Berichte des Meteorologischen Instituts
der Albert-Ludwigs-Universität Freiburg

Nr. 20

Andreas Matzarakis, Helmut Mayer
and Frank-M. Chmielewski (Eds.)

Proceedings of the
7th Conference on Biometeorology

Albert-Ludwigs-University of Freiburg, Germany
12-14 April 2010

Freiburg, April 2010

ISSN 1435-618X

Self-publishing company of the Meteorological Institute, Albert-Ludwigs-University of Freiburg, Germany

Print: Printing office of the Albert-Ludwigs-University of Freiburg

Editor: Prof. Dr. Helmut Mayer

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Documentation: Ber. Meteor. Inst. Univ. Freiburg Nr. 20, 2010, 584 pp.

Area usage and thermal sensation vs. thermal comfort conditions – Open air thermal comfort project in Szeged, Hungary

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Abstract

The aim of this study is to throw some light on the outdoor human thermal comfort investigations in Szeged. Methodology is described, which consists of micrometeorological measurements on the site, observation of visitors' area usage together with their characteristics, as well as questionnaire-based interviews on the subjective thermal sensation, human comfort and open air activity. As important part of the measurements, visitors' exact locations are marked on a map of the investigated resting place. Integrating these spatial data with the measured subjective and objective information within geoinformatical software (ArcView GIS in our case), make it possible to visualize the area usage according to many categorization, and to reveal relationships between the thermal environment, the usage of the area and the visitors' behavioural adaptation.

1. Introduction

Because of the current state of urbanization more and more people have to live or work in cities, which mean increasing number of citizens, affected by the strains of urban environments – thermal stress among others. This is the reason for many urban climate studies aim to analyze the thermal conditions in different urban structures. Large scale thermal comfort projects such as RUROS (e.g. Nikolopoulou and Lykoudis, 2006), Urban Climate Spaces (e.g. Knez and Thorsson, 2006) and KLIMES (e.g. Mayer et al., 2008) have multi- and interdisciplinary field of interest, and bring together human biometeorology (which is a complex scientific discipline itself), urban planning and psychology under a common roof.

There were no projects focusing on the thermal component of urban climate in a physiologically significant manner in Hungary until the 2000's. The first examination had performed in the city of Szeged (46° N, 20° E) (Gulyás et al., 2006). Similarly, the first investigation which used also human monitoring (questionnaire-based data collection) by the objective measurements and comfort-index calculations was also in this South-Hungarian city (Kántor et al., 2006). The aim of this study is to describe the diverse methodology applied in the proceeding long-term outdoor thermal comfort project in Szeged in the last 2 years and discuss the possible outcome of the results.

2. Study areas and measurement periods

Parks and squares may mitigate the harmful effects of cities by offering places for recreation and relaxation, functioning as "green islands" in the heavily build-up areas. Accordingly, two inner city squares were selected to study the area usage, the outdoor staying and thermal sensation of people in accordance with thermal comfort conditions. Due to the lack of mobile biometeorological station until summer 2009, sampling areas adjacent to the automatic meteorological station of the University of Szeged were selected. Szeged is a famous educational centre in Hungary attracting many students on the weekdays.

The first investigation site is a ca 5500 m^2 green area in the Ady Square and locates between the buildings of the University and the Information Centre. It is regularly visited by a high number of students throughout the academic year, which makes it suitable for thermal comfort studies using also human monitoring. The ca 6000 m^2 Honvéd Square lies also near to the automatic station and functions not only as resting place, but as playground too. It is visited by more age-groups than the other square where the younger subjects (in their twenties) dominate. Shading conditions are remarkably different between the two areas. In the first site visitors can chose from sunny, penumbra or shady exposures thanks to shading of buildings and/or various kinds of trees. Contrarily, the second square allows to take place mainly at the same penumbra conditions.

Three study periods were conducted till now: in late spring (April and May) 2008 and 2009, as well as in early autumn (September and October) 2009 (Table 1 shows details). Field surveys were carried out on every Tuesday, Wednesday and Thursday from 12 to 3 p.m. (CET, summer time), as early afternoon is the warmest period of day.

