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TEMPERATURE CONDITIONS OF BRNO CITY ON THE LEVEL OF MESOCLIMATE AND MICROCLIMATE

Abstract: The urban climate causes intensive physical stress with negative impacts on health. Stations with automatic measurement regime lying in potentially comparable climatic conditions but significantly different environmental conditions were selected in order to analyze the heat waves incidence. The urban climate was represented by the Brno-Zabovresky and Mendel Square stations and the suburban climate by the Brno-Turany and Jundrov stations. The number of tropical days in individual years, the number of days in heat waves, the sum of effective temperatures in heat waves above 30°C, the number of heat waves and the maximum and averages duration of heat waves were analyzed. The influence of albedo, emissivity and temperature (ir)regulation of different surfaces were also evaluated. The detailed study of climatic conditions at the stations placed in the city centre, outside the city centre and in the periphery proved that the mean annual temperature varies from 10.4 to 11.1°C. The maximum annual temperature varies from 36.1 to 37.9°C. The number of summer days varies from 178 to 260. The number of tropical days varies from 42 to 103.

Key words: urban climate, urban heat island, heat waves, surface temperature
Słowa kluczowe: klimat miasta, miejskia wyspa ciepła, fala gorąca, temperatura powierzchni

Introduction

One of the characteristic features of the of urban climate – the heat island existence – is an evident fact established by many scientific studies. An evaluation of its influence on mesoclimate and a possible influence on people depending on the size of an agglomeration, the density of built-up area, surface characteristics, *etc.* is a main current question. An urban area shows significantly higher temperatures than its surroundings. Temperature differences are greater at night than during the day and in winter than in summer and they are the biggest in periods of low wind or calm. The difference of the maximum temperature between the centre of Lodz and its suburban area reaches 8°C (Fortuniak *et al.* 2006). The relations between extreme weather situations (extreme temperatures, heat waves, *etc.*) and some health complications of city population are obvious as well. In such situations there is an increased mortality associated with chronic diseases, in particular cardiovascular, brain and vascular as well as respiratory tract diseases. It was found that for heat waves in summer, mortality was strongly associated with the duration of a heat wave (Tan *et al.* 2007). The significant spatial variability of the environment is the main problem for the modeling of urban climate. The main reason is the overlap of the original surface vegetation by infrastructure and buildings. Z. Bottyán and J. Unger (2003), C. Souch and S. Grimmond (2006) claimed that apart from meteorological conditions (radiation or advective character of the weather) also other factors such as the character of the built-up area, land use, relief, presence of larger water bodies, *etc.* markedly shape the spatial differentiation of the analysed meteorological elements in a given town. Satellite images, radar measurements and aerial technologies are used widely in urban climate studies (e.g. Voogt, Oke 2003). Aerial and satellite images allow to describe surface heterogeneity and its influence on microclimate. The term microclimate is often applied to space scales up to 100 m, while mesoclimate has an extension up to 100 km.

The urban climate causes intensive physical stress with negative impacts on health. One of the main risk factors is the incidence of long-term periods of high temperatures during the summer months, the so-called heat waves. A heat wave is defined as a differently long episode of extremely hot weather of a varying length. A meteorological dictionary (Sobíšek 1993) defines a heat wave as a period of summer heat lasting for several days during which the daily maximum air temperatures reach 30°C or more. The frequency, intensity and duration of heat waves did not increase generally during the 20^{th} century. But in the 21^{st} century, especially in the second half, the situation will be altered dramatically (Hupfer *et al.* 2009). Its wider impacts may include effects on the retail industry, ecosystem services and tourism. Adaptation to an increased frequency of heat waves should include soft engineering options and, where possible, avoiding the widespread use of air conditioning which could prove unsustainable in energy terms (McGregor *et al.* 2007).

