COLD AND HOT EVENTS IN URBAN ENVIRONMENT
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Abstract
Climate can strongly influence the living of town-dwellers, and cities have feedback on climate. The structure of a city including density and height of buildings, number and size of places covered by natural plants has a considerable effect on the development of heat island as well as smog situations. Nevertheless climate information is insufficiently used by city-planners. The features of heat island characterized by hot and even by cold weather give useful information about the structure of the town. Usually the crowded inner town is the warmest place opposed to the suburb. Our purpose was to find out local places which are strongly different from the expectation. We were looking for special artificial solutions which can be used to influence our local environment. First, clear summer and winter days were selected and analyzed. Then, synchronous observation of the studied Hungarian city (Budapest) measured at the urban and the suburban area was compared. The spatial distribution of UHI was analyzed on critical days together with composite of surface meteorological observations, satellite images and the lay-out plan of Budapest. Selected places was visited and analyzed in the context of urban fabric.

Key words: satellite image, temperature, urban planning

1. INTRODUCTION
This preliminary study intend to provide some convincing evidences for the positive and negative effects of man-made environment based on spatial distribution of different temperatures analyzed in the inner part of Budapest. Three different sources were merged. (i) Satellite images containing surface temperature measurements of sensor ASTER and MODIS (Barnes et al., 1998), which were selected due to their fine resolution. One pixel covers 90×90 m² and 1×1 km², respectively (NASA, 1999). The very fine spatial resolution of ASTER is able to provide appropriate information even on scale of block of houses. Typical clear days were analyzed by seasons in order to detect the area warmer than the surrounding environment including arbitrary and natural surfaces. (ii) Lay-out plan of Budapest was used to identify built-in types and (iii) Google Earth maps were used to control places.

The sensor ASTER was developed in order to estimate surface kinetic temperature using remote sensing information. Traditionally, air temperature is measured at 2 meter height in shadow. In large cities it is impossible to install a dense network of meteorological stations with standard measuring program, but satellite data may provide useful information with full horizontal coverage. Taking into account parallel data sets derived from satellite- and ground-based observations, some basic statistical analysis was carried out to evaluate the mean differences. Based on the results, important conclusions may lead to useful information mainly for heat alarming system, which mostly uses temperature data measured in the cooler suburban regions of the city instead of the more exposed inner city area.

2. DATA AND METHOD
Budapest is the capital of Hungary with about 1,7 million inhabitants. The city is divided by the river Danube. Area of the town is 525 km², the east half is plain, the west mostly hilly with 529 meter peak. Compare to the megacities the buildings are small with an average 30 meter height. Case study was carried out for summer and winter cases. Composite pictures summarized the information of temperatures derived from ASTER, the Google map, and city plan. The region was selected taking into account the complexity of the area containing industrial quarter, housing estates made from concrete, houses with gardens, parks, sport ground, lakes, cemetery and green roof. The series of composite pictures separates light and dark areas according to the given limit temperature increased step by step with 1 °C.

Satellite-based surface temperature data sets were collected between 2001 and 2008. Sensor ASTER is on-board satellite Terra, and sensor MODIS can be found on satellites Terra and Aqua (NASA, 1999). Both satellites move on a polar orbit and cross Budapest two times a day. Hourly mean ground-based air temperature observations overlapping the 2001-2008 periods were added at four stations of the Hungarian Meteorological Service. Basic statistical analysis was carried out to evaluate mean annual and monthly difference of temperature values.

3. RESULTS
3.1. Typical summer day

Considering the urban heat island we are going to discuss the analysis of a summer situation. At 6th July 2001 the weather was sunny, dry and calm due to an anticyclone. On the examined area the average kinetic surface temperature was 38 °C, the minimum was 13 °C, the maximum 53 °C. Kinetic surface temperature was increased step by step with one degree. A small cloud caused the lowest temperature value (13 °C). At 19 °C appeared the trace of the river Danube. At 24 °C it was recognized a cold point above the centre of the Kerepesi Cemetery, where the oldest and greatest tree of the city can be found. At 26 °C appeared the coldest part of the City Park on the northern border of the examined area. At 27 °C small parks, e.g. the coldest area of the public gardens and a small lake in the Orczy-Garden became visible. Analyzing the temperature range between 27 °C and 33 °C the boundaries of these water and green surfaces become visible very clearly.

It was realized, that places covered by old or high tree with closed crown level are colder then rare timbering. It demonstrates that the land use is not perfectly regulated, because it does not make any difference between the grass and the affersted sites. The main difference between land use categories is the rate of arbitrary covered area (%). Between 33 °C and 38 °C appears not only the positive impact of the water and green surfaces on climate, but the difference between the dense built living spaces. It was noticed that the temperature above dense built 6-8 storey buildings is always higher while in garden-cities lower then the mean value.

At 38 °C another interest was detected. In a yard the full-grown trees can cause even 5 degree difference. Housing estates might be similar to the garden cities in case of landscaping. We concluded that green areas, garden-cities and housing estates were colder than 43 °C. Areas, where the kinetic surface temperature characterized between 44 °C and 53 °C are practically the sites of the factories, other industrial areas, and the territories of the railway stations and railroads. Actually in Budapest the greatest roads (boulevards and circuits) are narrower than 90 metres, because of this we can not have any conclusion for the kinetic surface temperature of the roads and streets. By 46 °C there can be clearly seen the industrial areas, but only the hottest points of the railway stations can reach this degree.

