology and time variations (see for example OKE 1982).

By contrast, urban climate studies in the tropics are relatively recent and very sparse. The few studies that have been undertaken in tropical cities have been mainly based on urban/rural thermal contrasts established from climatological records. The need for information on tropical urban climates has been

Fig. 1: Mexico: Orientation map

stressed in the past (Chandler 1970, Oke 1982, Lee 1984). Topographical and synoptic controls are so important in the few cases studied that generalizations for the heat island phenomenon in the tropical realm are apparently not possible at this point. From the above it seems reasonable to pursue further studies on heat island for tropical urban areas in different topographical settings. These studies have revealed that heat islands in tropical environment show similar characteristics to those found for mid-latitude urban areas, as will be shown in this paper for several large cities in tropical Mexico.

Mean monthly and hourly urban, suburban, and rural temperature data were used for the cities of Mexico, Monterrey, Guadalajara (in inland valleys) and Veracruz (on the Gulf of Mexico coast) (fig. 1). Table 1 shows a description of the different urban, suburban and rural stations used in the analysis.

Table 1: Urban, suburban and rural stations used in the analysis

City	Urban	Suburban	Rural
Mexico City	Tacubaya Observatory (W of downtown)	Airport	Chalco
	San Antonio Abad Street (downtown)	Moyoguarda Street	Plan Texcoco
Guadalajara	Rayon Street (downtown)	Experiencia	Airport (20 km to SE)
Monterrey	Colegio Civil (downtown)	Sta. Catarina (to SW)	
Veracruz	(Observatory) (near wharf)		Loma Fina (15 km to W)

2. *Urban/rural cooling rate differences*

It is generally agreed (see Oke 1982) that urban/rural cooling rate differences may be attributed to the following causes:

(a) during the day the city stores more sensible heat than its surroundings;
(b) long-wave radiation loss is reduced at night by building obstruction;
(c) anthropogenic heat sources.

Thus, urban/rural cooling rate differences in tropical cities might be expected to differ from those observed in mid-latitude cities from contrasts in urban morphology, i.e. building density, construction materials, greean areas, etc. Since winters are relatively mild in Mexico energy for space heating is usually not significant, except perhaps for Monterrey (lat. 26°), where freezing temperatures are not infrequently observed during this season.

Urban and rural cooling rates for Mexican cities are shown in fig. 2 for a month typical of the dry season (January), when the heat island phenomenon is best displayed on calm, clear nights. It can be seen from fig. 2, where the corresponding curve for Vancouver is also shown, that cooling rates for inland Mexican cities are either somewhat higher (Mexico City) or lower (Guadalajara) than the observed rates in Vancouver during the summer. The lowest cooling rates correspond to Monterrey, where perhaps energy for space heating may become significant in January and therefore contribute to reduce the nocturnal loss of heat by radiation. Cooling rates for a rural location near Mexico City (Plan Texcoco) nearly approximate, during the first five hours after sunset, the values given by the Brunt (1941) formula also shown in fig. 2.

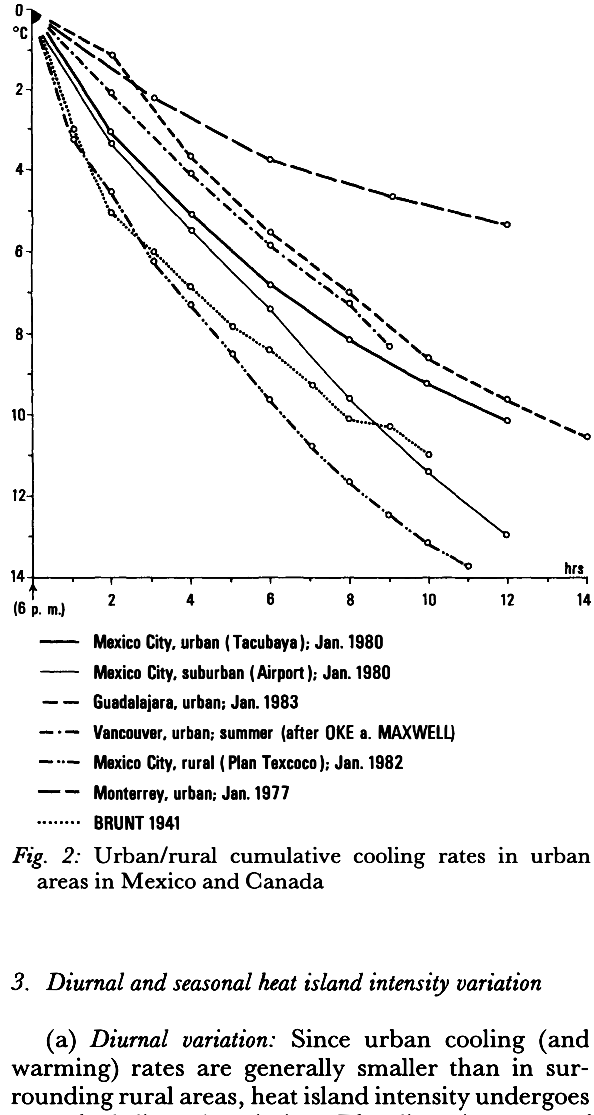

Fig. 2: Urban/rural cumulative cooling rates in urban areas in Mexico and Canada

3. *Diurnal and seasonal heat island intensity variation*

(a) *Diurnal variation:* Since urban cooling (and warming) rates are generally smaller than in surrounding rural areas, heat island intensity undergoes a marked diurnal variation. The diverging rates of cooling between the urban and rural environments (see curves for Mexico City, fig. 2) result in a steady increase in intensity to a maximum at around the end of the cooling period at about sunrise (fig. 3a). This pattern of behaviour differs somewhat from mid-latitude experience where the peak in heat island intensity is observed 3 to 5 hours after sunset in calm, clear summer nights (Oke a. Maxwell 1975).