In Central Europe the appearance of a heat wave is conditioned by the advection of tropical air masses or intensive radiation heating of polar air hovering above overheated land in an anticyclone area. Much attention is focused worldwide on the research of extreme temperature events. K. E. Kukel *et al.* (1996) studied the intense heat wave which hit Chicago in July 1995. J. Kyselý and J. Kalvová (1998) analyzed the incidence of heat waves in the South Moravian region of the Czech Republic. The temporal variability of heat waves was described by J. Kyselý (2003) and an analysis of mortality related to heat stress was carried out by J. Kyselý and R. Huth (2004). The term "heat wave" is a relative one due to climatic conditions of a specific location. Temperatures which are considered normal for humans and other organisms in warmer areas tend to be regarded abnormal in colder areas. Therefore the WMO recommends to define a heat wave as a period during which the daily maximum air temperature in five consecutive days is at least 5°C higher than the normal average daily maximum for a given period (Heat Wave Duration Index HWDI) (Frich *et al.* 2002). J. Kyselý and J. Kalvová (1998) defined a heat wave as a period that simultaneously satisfies the following three conditions: at least 3 days with the daily maximum air temperature ≥30°C, the average daily maximum air temperature for the entire period ≥30°C and the daily maximum air temperature in all days ≥25°C. The Royal Netherlands Meteorological Institute defines a heat wave as a period of at least 5 days with the daily maximum air temperature of 25°C and higher which includes at least 3 days with the daily maximum temperature of 30°C and higher (Huynen *et al.* 2001). For the purposes of mortality analysis during heat waves J. Kyselý and R. Huth (2004) defined a heat wave as a period, lasting for at least three days, during which the daily maximum air temperature is 30°C and higher.

Materials and methods

Sites lying in potentially comparable climatic conditions but significantly different environmental conditions were selected in order to analyze the incidence of heat waves. One site was located in the city centre, the second lay on the edge of the city out of the reach of the urban environment effects. For the purposes of the study two climatic stations of the Czech Hydrometeorological Institute (CHMI) were selected. The urban climate is represented by the Brno-Zabovresky station and the suburban climate by the Brno-Turany station. The results are presented for the longest possible period, i.e. from 1987 when measurements at the Zabovresky station began till 2008 (22 years). The Brno-Zabovresky station is located in the vicinity of the CHMI Brno branch in the Zabovresky area. The Brno-Turany station is located close to the Brno airport on the outskirts of Brno (Fig. 1). The analysis was performed on homogenized

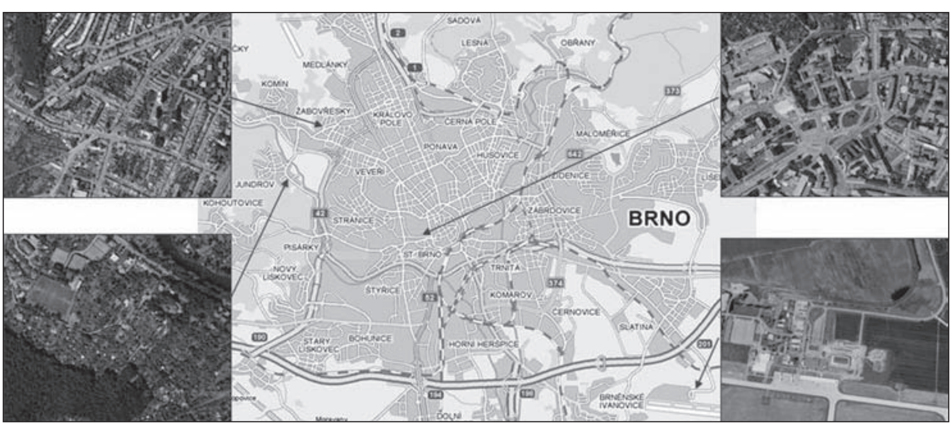

Fig. 1. Map of the city of Brno with aerial photographs of selected stations (Zabovresky – top left, Jundrov – bottom left, Mendel Square – top right, Turany – bottom right)

Ryc. 1. Mapa Brna ze zdjęciami lotniczymi wybranych stacji (Zabovresky – w lewo na górze, Jundrov – w lewo na dole, Plac Mendla – w prawo na górze, Turany – w prawo na dole) data of the daily maximum air temperature. The basis of the data was obtained by measurements at the CHMI station network, which were checked for the presence of errors (by comparing the difference with the surrounding stations and with expected values calculated by geostatistical methods, *etc.*) and then tested for the presence of inhomogeneities using statistical tests and the reference series with a subsequent correction of inhomogeneities. Missing values were completed by using IDW method (Štěpánek, Zahradníček 2008). The heat wave calculation was performed with the ProClim software. A heat wave was defined as a period of at least 3 consecutive days with the maximum daily air temperature ≥30°C.

