ATTEMPT TO EVALUATE THERMAL ENVIRONMENT IN THE AREA WITH A LACK OF URBAN SPATIAL INFORMATION DATABASE

Toshiaki Ichinose*, Yohei Shiraki**, Futoshi Matsumoto***, Jun Lu****, Keisuke Hanaki*****

*National Institute for Environmental Studies (NIES), Tsukuba, Japan;
(16-2 Onogawa, Tsukuba, J-3058506 Japan, e-mail: toshiaki@nies.go.jp)
**Rissho University, Kumagaya, Japan;
***National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Japan;
****Chongqing University, Chongqing, China;
*****University of Tokyo, Tokyo, Japan

Abstract

In this study, the authors analyzed the data of thermal environmental indicators observed in typical thermal stress days in Chongqing City, an outstandingly growing megalopolis in China. And they calculated the physiological thermal indicators at several observation points with various landscapes in the city, and discussed on these temporal and spatial features from the viewpoint of urban structure around them. In the process, because it was impossible to access to electronic spatial information database such as urban planning GIS data and so on, the physiological thermal indicators calculated using observation results were compared to results of numerical simulation using the sky view photograph by fish-eyes lens and Rayman Model. Then the both results agreed well. This means the physiological thermal indicators can be calculated with some accuracy by simple method, even if in the field without detail electronic spatial information database. It is considered that this method is useful for evaluation of thermal environment in the area with a lack of urban spatial information database.

Key words: heat island, thermal environment, fish-eye lens, physiological indicator, GIS data

都市空間情報基盤不足地域における熱環境評価の試み

一ノ瀬　俊明[1]*・白木　洋平[2]・松本　太[3]・盧　軍[4]・花木　啓祐[5]

[1]独立行政法人国立環境研究所　社会環境システム研究領域

（〒 305-8506 茨城県つくば市小野川16-2 * E-mail: *toshiaki@nies.go.jp*）

[2]立正大学　地球環境科学部（〒 360-0194 埼玉県熊谷市万吉1700）
[3]独立行政法人産業技術総合研究所　人間福祉医工学研究部門
（〒 305-8566 茨城県つくば市東1-1-1）
[4]重慶大学　城市建設与環境工程学院
（〒 400044 中国・重慶市沙坪垻区沙正街174）
[5]東京大学　大学院工学系研究科都市工学専攻
（〒 113-8656 東京都文京区本郷7-3-1）

近年の成長が著しい中国の巨大都市である重慶において2004年8月の典型的暑熱問題日に観測された暑熱環境指標関連のデータを解析し，当該都市内の景観の異なる複数地点における体感温熱指標を計算し，その空間的時間的特徴について，周辺都市構造からの検討を行っている．その過程において，都市計画 GIS データなどの電子空間情報基盤へのアクセスが不可能であったため，魚眼レンズを用いた天空写真および RayMan Model を用い，観測で求められた体感温熱指標の数値計算による検証を行い，計算値との良好な一致をみた．このことは，精緻な電子空間情報基盤が存在しないフィールドにあっても，簡便な手法によって一定の精度で体感温熱指標が算出できることを意味する．この手法は，都市空間情報基盤不足地域における熱環境評価にとって有益と考えられる．

キーワード： ヒートアイランド，熱環境，魚眼レンズ，体感気候指標，GIS データ

1. INTRODUCTION

Chongqing is one of the megalopolises in southwest China whose recent growing is outstanding. Its hot and humid summer climate is famous. Its characteristic location in a basin and the concentration of emission sources induces severe air pollution. In this study, the authors analyzed data observed on typical thermal stress days of Aug. 2004 in Chongqing. They computed thermal comfort indices at several points of Chongqing at different landscapes, and discussed on their spatial and temporal features for recommendations on urban planning. The RayMan Model (Matzarakis *et al.*, 2006) used in this study is a versatile tool to simulate numerically thermal comfort indices. It can be used at points where data related to the radiation environment, like shapes of surround buildings etc., is available to input into the model. In general, high resolution digital maps, like GIS database on urban planning in Chinese cities, are kept secret and are not accessible to foreign researchers. Therefore, to compute the radiation environment, we need to acquire data on shapes of surround buildings by some simple methods, since we can not access any digital spatial information database on distribution of buildings inside cities. In this study, for the purpose to validate precision of RayMan Model, the authors prepared the required information based on sky view photograph using fish-eye lens. They compared observed thermal comfort indices with the ones numerically simulated with RayMan Model inputting the prepared information (Fig. 1). Even in fields without high resolution digital spatial information database, if it is available to compute thermal comfort indices with some accuracy in some simple methods, this idea is useful to evaluate thermal environment in the area with a lack of urban spatial information database.

