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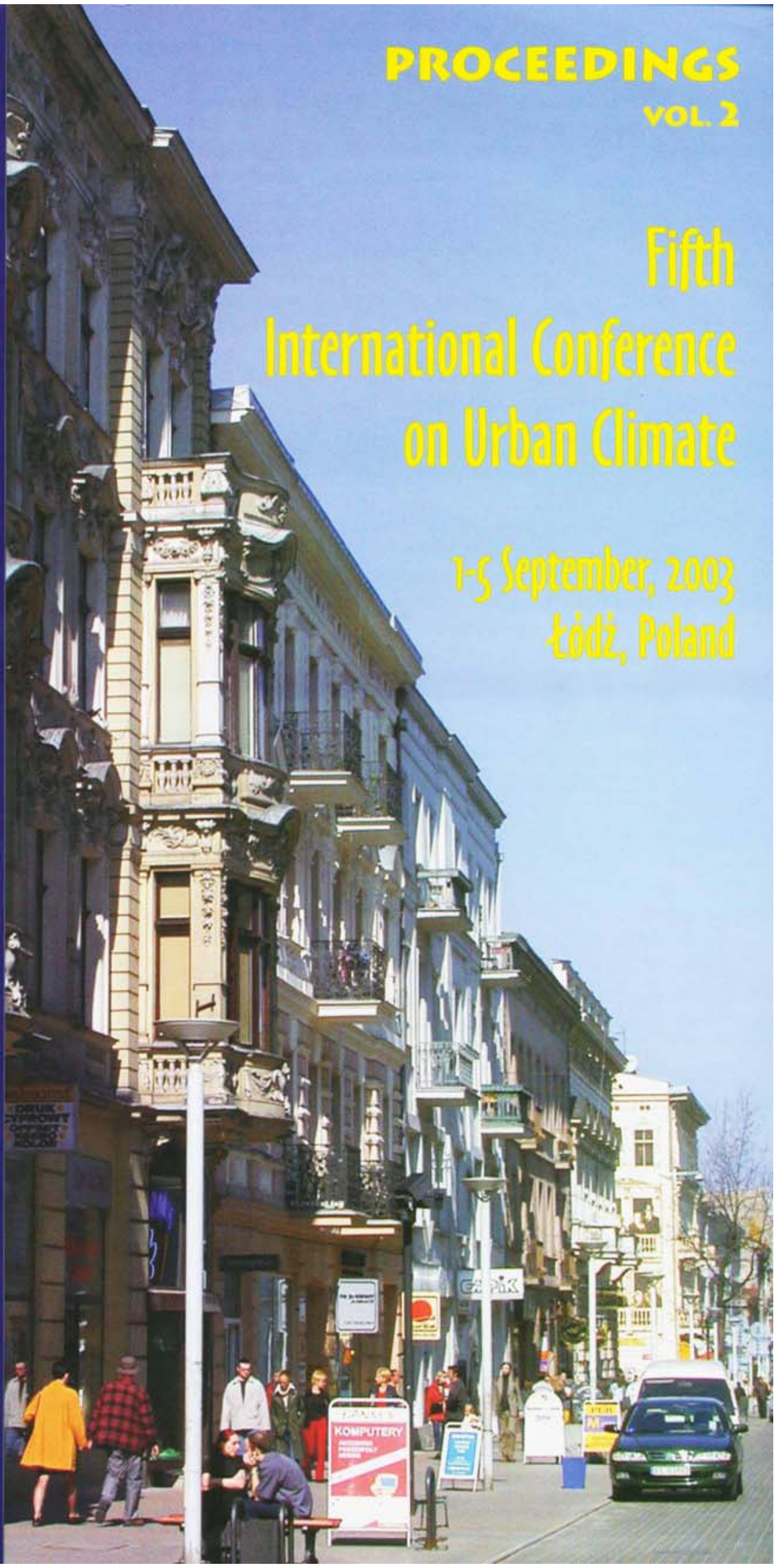

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HUMAN-BIOMETEOROLOGICAL ASSESSMENT OF URBAN STRUCTURES

Andreas Matzarakis* and Helmut Mayer
University of Freiburg, Germany

Abstract

Methods of modern human-biometeorology have to be applied for the planning-oriented assessment of atmospheric impacts on human beings. This study aims to the human-biometeorological assessment of the thermal environment within different urban structures. Some examples are discussed for the city of Freiburg (southwest Germany) using the physiologically equivalent temperature PET as thermal index.