Apart from the mentioned stations, the data from special urban stations with the automatic regime (Mendel Square – the centre of Brno, and Jundrov – a rather suburban locality in the western part of Brno) was used for more detailed descriptions of spatial variability of the chosen urban area (Fig. 1). The stations were built to determine the heterogeneity of urban climate in Brno. The results of mobile measurements of chosen parameters of typical urban surfaces were also included in the paper.

Results

The highest number of heat waves at the Brno-Zabovresky station was found in 1992 and 1998 and at the Brno-Turany station in 2003 (Fig. 2). The maximum number of days in a heat wave was reached in 1994 (at Brno-Zabovresky it was 32 days and at Brno-Turany it was 24 days; Fig. 3). The average length of a heat wave in Zabovresky was 8 days and in Turany 7. The maximum length of a heat wave occured in 1994 – it was 19 days long at Zabovresky and 17 days at Turany. The maximum number of heat waves

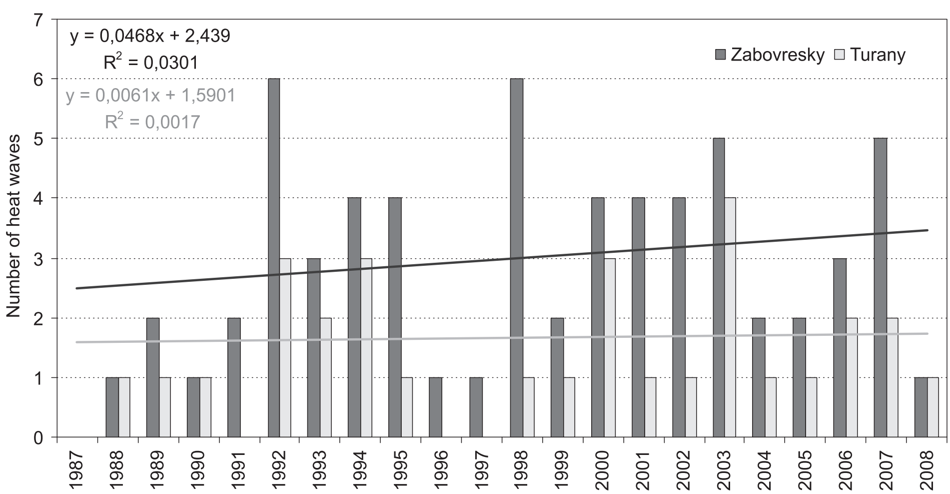

Fig. 2. Number of heat waves

Ryc. 2. Liczba fal gorąca

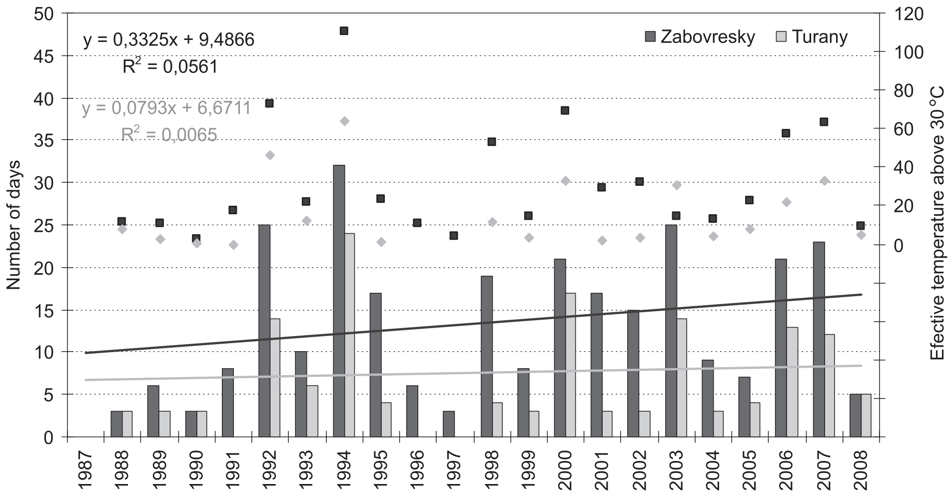

Fig. 3. Number of days in heat waves and their sum of effective temperatures above 30°C

Ryc. 3. Liczba dni w falach gorąca i ich suma temperatury efektywnej powyżej 30°C

per year was detected in 1992 and 1998 at the Brno-Zabovresky station and in 2003 at the Turany station. The results show that the values of the monitored characteristics were significantly higher at the Brno-Zabovresky station (representative of the urban environment) than at the Brno-Turany station (suburban environment).

