American Meteorological Society
97th ANNUAL MEETING | SEATTLE

22–26 January 2017 | Seattle, WA

Abstract ID: 312414

Radiation Conditions at a Central European Square in a Hot Summer Day – a Case Study from Szeged, Hungary

Á. Takács, C.V. Gál, Á. Gulyás, M. Kiss, N. Kántor

UNIVERSITY OF SZEGED · DALARNA UNIVERSITY · MUTK

INTRODUCTION

In the light of continued urbanization and projected rising temperatures, mitigating the impact of extreme heat events is a pressing issue for both urban dwellers and city officials. The main source of heat stress in the summer is radiation load, which is quantified as mean radiant temperature (T_{mrt}).

Within a wider framework to evaluate the influence of various urban features and nature based solutions on the radiative environment, this study is conducted with a dual aim

(a) to assess the impact of vegetation and different facade orientation on T_{mrt},

(b) and to evaluate the performance of three, popular numerical models in predicting T_{mrt} values in complex urban environments.

STUDY AREA

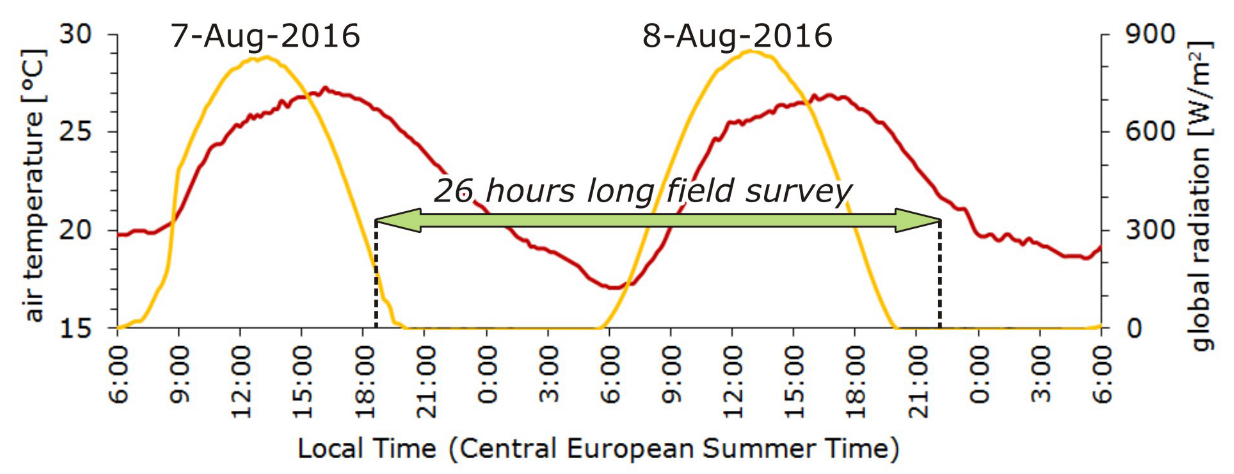
Szeged, Hungary, Europe (46.3°N, 20.1°E)

Bartók sq. (110 m x 55 m) & surrounding streets

5 survey points

Fisheye photo of the survey points

Background Weather



ON-SITE MEASUREMENTS

26 hours long temperature and radiation measurements

2 urban-biometeorological stations

- one located at the middle of the square (P5 on the map)
- one station circled among P1–P4: 15 min/point

Measured parameters:

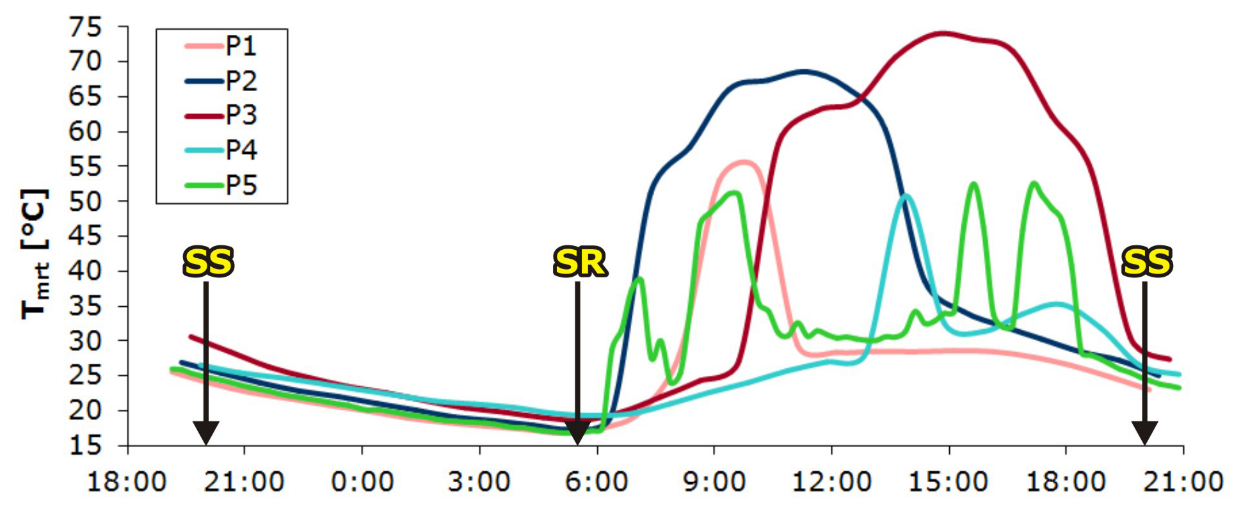
short- and long-wave radiation flux densities from 6 perpendicular directions K_i [W/m²] and L_i [W/m²]