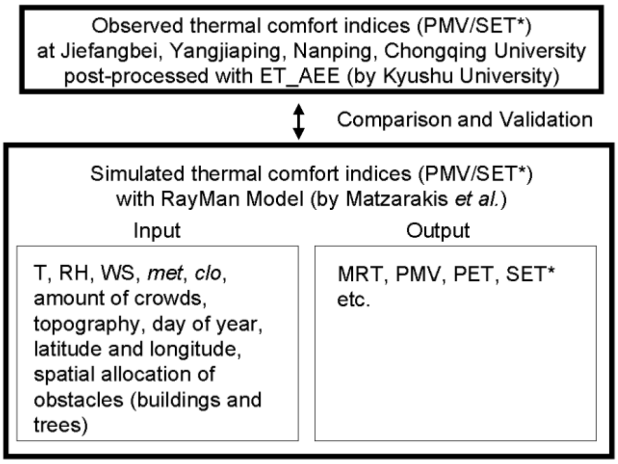

Fig. 1 Procedure of data handling

2. METHODS

The outline of observation at several points in Chongqing is as follows;

Jiefangbei, Aug. 7, 2004: city center with small SVF (sky view factor)
Yangjiaping, Aug. 8, 2004: an open space with large SVF
Nanping, Aug. 9, 2004: street canyons close each other (E-W and S-N orientations)

Distances between each two points are less than 15 km. We can assume that these points share a common climatological background of wider scale than urban area. During this field campaign there were few clouds, no rain and enough solar radiation. They were, therefore, typical thermal stress days. During observations in Jiefangbei and Yangjiaping, measurement at the reference site (Fig. 2), an open space in the campus of Chongqing University, was synchronized with them.

Fig. 2 Reference site at Campus A of Chongqing University (Shapingba)

At each observation point at several times a day (one sequential observation has been 60 minutes), the authors measured air temperature (T), relative humidity (RH), wind speed (WS), mean radiant temperature (MRT) in intervals of 1 minute. They used AM-101 (Amenity Meter: Kyoto Electronics Manufacturing Co., Ltd.) for measuring MRT and this MRT, calculated inside AM-101 based on the measured T, globe temperature (Tg) and WS, shows positive correlation with WS. However, in the data processing using ET_AEE (introduced later), thermal comfort indices will be calculated with given WS as a parameter. If we use MRT including some influence of WS, effect of WS will be counted twice. Therefore, we need to eliminate such impact of WS. On most data observed in this campaign, there was a linear relation between WS and measured MRT. So, the authors extracted MRT corresponding to WS=0 on the graphs and used them as MRT for the following processes. These MRT were defined as values at the middle time of every sequential 60 minutes' observation (e.g. 8:30 in case of 8:00 to 9:00). Therefore, all evaluated results in the later analyses are at the middle time of every sequential observation. Simultaneously, the authors have taken data of surrounding surface temperature with 2D infrared imager, and sky view photograph with digital camera connecting a fish-eye lens.

Table 1 Relations between PMV and physiological thermal senses

PMV	sensation	stress	PPD (%)
-0.5			10
	comfortable	no	
0.5			10
	slightly warm	slight	
1.5			50
	warm	moderate	
2.5			90
	hot	strong	
3.5			100
	very hot	extreme	

PPD: Predicted percentage dissatisfied

The authors applied PMV (Fanger, 1972) and SET* (Gagge *et al.*, 1986) as thermal comfort indices. These indices were used in many previous studies (e.g. Matzarakis *et al.*, 2006) and were regarded to represent human physiological thermal senses (Table 1). PMV and SET* were calculated with the free software ET_AEE developed at Kyushu University inputting mean values (T, RH, WS) for every sequential observation, above-mentioned MRT, *clo* value (0.5 as assuming summer clothing), *met* value (1.5 as assuming outdoor walking).

