MISCELLANEA GEOGRAPHICA

WARSZAWA 1992 Vol. 5

Jolanta Wawer

THE IMPACT OF WEATHER CONDITIONS ON THE INTENSITY OF THE URBAN HEAT ISLAND IN WARSAW

The urban heat island in Warsaw (higher air temperature in the city than in its surroundings) is a frequent phenomenon. This does not mean, however, that it occurs every day and has the same intensity. This phenomenon appears as a result of variations in radiation balance, varied thermal conductivity, differences in heat storage capacity between the city and the out-of-town areas, influence of anthropogenic ("artificial") heat, and of air pollution. The range and character of changes of the thermal regime in the city in comparison with its surroundings are influenced by weather conditions existent during the day: a degree of cloudiness, direction and velocity of wind depending on the synoptic situation, and the kind of the air mass. The problem of this relationship is presented in this paper.

Numerous publications on this subject (Landsberg 1983, Hess et al. 1989, Lewińska et al. 1982, Stopa-Boryczka 1988, Taesler 1980) show that the greatest thermal differentiation, that is the greatest intensity of the heat island, appears between a city and its suburbs, and that it occurs most frequently in the city centre.

The formation of the urban heat island in Warsaw was analyzed on the basis of examination of difference of air temperature (Δt) in the city centre (Warsaw University Station) and in the suburbs (Okęcie Airport Station).

For the purpose of the analysis, daily meteorological data, thermograms and Synoptic Bulletins of the Institute for Meteorology and Water Economy from the two stations, from the periods 1961-1965 and 1976-1980, were used. A detailed analysis was made of cases of great thermal differentiation ($\Delta T > 3°C$) with regard to weather conditions.

The diurnal course of the intensity of the urban heat island (ΔT) in Warsaw depends on the season (length of day, time of daily insolation). Generally speaking, a heat island occurs in the cool season (in particular from December till March) usually for 24 hours, and a rapid increase of its intensity falls between 16.00 and 18.00 hours. A maximum of its intensity is found most often between 21.00 and 24.00 hours (sometimes a little later); sometimes a second maximum is observed around 3.00-5.00 hours a.m. The intensity falls between 6.00 and 7.00 hours.

Table 1

Values of rates of heating and cooling of air in the centre of the city and in suburbs, in seasons of a year (°C/h)

Seasons	Rate of heating °C/h		Rate of cooling °C/h	
	Centre	Suburbs	Centre	Suburbs
Winter	0.2 - 1.0	1.5 - 2.5	0.1 - 0.7	1 - 3
Spring	0.3 - 2.0	1 - 3	as in winter	
Summer	around 1	1 - 3	1	1 - 5
Autumn	1 - 2	1 - 3	1 - 2	2 - 3

During a meteorological winter (December, January, February) a great intensity of the urban heat island ($\Delta T > 3^{o}C$) was related to the anticyclonic situation from over Central Europe or Poland, or from over Southern Europe and in weak-gradient situations in the masses of continental, polar (PPk) and polar, maritime, old (PP_{ms}), rarely arctic (PA) air. A strong development of the urban heat island was encouraged by a situation of frosty (air temperature below -5°C), cloudless and windless weather, or with very weak or weak winds from the South or from the West. This season witnessed the highest differences in temperature (ΔT) between the city centre and its suburbs, amounting to 9-10.5°C.

Table 2

Most frequent synoptic situations and kind of mass of air on days of great intensity of the heat island

Synoptic situation	Mass of air
WINTER	
High pressure over Central Europe or Poland High pressure over Southern Europe Weak-gradient situations High pressure over Western Europe or Scandinavia	polar continental polar maritime old arctic
SPRING	
High pressure over Central Europe or Poland High pressure over Southern Europe High pressure over Western Europe or Scandinavia Weak-gradient situations	polar maritime old polar continental polar maritime arctic old
SUMMER	
High pressure over Central Europe or Poland Weak-gradient situations High pressure over Southern Europe High pressure over Western Europe or Scandinavia	polar maritime old polar continental
AUTUMN	
High pressure over Central Europe or Poland High pressure over Southern Europe High pressure over Western Europe Weak-gradient and frontal situations	polar maritime old polar continental polar maritime warm

In the spring (March, April, May) varied and changing weather conditions occur so that diurnal courses of ΔT are differentiated.

The heat island clearly manifests itself from 17.00-18.00 hours (in March and April) or between 18.00 and 20.00 hours (in May), usually reaching its maximum around midnight. It markedly weakens around 7.00-8.00 hours. Between 10.00 and 15.00 hours the heat island is barely observed or completely disappears (it is cooler in the city than in the suburbs). The synoptic situations favourable to strong development of the heat island were anticyclonic structures in a warm (April, May) or frosty (March) air mass with little cloudiness and windless weather. The highest values of ΔT reached 8.7°C.

In summer (June, July, August) the urban heat island starts to develop clearly after 18.00 hours, and sometimes a little later. Its maximum usually falls between 22.00 and 24.00 hours (2-3 hours after sunset) or at 1.00 and 4.00 a.m. The value of ΔT clearly decreases between 6.00 and 8.00 a.m. In the day-time the island disappears completely. A strong development of intensity of the urban heat island was favoured by an anticyclonic weather in the warm masses of polar air, continental or maritime, old, cloudless and windless. Extreme thermal differentiation between the city centre and its suburbs did not exceed 8°C.