Figure 4 presents a comparison of three years of measurement of air temperature at special urban climatological stations (Mendel Square – M, Jundrov – J), a standard

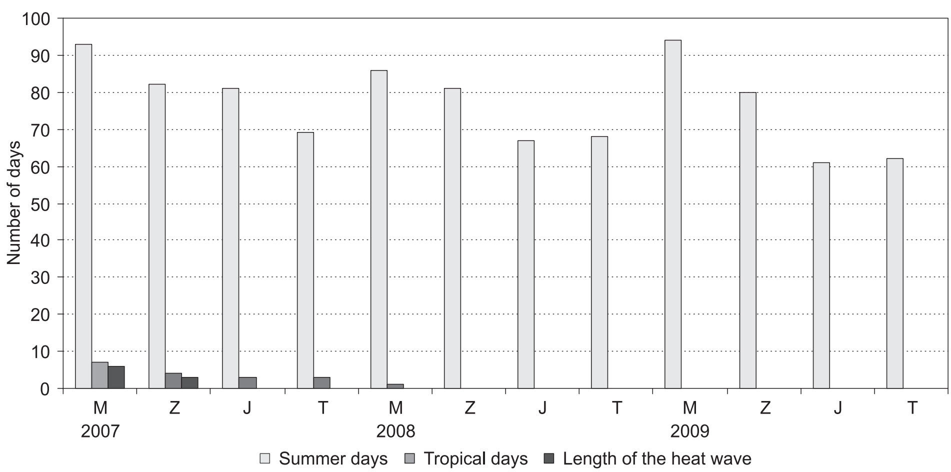

Fig. 4. Chosen temperature characteristics of the Brno urban and suburban stations

Ryc. 4. Wybrane wskaźniki termiczne brneńskich stacji miejskich i podmiejskich urban climatological station Zabovresky (Z) and a suburban station Turany (T). The influence on chosen temperature characteristics is evident.

The influence of albedo, emissivity and temperature (ir)regulation of different surfaces are displayed in figures 5, 6 and 7. The temperature of a standard urban

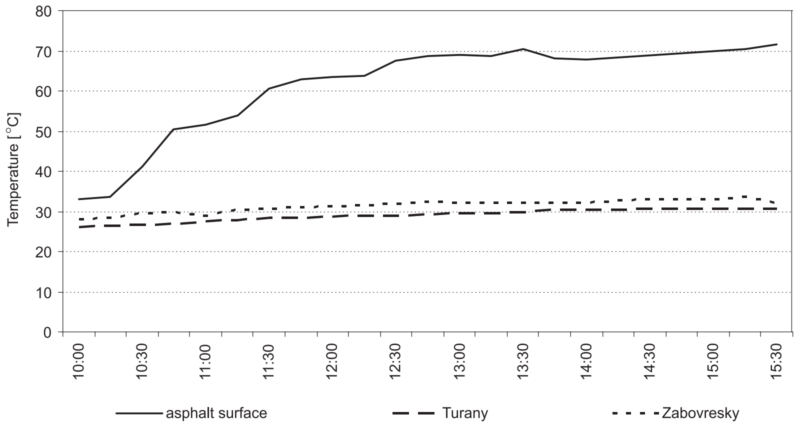

Fig. 5. Temperature of the asphalt surface measured with an infrared thermometer at the Zabovresky station and air temperature measured at 2 m height at the Zabovresky and Turany stations (22nd August 2009)

Ryc. 5. Temperatura powierzchni asfaltowej na stacji Zabovresky mierzona za pomocą termometru podczerwonego i temperatura powietrza mierzona na wysokości 2 m na stacjach Turany i Zabovresky (22 sierpnia 2009)

