

# **Berichte des Meteorologischen Instituts der Albert-Ludwigs-Universität Freiburg**

**Nr. 18**

**Helmut Mayer and Andreas Matzarakis (eds.)**

## **5<sup>th</sup> Japanese-German Meeting on Urban Climatology**

**Albert-Ludwigs-University of Freiburg, Germany  
October 2008**

**Freiburg, March 2009**



## **Differences in the thermal bioclimatic conditions on the urban and rural areas in a southern Hungarian city (Szeged)**

Ágnes Gulyás<sup>1</sup>, Andreas Matzarakis<sup>2</sup>, János Unger<sup>1</sup>

<sup>1</sup>University of Szeged, Department of Climatology and Landscape Ecology, Hungary

<sup>2</sup>Meteorological Institute, Albert-Ludwigs-University of Freiburg, Germany

### **Abstract**

The aim of this study is to compare the bioclimatic situation of a city and the surrounding rural area on the example of a Southern Hungarian city (Szeged). To examine the frequency of the one hour averages of the PET index, it is shown that due to the strong direct radiation a strong or extreme heat stress values has 1.1 % higher occurrence in the rural areas compared to the urban ones. But considering the PET averages through the whole examined time period, it is 14 % higher in the urban areas. This effect is more pronounced in summer, when daytime with extreme heat stress is followed by night with 7-8 °C higher PET values in the city. During these times, the human body cannot regenerate in the nights before the repeated extreme heat stress occurs again during daytime. This makes the urban bioclimatic conditions (in summer, especially during heat wave) more demanding, compared to the rural ones.

### **1. Introduction**

Characteristic climatic phenomena, occurring in cities (urban climate, urban heat island) generates special environments for their residents. The climatic effects of the cities can enhance the thermal stress of the residents (in summer, especially during heat waves), or attenuate it (in winter). The highest intensity of the urban heat island is formed several hours after sunset keeps the extent of the heat stress at high levels in addition to the strong heat stress during the daytime. This shortens the regeneration possibilities of urban inhabitants during the night (Gulyás et al., 2006).

One of the most popular thermal index in the bioclimatic researches is the PET (Physiologically Equivalent Temperature). PET is defined as the air temperature at which the human energy budget for the assumed indoor conditions is balanced by the same skin temperature and sweat rate as under the actual complex outdoor conditions to be assessed (e.g. Mayer and Höppe, 1987; Höppe, 1999).

The aim of this study is to compare the bioclimatic situation of a city and the surrounding rural area on the example of a Southern Hungarian city (Szeged).

### **2. Study area and methods**

Szeged is located in the southern part of Hungary (46°N, 20°E) at 79 m above sea level on a flat plain. The base of the street network is a circuit-avenue system, with several different land-use types from the densely built centre to the detached housing suburb region (Fig. 1).

Szeged is in the climatic region *D.I* according to Trewartha's classification (continental climate with a long warm season). The annual mean temperature is 10.4 °C and the amount of precipitation is 497 mm, the annual mean sunshine duration is 2100 hours.

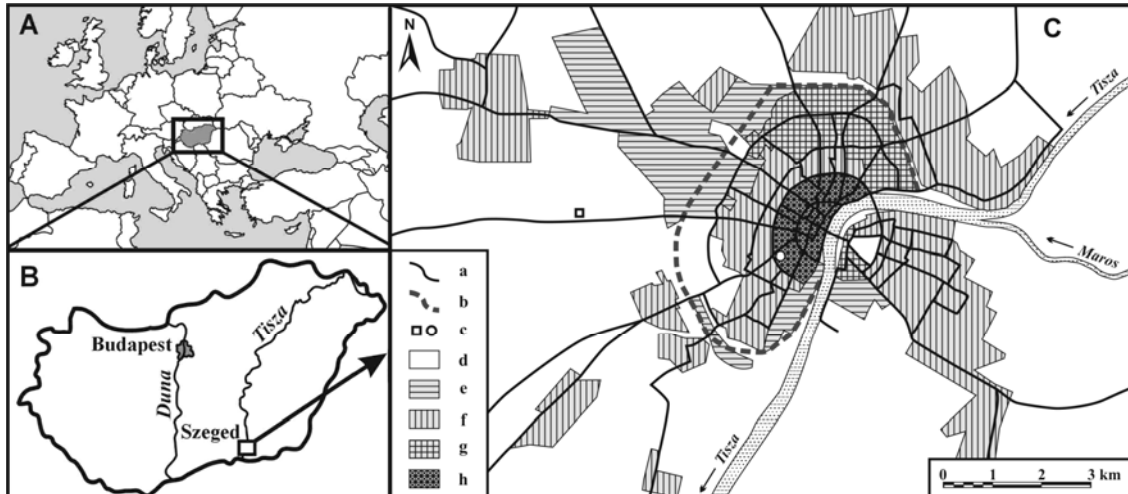


Fig. 1: Geographical location of Hungary in Europe (A), of Szeged in Hungary (B), characteristic land-use types and road network of Szeged (C), a: road, b: circle dike, c: measuring point in the city centre (○) and in the rural area (□), d: agricultural rural area, e: industrial area, f: 1-2 storey detached houses, g: 5-11 storey apartment buildings, h: historical city core with 3-5 storey buildings