In the northern corner of the examined area where the Thököly boulevard crosses the Hungária circuit is an industrial site where the kinetic surface temperature is extremely differs from the temperatures of the other industrial sites. The kinetic surface temperature of these other industrial sites is usually between 45 °C and 54°C but here in this small area the temperature is only 41 °C. After the examination of this it was recognize, that here is a great office block. The inner yard of the building is almost completely paved for car parking and there is only a small green place in the middle of the pavement. Further analyzes helped to recognize that this building is colder than the other industrial sites and even colder than the neighbouring living spaces. We have found only one difference which can explain this anomaly. The roof of this office building is covered with a green roof, which is greater than 1000 m². Probably a green roof in such a size can change so much the albedo and the thermal conditions, that it became detectable from the space, too.

3.2. Spring case study

During the analysis of the spring (2002.05.04) image the average kinetic surface temperature was fined 34,5 °C, the minimum kinetic surface temperature was 15 °C, the maximum 44 °C. Between 15 °C and 24 °C we can see only the line of the river Danube, which means that all other surface were warmer than 24 °C. At 18 °C the bridges on the river Danube become clearly visible. By 25 °C appears first a green of the City Park in the Kerepesi Cemetery as happened in summer. The lake of the Orczy-Garden and the colder points of the Folk Park appeared at 26 °C. The coldest point of the Kerepesi Cemetery is just at 27 °C. In the range of 27 °C and 34 °C the situation remind us to the summer image. By 33 °C the Köztársaság Square became clearly visible. This square consists of two parts: the bigger part is a small park, and the smaller part is a theatre and the surrounding pavements. When we subjective examined the square we recognized that the roof of the theatre is covered with zinc. By 33 °C is clearly visible the cold L-shaped green area and the hot square of the theatre. Between 35 °C and 44 °C the situation is also very similar to the summer image. It is important to talk about a building which is out of the examined area. This building is the main block of the Corvinus University of Budapest at the bank of the river Danube. Here is no industrial activity, but the inner yards of this block is covered by glass roof. This building can be detected by 41 °C, similar to the warmest industrial sites (e.g. factories).

3.3. Clear winter day

In winter time even the badly insulated roofs become visible. Picture show the weather of 2nd February 2003. In the selected districts of Budapest the average kinetic surface temperature was -1 °C, the minimum was -6 °C and the maximum 5 °C. The coldest point was a railway overpass out of the examined area. Between -6 °C and -3 °C the parks and the greatest opened areas without thermal activity appeared. At -3 °C the boundaries of the greater parks and green parcels become clearly visible. Between -2 °C and -1 °C can be seen, that the garden cities are colder and the dense built areas close to the city centre are warmer. In the range 0 °C and 2 °C the water surface of the river Danube become very clearly visible, this means that in winter the water surfaces are heating their
environment and the parks are colder than their environment. By 2 °C only a few hot points can be seen. After resembling these hot points with the Google Earth image and the land use map we concluded that not the land use is important, but the covering materials of the roofs. These observations strengthen what we recognized by the spring image, that the metal and glass covered roofs heats their environment the most. This impact is more dominant, when the building is heated from inside.

3.4. Comparison of satellite- and ground-based temperature

According to the literature the temperature should reproduced within about ±1.5 °C precision. Our experiences are illustrated by annual mean differences of satellite- and ground-based observations (Fig. 2.). The range varies between 0.43 and 1.03 °C. Smaller temperature difference values are found in the inner town (Kitaibel street), and larger in the less densely built-in suburban area (Lőrinc). The difference has a remarkable annual cycle (Fig. 3.), with a positive peak in summer and negative in winter. It means that surface temperature values calculated from thermal emissions overestimated the air temperature measured in standard meteorological stations by 1.5-3 °C in summer and underestimated by 1-2.5 °C in winter. The smallest differences between satellite- and ground-based temperature observations can be found in the Kitaibel street and Újpest representing the inner city regions. The best fit of the two different measurement methodologies were detected in March and October (the mean difference does not exceed 0.5 °C).

4. TABLES AND FIGURES

Fig. 1.

Summer day in XVIII district of Budapest at 06.07.2001.

Shadow covers are below 38 °C.
5. CONCLUSIONS

Having analysed infrared images and resembling them with the land use map with the Google Earth image the following conclusions can be drawn: green areas make the urban heat island smaller in every season. This impact is naturally the greatest in summer. The type and size of the plants is very important, huge trees, which crowns reach each other can cause the biggest impact. Surface covered by vegetation even in small inner gardens are much cooler then arbitrary covered environment. Water surfaces, like rivers and lakes have significant cooling effect in summer and heating effects in winter. Even relatively small water surfaces can cause quite a big (positive) impact.

The resembling of the infrared images and the land use map reflects our assumptions. The parks and other green areas are the coldest places, the garden-cities are colder than the dense built living spaces. The huge paved sites, the territory of railway stations, factories and other industrial places are the hottest point of the city both in summer and in winter. In some cases the kinetic surface temperature strongly differed from our expectation. Such anomalies appeared on those images which were covered by buildings. Green roofs are effective tools again urban heat island. But the huge glass and metal covered roofs extremely enlarged the urban heat island effect in their environment. In winter this means a very large thermal loss and that appears negatively in the energy use of buildings.

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