3. RESULTS

Around Jiefangbei there is a large scale pedestrian road. It is one of the highly concentrated commercial zones in Chongqing. There is almost no green space. The ground is covered with anthropogenic materials and the surface temperature exceeds 50 deg C in mid-day. Density of high building is large and SVF is small (Fig. 3). In the morning, at Jiefangbei with less SVF and less solar gain to the ground, both of MRT and thermal comfort indices were small (Fig. 4; Table 2). On the other hand, at Chongqing University with more SVF and enough green space, the thermal comfort indices were smaller than Jiefangbei in the evening. On the one–day sequence of data, PMV seems to be strongly influenced by MRT and SET* seems to be influenced by MRT and WS.

Fig. 3 Observation point at Jiefangbei

8:15-9:15	T (℃)	RH (%)	WS (m/s)	MRT (℃)	PMV	SET* (℃)	
Jiefangbei	28.2	70.1	0.89	29	1.08	26.2	
Chongqing U.	29.1	68.7	1.29	38	1.96	28.3	
mid-day	T (℃)	RH (%)	WS (m/s)	MRT (℃)	PMV	SET* (℃)	
Jiefangbei	32.9	54.9	1.9	45	3.4	30.6	11:00-12:00
Chongqing U.	34.8	49.4	2.11	52	4.48	32.4	12:00-13:01
17:00-18:02	T (℃)	RH (%)	WS (m/s)	MRT (℃)	PMV	SET* (℃)	
Jiefangbei	34.5	46.9	0.51	34.5	2.92	32.2	
Chongqing U.	34.8	49.3	0.9	33	2.92	30.7	

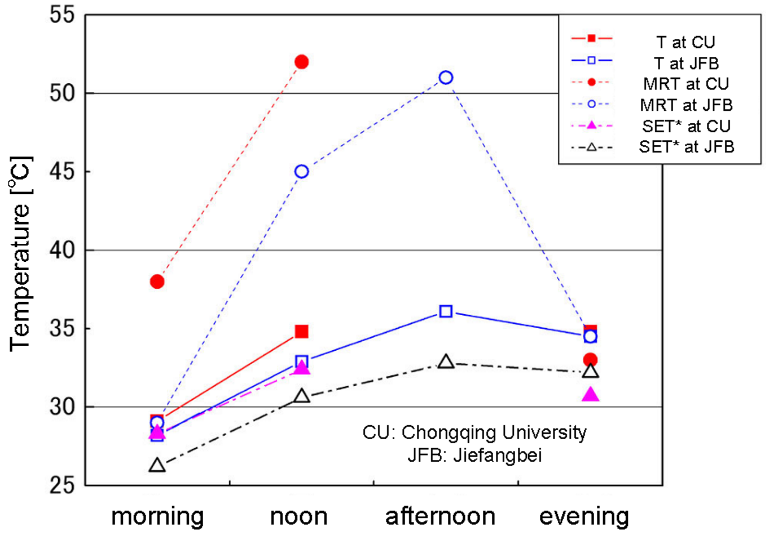

Fig. 4 (Table 2) Outline of observed data at Jiefangbei (Aug. 7, 2004)

”afternoon” means 14:00-15:00.

4. DISCUSSION

RayMan Model developed by Matzarakis *et al.* (2006) at the Meteorological Institute, University of Freiburg is for evaluating radiation environment, e.g. spatial arrangement of obstacles for radiation like buildings and trees composing urban surfaces, or influences of clouds. It is a tool to numerically simulate thermal comfort indices at any points inputting data on shapes of building etc. related to the radiation environment. Then, it is available to use for local scale evaluation like urban planning. Main outputs of this model are MRT and thermal comfort indices like PMV, PET and SET*. A comparison between simulated results with this RayMan Model and observed results in Freiburg, Germany revealed that MRT showed better agreement in spite of some error in daytime (Matzarakis and Mayer, 2000). They have not tested RayMan on SET* and PMV, therefore the authors tried to test them. First, the authors extracted values of SVF from sky view photographs taken with fish-eye lens (Fig. 5). Secondly, they measured the distribution of surrounding buildings. At each evaluation site, they utilized a laser-range finder (Nikon LASER800S) to measure the distances to the walls of buildings. Finally they used T, RH, WS measured and *clo*, *met* assumed. The amount of clouds was extracted from sky view photographs. Figure 6 shows comparisons between calculated thermal comfort indices using observed data and simulated ones with RayMan Model. SET* and PMV shows good agreements between them. Especially PMV shows a high correlation.

