Evaluation of urban heat island effects in Budapest, Hungary in the framework of an international project

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Abstract. Budapest is one of the eight regions of Central Europe that is studied by the Urban Heat Island Project financed by Central Europe Programme. The project intends to (i) provide a deeper knowledge on the man-made risk of the UHI and its interactions with global climate change, (ii) establish a permanent transnational network for monitoring the phenomenon and its development; (iii) set up suitable strategies for the mitigation of and the adaptation to UHI; (iv) improve current land-use planning tools and civil management systems according to mitigation and adaptation strategies. This paper is aimed to evaluate climate elements measured in Central European cities to detect the effect of urban heat island phenomena. In addition spatial and temporal characteristics of air temperature and urban heat island intensity have been presented by using observations at fixed sites (representing urban and rural locations). The UHI effects are directly related to (and worsened by) the climate change phenomena, where it is expected that a greater increase in the average temperature could be observed in a city than a rural, regional site. Final goal of the project is to increase our knowledge about the relationship existing between climate change and UHI phenomena. These studies can help in introducing new urban planning tools to mitigate the UHI phenomenon and prevention plans to reduce the hazard related to the heat spikes in Budapest. An urban region in the central part of Budapest will be presented as a pilot action, where the UHI mitigation measures (for example: cool roof, green roof, cool pavement, planting trees and vegetation) have been already introduced. The applied mitigation and adaptation strategies can be a good example for stakeholders to follow. Furthermore the Decision Support System developed by the project community is intended to help policy makers to compile useful information from urban climate observations, technical descriptions of a given area, predictions of numerical models.

Key words

Urban heat island, climate change, mitigation strategies.

Introduction

The urban heat island (UHI) is a microclimatic phenomenon that occurs in the metropolitan areas. It consists in a significant increasing of the temperature in the urban area respect to the surrounding peri-urban and rural neighbourhoods.

This phenomenon is known and studied since eighties and is caused by:

- physical characteristics of the surfaces, such as concrete and asphalt, that absorb rather than reflecting solar radiation;
- lack of natural evaporative surfaces (vegetation) that, in rural areas, contribute to maintain a stable energy balance;
- augmentation of the vertical surface that both provide an increased surface absorbing and reflecting solar radiation as well as block winds that could contribute to the lowering of the temperature;
- human activities that mainly consists in heat produced by heating and cooling plants and buildings, industrial activities, vehicles, etc.;
- high level of pollutants that alter the radiative nature of the atmosphere.

The intensity of UHI phenomenon increases in proportion to the dimension and population of the urban area; consequently, it is doomed to become more severe in the coming years due to the constant growing of number of people living in urban areas.

The UHI effects are directly related to (and worsened by) the climate change phenomena, where it is expected that an increase in the average temperature has a stronger and immediate effect on the health of people living in cities, and particularly of the vulnerable groups (the thick and the elderly).

In this paper an international project - called "UHI", financed by the Central European Programme and the European Regional Development Fund - will be introduced. This project was formed to study of the UHI phenomena in Central Europe and to disseminate adaptation and mitigation strategies to policy makers and public.

Project objectives

UHI Project aims at developing mitigation and risk prevention and management strategies concerning the urban heat island phenomenon. UHI Project wants to boost transnational discussion among policy makers, local administrators and professionals that will bring to developing policies and actions for preventing, adapting and mitigating the natural and man-made risks arising from the UHI phenomenon.

In particular, the project intends to:

- Provide a deeper knowledge on the man-made risk of the UHI and its interactions with global climate change.
- Establish a permanent transnational network for monitoring the phenomenon and its development.
- Set up suitable strategies for the mitigation of- and the adaptation to UHI.
- Improve current land-use planning tools and civil management systems according to mitigation and adaptation strategies.