Human-biometeorological relevant data (air temperature ( $T_a$ ), relative humidity ( $RH$ ), wind velocity ( $v$ ) and global radiation ( $G$ )) were measured on two different sites of the city (Fig. 1C), with Vaisala meteorological stations. One of them (**h**) is situated in the city centre on a heavily built up area, and the other (**h\***) one on the rural, agricultural area. The examined time period is between March and November (the most important period for outdoor activities) in 2003. PET comfort index was calculated using the RayMan model (Matzarakis et al., 2007).

### 3. Results

Considering the average of PET through the whole examined time period, the difference is 14 % higher in the urban areas. While there is no considerable difference between highest PET values of the two examined areas (0.4 °C), the difference between the minimum PET values is much higher (6.4 °C).

It is shown in Fig. 2 that extremities have higher occurrence in the rural areas compared to the urban ones: frequency distribution of the strong or extreme heat stress is 9.1 %, of the strong or extreme cold stress 38.7 % during the examined period.

The occurrence of the periods without thermal stress is two times higher in the city, than outside: 16.7 % between March and November.

As the average of  $\Delta PET_{u-r}$  values in Fig. 3 shows the heat load is higher on the urban areas in each month of the examined time period ( $\Delta PET_{u-r}$  is positive) and the difference between the urban and rural area is higher in the night (between 22 and 05 CET) especially in the summer months.

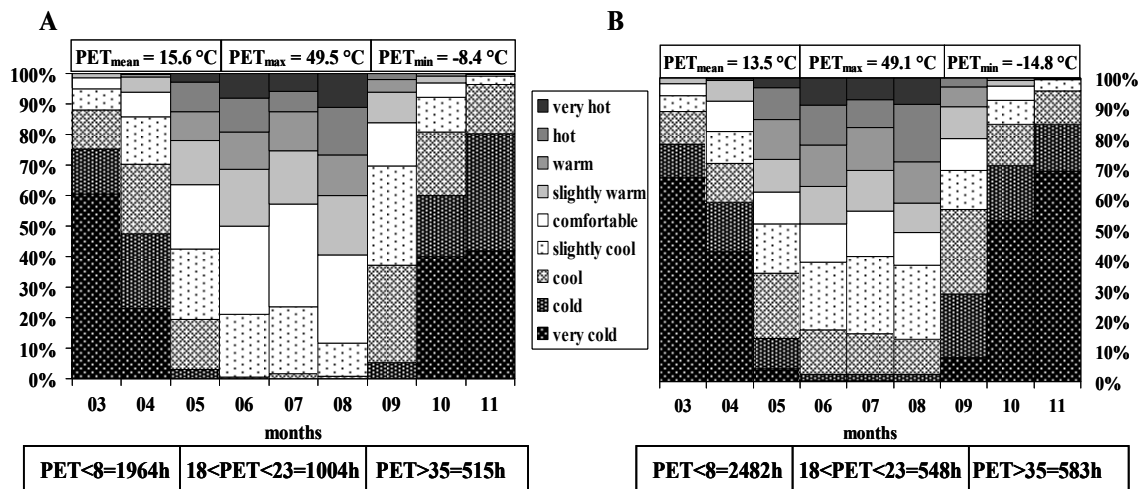


Fig. 2: Frequency of PET (one hour averages) and different grades of physiological stress at the urban (A) and the rural (B) area from March to November 2003 in Szeged

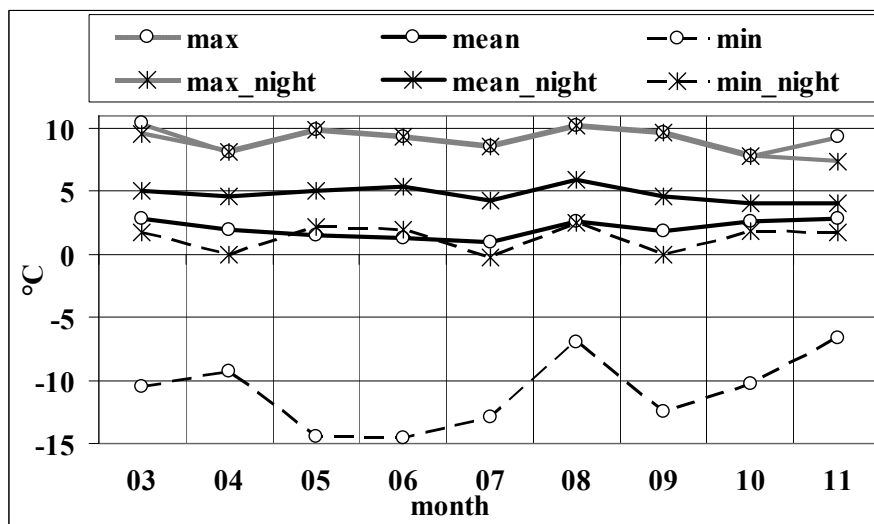


Fig. 3: Mean, maximum and minimum  $\Delta PET_{u-r}$  all day and in the night (22-05 CET) between March and November 2003 in Szeged