Table 1: Outdoor thermal comfort investigation periods in Szeged according to study area and methodology

<table>
<tr><th rowspan="3">STUDY AREA</th><th colspan="3">HUMAN MONITORING</th></tr>
<tr><th colspan="2">OBSERVATIONS</th><th rowspan="2">QUESTIONNAIRES</th></tr>
<tr><th>Momentary attendance</th><th>Cumulative attendance</th></tr>
<tr><td>Ady Square</td><td>spring 2008, 2009, autumn 2009
13 + 14 + 15 days</td><td>spring 2008, 2009, autumn 2009
14 + 14 + 14 days</td><td>autumn 2009
9 days</td></tr>
<tr><td>Honvéd Square</td><td>spring 2009, autumn 2009
15 + 15 days</td><td>spring 2009, autumn 2009
15 + 15 days</td><td>autumn 2009
5 days</td></tr>
<tr><td rowspan="2"></td><td colspan="2">STATIONARY STATION</td><td>MOBILE STATION</td></tr>
<tr><td colspan="3">MEASUREMENT OF METEOROLOGICAL VARIABLES</td></tr>
</table>

3. Observations and stationary measurements

Thermal comfort investigations which concentrate on urban public areas need specified and detailed information about the investigated area and about the visitors. Human monitoring with simultaneous measurement of meteorological variables (to calculate thermal comfort indices) can provide these data.

At the time of the first two investigation periods (spring 2008 and 2009) biometeorological station was no available for recording the thermal comfort variables in the height of 1.1 m a.g.l. reference height. Therefore questionnaires were dispensed and observations were carried out only in squares adjacent to the automatic stationary station (Table 1). Temperature and humidity sensors locating at 2 m a.g.l. while wind velocity and global radiation sensors locating at the top of the university building (Table 2). Wind speed data were reduced at the reference height of 1.1 m. The comfort indices PMV (Predicted Mean Vote) and PET (Physiologically Equivalent Temperature) are calculated with the RayMan model (Matzarakis et al., 2007), and refer to a person (default: 1.75 m, 75 kg, 35 years old standing male) who stays in the sun (because there was no radiation reduction). Comparing the observations data with these indices we are able to study the weather-related area usage and behavioral adaptation of visitors.

Table 3: Instrumentation of the stationary and mobile stations

PARAMETER	STATIONARY STATION	MOBILE STATION	
air temperature	HMP 35D, Vaisala, 2 m a.g.l.	THERMOCAP	as part of WXT 520, Vaisala, 1.2 m a.g.l.
relative humidity	HMP 35D, Vaisala, 2 m a.g.l.	HUMICAP	
wind speed	WAA 15A, Vaisala, 26 m a.g.l.	WINDCAP	
short-wave radiation	CM 11, Kipp & Zonen, 20 m a.g.l.	CM 3	as part of CNR 1, Kipp & Zonen, 1.1 m a.g.l.
long-wave radiation		CG 3	
data recording	MILOS 500, Vaisala	pendrive	
averaging period	10 min	1 min	

Observations consisted of counting people lingering on the squares in every 10 minutes (momentary attendance) on the one hand and measuring the visitors cumulatively in given time intervals on the other hand (Tables 1 and 3). In the Ady Square – beyond the total number of subjects – we noted also how many people stayed in the sun, penumbra and shade. In the case of the other site the momentary counting was made according to whether the subject was rather passive (stand, sit, lie) or active (play, walk around).

The cumulatively measurements occurred between 12 and 3 p.m. in six half hour and twelve 15-minute intervals in the Ady and Honvéd Square respectively. The locations of the visitors staying at least 5 minutes in a given time-period were marked with ID numbers on the map of the area. Each interval on each measurement day has its own map and a connected table containing some characteristics of the marked visitors (see detailed in Table 3). The cloud cover was also noticed (clear / cloudy / overcast), as determination of the subjects' exposure was possible only when it was shiny. It is important to note, that the above presented observation method can cope only with "resting place conditions" and mainly sedentary visitors, as marking the spatial position of too many active subjects can not accomplish. Therefore, we ignored the lots of children on the playground on the Honvéd square and measured only the visitors sitting on benches.