UHI Project is developed in 8 of the most relevant metropolitan areas and MEGAs (Mega Urban Regions) of Central Europe cooperation programme:

- the metropolitan cluster of Bologna – Modena (IT)
- the urban corridor of Venice – Padua (IT)
- Vienna (AT)
- Stuttgard (D)
- Lodz & Warsaw (PL)
- Ljubljana (SI)
- Budapest (HU)
- Prague (CZ).

The Project involves sixteen partners (environmental monitoring agencies, meteorological and hydrological institutions, universities as scientific background, city development authorities and municipalities) from seven countries in the Central European region. The program started in May, 2011 and it will be finished in April, 2014.
The project has four important workpackages, one deals with collecting recent knowledge of the UHI phenomena, the second one tries to establish a common methodology for fixed urban climate monitoring networks. Third one uses numerical models for urban climate simulation and tries to find interactions between urban climate and global climate change phenomena. The fourth workpackage gives the best practice from each studied areas for successful mitigation strategies introduced by municipalities. The UHI project website (www.eu-uhi.eu) - hosted by Hungarian Met Service (HMS) web server - was developed and continuously improved according to requirements and instructions of the Central Europe Programme.

Evaluation of the urban heat island intensity, daily variations

The UHI magnitude is characterized by heat island intensity, which is the temperature difference of an urban and rural area ($\Delta T_{urban\text{-}rural}$). This temperature difference has diurnal and seasonal variations; that is usually larger at night and in winter (Figure 1).

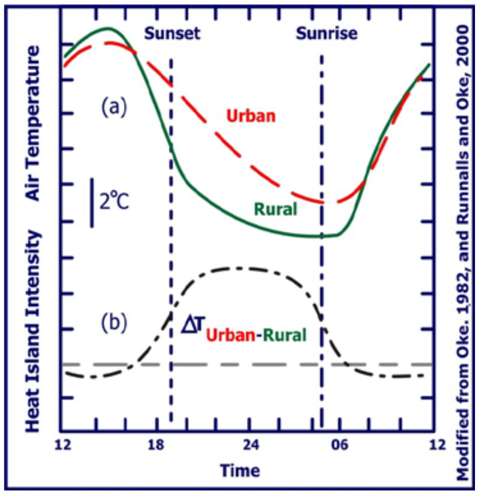

Figure 1. *Diurnal variation of the urban heat island intensity*

The participating owners of meteorological data were asked to select two weather stations, urban and rural, which represent the typical urban and rural settings of the city. The project partners were also asked to provide climate data (air temperature, wind speed and precipitation) recorded at the two selected weather stations for a period of 7 consecutive days. It was stressed that the data should be suitable for the analysis of urban heat island intensity, that the dates chosen should be from the summer of 2011, that the air temperatures during the whole period should be considerably high, and that the wind speed should preferably be below 5 m/s for most of the time.
The result of the observations are summerized in figures like Figure 2, which shows average hourly UHI intensity for the reference week. The comparisons reveal that UHI exist in all participating cities mainly during nighttime. All cities except Stuttgart have also showed much higher nocturnal UHI intensity values than the corresponding daytime values. By comparing the daily mean amplitude of UHI intensity, it seems that almost every city showed its own pattern of UHI intensity change during the whole day. Thus, in Warsaw, for example, UHI intensity level ranges from around 2K during daytime to almost 7K during the night, while in Stuttgart levels remain almost the same, ranging from 1K to 2K.

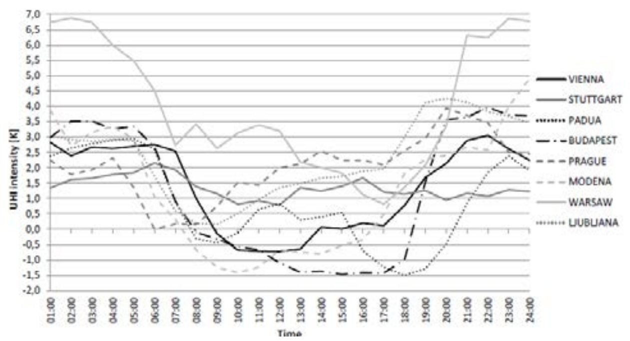

Figure 2. Mean hourly UHI intensity for the reference week (Mahdavi et al, 2012)

