VALIDATION OF MODELLED MEAN RADIANT TEMPERATURE WITHIN URBAN STRUCTURES

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1. INTRODUCTION

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). The mean radiant temperature \( T_{\text{mrt}} \) is the most important meteorological input parameter to obtain the human energy balance during summer weather conditions and shows the greatest variations. Therefore, \( T_{\text{mrt}} \) has the strongest influence on thermophysiological significant indices (MATZARAKIS, 2000) which are derived from models for the human energy balance (MAYER, 1993).

The objective of this paper is to present comparisons of measured \( T_{\text{mrt}} \) in urban areas and estimated \( T_{\text{mrt}} \) by RayMan model (MATZARAKIS et al., 2000).

2. METHODS

The mean radiant temperature can either be obtained from separate measurements of solar (shortwave) and terrestrial (longwave) radiation fluxes or by integral measurements (HÖPPE, 1992, MATZARAKIS, 2000).

In literature, methods of estimating radiation fluxes based on parameters including air temperature, air humidity, degree of cloud cover, air transparency and time of the day of the year have been well documented. The albedo of the surrounding surfaces and their solid angle proportions must also be specified.

The model RayMan (Fig. 1) which is presented here is well-suited for the calculation of radiation fluxes especially within urban structures, because it takes into consideration various complex horizons (MATZARAKIS et al., 2000).

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3. RESULTS

In the field of urban climatology and human-biometeorology the most important question is, how an object of interest is exposed to radiation field conditions especially if the object is shaded or not. Hence, in the presented model the 3-D radiation field and shading by urban and natural obstacles is included. The final output of the model is however the calculated mean radiant temperature which is required in the energy balance model for humans and thus for the assessment of urban bioclimate and the resulting thermal indices, e.g. PET (MATZARAKIS, 2000). The model is developed based on the German VDI-Guidelines 3789, Part II (VDI, 1994), Part III (2001) and 3787 Part I (VDI, 1998).

As a typical example Fig. 2 gives the relationship between the measured \( T_{\text{mrt}} \) and the humanbiometeorological thermal index PET. The latter refers to measurements at different sides of streets and under a tree, and are market out as the measurement sites for human-biometeorological evaluations of urban structures. They are well correlated.

Fig. 1. Window menus of RayMan 1.3 allowing import and export of urban structures for the calculation of mean radiant temperature \( T_{\text{mrt}} \) and thermal indices.
Fig. 3 gives the relationship between modelled $T_{mrt}$ with RayMan and measurements that were carried out on July 17$^{th}$, 18$^{th}$, 19$^{th}$, 25$^{th}$ and August 2$^{nd}$ 2001 in Freiburg, southwest Germany.

FIG. 2. Relationship between $T_{mrt}$ and PET for July 17$^{th}$, 18$^{th}$, 19$^{th}$, 25$^{th}$ and August 2$^{nd}$ 2001 in Freiburg.

FIG. 3. Relationship of measured mean radiant temperature $T_{mrt}$ measurement and computed mean radiation temperature $T_{mrt}$ modeled by RayMan for July 17$^{th}$, 18$^{th}$, 19$^{th}$, 25$^{th}$ and August 2$^{nd}$ 2001 in Freiburg.

CONCLUSIONS

For the evaluation of thermal component of urban and regional climate precise and high resolution radiation data of the whole surrounding is necessary.

Results emanating from the model RayMan are validated with the results from micro-meteorological measurements in urban areas in Freiburg. This validation shows that the calculated mean radiant temperature by RayMan agrees with the measured values. The calculation of radiation fluxes in complex structures by RayMan is an easy way to obtain data for the determination of the thermal component of urban climate and thermal bioclimate.

RayMan is able to do the latter and is available for general use (http://www.mif.uni-freiburg.de/rayman).

REFERENCES

Matzarakis, A., 2000: Modelling of radiation fluxes in urban areas and their relevance to thermal conditions of humans. Third Symposium on the urban environment. 163-164.