Interval-observations data (tables of personal characteristics and investigation maps) were digitized within geoinformatical software ArcView GIS. Then the 15-minute or half hour averages of the thermal comfort measures derived from the stationary station were attached to these subjective data according to the time of the measurement.

Table 3: Recorded parameters in the course of observations

	ADY SQUARE	HONVÉD SQUARE
Momentary attendance	*in every 10 minutes* according to exposure (sun / penumbra / shade)	*in every 10 minutes* according to activity (active / passive)
Cumulative attendance + Table of characteristics	*in half hour intervals* location (marked on a map with ID number) gender (male / female) age (child / young / middle aged / old) clothing (<0.5 clo / 0.5-1 clo / 1 clo<) activity (active / passive) exposure (sun / penumbra / shade)	*in 15-minute intervals* location (marked on a map with ID number) gender (male / female) age (child / young / middle aged / old) clothing (<0.5 clo / 0.5-1 clo / 1 clo<) (*only visitors sitting on benches*)

4. Questionnaires and measurements with mobile biometeorological station

Since autumn 2009 the examinations have been completed with structured interviews and on-site measurements with a biometeorological station. This unit is well suited to record thermal variables on different points of the study area next to the questioned individual and includes appropriate rotatable instrument to measure the short- and long-wave radiation flux densities from the 6 main directions. All meteorological variables necessary for PET and PMV are measured at the adequate height of 1.1-1.2 m (Table 2).

To calculate PMV exactly, we enter these data into the RayMan model together with the personal data (sex, age, height, weight), clothing, activity and position (posture) of the interviewee, recorded in the first part of the questionnaire. The noted clothes and activity are converted to clothing insulation value and heat generated by activity (active metabolism) according to Fanger (1972) as well as VDI 3787 (1998).

Beyond these personal parameters the subjects were asked to tell about their health conditions, general feelings, urban vs. open-air attitude, time spent in the place, housing area, reasons for their visit and opinions on the design of the area. To construct the list of queries many ideas from Lin (2009), Knez and Thorsson (2006) and Nikolopoulou and Lykoudis (2006) were adopted and modified more or less.

The main part of the questionnaire concerned to the thermal environment. The questioned individuals reported their thermal sensation – named Actual Sensation Vote or TSV Thermal Sensation Vote – based on a semantic differential scale. This scale (left side of Fig. 2), in contrast with the usually adopted ones, allows of marking thermal sensation more precisely. Consequently, subjective feelings could be compared to the index values (which are rarely round numbers) calculated from the measured parameters. After thermal sensation, the interviewees reported also their assessment of their overall comfort state (discomfortable / comfortable).

Another semantic differential scales were used for measuring the respondents' perceptions about the momentary air temperature, wind velocity, air humidity and solar radiation (Fig 2. right side). There were also four questions for the preference for better conditions, i.e. any changes (decrease / no change / increase) in the cases of the individual weather parameters.

The last two questions referred to behavioral adaptation to hot and cold conditions, as it is an important factor in outdoor thermal comfort. The interviewees were asked to choose maximum 3-3 adaptation measures they would take if they feel it is too hot or too cold (according to Lin, 2009).

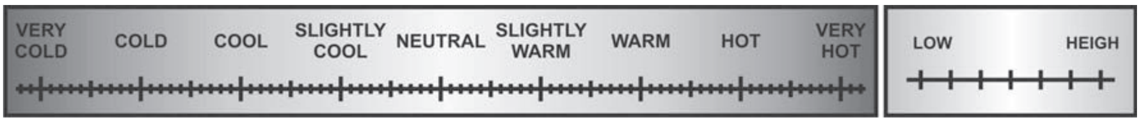

Fig. 2: Semantic differential scales used to measure the interviewees' thermal sensation (left side) and perception of individual weather parameters (right side)

Spatial locations of the subjects were marked with ID numbers on the map of the area (Ady Square or Honvéd Square) and digitized within ArcView in the same way as in the cases of interval-based observations.