Determination of the measuring program of stations

According to the main purposes of the project the following activity would like to give help in choosing measurement locations, identifying also sampling infrastructures to be developed in the single urban areas. First of all it is very substantial to clearly determine the purpose of the station: (i) to monitor the greatest impact of the city; (ii) more representative or typical district; (iii) characterize a particular site, where there may be perceived to be climate problems or where future development is planned. Choosing a location and site for urban stations there are three scales of interest in urban areas studies: macro, local and micro on horizontal scales (*Oke, 1984, 2004, 2006*). Horizontal and vertical representativeness of the stations should be also specified. After that the essential next step in selecting urban station sites is to evaluate the physical nature of the urban surroundings and urban terrain (structure, cover, fabric, metabolism).

The most importantly measured UHI elements are: temperature, humidity, wind, precipitation, and solar radiation. Wide range of technical parameters (like time resolution, accuracy, range, uncertainty and calibration requirements etc.) of these meteorological measurements (WMO Guide, 2008) must be also mentioned in the developing of UHI observations techniques and evaluations processes.

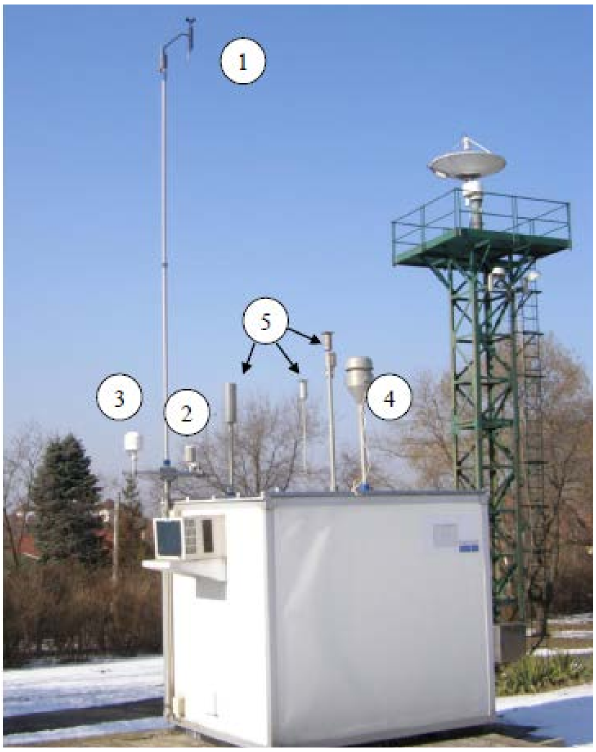

Figure 3. *Example of urban monitoring station; meteorological sensors: wind (1), temperature (2), global solar radiation (3), precipitation (4), air quality (5) gas and aerosol samplers.*

The complexity of the urban environment sets special requirements for siting the observation equipment to provide representative values of a given urban zone, which are not much affected by nearby buildings or pollution sources. The interpretation of atmospheric conditions between measuring sites requires detailed surface characteristics involved urban scale numerical models. Models are able to more accurately calculate meteorological conditions in the layers close to the surface.

Mitigation strategies

The project includes the review of a wide range of possible mitigation actions for lowering the negative effects of UHI in cities. Most of the actions that are commonly employed can be divided into three main realms of interventions: buildings, pavements, and vegetation (see Table 1.)

Mitigating the effect buildings have on urban heat islands primarily involves changing the material properties of buildings or the geometry of the urban settings created by buildings (for example, changing the typical street section). While the first strategy deals mainly with the thermal performance of buildings, the other has to do much with the way air currents can remove excess heat from areas between buildings (streets, passageways).