The amplitude of the diurnal heat island intensity curve is much greater for Mexico City (about 8 °C) than for smaller cities, showing the relationship between city size and maximum heat island intensity that has been observed in mid-latitude urban areas (see Oke a. East 1971). Larger early daytime rural heating erodes urban/rural temperature contrasts until the heat island reaches a minimum in the afternoon. In the case of a coastal urban area (Veracruz) advection of cool air by the sea breeze produces lower temperatures in the urban area (cool island) in the afternoon (fig. 3a).

(b) *Seasonal variation:* It has been well established for mid-latitude cities that the main meteorological variables governing heat island intensity are wind force and cloud cover (Sundborg 1951, Chandler 1965). Seasonal variation of these two variables is closely related to synoptic controls which, for the cities studied here are characterized by: (i) dry weather with mostly clear skies during the cool season (Nov.-Apr.) associated with anticyclonic conditions, and (ii) wet season with cloudy skies and frequent showers in the afternoon.

Seasonal variation of wind and cloud conditions induce changes in turbulent and radiative transfer of heat that produce the urban/rural thermal changes examined here. For the selected Mexican cities the highest heat island intensities are observed during the dry season, when frequency of surface radiative inversions is maximum (fig. 3b). For mid-latitude cities atmospheric stability has also been shown to have a good correlation to heat island intensity

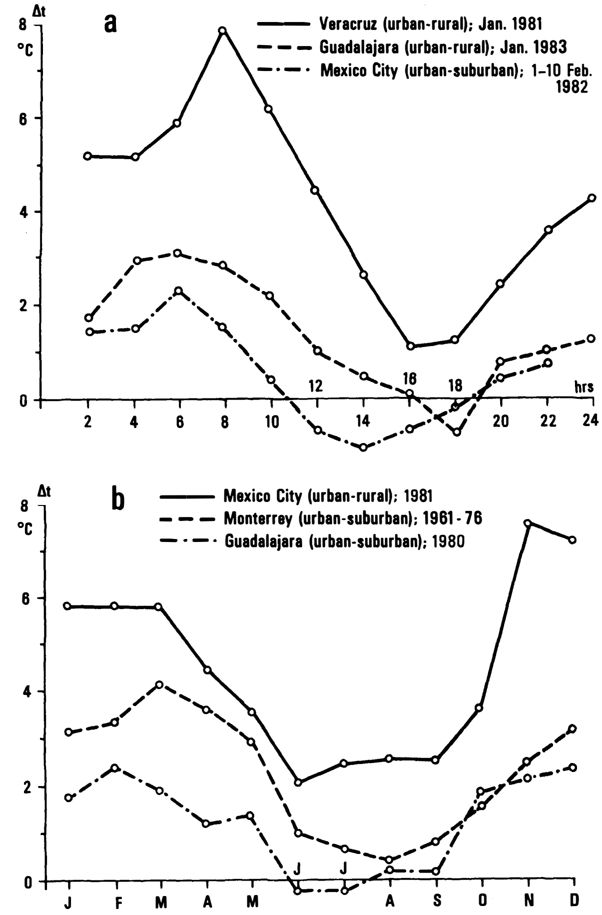

Fig. 3: Diurnal (a) and seasonal (b) heat island intensity variation for Mexican cities

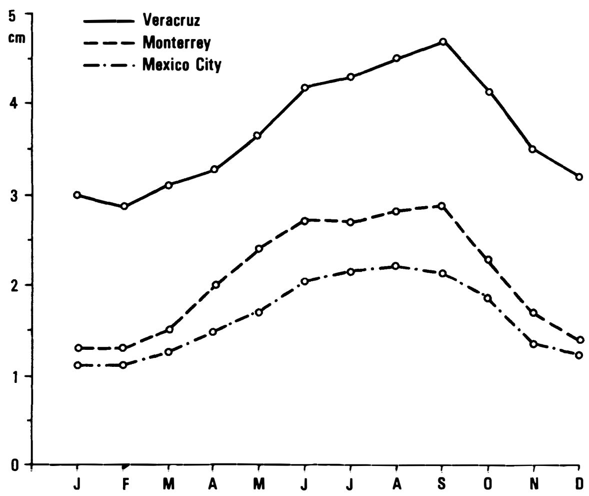

Fig. 4: Mean monthly variation of precipitable water (1965–74) for some Mexican cities (surface to 500 mb)

(LUDWIG 1970). During the wet season a drastic increase in humidity content (fig. 4) and more turbulent conditions brought about by the Trade-wind current, reduce the intensity of heat islands to a minimum (fig. 3b).

4. Conclusions

Urban heat island development for some urban areas in tropical/subtropical Mexico resembles in broad outline those observed for mid-latitude cities. However, some differences may be pointed out regarding the timing of heat island intensity:

(a) Heat island intensity for the cities examined attains a peak value at the end of the cooling process near sunrise. The magnitude of this peak bears a relation with the size of the urban area and is affected by geographic location (valley/coast).

(b) In some cases a cool island may develop in the afternoon.

Synoptic controls determine a seasonal variation in heat island intensity. The maximum heat island intensities are observed during the dry season, when calm, clear skies prevail as a result of anticyclonic flow. During the wet season heat islands are weak or non existent. The higher humidity and turbulent conditions prevailing during the wet season produce weak urban/rural temperature contrasts and, not infrequently, cool islands develop in the afternoon hours.

These results have ecological and economical implications. The added warmth of the city during the warm season increases heat strees on humans. Higher temperatures may speed up the process of chemical weathering, especially in tropical low-lands and coastal areas in Mexico. Detrimental effects of heat islands may be reduced by planning of parks and other green spaces.

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