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Assessment of the microclimatic and human comfort conditions in a complex urban environment: Modelling and measurements

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Abstract

Several complex thermal indices (e.g. Predicted Mean Vote and Physiological Equivalent Temperature) were developed in the last decades to describe and quantify the thermal environment of humans and the energy fluxes between body and environment. Compared to open spaces/landscapes the complex surface structure of urban areas creates an environment with special microclimatic characteristics, which have a dominant effect on the energy balance of the human body. In this study, outdoor thermal comfort conditions are examined through two field-surveys in Szeged, a South-Hungarian city (population 160,000). The intensity of radiation fluxes is dependent on several factors, such as surface structure and housing density. Since our sample area is located in a heavily built-up city centre, radiation fluxes are mainly influenced by narrow streets and several 20–30-year-old (20–30 m tall) trees. Special emphasis is given to the human-biometeorological assessment of the microclimate of complex urban environments through the application of the thermal index PET. The analysis is carried out by the utilization of the RayMan model. Firstly, bioclimatic conditions of sites located close to each other but shaded differently by buildings and plants are compared. The results show that differences in the PET index amongst these places can be as high as 15–20 °C due to the different irradiation. Secondly, the investigation of different modelled environments by RayMan (only buildings, buildings + trees and only trees) shows significant alterations in the human comfort sensation between the situations.

Keywords: Urban environments; Thermal comfort; Physiological Equivalent Temperature; Szeged; Hungary

1. Introduction

Human beings are subjected to various kinds of stress in the urban environment. The most important ones are the meso- and microclimatic conditions, which differ significantly from that of rural areas. The main reason for this is the alteration of the surface structure (e.g. proportion of the built-up area, 3D geometry of the buildings and trees) triggering particular urban climate phenomena (e.g. urban heat island, changes in the radiation fluxes).

An important task of the bioclimatological research is to evaluate the thermal environment of human beings, since it determines the energy balance of the body and consequently its comfort sensation [1]. The physiologically relevant assessment of urban climate, and especially different urban microclimates, requires the use of methods and indices which combine meteorological parameters with thermo-physiological parameters [2,3]. Urban and regional planners are demanding easily understandable methods for the thermal component of climate in order to facilitate comfortable urban microclimates [1].

Human bioclimatological studies carried out in summer have a specific importance, because the urban heat island forming several hours after sunset keeps the

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extent of the heat stress at high levels in addition to the strong heat stress during daytime. This shortens the regeneration possibilities of urban residents during the night. Based on the foregoing, the human thermal comfort issues and quantitative bioclimatological indices generate valuable information for urban planners and architects. The obtained data and suggestions can contribute to the planning process to achieve more suitable urban environment and healthy environment, e.g. to increase the well-being of the urban population by mitigating heat stress in summer.

This study is based on earlier bioclimatic and recent urban climate studies in the South-Hungarian city Szeged. According to these studies an urban heat island intensity of 2.7 °C on annual average can be measured in Szeged, which can increase to 6.8 °C during clear, anticyclonal weather conditions [4]. The results show a significant additional heat load to the human body, especially in summer. In former bioclimatic studies, with the aid of suitable indices for the available dataset, differences in the annual and diurnal variation of human bioclimatic characteristics between an urban and rural environment are evaluated over a 3-year period [5]. These indices were the thermohygrometric index (THI), defined by air temperature and relative humidity, the relative strain index (RSI), defined by air temperature and vapour pressure, and additionally the number of ‘‘beergarden days’’ defined by air temperature at 21:00 h. It was shown that, due to the increased heat stress, the modification effect of the city is rather negative in summer, while it improves the thermal sensation by shortening the unfavourable cold periods in winter.

The aim of this study is to demonstrate the importance and potentials of the quantitative evaluation of human comfort and heat stress. Findings are of use for city planning and architects, as shown for the city of Szeged, situated in the southern part of Hungary. The study applies a two-way approach while focussing on the same study area: (a) the modelling and alteration of the surface structure, and (b) an evaluation based on sophisticated microclimate measurements to reveal the human bioclimatological features of the study area.

2. Study area and methods

2.1. Study area

Szeged is located in the southern part of Hungary (46°N, 20°E) at 79 m above sea level on a flat plain (Fig. 1A–B). River Tisza passes through the city, otherwise, there are no large water bodies nearby. 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. 1C). The city's population of 160,000 lives within an administration district of 281 km^2, but the highly urbanized area is restricted to an area of about 30–35 km^2.

Szeged is located in the climatic region Cf according to Köppen's classification (temperate warm climate with uniform annual distribution of precipitation) or in the climatic region D.1 according to Trewartha's classification (continental climate with a long warm season) [6]. The annual mean temperature is 10.4 °C and the amount of precipitation is 497 mm.

The investigated sample area (200 × 200 m^2) in Szeged is situated in the heavily built-up city centre region with narrow streets and several 20–30-year-old (20–30 m tall) deciduous trees (Fig. 2). The area is crossed by a busy road (Petőfi av.) with a tram rail in a direction of NE–SW and by two narrow by-streets. One of the by-streets (Batthyány str.) has a NNW–SSW direction and the other (Egyetem str.) is parallel to the avenue. The

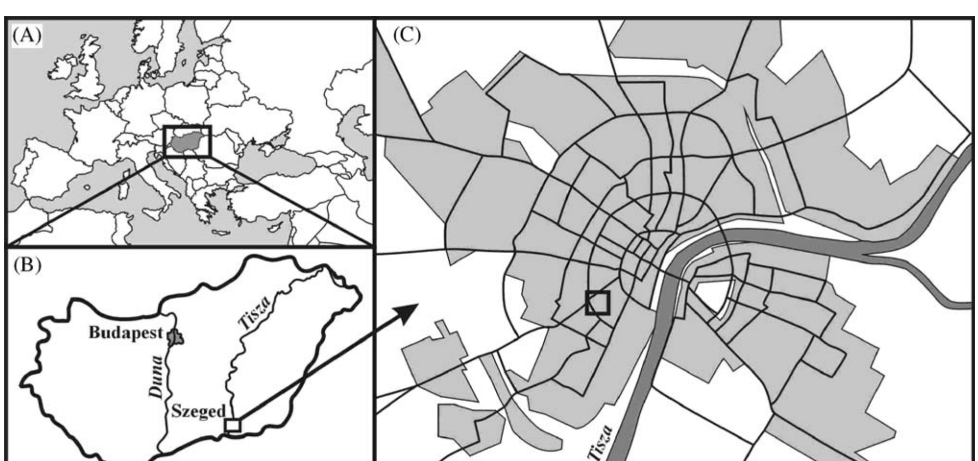

Fig. 1. Geographical location of Hungary in Europe (A), of Szeged in Hungary (B), built-up area and road network of the city (C) and the location of the 200 × 200 m sample area in the city.