Pavements play an important role in the formation of the UHI phenomenon, since conventional paving materials (mainly concrete and asphalt) tend to absorb large amounts of solar radiation during daytime and to release it to the cooler surrounding air. Another property of these paving materials is their limited permeability to water, which prevents the absorption of water in the ground and thus reduces the evaporation potential of the ground surface, which may help in reducing air temperatures.

Table 1*. List of common UHI mitigation measures*

	Measure	Expected benefits
Buildings	Cool roofs	Reducing cooling load, reducing ambient air temperature, improving building envelope quality
	Green roofs	Shading and evapotranspiration
	Green facades	Reducing ambient air temperature, shading properties, natural cooling, control airborne pollutants, energy efficiency
	Façade surface and construction selection/retrofit	Reducing cooling/heating load, reducing ambient air temperature, improving building envelope quality
	Geometry of urban canyon (new projects)	Fresh air advection , cool air transport into the city
Pavements	Cool pavements	Decreasing ambient air temperature
	Pervious pavements	Storm water management
Vegetation	Planting trees within the urban canyon Parks, green areas	shading and evapotranspiration, lower peak summer air temperatures, reducing air pollution

Trees and vegetation reduces ambient air temperature by evapotranspiration and shading and is therefore expected to help in mitigating UHI intensity levels. The common practices within this scope are the planting of trees and vegetation in existing urban fabric (mainly city streets), or the creation or preservation of wider green areas (parks, groves) within the urban fabric.

The Hungarian Pilot Action Area

For the evaluation of urban heat island mitigation measures every country was asked to select pilot area where they can demonstrate the successful results of measures introduced by local governement. In Budapest "Bel-Buda City Center" was chosen for Pilot Area. Its location is in downtown of Budapest as Figure 4 shows (square measure of the area: 0,48 km^2). Mitigation measures were implemented in the following sections of the Pilot Action Area:

1. Brownfield rehabilitation- former Ganz factory, now it is Park Millenáris.
2. Planting trees in a narrow street - Lövőház Street
3. Establishment a public garden - Mechwart Square
4. The highest building of Pilot Action Area
5. The headquarter of the Hungarian Meteorological Service supplies meteorological measurement from the Pilot Action region (in Figure 4 numbers indicate locations of interventions and an urban climate observing site).

The history of the industrial part of the Pilot Action: A Ganz factory was built in this place in 1884, which produced machines and many kinds of electronic products until 1990. The new cultural and recreation center was planned on the brownfield area, the habilitation started in 2000, which was awarded by the Europa Nostra Prize.

Figure 4. *The area of the Pilot Action in Budapest*

The introduced measures for UHI effects adaptation and mitigation in Bel-Buda City Centre are:

- Growing green surface and
- Growing water surface,
- Planting trees.
- Tidied green surfaces and parks.

Aims of local government during the development of Bel-Buda City Centre were to:

- Diminish the noises coming from the traffic
- Rebuilding of the public areas
- Rehabilitation of houses
- Growing shopping facilities
- Development of public transport
- Establishment social and cultural facilities
- More facilities for sport and for recreation.

These studies can help in introducing new urban planning tools to mitigate the UHI phenomenon and prevention plans to reduce the hazard related to the heat spikes in Budapest.

Further plans

In the future we would like to develop the UHI Atlas for the Central European region. These maps will be presented in the UHI website and they will be easily available for wide public.

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References

Mahdavi, A., Orehounig, K., Kiesel, K., Vuckovic, M. and Aleksandrowicz, O., 2012: Observations on UHI effect in participating cities. *UHI project report* WP5.

Oke, T.R., 1984: Methods in urban climatology. In *Applied Climatology, Zürcher Geograph. Schrift.*, 14**,** 19-29.

Oke T.R., 2004: Siting and exposure of meteorological instruments at urban sites, 2004 27th NATO/CCMS *International Technical Meeting on Air Pollution Modelling and its Application*, Banff, 25-29 October, 2004.

Oke T.R., 2006: Initial guidance to obtain representative meteorological observations at urban sites.

Guide to Meteorological Instruments and Methods of Observation WMO-No. 8, 2008.