Key words: Thermal Indices, Physiologically equivalent temperature PET, Urban Structures, RayMan

1. INTRODUCTION

The thermal component of the urban climate covers the total energetic conditions within the urban air characterized by radiation fluxes as well as sensible, latent, soil, building and anthropogenic heat fluxes. For the comprehensive evaluation of the thermal bioclimate of humans, it is necessary to consider, amongst other factors, all the meteorological parameters, which affect the human energy balance. They are summarized as thermal factors (VDI, 1998).
In most European countries and Japan, there is a strong interest about results and information on applied urban climatology, which can incorporated into urban planning processes.

2. METHOD

The human energy balance represents the fundamental principle for the human-biometeorologically significant assessment of the urban thermal environment. There exist some formulations for the human energy balance which can be distinguished by different approaches for single energy fluxes. On the basis of models for the human energy balance, thermophysiological indices such as PMV, PET or OUT_SET* were developed which enable an adequate assessment of the thermal component of the urban climate (VDI, 1998; Matzarakis et al., 1999; Matzarakis, 2001).

3. EXEMPLARY RESULTS

Results of investigations on the human-biometeorologcial assessment of urban climate can presented in form of maps, frequency distributions or temporal variabilities. Due to their spatial resolution, thermal bioclimate maps are most suited for the application in urban planning.

3.1. Thermal index PET for different conditions in Freiburg, southwest Germany

As an exemplary result for the assessment of the thermal environment of people in a medium sized European city, the physiologically equivalent temperature PET (Matzarakis et al., 1999) was calculated for the permanent urban climate station of the Meteorological Institute, University of Freiburg (Germany), which is located at the top of a 50 m high rise building in the northern downtown of Freiburg. The calculations of PET have been carried out by the radiation and thermal bioclimate model RayMan (Matzarakis et al., 2000). A screen shot of the RayMan model is shown in Fig. 1, where some opportunities of input and output formats are given. RayMan is available for general use (http://www.mif.uni-freiburg.de/rayman). Frequencies of PET classes, according to Matzarakis and Mayer (1996), for the year 2001 are shown in Fig. 2. For all hours of 2001 (including winter), 14.2 % reach warm or even hot conditions according to PET classes or conditions. From that kind of results background information about the thermal bioclimatic conditions in a city can be obtained.
People in cities have a great mobility as they use a lot of different urban structures in their daily mobility. Therefore, a human-biometeorological assessment of the thermal environment within different urban structures is of interest. For the hottest day of the year 2001 (2nd August), the temporal course of PET at different urban structures in northern downtown of Freiburg is presented in Fig. 3. The objective of this experimental case study was the quantitative assessment of the thermal environment of people within different urban structures in a horizontal distance of approximately 100 m.

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* *Corresponding author address*: Andreas Matzarakis, Meteorological institute, University of Freiburg, Werderring 10, D-79085 Freiburg; e-mail: andreas.matzarakis@meteo.uni-freiburg.de