The highest difference (max  $\Delta PET_{u-r}$ ) can be observed during the night, except early spring and late autumn. The heat load values can be higher outside the city (negative  $\Delta PET_{u-r}$  values), but this phenomenon never occurs at night.

In the summer of 2003, a heat wave hit Europe, and also Hungary. Very high daytime temperatures mostly in anticyclonic situation dominated the whole month with mainly low wind speed.

As the Fig. 4 shows the distribution of the PET index is similar in the urban and rural areas during the day. The highest values of the extreme heat load are measured between morning to late afternoon and are higher in the urban areas (exceeded up to 49 °C). But

at night cold stress can be observed more frequently in the rural areas with higher occurrences of slightly cool, and cool thermal sensation category.

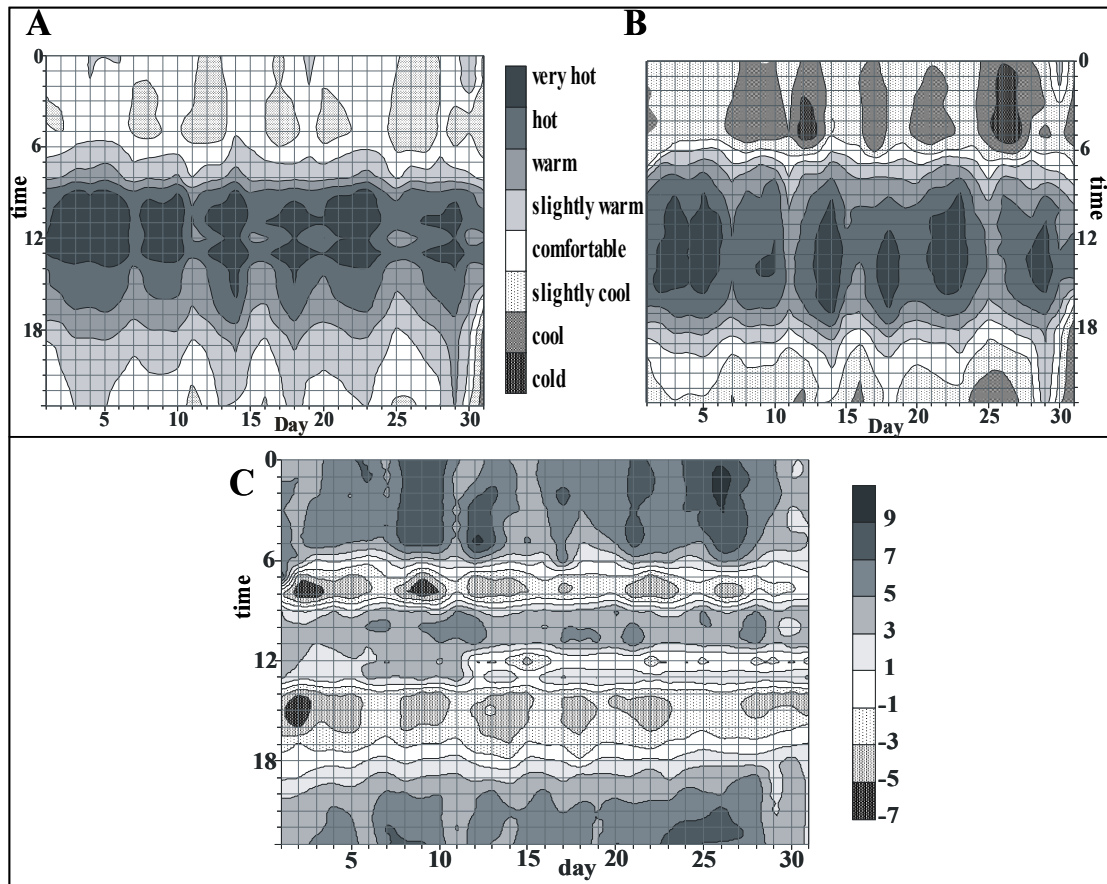


Fig. 4: Characteristics of the bioclimatic conditions through the PET (°C) index in one hour averages on the urban (A) and the rural (B) area and  $\Delta\text{PET}_{u-r}$  (C) of August 2003 (time is in CET)

As the Fig. 5A shows the daily progress of the mean PET index is similar, but the values of the urban area are above the rural ones all day, except at about 7 am and between 17 and 19 CET.