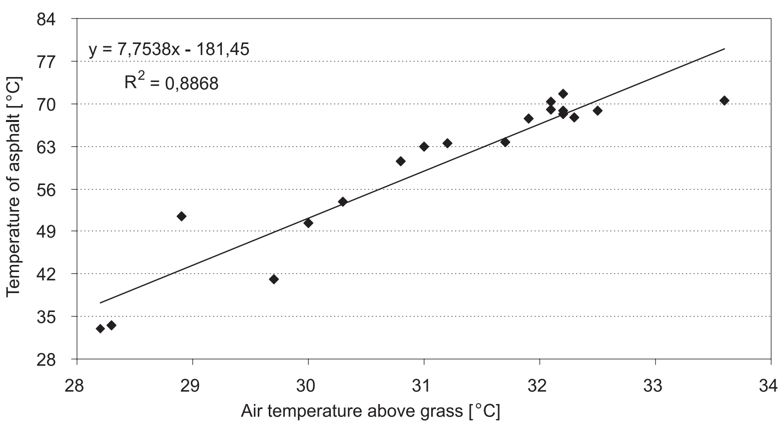

Fig. 6. Relation between the asphalt surface temperature and air temperature measured at 2 m height above grass at the Zabovresky station (22nd August 2009)

Ryc. 6. Zależność pomiędzy temperaturą powierzchni asfaltowej i temperaturą powietrza na wysokości 2 m nad powierzchnią trawiastą na stacji Zabovresky (22 sierpnia 2009)

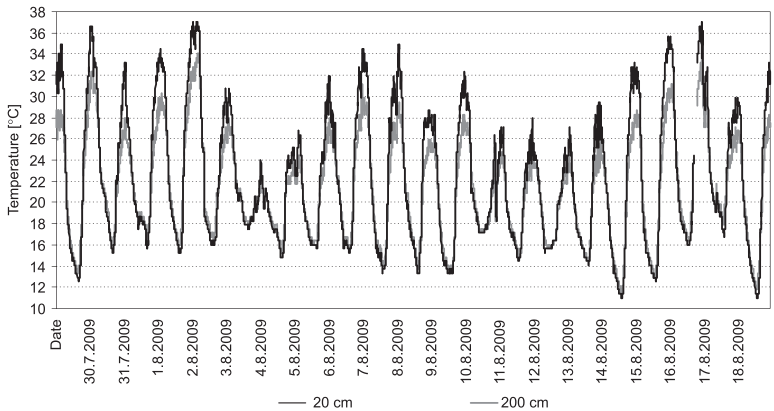

Fig. 7. Temperature above the asphalt surface (20 cm – ground surface level, and 200 cm – standard level) at the Zabovresky station during the summer months of 2009

Ryc. 7. Temperatura nad powierzchnią asfaltową (20 cm – wysokość przy ziemi i 200 cm – wysokość standardowa) na stacji Zabovresky w miesiącach letnich w roku 2009

surface can differ by several tens of centi-degrees from the temperature measured at a standard climatological station (grass surface). The influence of surface on the surrounding temperature is shown in figure 7 (course of air temperature at the ground level – 20 cm and the standard height of 200 cm). Air temperatures above a standard urban surface are much higher during sunny days and much lower at night. It has a negative impact on the city mesoclimate.

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Warunki termiczne miasta Brna w skali mikro- i mezoklimatu

Streszczenie

Klimat miasta wywiera silny negatywny stres na zdrowie ludzi. Szczególnie uciążliwe dla mieszkańców miast są długo utrzymujące się fale upałów. Do analizy dni gorących wybrano dane klimatologiczne ze stacji automatycznych położonych w potencjalnie porówywalnych warunkach klimatycznych, ale w wyraźnie odmiennych warunkach środowiskowych. Klimat miasta reprezentują stacje: Brno-Zabovresky i Plac Mendla, natomiast klimat podmiejski reprezentują stacje: Brno-Turany i Jundrov. Przeanalizowano następujące charakterystyki cieplne: liczba dni upalnych w poszczególnych latach, liczba dni w falach gorąca i suma temperatury efektywnej przekraczającej 30°C, liczba fal gorąca oraz maksymalny i średni czas trwania fal gorąca. Oszacowany był ponadto wpływ albedo, współczynnika emisji i modyfikacji temperatury przez poszczególne powierzchnie. Szczegółowe studium warunków klimatycznych na stacjach w centrum miasta, poza centrum i na jego obrzeżu wykazało, że średnia

roczna temperatura zmienia się od 10,4 do 11,1°C. Maksymalna roczna temperatura powietrza osiąga wartości od 36,1 do 37,9°C. Liczba dni gorących wynosi od 178 do 260, a liczba dni upalnych zmienia się od 42 do 103 w ciągu roku.

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