ANALYSIS OF URBAN LOCAL CLIMATE USING IN-SITU MEASUREMENTS

CSENGE DIAN [1], RITA PONGRÁCZ [1],
JUDIT BARTHOLY [1], ZSUZSANNA DEZSŐ [1]

ABSTRACT. - Analysis of Urban Local Climate Using In-Situ Measurements Concentrated human presence evidently modifies the natural environment. On local scale, one of the major effects is related to urban areas. Recently, we have started in-situ urban measuring program in a downtown district of the Hungarian capital. The study area within Budapest is located near the river Danube in the southern central part of the city, and mainly consists of 3- and 4-storey older and newly built buildings, which is a result of the local government concentrated efforts completing several block rehabilitation programs starting from 1980s. Since 1993 in the most densely built inner part of the district entire blocks were renovated and modified in order to create more liveable environment for the citizens. Within the framework of these programs, inner parts of the blocks were demolished, thus, inside the blocks more common green areas could be created. The resulting climatic effects are evaluated now on the basis of temperature and relative humidity measurements. Our main goal is to analyze whether the generally positive changes of the built environment can also be recognized in the urban heat island effect of the rehabilitation area.

Keywords: urban heat island, air temperature, relative humidity, district of Budapest

1. INTRODUCTION

One of the main environmental impacts of large cities is the urban heat island (UHI) effect. UHI can be characterized by its intensity, which means the difference between urban and rural temperature. To determine the UHI intensity, several variables can be used, e.g., regular meteorological air temperature measurements at 2 m level (e.g., Oke, 1973), ground-based air temperature measurements using a moving vehicle (e.g., Unger et al., 2000), surface temperature data calculated from radiation measurements of satellites (e.g., Price, 1979; Pongrácz et al., 2006), or remotely sensed surface temperature measurements placed on board of an aircraft (e.g., Ben-Dor and Saaroni, 1997). When surface temperature is used to describe the urban climate conditions, surface UHI (SUHI) effect can be evaluated. Within the framework of the urban climate research at the Department of Meteorology, Eötvös Loránd University, Budapest (Dezső et al., 2005, Pongrácz et al., 2006, 2010), SUHI effects of several Hungarian and Central European cities have been analyzed using remotely sensed

[1] Eötvös Loránd University, Department of Meteorology, Budapest, H1117, Pázmány st. 1/a. Hungary
E-mails: diancsenge@gmail.com, prita@nimbus.elte.hu, bartholy@caesar.elte.hu, dezso.zsuzsanna@ttk.elte.hu

surface temperature. In this current paper, the focus is on a smaller subregion of the Budapest agglomeration area, namely, one of the 23 districts of the Hungarian capital. Ferencváros, the 9th district of Budapest is located along the river Danube, which divides the entire city and the downtown region into two parts. Ferencváros itself is a very heterogeneous part of the city consisting of 3- and 4-storey old buildings, block houses with either 4 or 8 levels, brown industrial areas, and large areas occupied by the railways system. Partly due to the functional and structural changes of special subsections of the district substantial local climatic changes occurred in the past few decades. The local government made concentrated efforts to improve the environment for the citizens starting from 1980s. Since 1993 in the most densely built inner part of the district entire blocks were renovated and modified. Within the framework of block rehabilitation programs inner parts of the blocks were demolished, thus, inside the renewed blocks more common green spaces could be created. Moreover, several parks have been enlarged, and small green areas have been created along the streets (Local Government of Ferencváros, 2010). The overall increase both in terms of number and spatial extension of green areas is illustrated in Fig. 1.