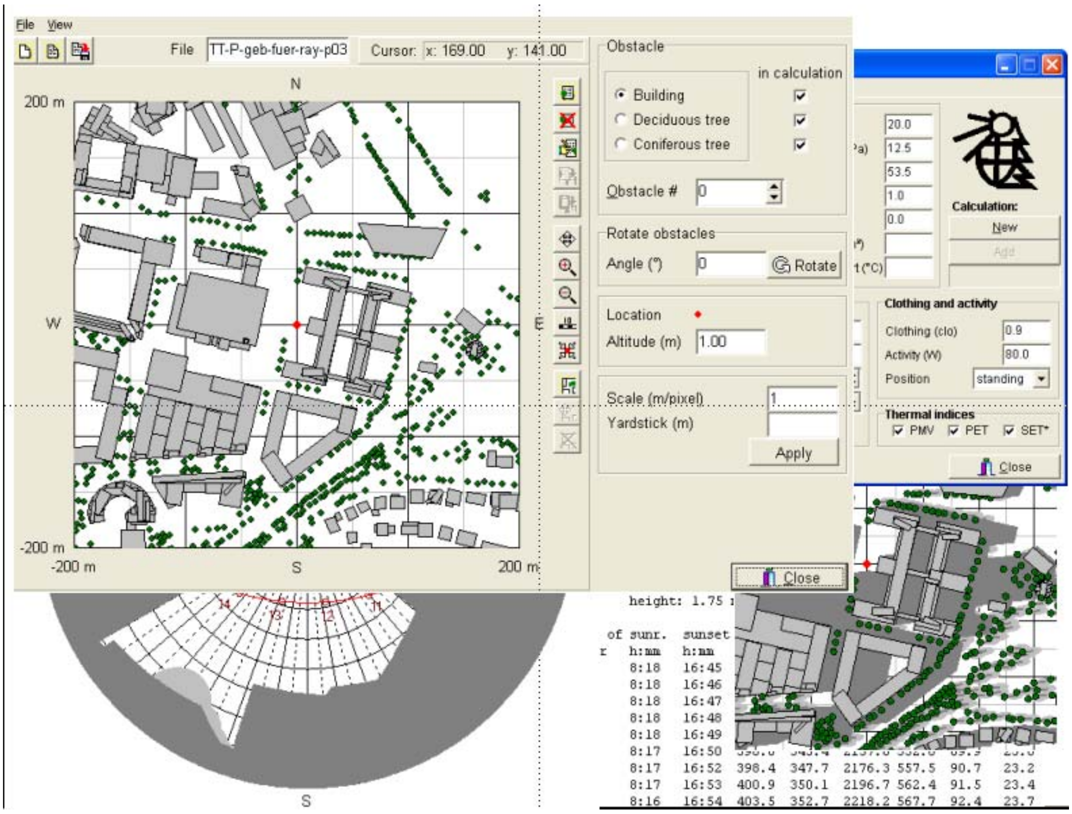

Fig. 1: Screen shot of the RayMan model

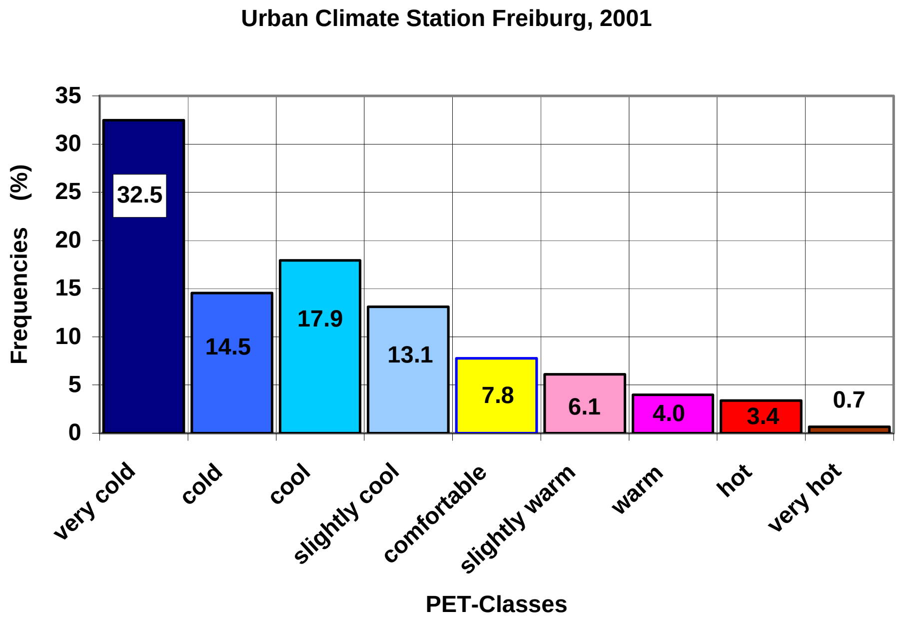

Fig. 2: Frequencies of classes of the physiologically equivalent temperature PET calculated for the permanent urban climate station of the Meteorological