

The incidence of heat index levels in urban areas of Brno

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Abstract. Urban climate is increasingly becoming the aim of study not only for climatologists. Building bigger cities changes radiation and energetic balance as well as values and trends of individual meteorological elements. The “urban heat island” becomes a familiar concept. The climate evaluation of Brno with the help of temperature indexes was done while using the database of meteorological elements in the years 2006 to 2008. The calculations of temperature-humidity index, temperature index and Humidex were performed. The achieved results indicate that the situation from the category “extreme caution” appear in Brno as opposed to Brno surroundings. Also a relatively high number of days with temperature discomfort appear here. Temperature load can cause degradation of organism with hazardous groups of inhabitants.

Introduction

The city climate problem and its influence on man becomes frequently a theme of scientific works. Also specialized conferences focused exclusively on this problem are held. A lot of issues are investigated, such as the definition of Urban Heat Island (UHI) in the individual parts of territory, measurement and modeling of microclimate in individual typical urban areas, bioclimatic studies about the influence on inhabitants, suggestions for the reduction of the negative climate effect on inhabitants. A series of indexes to characterize bioclimatology properties of urban atmosphere is used in the world. These indexes take into consideration various number of meteorological elements.

Čabajová (in: Kolektiv, 1979) used equivalent temperature to characterize differences between individual urban parts from the point of view of climatology.

Air temperature and humidity enters the calculation in the case of equivalent temperature. Similarly, a series of indexes is constructed while the most commonly used indexes are THI (Temperature Humidity Index), HI (Heat Index), HUMIDEX and others.

Temperature-Humidity Index THI:

THI was used for the determination of temperature comfort in the works by Toya et al. (2007). Yilmaz et al. (2007) used THI for quantification of temperature comfort over various vegetation and artificial surfaces. The THI calculation as used by Unger (1999) follows:

$$\text{THI } (^{\circ}\text{C}) = T - (0.55 - 0.0055\text{RH}) * (T - 14.5)$$

where T – air temperature ($^{\circ}\text{C}$)

RH – relative air humidity (%)

Optimum temperature conditions for human organism are within the range of 15 to 20 $^{\circ}\text{C}$.

Heat Index HI

HI index expresses felt temperature as combination of air temperature and humidity. HI index was defined by R.G. Steadman in 1979 and is used mostly in the U.S. It is also called Apparent Temperature (AT). The following equation is used for HI calculation:

$$\text{HI } (^{\circ}\text{F}) = -42.38 + 2.049 * T + 10.143 * \text{rh} - 0.2248 * T * \text{RH} - 0.0068378 * T^2 - 0.05482 * \text{RH}^2 + 0.001229 * T^2 * \text{RH} + 0.0008529 * T * \text{RH}^2 - 0.00000199 * T^2 * \text{RH}^2$$

where T – air temperature ($^{\circ}\text{F}$)

RH – relative air humidity (%)

The HI index is calculated only for temperatures above 20 $^{\circ}\text{C}$ (68 $^{\circ}\text{F}$). The calculated value expresses the degree of health hazard for hazardous groups of inhabitants.

Humidex

The Humidex index was used for the first time in 1965 in Canada and has been used there till now. The following equation is used for Humidex calculation:

$$\text{humidex} = T + (0.5555) * (e - 10.0)$$

where T – air temperature ($^{\circ}\text{C}$)

e – actual vapor pressure (kPa)

This equation is similar to that for calculation of equivalent temperature as used by Čabajová (in: Kolektiv, 1979):

$$T_e = T + 15e$$

where T – air temperature ($^{\circ}\text{C}$)

e – actual vapor pressure (kPa)

Material and methods

The data from four measurement places were processed in order to study time and space variability of bioclimatology indicators in Brno. These data comprise the summer season (April – September) in the years from 2006 to 2008. Two of the places, Tuřany and Žabovřesky, are part of station network of ČHMÚ. Another two places, namely Jundrov and Mendlovo Square are part of the network built for the purpose of climate study in Brno. All stations are automatic, with measurement period of 15 minutes. Two categories of Heat Index, “caution” and “extreme caution” were used.