During the meteorological autumn (September, October, November) there is a considerable differentiation of ΔT values as well as of weather conditions. In September and October the heat island manifests itself clearly from 16.00 to 18.00 hours, reaching the greatest intensity around 21.00-3.00 hours at night and decreases or disappears between 6.00 and 9.00 a.m. In November, the heat island rarely exceeds 3°C. A strong development of the island was favoured by warm weather in the anticyclonic structures from Poland or Southern Europe, or in weak-gradient situations in the polar, continental air masses, cloudless and quiet or with very weak and weak winds from the Southern sector. An extreme intensity in this season reached the value of 8.1°C.

The formation of the thermal contrasts between the city centre and the suburbs is the result of a different rate of heating, in particular of cooling of the air in the built-up areas of the city in comparison with a different environment in the suburbs. Differentiation of values of both rates (°C/h) was examined in a more detailed way on the days of strong development of the urban heat island.

A rate of heating and cooling of air is always higher in the suburban areas irrespective of the season of the year; it is only values of the two indices, varying according to the season, that change (see Table 1).

Summing up it should be said that a decisive role in shaping the urban heat island should be attributed to weather conditions, mainly to little cloudiness (from 0 to 2) and small wind velocity (up to 5 m/sec). Of importance is also direction of wind, particularly from the Southern and Western sectors. The character of impact of these elements on the intensity of the urban heat island (ΔT) was also determined by the synoptic situation (chiefly anticyclonic structures having their centre over Central Europe or Poland and over Southern Europe, as well as weak-gradient situations), and a kind of the air mass (most often polar, continental and maritime, old air)

(Table 2). In winter and spring the heat island was an almost daily phenomenon but its intensity was usually small (ΔT up to 1.5°C) or moderate (ΔT up to 3°C). Yet in summer and early autumn great intensity of the heat island occurred much more frequently (ΔT >3°C). The highest extreme of intensity of the heat island (ΔT_{max}) could happen in any season of the year but the highest probability of its occurrence in winter is a frosty, cloudless and windless anti-cyclonic weather or a weak- gradient situation in a mass of polar continental air.

Table 3 shows the average and extreme values of thermal differentiation between the city centre and the suburbs throughout the seasons of the year. The conclusions obtained confirm the results of research published in Polish and foreign literature.

Table 3

Average and extreme values of differences in air temperatures between a city and suburbs (ΔT), in seasons of the years

Average values	Extreme values
WINTER	
By day around 0.5°C By night around 3°C	9.1°C 14.XII. 1963 h. 21.00 10.5°C 19.II.1978 h. 21.00
SPRING	
By day around 0°C By night 1-3°C	8.7°C 1.III.1963 h. 24.00 7.0°C 11.V.1977 h. 4.00
SUMMER	
By day around 0°C or <0°C By night 2-4°C	7.6°C 20.VIII. 1965 7.9°C 5.VI.1978 h. 4.00
AUTUMN	
By day around 0°C or < 0°C By night 2-4°C	8.1°C 7.X.1964 h. 3.00 7.5°C 13.IX. 1979 h. 4.00

Warsaw is characterized by a typical thermal regime peculiar to cities of over one-million inhabitants. Extreme values of ΔT in Warsaw reach 10°C, these cases occurring only during frosty, dry, windless and cloudless weather because in summer these values are slightly lower (around 8°C). Such high values of intensity of the heat island are characteristic of Warsaw (the largest city in Poland) only because in other towns values higher than 8.5°C were not found. In European cities values of ΔT are slightly lower or similar (5.5°C in Sofia, 7.6°C in Bratislava, 10°C in Helsinki) while in American cities they exceed 10°C.

REFERENCES

Hess M., Niedźwiedź T., Obrębska-Starklowa B., 1989, "Bioklimat Krakowa" (Bioclimate of Cracow), *Zeszyty Naukowe UJ, Prace Geograficzne* No. 73, *Prace Instytutu Geografii UJ* No. 95.

Landsberg H., 1983, (translation), *Klimat goroda*, Gidrometeoizdat, Leningrad.

Lewińska J., Zgud K., Baścik J., Bartosik J., Czerwieniec M., 1982, *Wpływ miasta na klimat lokalny (na przykładzie aglomeracji krakowskiej)* (The influence of town development on local climate /the example of Cracow agglomeration/), IKŚ, Warszawa.

Mierzwiński B., 1988, "L'influence des conditions atmosphériques sur l'île urbaine de la chaleur à Varsovie, *Miscellanea Geographica*, Warszawa.

Taesler R., 1980, "Studies of the development and thermal structure of the urban boundary layer in Uppsala", *Meteorologiska Institutionen Report* No. 61, Uppsala.

Stopa-Boryczka M., 1988, "Air temperature field deformation under the influence of built-up area in Warsaw", *Miscellanea Geographica*, Warszawa.