Institute, University of Freiburg (Germany), in 2001

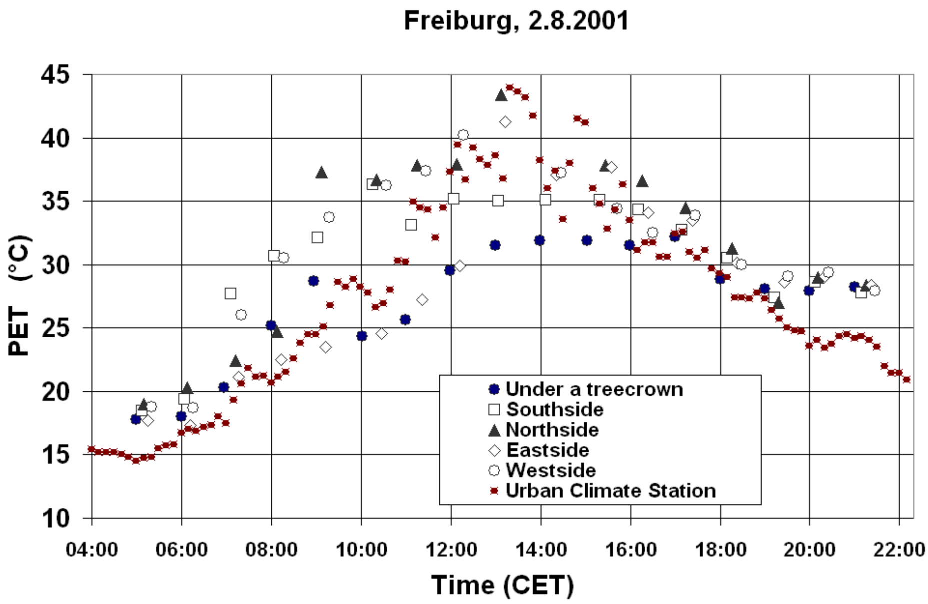

Fig. 3: Physiologically equivalent temperature PET at different urban structures within the lower Urban Canopy Layer in Freiburg (southwest Germany) on the hottest day of the year 2001 (2 August 2001)