Results and discussion

As expected, the frequency of high values of indexes is the highest of all in Mendlovo Square. The frequency of high values becomes lower in the direction towards the city boundaries and the lowest values were measured in the reference station in Tuřany. The values of indexes in the “caution” category are increased by 44 to 61% in Mendlovo Square in comparison with the values measured in Tuřany. The differences in the frequency of high values in the category “extreme caution” are even bigger (Figure 1). The value of index in this category was measured only once in Tuřany every year from 2006 and 2008 while values of 260 and 79 were measured in the city centre. The year of 2007

was the warmest year of the three measured years and a significant increase of values in this category was observed in the stations placed out of the city centre and in Tuřany. This fact suggests that small changes of the average temperature can lead to a dramatic growth of days with a high temperature load on inhabitants, even in the places where the frequency of such values of indexes was negligible in the past.

The highest frequency of values in both categories during daytime was registered around 1 to 2 p.m. The highest frequency was measured again in Mendlovo Square while the values become lower in the order of mention in the stations in Źabovřesky, Jundrov, with the lowest frequency being measured in Tuřany.

Continuous periods are more important than absolute numbers of frequency of HI in the individual categories from the point of view of the temperature load on inhabitants. The organism has no chance to relax temporarily at lower temperatures. Thus, we have created the database of all continuous periods with the occurrence of “caution” or the higher index category, period length at least 2 hours and maximum gap of 30 minutes.

At first glance it can be seen that longer periods appear more frequently in the city centre than in the city boundaries. These periods appear in less than 12% of all days in the summer season in Tuřany station. The trends of individual stations are close to each other if the period extends. The period length of individual stations is similar if the period occurrence is less probable. The longest period takes 14 hours, thus all periods are broken at least at night.

Further, it has been found that there is no proportion between the period length in the city and in Tuřany for periods with “caution” and a higher category. This relation cannot be expressed by any simple proportional coefficient as in principle there are three types of days with various relation between period lengths:

1. Period length in Tuřany is significantly shorter than the period length of a station in the city
2. Period length in Tuřany is similar to that of a station in the city
3. All other cases between the two above-mentioned situations

Conclusions

The present paper has shown a survey of indices most frequently used for the determination of human temperature comfort or discomfort in relation to the air temperature and humidity. HI index calculated from four measuring stations and quarter-hour samples in the years from 2006 to 2008 indicates that “caution” category appears more in the station placed in the city centre than in

the station placed out of city build-up area. The difference is 44 to 61%.

Also the second index category “extreme caution” can be expected more frequently in the city than outside the city limits. However, the increasing temperature discomfort on inhabitants related to the increasing average air temperature can be found also outside of the city boundaries. This is valid especially for hazardous groups of inhabitants.

But, although the qualification scales of most indexes are focused on the quantification of the increased temperature load, it can be concluded that the danger of organism degradation due to temperature load appears more frequently in the city, but at the same time the “pleasant” period becomes longer, namely in spring and autumn months and in morning and afternoon hours in summer.

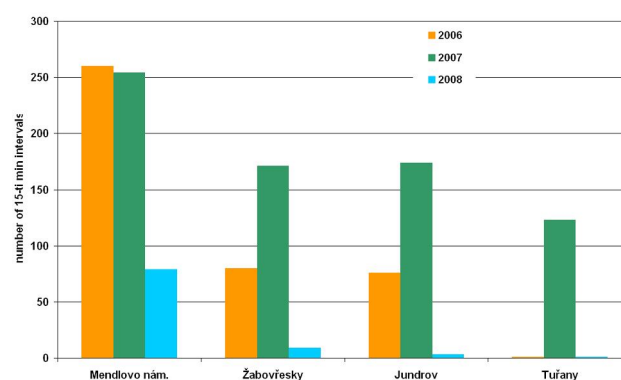


Figure 1: Frequency of category “extreme caution” in various years

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