The first peak of the urban area disappears in the late morning, due to the decreased wind speed, caused by the roughness of the urban areas and the slight heat excess calculated in this time of the day. The PET values of the rural areas can be higher than the urban areas only about three hours per day early morning and in the late afternoon due to the strong and undisturbed solar radiation on the rural areas (Fig. 5B). The second pronounced peak is started to be formed after sunset and reaches the highest values (7-8 °C higher on urban areas) around 2-3 am to correlate with the urban heat island phenomenon. This means two categories differences in the thermo-physiological stress level.

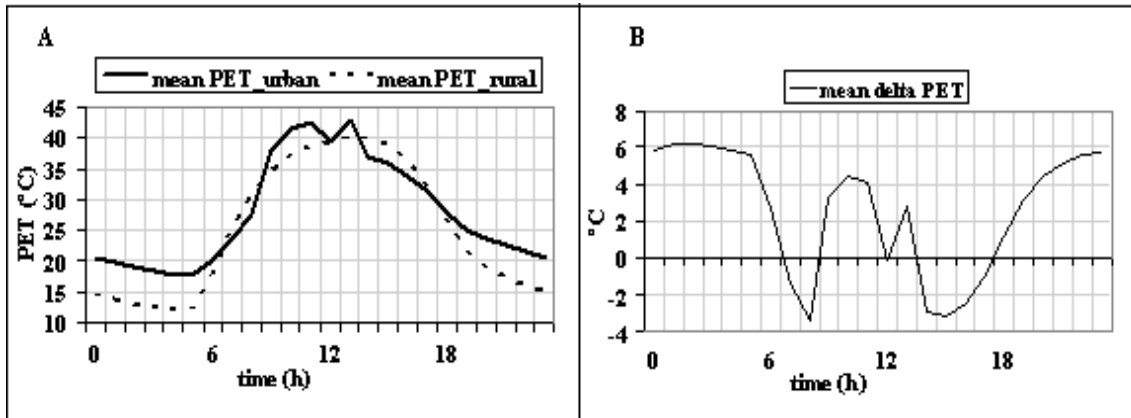


Fig. 5: Daily progress of PET at urban and rural areas (A) and of mean  $\Delta\text{PET}_{u-r}$  (B) in August 2003

#### 4. Conclusions

The aim of this study was to compare the bioclimatic situation of a city with continental climate and the surrounding rural area.

- (i) Using the PET index, we could detect significant difference between the two areas.
- (ii) The heat load of the urban area was more even, with less extremities, compared to the rural one. This may increase the comfort of the residents of the city, especially in spring and autumn, because cold stress is lower during the nights.
- (iii) In summer however, especially in heat waves, this even heat load is not unequivocally positive phenomenon. Due to the lower direct radiation caused by smaller sky view factor values (obstacles of the city: buildings, trees), the occurrence of the extreme high heat stress is lower in the urban areas. During the night however the decrease of the heat load is significantly smaller (due to the UHI) in the city than in the surrounding rural areas. This effect reduces the regeneration chance of the human bodies before the heat stress of the next day. Thus the occurrence of the comfort thermal sensation category is higher in the city apparently, but it does not mean better bioclimatic situation especially during the heat waves.

#### Acknowledgements

This research was supported by the Hungarian Scientific Research Fund (OTKA K-67626).

#### References

- Gulyás, Á., Unger, J., Matzarakis, A., 2006: Assessment of the microclimatic and human comfort conditions in a complex urban environment: modelling and measurements. *Build. Environ.* 41, 1713-1722.
- Mayer, H., Höppe, P., 1987: Thermal comfort of man in different urban environments. *Theor. Appl. Climatol.* 38, 43-49.
- Höppe, P., 1999: The physiological equivalent temperature - an universal index for the biometeorological assessment of the thermal environment. *Int. J. Biometeorol.* 43, 71-75.

Matzarakis, A., Rutz, F., Mayer, H., 2007: Modeling radiation fluxes in simple and complex environments - Application of the RayMan model. *Int. J. Biometeorol.* 51, 323–334.

**Authors' addresses:**

Ágnes Gulyás (agulyas@geo.u-szeged.hu)

Prof. Dr. János Unger (unger@ geo.u-szeged.hu)

Department of Climatology and Landscape Ecology, University of Szeged  
Egyetem u. 2., H-6722 Szeged, Hungary

Prof. Dr. Andreas Matzarakis (andreas.matzarakis@meteo.uni-freiburg.de)

Meteorological Institute, Albert-Ludwigs-University of Freiburg

Werthmannstr. 10, D-79085 Freiburg, Germany