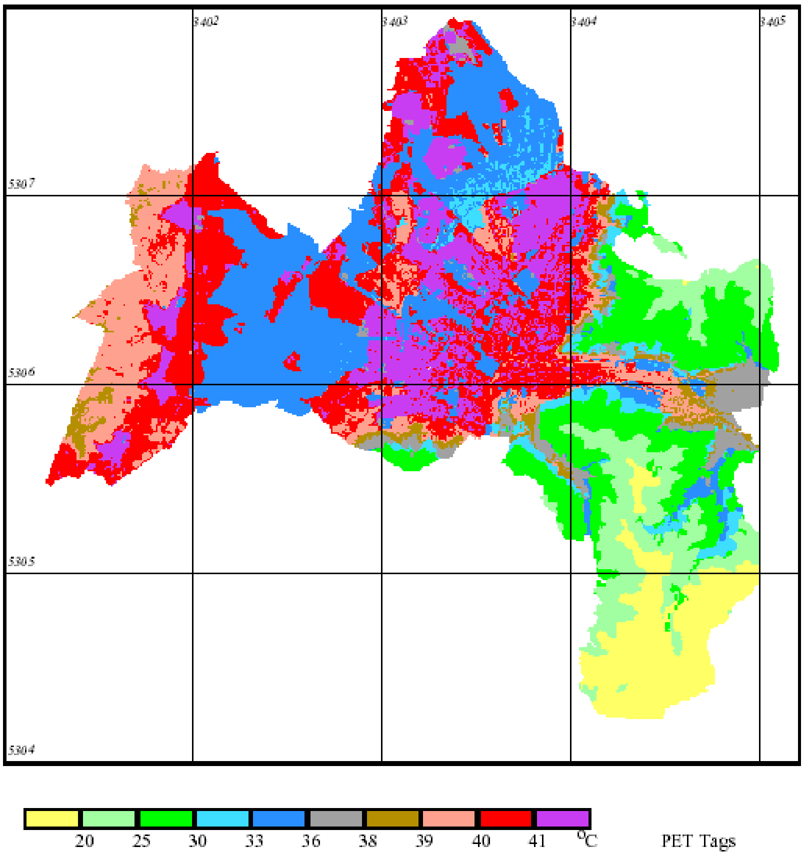

Fig. 4: Spatial distribution of the physiologically equivalent temperature PET in Freiburg (southwest Germany) on 8 July 2002, 15 CET

The major distinction between the sites was the sky view factor which was reduced at one site by the canopy of trees. All meteorological parameters necessary to calculate PET were recorded by use of a specific mobile human-biometeorological measuring unit. The results in Fig. 3 reveal clearly lower PET values in the below-canopy space indicating a lower heat stress for people than at the other sites (PET values around 20 °C correspond comfortable conditions, higher PET values indicate increasing thermal stress).
The sky view factor is the most important factor in the different comparing structures. The lower the sky view factor, the lower is the perception of thermal stress by people within the urban structures, because the major effects of a tree canopy or high buildings in the daytime are the reduction of the direct solar radiation in the below-canopy space and the shaded sidewalks within urban canyons.

3.2. Thermal bioclimate mapping

Results of investigations on the thermal bioclimate carried out at single points, as shown in Figs. 2 and 3, are of interest for process analysis but not suited for application by urban planners. They prefer detailed information on the spatial bahaviour of the human-biometeorological conditions for the decision-making. To provide spatially resoluted information on the thermal bioclimate, numerical or statistical models can be applied.
In the case of Freiburg, measurements of air temperature and air humidity have been carried out at 89 sites with different urban land use on a hot summer day in July 2002. A numerical micro-scale model, according to Hoskar (1984), has been run for the determination of the wind conditions in the day- and nighttime. The short- and long-wave radiation fluxes as well as the resulting mean radiant temperature has been estimated by the RayMan model (Matzarakis et al., 2000) for the different measurement sites. The PET conditions were calculated for all measurement sites for the day and night situation. Based on thermal images (made for the time of the ground-based measurements) as well as land use and topography information, the PET values have been transferred from points into the space by use of a statistical model. The PET distribution for the whole city of Freiburg in a 50 m resolution is presented in Fig 4. The areas with very high values (PET > 35 °C) can be mostly found in the high-urbanized areas of Freiburg. Though (1) there is only a specific situation given in Fig. 4, (2) bioclimatic conditions show a pronounced temporal variability conditions and (3) the urban climate is a three- and not a two-dimensional phenomenon, that kind of information can be used well in urban planning processes, because it identifies areas with high thermal loads for people or areas suited for an intense building density.

4. CONCLUSIONS

The exemplary results presented before indicate that results obtained by the application of modern human-biometeorological methods are a qualified offer to urban planning. Despite great efforts in human-biometeorology in the last decades, some deficits, however, exist (e.g., targets for different urban land use types) which are the objectives for the future research in urban human-biometeorology.

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