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URBAN HEAT ISLAND IN LARGE AND SMALL CITIES

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Abstract

Urban Heat Island (UHI) is well recognized in large cities. However, research dealing with small cities are very rare. In the paper the results of the studies carried out in several cities in Poland, with various area and population, are discussed. It was found significant differences in UHI intensity caused by air mass. The influence of the size of the city on UHI was considerably lower then expected and reported in previous research.

Key words: urban heat island, air masses, urban climate, Poland

1. INTRODUCTION

Heat island is a typical feature of urban climate. The previous studies give quite good knowledge regarded large cities located at the lowlands (Blazejczyk 2002, Fortuniak 2003, Oke 1987). However, there is still few research dealing with small cities as well as in the cities of specific locations (e.g. seashore, mountain). The aim of the paper is to present the results of the studies carried out in several cities in Poland. The cities were located both, at the lowlands and in the sub-mountain area. They were also differentiated in the size (from the population of 4 500 up to 1.5 million). The intensity of urban heat island was also studied in relation to air masses.

2. MATERIALS AND METHODS

The cities studied were gathered into three groups depending on its area and the number of inhabitants:

- great cities – Warsaw with the area of 517 km^2, divided on Downtown with about 1mln inhabitants and Praga with about 500.000 inhabitants and Poznan with the area of 261 km^2 and almost 600.000 inhabitants
- middle city - Bydgoszcz (134 km^2 in area and population of 200.000)
- small cities – Glucholazy (area of 7 km^2 and population of 15.000) and Suprasl (6 km^2 and 4500 inhabitants) (Year book, 2004)

Data from Warsaw, Poznan, and Glucholazy came from June (Warsaw 01-30 June 2001, Poznan 14-30 June 2005, Glucholazy 14-26 June 2001). In Bydgoszcz the investigations were carried out from July 17th to September 30th 2004. In Suprasl however, the measurements took place from June 27th to July 15th 1994. In majority of the sites air temperature was registered with the use of HOBO Pro miniloggers with 10 min. averaging. Only in Suprasl it was used standard meteorological minimal and maximal thermometers.

The data of average, minimal and maximal air temperature were used to calculate Urban Heat Island intensity (defined as deviation of temperature at urban station in relation to reference station situated in the rural area). Observational data of air temperature were completed by information dealing with air masses covered the area of investigation. Air masses was specified on the base of surface synoptic charts of Europe from 00:00 UTC, published in Daily Meteorological Bulletin of IMGW.

In Warsaw the reference station Borowa Gora represents rural area about 30 km north of the city. Downtown station was placed in the court in the centre of Warsaw. This point was surrounded by 20 meters high buildings and it was shaded in particular hours a day. Station Praga was located inside dense 2-3 floors building site, which is characteristic for the most part of Warsaw. It was exposed on the solar radiation almost all the day. The HOBO loggers were placed 1.5 meters above the ground (Blazejczyk 2002).

In Poznan reference stations Lawica was situated in an airport. Second station was placed in the centre of the city, on the roof of University Hospital 1.5 meters above special wooden platform.

In Bydgoszcz reference station Myslecinek was placed about 10 km away from the centre of the city in the rural area. The urban station was in the centre on the roof of two-floor building of Bydgoszcz University, 1.5 m above the roof (Metel, 2004, Rekowski, 2004).

In Glucholazy the reference station was located 2 km from the city centre in the garden plots. Urban station was situated in the centre of the city, close to the market square, among dense, high building. The loggers were placed 1.5 meters over the ground surface (Blazejczyk, Kuchcik, ed., 2003).

In Suprasl the reference station was situated in the open air area 2 km from the city centre on the slightly inclined to south slope. Urban station was located in the small court. The point was obstructed by buildings and trees from east, south and west and was shaded till 7:30 a.m. and from 5:30 p.m. (Kozlowska-Szczesna et al, 1995).

The intensity of urban heat island in specific air masses was studied in Warsaw from June to December 2001. In this purpose the average deviations of minimal air temperature in air masses were calculated. The following air masses were define: arctic air (A), polar-continental air (PC), polar-maritime air (PM), polar-maritime transformed air (PMt) and subtropical air (S).

3. RESULTS

3.1. General features of UHI

When analysing deviations of average (dt avg), maximum (dt max) and minimum (dt min) daily temperatures observed in cities of different size in relations to suburban area several peculiarities were found. Positive values of deviations indicate the warming effect of urban structure in the analysed places (Fig. 1).

