# JOHANNESBURG'S URBAN HEAT ISLAND

Prof. P.D. Tyson, University of the Witwatersrand.

(Some extracts from a talk which was given at a meeting of the National Association for Clean Air in Johannesburg in 1971. Prof. Tyson is Head of the Department of Geography at the University of the Witwatersrand and has an interest in meteorological processes and their effects upon atmospheric pollution.)

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A large body of information relating to the modification of the atmosphere near the ground by cities is available and has been summarised by Kratzer (1958), Landsberg (1961) and others. The most obvious manifestation of a distinctive urban climate is the occurrence of urban heat islands over cities. Whereas the surface form of these islands is well documented, the same cannot be said of the vertical structure of the air above cities.

Information on the nature of the urban atmospheric environment, particularly its spatial and temporal variation, is necessary, not only for the theorist but also for the applied climatologist seeking to halt the deterioration of urban atmospheres by pollution.

Horizontal temperature distributions show marked discontinuities between rural and urban surfaces. The heat islands are usually quite distinctive and follow the outlines of built-up areas and local topographic drainage lines. An example is given in figure 1. Where cities have coastal locations, are surrounded by large water bodies or are located on watersheds, the separation of the urban modification of the climate from other effects becomes difficult. That topography is not the sole

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cause of the Johannesburg heat island shown in figure 2(a) is seen by the transgression of the zone or urban warming across the shallow valley of the central area (figure 2(b)).

The first study to distinguish differences between low-level lapse rates above urban and rural surfaces was that of Duckworth and Sandberg in 1954. They showed that over San Francisco 25 out of 32 soundings above the city evidenced isothermal or lapse conditions near the ground whereas simultaneous observations over an outlying rural area showed surface inversions on 30 occasions. The possible explanations offered for the elevated cooling above the city were: vertical mixing of the air over the urban area, the effects of a large-scale urban convection cell, radiative loss of heat from the top of the pollution layer and variations in the wind field between 30 and 300 m.

Of the explanations offered for the cross-over effect, Bornstein favours that of radiative cooling. This has been supported by recent theoretical work of Atwater who shows that infrared radiative cooling from the top of pollution layers can produce the cooling necessary for the formation of elevated inversions over cities.

## THE VERTICAL DISTRIBUTION OF TEMPERATURE OF JOHANNESBURG

The Johannesburg Heat Island Project has been running since mid 1970. Surface observations are taken at many points throughout the urban area and on the Brixton and Hillbrow towers (200 m high). Occasional helicopter soundings of temperatures and ground observations of nocturnal radiation are also undertaken.

Preliminary examination of the data shows that despite the complicating effect of the location of the city on a major watershed, the urban heat island can be discerned to a

height of a few hundred metres above the surface. Two examples are given:

On 1st September 1971 the urban heating effect was weakly developed to a height of about 200 m above the surface at 1800 hours (figure 3). At 0545 the next morning the layer was only 100 m deep with a pronounced region of elevated cooling at a height of 1500-200 m above the ridges. Above this an elevated inversion was to be observed. It would appear that the isothermal layer in the 1805 hour urban lapse rate developed into the cool layer evident next morning and, as a result of a process starting before sunset and continuing throughout the night. Elevated radiational cooling appears to offer the best explanation for this set of observations. No distinct urban boundary layer could be observed.

On the 21st September no clearly defined warming effect could be detected at 1835 hours. By 0530 hours the next morning however, a pronounced area of warming was evident to a height of 600 metre. The warm air was clearly being advected northwards to beyond Halfway House ridge by the southerly wind to produce a distinct temperature discontinuity over the northern suburbs at a height of about 200-300 metres above the ground (figure 4).

## CONCLUSION

Until the main body of observations has been carefully analysed, it is impossible to say which of the two situations, if either, is typical of conditions above Johannesburg. The do serve, however, to illustrate the complexity of the conditions obtaining. The two models may not be mutually exclusive and may act concurrently.

Johannesburg's climate is dominated by anticyclonic circulation patterns and attendant large-scale subsidence of air. This is most pronounced in winter when subtropical subsidence inversions may occur with a frequency exceeding 70%. Because of the anticyclonic control of climate and because of the high altitude of Johannesburg (1800 m ) surface radiation inversions and local topographically-induced surface winds are common features of the climate. In addition the fact that the most urbanised parts of the city are to be found on the highest parts of the watershed, must be allowed for. Thus the isolation of urban modification of Johannesburg's climate is no simple exercise in data analysis.

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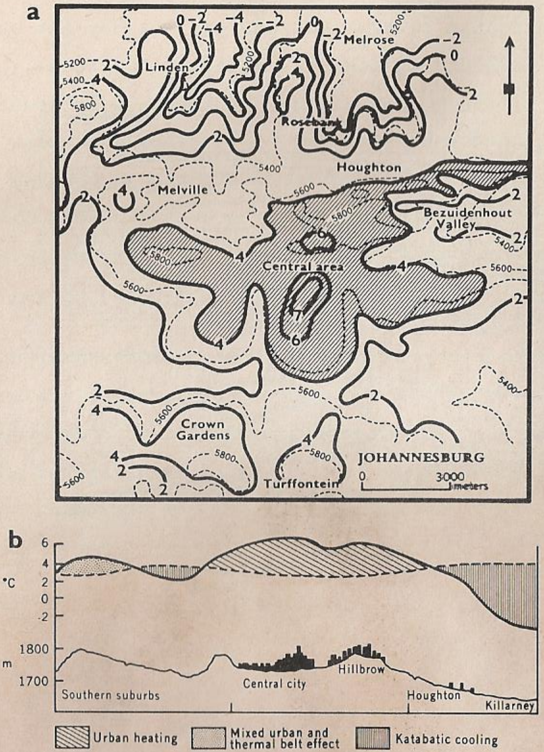
Figure 1.



Figures 2(a) & 2(b)

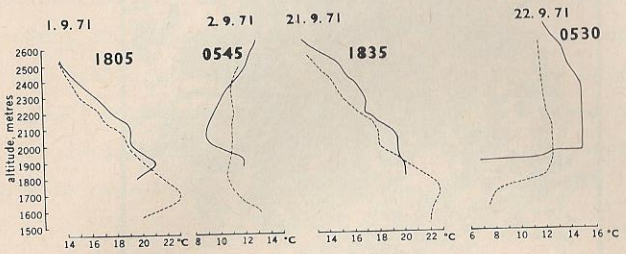


Figure 3.

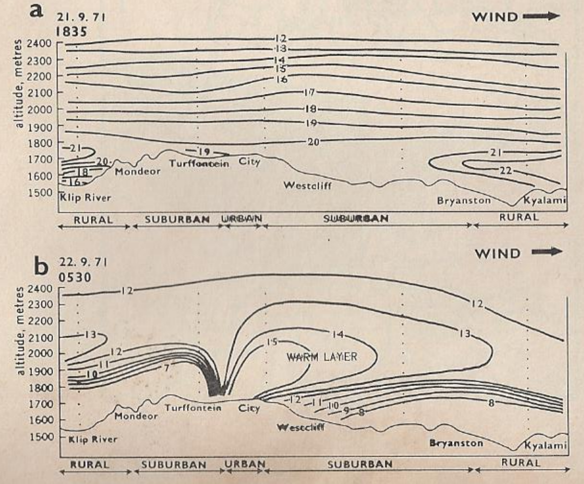


Figure 4.