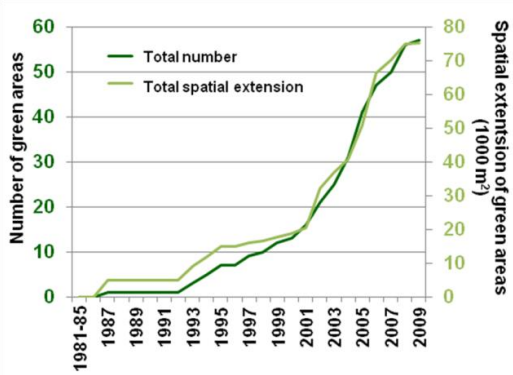

Fig. 1. ***Increase of the green areas in Budapest-Ferencváros***

2. MEASUREMENTS

In order to extend our satellite-based earlier studies (e.g., Pongrácz et al., 2015) we have recently started an in-situ urban measuring program in the rehabilitation region of Ferencváros. In this urban climate measurement program air temperature and relative humidity are recorded with Voltcraft HT-200 instruments along a pre-defined path consisting of 22 measuring points (Fig. 2), which covers the studied area. The measuring sites are selected at different representative points of the district, such as green parks, narrow streets, paved squares and roads. The whole measuring path is divided into two parts, where the measurements are recorded simultaneously (from 101 to 112, and 201 to 212 with the identical starting and ending sites, i.e., 101 is identical to 201, and 112 is 212) lasting about 1-1.5 hours. Then, the measurements are recorded along the same two paths but in reverse order (i.e., starting from 112/212, and ending at 101/201). In

order to temporally adjust the measurements, two records from the consequent (and reversed) partial paths are averaged over each site resulting in an average value being representative for a virtual time. More precisely, since the moving speeds between sites and the distances between sites are not perfectly identical, this virtual time is given as a 10-20 minute time period. For calculating the urban heat island intensity, temperature measurements are compared to the hourly recorded data of the Budapest synoptic station (ID number: 12843) located in the southeastern suburb district of the city. Similarly, difference between relative humidity measurements are calculated and analyzed.

201: Ferenc bld. / Tompa st.	101: Ferenc bld. / Tompa st.
202: Bakáts sq. / Tompa st.	102: Tompa st. / Liliom st.
203: Bakáts sq. / Ráday st.	103: Liliom st. / Tűzoltó st.
204: Ráday st. 42	104: Tűzoltó st. / Bokréta st.
205: Ráday st. / Biblia st.	105: Ferenc sq.
206: Ráday/Erkel st	106: Balázs Béla st. / Thaly Kálmán st.
207: Kálvin sq.	107: Univ. Building
208: Lónyay st. / Gönczy Pál st.	108: Kerekerdő Park
209: Csarnok sq.	109: Márton st./ Gát st.
210: Building Bálna	110: Mester st. /Viola st.
211: Nehru Park	111: Mester st. / Tinódi st.
212: Boráros sq.	112: Boráros sq.

Fig. 2. ***Measuring points along the predefined path***

The measuring program started in early spring of 2015, the dates are listed in Table 1. The measurements are scheduled once a week (on Friday), from about noon until the late evening. The on-going measuring program involves BSc students specialized in Earth sciences and MSc students specialized in meteorology, therefore, 8 dates were completed in the spring semester of 2015, and another 8 dates in the autumn semester of 2015. During the summer three consecutive days were selected for the measuring program in early July, and the

last Friday of August. We are planning to extend further the measuring program at the study area and complete several entire years of measurements, so the seasonal cycle of temperature and relative humidity differences will be analyzed as well, as the inter-annual variability and changes.

Table 1. ***Measuring dates during 2015***

Spring	Summer	Autumn
20 March	6 July	18 September
27 March	7 July	2 October
3 April	8 July	9 October
10 April	28 August	6 November
17 April		13 November
24 April		20 November
8 May		27 November
15 May		4 December

3. RESULTS AND CONCLUSIONS

Among the measuring dates one is selected here for detailed analysis. Since UHI together with a heatwave result in excessive heat stress for humans, and thus, significant health consequences, measurements on one of the heatwave days (7 July) occurred in the summer 2015 are presented. The entire heatwave period in the Pannonian Basin was dominated by a strong anticyclone over Central/Eastern Europe with clear sky conditions. The averaged air temperature values and the differences compared to the Budapest-Pestszentlőrinc synoptic station throughout the day – starting from about 14 pm to 21 pm – are shown in Fig. 3.