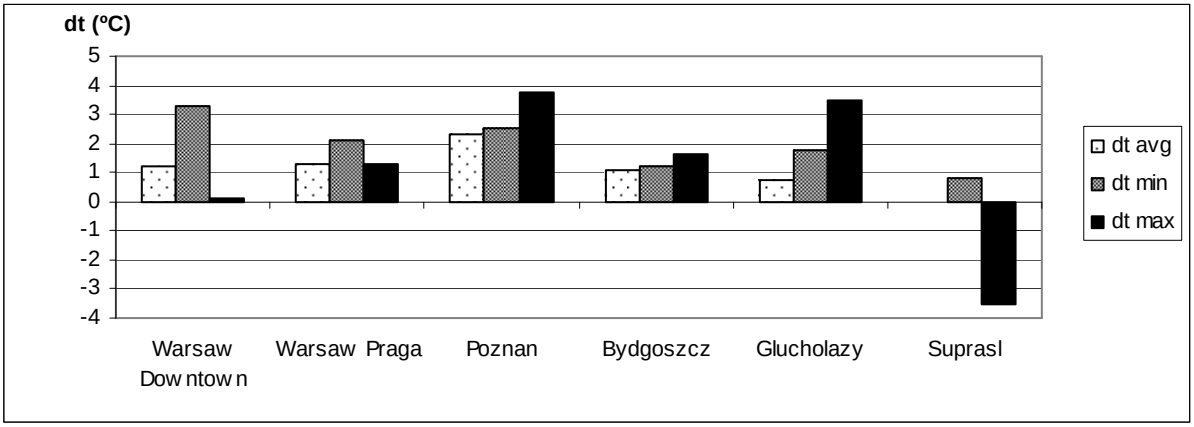

Fig. 1 Average deviations (dt) of mean daily (dt avg), minimal (dt min) and maximal (dt max) air temperature in the studied cities from air temperature observed in rural area.

The higher minimal air temperature in the city in comparison to rural area confirms the occurrence of urban heat island. The biggest dt min values were observed in Warsaw Downtown (3.3°C). The measuring stand in Downtown is surrounded by high buildings typical for city centres. In Praga, a district of Warsaw with low buildings, dt min values are about 2.1°C. In the centre of Poznan dt min is smaller than in the centre of Warsaw and they amount 2.5°C. In the central part of Bydgoszcz and Suprasl dt min is 1.2 and 0.8°C, respectively. Relatively intensive UHI was observed in small city Glucholazy. The deviation of minimal temperature in each city indicates a clear influence of the city size on the intensity of urban heat island (Fig. 2). However the differences observed within the same city (Warsaw) are due to the type of buildings.

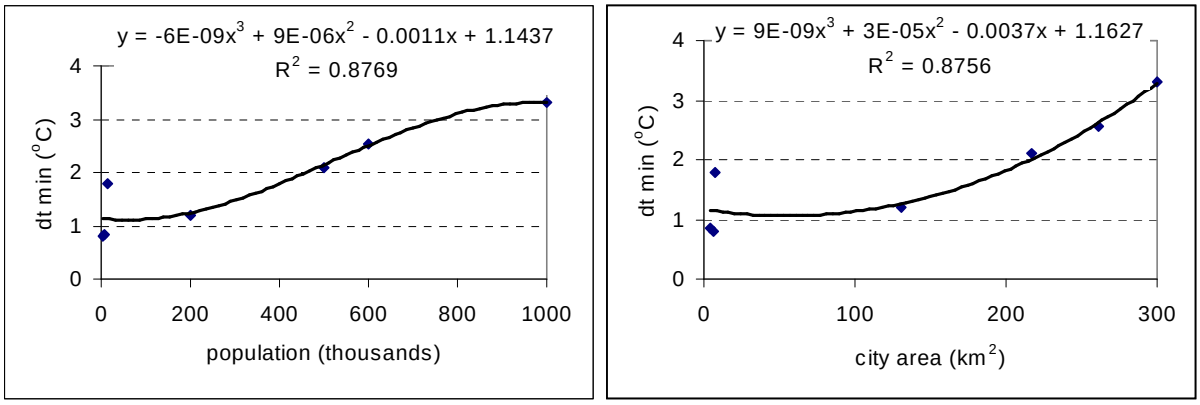

Fig. 2. Deviation of minimum air temperature in the city in relation to rural area (dt min) as a function of population of the city (left panel) and its area (right panel).

The deviations of maximum and average daily temperature shows also that UHI occur not only at night but also during daytime hours. However, the relationship between the size of the city and daytime UHI is weakest then for night UHI. In general maximum temperature depends mainly on the exposure of a measuring stand. The stand in Warsaw Downtown where dt max amounts to only 0.1℃ is shaded by buildings during midday and air is there heated similarly like in the rural area. Only in very small city (Suprasl) UHI is not observed during the day (Fig. 1).

It is also interested to compare the daily course of air temperature in the city and its suburbs. On the example from Warsaw (averaged values for June 2001) is well seen the dynamic of UHI. The heat surplus in the downtown is observed starting from about 7 p.m. (an hour before the sunset) and is lasting till 7 a.m. (three hours after the sunrise). In before noon air temperature in the city is lower then in rural area because of shading the surface. However, in the afternoon great insolation of the stand provoke daytime UHI (Fig. 3).

