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THE DIFFERENCES OF TEMPERATURE BETWEEN THE DOWNTOWN AND THE PERIPHERIES OF WARSAW IN THE YEARS 1933–1998

The systematic measurement of air temperature in Warsaw was started in 1825 at the Astronomical Observatory, where it is being carried out until today. The Observatory was initially outside of town, but, as years passed, it was surrounded by urban structures, although it still remained in an important green area.

In 1932 a weather station was established at the airport of Okęcie, within the far south-western periphery of the town. As the town develops, it slowly approaches the airport, but the station is nowadays, and will yet for some time in the future be located in an open space, and it is characterised by the climate features proper for the non-urban areas.

A comparison of air temperature values from these two stations for the period 1933–1998 gives an idea on the intensity of the urban heat island during 66 years, encompassing also the period of the World War II, the post-war reconstruction, and the following growth of the town.

The average difference of temperature between the Observatory and Okęcie (Δt) in the period 1933–1998 was 0.38 K. This average changes across months of the year from 0.21 K in November to 0.53 K in July. In terms of the seasons of the year this difference equals 0.28 K in winter, 0.31 K in autumn, 0.44 K in spring, and 0.49 K in summer.

During the whole period of 66 years the annual average of the differences were the smallest in the 1940s and in the first half of the 1950s (between 1945 and 1948: 0.20 K). They clearly increased in the first half of the 1960s (in 1964 and 1965: 0.70 K), after which they decreased to the values close to the averages for the whole period considered. An increase of the differences Δt appeared again in the 1990s, and especially in the recent years, attaining the values exceeding any of those recorded before (in 1996: 0.80 K), see Table 1.

The course of the values of Δt in the particular seasons of the year was similar, and this consistency was best visible in the periods when the highest values were attained, i.e. 1961–1965 and 1996–1998. The lowest values occurring in the years 1941–1955 in terms of the seasons of the year took place in the different five-year periods (see also Table 1).

Table 1.

Average values of temperature difference (in K) between downtown Warsaw (Astronomical Observatory) and the peripheries (Okęcie) in the years 1933–1998

Years	Winter	Spring	Summer	Autumn	Whole year
1933–1935	0.23	0.47	0.53	0.37	0.33
1936–1940	0.16	0.44	0.52	0.30	0.40
1941–1945	0.10	0.26*	0.48	0.14*	0.24
1946–1950	0.06*	0.32	0.38	0.18	0.22*
1951–1955	0.18	0.32	0.24*	0.16	0.22*
1956–1960	0.14	0.34	0.46	0.34	0.36
1961–1965	0.54	0.66	0.58	0.48	0.58
1966–1970	0.40	0.48	0.40	0.28	0.38
1971–1975	0.30	0.40	0.44	0.38	0.38
1976–1980	0.30	0.40	0.54	0.16	0.38
1981–1985	0.34	0.40	0.44	0.32	0.40
1986–1990	0.22	0.36	0.44	0.26	0.32
1991–1995	0.44	0.54	0.86	0.46	0.54
1996–1998	0.57	0.77	0.93	0.53	0.77
1933–1998	0.28	0.44	0.49	0.31	0.38

The lowest values are asterisked, while the highest ones — underlined.

In spite of the distinct sub-periods of increase and decrease of the Δt, a weak upward tendency was identified, at the limit of statistical significance, amounting to approximately 0.01 K per 5 years. This tendency is certainly linked with the expansion of the area of urban structures, as well as with the changes taking place in the immediate vicinity of the weather station Warsaw — Astronomical Observatory. This station is located within the Botanical Garden of the University of Warsaw, where a couple of years ago a pavilion of bricks was constructed close to the meteorological instruments. Besides, the neighbouring trees have grown considerably. This, altogether, is advantageous for the maintenance within the small glade, where the instruments are located, of a higher temperature than in an open space. These local factors could in the recent years have a greater influence on the thermal conditions in the vicinity of the station than the development of the city as a whole.

Against the background of the general upward tendency a clear decrease of the values of Δt in the years between 1940 and 1957 comes forward very distinctly. This is beyond any doubt caused by the destruction of the town during the war, and especially during the Warsaw Uprising in 1944. The whole of the central part of the city was burned down and destroyed, and 42% of buildings in Warsaw underwent a complete destruction. It was only in the second part of the 1950s, when a significant part of downtown Warsaw was rebuilt, that the magnitude of the difference between the Observatory and Okęcie returned to the level from before the war.

In the further course of the values of Δt attention is attracted to their strong increase at the beginning of the 1960s, followed by a decrease and the level maintenance during the next some 20 years, although an important growth of the town at that time would have made anyone expect an increase of the value of Δt. The reasons for this phenomenon should probably be sought in the changes of atmospheric circulation in this period.

The studies of the urban heat island in Warsaw showed that it changes to a certain extent its location depending upon the direction of wind. When the winds blow from the south-west, so that Okęcie is on the windward side of the town, the temperature difference between downtown and Okęcie gets very distinct, attaining sometimes even 10K. When winds blow from the north-east, the heat island is shifted towards the south-west and can also encompass Okęcie. Thereby, the temperature difference is decreased or liquidated altogether.