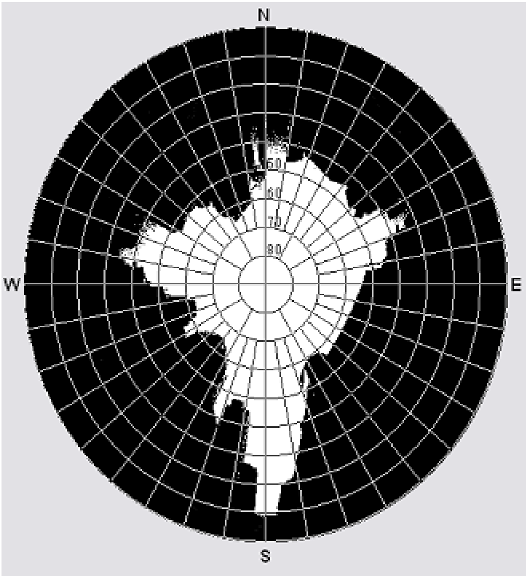

Fig. 5 Example of sky view photograph by fish-eye lens to generate data on buildings to be input to RayMan Model: Overlayed on Wulf-net to calculate SVF

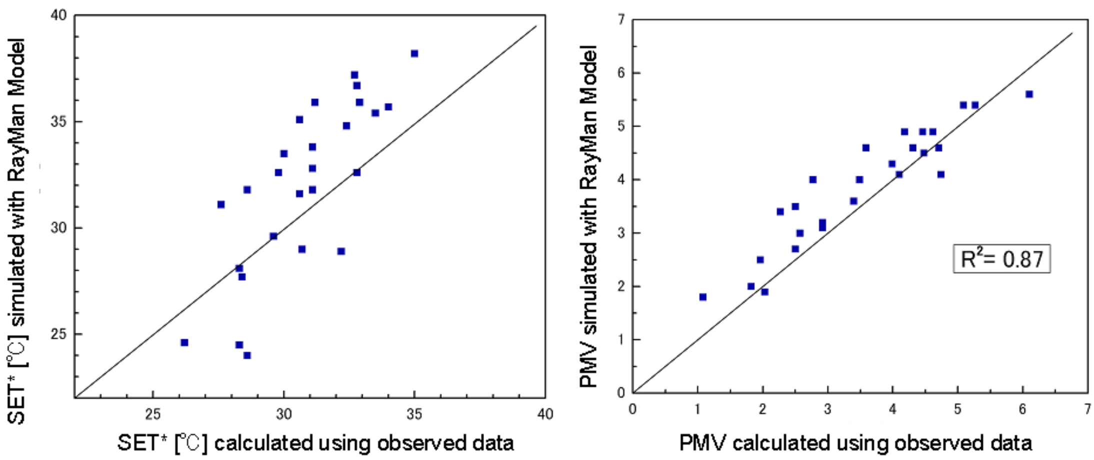

Fig. 6 Comparison between thermal comfort indices: calculated using observed data (x-axis) and simulated with RayMan Model (y-axis)

5. CONCLUSION

Thermal comfort indices calculated using observation results were compared to results of numerical simulation using the sky view photograph by fish-eye lens and RayMan Model. Both results agreed well. This indicates the thermal comfort indices have some provability to be computed with some accuracy in some simple methods, even at locations without detailed digital spatial information database.

References

Fanger, P.O. (1972), Thermal comfort, New York, McGraw-Hill.

Gagge, A.P. *et al*. (1986), "A standard predictive index of human response to the thermal environment", ASHRAE Transactions, 92-2B, pp. 709-731

Matzarakis, A. and Mayer, H. (2000), "Atmospheric conditions and human thermal comfort in urban areas", 11th Seminar on Environmental Protection "Environment and Health", pp. 155-166

Matzarakis, A., Rutz, F., Mayer, H. (2006), "Modeling the thermal bioclimate in urban areas with the RayMan model", Proc. of PLEA2006, pp. II-449-II-453