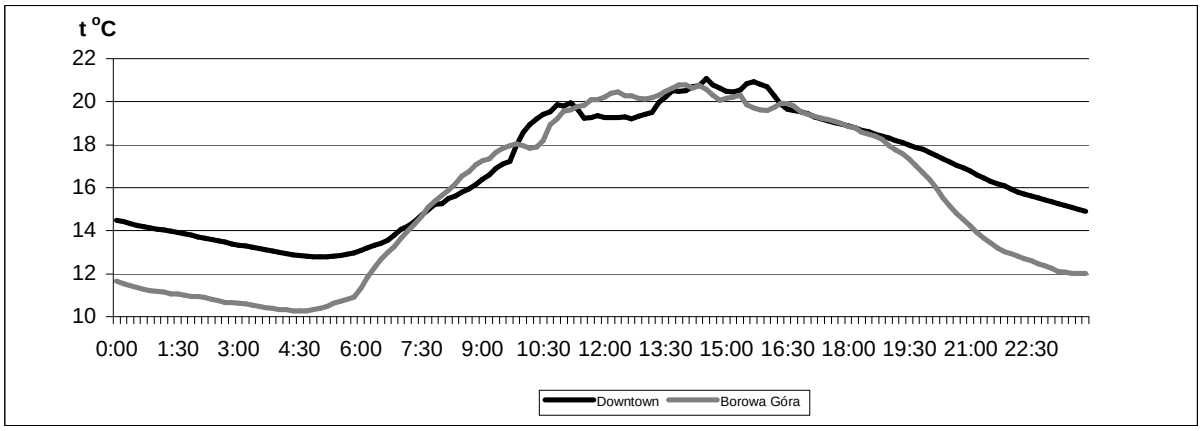

Fig. 3. Daily course of air temperature in the rural area (Borowa Gora) and in Warsaw Downtown, data averaged for 01-30 June 2001.

3.2. Air masses and UHI

The occurrence of the urban heat island has also been examined in relation to air-masses. The differences between dt min in various air-masses are not too big. In the Warsaw Downtown the most intensive UHI occurs at polar maritime transformed and polar continental air masses. Significantly low dt min values are characteristic for polar-maritime and arctic air-masses. However, in Praga, the separate part of Warsaw, the differences in dt min are insignificant (Fig. 4).

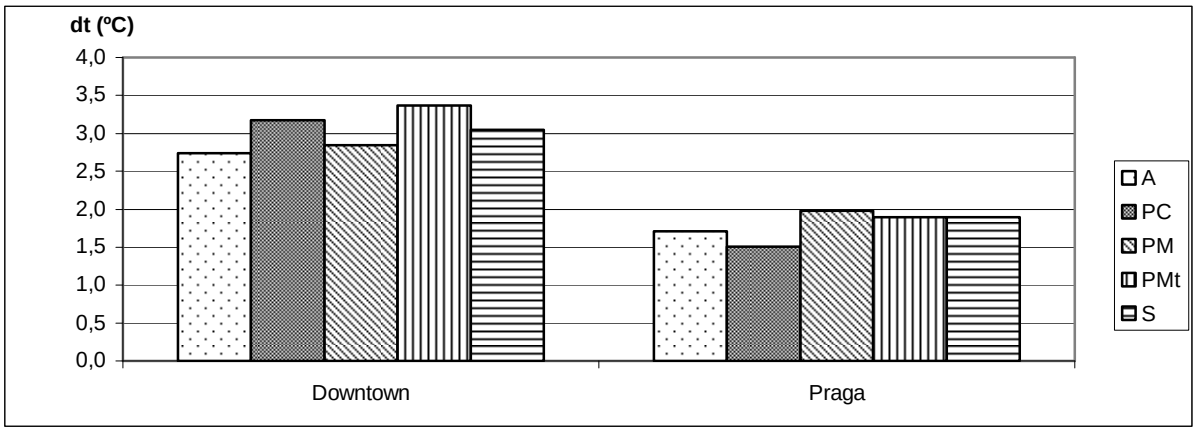

Fig. 4. Mean deviation of minimal air temperature (dt min) at Warsaw Downtown and Praga from temperature observed at reference station (Borowa Gora - rural area) in various air masses, June-December 2001, explanation of air mass in the text.

4. CONCLUSIONS

Urban heat island is a typical feature of urban climate. UHI was observed in all studied cities, also in the small ones. In large cities UHI occurs not only at the night hours but also during the daytime. However, daytime UHI intensity depends on the insolation of the specific site.

Urban heat island depends also on the size of the city. UHI can be estimated as a function of a population of the city and/or as a function of the city area.

Intensity of urban heat island is influenced by air mass that cover the investigated area. The highest dt min values are noted at polar continental and polar maritime transformed air masses. However, advection of fresh polar maritime air results in reduction of UHI.

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