5. Discussion: main possibilities of analysis

I. Momentary attendance in the function of the actual thermal conditions

Taking the dataset from the 10-minute observations and the 10-minute meteorological data measured by the stationary station, area usage of the investigated squares can be discussed in accordance with the weather and thermal comfort conditions. Besides total number of visitors, relative attendance of certain groups (made on the basis of position or activity) can also be represented in the function of the selected objective parameters.

II. Behavioural adaptation to and area usage patterns by different thermal situations – derived from observations in different intervals

In the cases of both squares, we are able to study the weather-related area usage of people grouped either gender or age-categories, as well as to study their behavioral adaptation by analyzing the changes of clothing-categories according to the measured or calculated thermal parameters. This can be pointed out with activity categories and visitors' exposure similarly, from the more detailed dataset collected in the first square.

In the case of Ady Square, the use of ArcView make it possible to show the presence in spatio-temporal manner and make area usage maps according to different categorization. The markers of visitors may be coloured by any measured or observed data, e.g. day and/or time-interval of the presence; weather parameters or thermal comfort during the interval of the observations; the numerous personal data collected on the field measurements. Determination of what are the preferred sectors (sub-areas) at different weather conditions might be a very important result. The commonly used forms representing the results of statistical analyses (diagrams, tabulations, statistical measures) become very informative together with these area usage maps (e.g. Fig. 3).

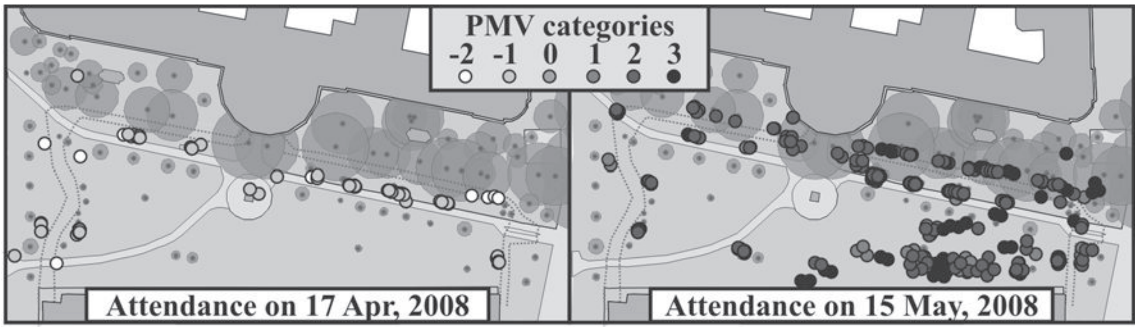

Fig. 3: Visitors' distribution on the Ady Square on two days – markers are coloured according to the thermal comfort conditions during the observation intervals

III. Results from evaluation the questionnaire survey

The simultaneously collected meteorological and personal data make it possible to compare the actual thermal sensation, the weather perceptions and preferences with the objective measures of thermal environment and to reveal objective and subjective factors affecting thermal sensation, human comfort and area usage. The use of the GIS software makes easy the data management and helps to demonstrate exactly the circumstances of the interviews.

6. Conclusion

This paper described the outdoor thermal comfort project proceeding in Szeged from methodological point of view. Investigations focus on urban parks and squares, as there is an increasing need for urban public environments offering places for relaxation, recreation and promoting the social activity. The project aims to reveal relationships between the thermal environment and the visitors' reactions manifests itself in their thermal sensation, weather perception and preference, behavioural adaptation as well as area usage patterns. The required data for the comprehensive analysis derived from field surveys: observations and structured conversations conducted together with measurements of the thermal environment.

The observation method consists of marking the visitors' exact spatial locations together with their personal characteristics can cope only with sedentary people, consequently it can be used only in resting places. However, momentary counting of people, interviews and on-site biometeorological measurements can be carried out in other city structures, too. The use of the GIS software to represent the spatial results i.e. the created area usage maps may easies the communication with urban planners and decision makers.

Acknowledgement

The research is supported by the grant of the Hungarian Scientific Research Fund (OTKA K-67626)

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