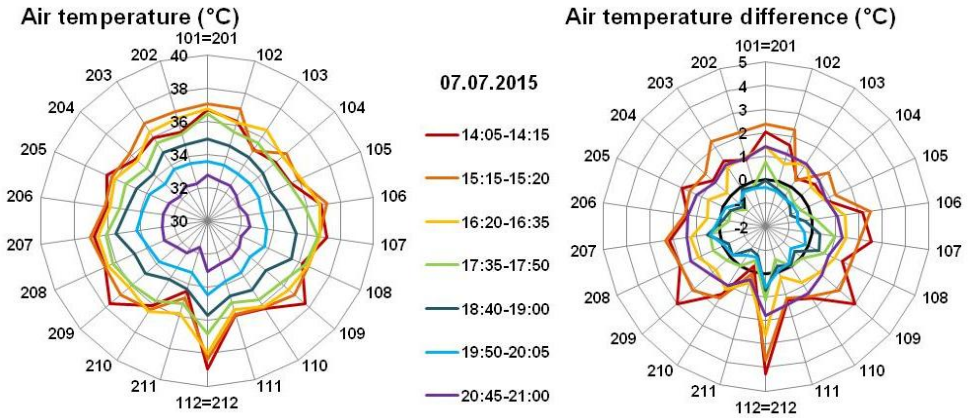

Fig. 3. ***Averaged temperature and UHI intensity values along the measuring path during the 7 measuring periods, 7 July 2015***

The warmest site was the Boráros square, which is a large paved square near the river Danube with main stations of the public transportation system and partially surrounded by 4-storey buildings. The recorded temperature exceeded 38 °C between 14 pm and 16:30 pm. The coolest sites were the greener spaces (i.e., park along the Danube, 211; park in the rehabilitation area, 105). Towards the evening (starting around 17:30 pm) the cooling rate until the end of the measurements (around 21 pm) at all the measuring sites was about 1.5-2 °C/h. However, the air temperature stayed still above 30 °C. As far as the UHI intensity, the largest values occurred at the largely paved Boráros square (112=212). The largest temperature difference between our measurements and the Budapest-Pestszentlőrinc synoptic station exceeded 4 °C.

Similarly to the air temperature, results of the relative humidity measurements are shown in Fig. 4. Due to the temperature dependence, opposite tendencies can be recognized, i.e., lower relative humidity values were generally recorded at the warmer sites than at the cooler sites. This is also valid for the relative humidity differences compared to the air temperature differences, namely, smaller difference values are found at the sites where UHI intensity is larger.

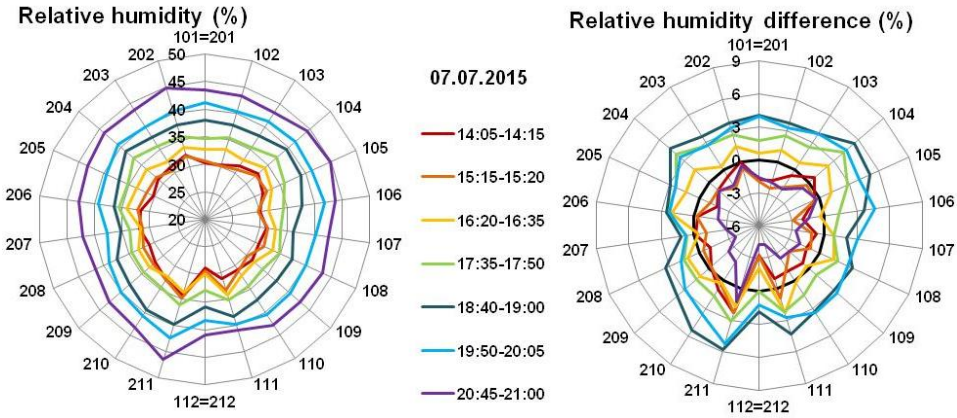

Fig. 4. ***Averaged relative humidity values and the difference from the Budapest-Pestszentlőrinc synoptic station along the measuring path during the 7 measuring periods, 7 July 2015***