Since the changes in Δt during 66 years were dependent mainly upon other factors than atmospheric circulation, the study of dependence of Δt on the type of circulation was limited to the period 1961–1980. During these 20 years the shares of circulation from the south-western and north-eastern sectors were undergoing drastic changes. The first half of the 1960s was characterised by the highly frequent circulation from the south-western sector and a rare circulation from the north-eastern sector (in 1961, respectively, 162 days and 38 days). In 1970s there was a strong increase of the frequency of circulation types from the north-eastern sector and a drop in the number of those from the south-western sector (in 1976 — respectively — 147 and 55 days). The respective averages in the whole sub-period of 1961–1980 were 97 and 100 days. As mentioned before, during this sub-period there was first a distinct increase of Δt, followed by a decrease. The city was at that time already rebuilt in its majority, and was gradually developing.

In the analysis of the links between Δt and the atmospheric circulation, the types of circulation were referred to conform to the classification of Osuchowska-Klein (1978, 1991). In view of the leftward shift of the wind direction with respect to the circulation direction — by some 20° in case of those from the southern and western sectors, and by some 40° for the north-eastern sector (Kossowska-Cezak, Nurzyńska, 1999), the frequencies of the following six types were accounted for: anticyclonic — 1. western, and 2. south-western, and cyclonic — 3. western and 4. south-western, these types conducive to an increase of Δt, as well as 1. anticyclonic north-eastern, and 2. cyclonic north-eastern and eastern, as leading to a decrease in Δt. Besides, the relations of Δt with the frequency of the anticyclonic types of circulation and with the average temperature value, were considered. The analysis was carried out for seven various time interval types: for the whole year, for the four seasons of the year, for the period between May and July ($\Delta t > 0.5$ K), as well as for November and December ($\Delta t < 0.3$ K).

It was concluded that the relation between the Δt and the characteristics

mentioned in the majority of time intervals is either not observed or very weak (correlation coefficient values below statistical significance), implying the complex nature of conditions in which the urban heat island appears. The relations considered were seen most clearly in the annual and winter average values, as well as in the spring, in November and December.

Although the value of Δt increases from winter to summer, it decreases with temperature both for separate seasons of the year and for the whole year: in the whole year by approximately 0.07 K/1 K, in November and December, likewise, by 0.07 K/1 K, in winter by 0.06 K/1 K, and in spring by 0.10 K/1 K. This relation between air temperature and the value of Δt explains the appearance of an especially high thermal differentiation between the downtown and the peripheries in the first half of the 1960s, when a series of very frosty winters occurred (especially in 1963).

The relation between the values of Δt and the atmospheric circulation was not observed in case of anticyclonic types, although it might have been expected that their increased share ought to be conducive to an increase of Δt, especially in the warm season of the year. The decreased cloudiness during an anticyclonic weather should namely facilitate appearance of thermal contrasts on a local scale. This relation was distinct solely during winter: an increase of frequency of the anticyclonic types by 10 days during the whole season was associated with the increase of the Δt by 0.08 K. This constitutes a confirmation of the relation between Δt and air temperature, since its lowest values occur during winter when circulation is anticyclonic.

The relation between the values of Δt and the direction of circulation was most pronounced in the case of south-western circulation, conducive to an increase in Δt. If there were no circulation from this direction, the annual average of Δt would be 0.29 K, while in case only this circulation existed — the annual average would attain 0.80 K (relation at the limit of statistical significance). A reverse direction of this relation was observed, on the other hand, in winter. Thus, in this season of the year, in case of the uniquely south-western circulation, it should have been warmer at Okęcie than in downtown Warsaw. This is linked with the fact that the warmest air masses come during winter from this direction. Such a connection is confirmed by the relation between the values of the Δt and the frequency of the north-eastern circulation (though this relation is statistically insignificant). An increase of frequency of appearance of this circulation would bring on the average in the year a decrease in Δt. Were there no such circulation at all, the annual average of the Δt would be 0.59 K, while in case only this circulation existed, there would be an evening out of average temperatures, i.e. $\Delta t = 0.0$ K, meaning that the urban heat island would move with the wind in the direction of Okęcie. Conversely in winter — the increase of frequency of this circulation is accompanied by the increase of the value of Δt (in the complete absence of this circulation $\Delta t = 0.26$ K, for this circulation only — $\Delta t = 0.88$ K). This means that when the coldest air masses come in winter from the north-east, the heat island, linked with the inflow of heat from the artificial

sources, appears very clearly, but is limited to the compact urban overbuilt area.

The analysis presented, concerning the features of temperature difference between downtown Warsaw and its peripheries, shows that the formation and dynamics of the urban heat island, appearing through this temperature difference, is a very complex phenomenon, resulting from the action of numerous factors. It is first of all related to the territorial development of the town and to the nature of urban structures, especially in the nearest vicinity. It also depends, though, upon the meteorological factors, whose influence changes, additionally, during the year. One should emphasise, as well, that the results related to the urban heat island, obtained from only two weather stations — an urban and a peripheral — cannot constitute the basis for generalisations, since the results obtained refer uniquely to a concrete situation: the location of the station with respect to town and the nature of circulation in the period of analysis.

REFERENCES

Kossowska-Cezak U., Nurzyńska M., 1999, Zależność warunków wiatrowych w Warszawie od typu cyrkulacji atmosferycznej [Dependence of wind conditions in Warsaw on atmospheric circulation]. *Proceedings of the conference "Klimat i bioklimat miast"*, Łódź.

Osuchowska-Klein B., 1978, *Katalog typów cyrkulacji atmosferycznej* [The catalogue of the atmospheric circulation types], WKiŁ, Warszawa.

Osuchowska-Klein B., 1991, *Katalog typów cyrkulacji atmosferycznej (1976–1990)* [The catalogue of the atmospheric circulation types (1976–1990)], IMGW, Warszawa.