In order to visualize the relationship between the air temperature and relative humidity differences, the values for the individual sites shown in Figs. 3 and 4 are averaged, and plotted in Fig. 5. It can be clearly seen that the UHI intensity values between 17:30 pm and 20:00 pm were quite low, close to zero (implying that the suburban temperature and the inner-city temperature did not differ significantly). Since the last measuring period was already after the sunset at 20:44 pm, the well-known increase of UHI intensity after the evening (e.g., Oke, 1982) was detected in our measurements.

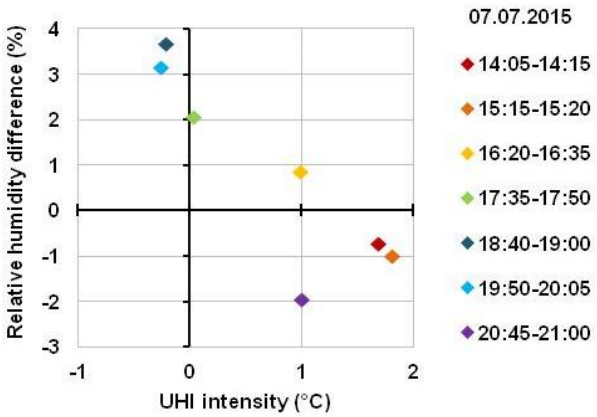

Fig. 5. ***Relationship between the averaged UHI intensity values and relative humidity differences relative to Budapest-Pestszentlőrinc synoptic station data during the 7 measuring periods, 7 July 2015 (sunset occurred at 20:44)***

As already mentioned, the measuring program has just started, and we are planning to continue throughout 2016 and beyond in order to build year-round datasets for analysing the seasonal cycle of temperature and relative humidity differences as well, as the diurnal changes and the spatial structure within the study area.

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REFERENCES

1. Ben-Dor, E., Saaroni, H. (1997), *Airborne video thermal radiometry as a tool for monitoring microscale structures of the urban heat island*. International Journal of Remote Sensing 18, 3039-3053.
2. Dezső, Zs., Bartholy, J., Pongrácz, R. (2005), *Satellite-based analysis of the urban heat island effect*. Időjárás – Quarterly Journal of the Hungarian Meteorological Service 109, 217-232.
3. Local Government of Ferencváros (2010), *Rehabilitation of Budapest Ferencváros*. Budapest, 80p.
4. Oke, T.R. (1973), *City size and the urban heat island*. Atmospheric Environment 7, 769-779.
5. Oke, T.R. (1982), *The energetic basis of the urban heat island*. Quarterly Journal of the Royal Meteorological Society 108, 1-24.
6. Pongrácz, R., Bartholy, J., Dezső, Zs. (2006), *Remotely sensed thermal information applied to urban climate analysis*. Advances in Space Research 37, 2191-2196.

7. Pongrácz, R., Bartholy, J., Dezső, Zs. (2010), *Application of remotely sensed thermal information to urban climatology of Central European cities*. Physics and Chemistry of Earth 35, 95-99.
8. Pongrácz, R., Bartholy, J., Dezső, Zs., Dian, Cs. (2015), *Analysing the climatic effects of local block rehabilitation programs in Budapest-Ferencváros*. Proceedings of the 9th International Conference on Urban Climates (ICUC9), Toulouse, France. 20-24 July 2015. Extended abstract, 6p.
9. Price, J.C. (1979), *Assesment of the heat island effect through the use of satellite data*. Monthly Weather Review 107, 1554-1557.
10. Unger, J., Bottyán, Zs., Sümeghy, Z., Gulyás, A. (2000), *Urban heat island development affected by urban surface factors*. Időjárás – Quarterly Journal of the Hungarian Meteorological Service 104, 253-268.