Calculation of mean radiant temperature T_{mrt} [°C]:

$$T_{mrt} = \sqrt[4]{\frac{S_{rad}}{a_l \cdot \sigma}} - 273.15 \qquad S_{rad} = \sum_{i=1}^{6} W_i \cdot (a_k \cdot K_i + a_l \cdot L_i)$$

- radiation absorbed by the human body S_{rad} [W/m²]
- Stefan-Boltzmann constant σ (5.67 x 10^{-8} W/m²K⁴)
- long-wave radiation absorption coefficient a_l (0.97)
- short-wave radiation absorption coefficient a_k (0.7)
- directional weighting W_i: 0.22 for N, S, E, W, 0.06 for up, down

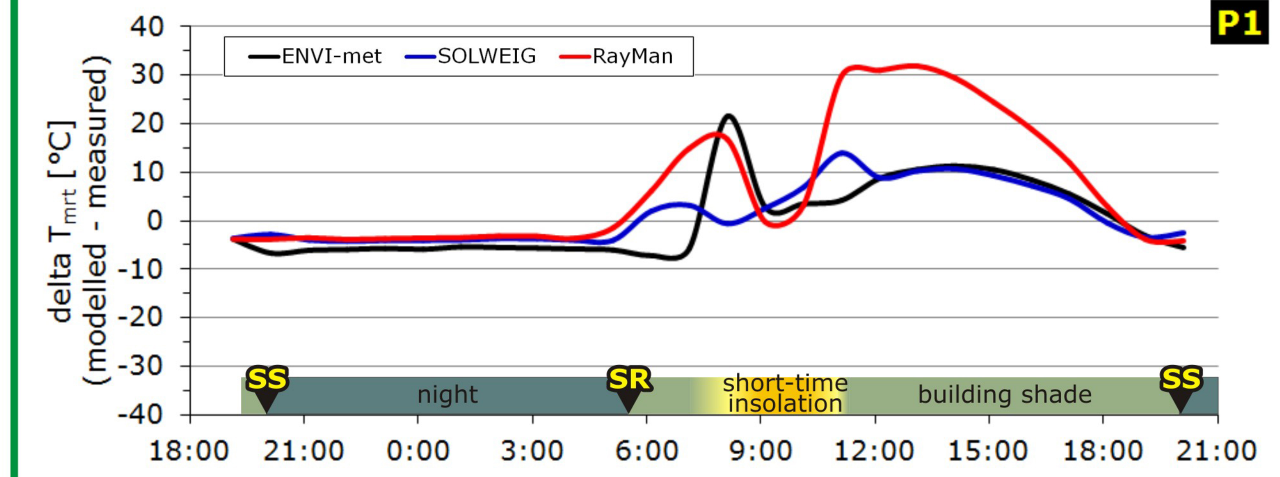
RESULTS OF THE FIELD SURVEY

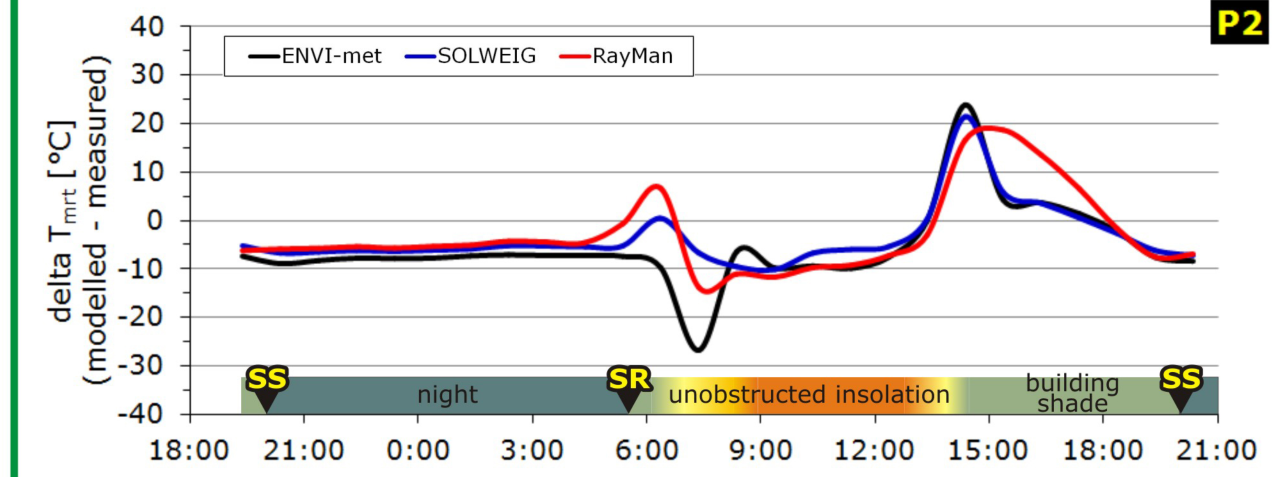


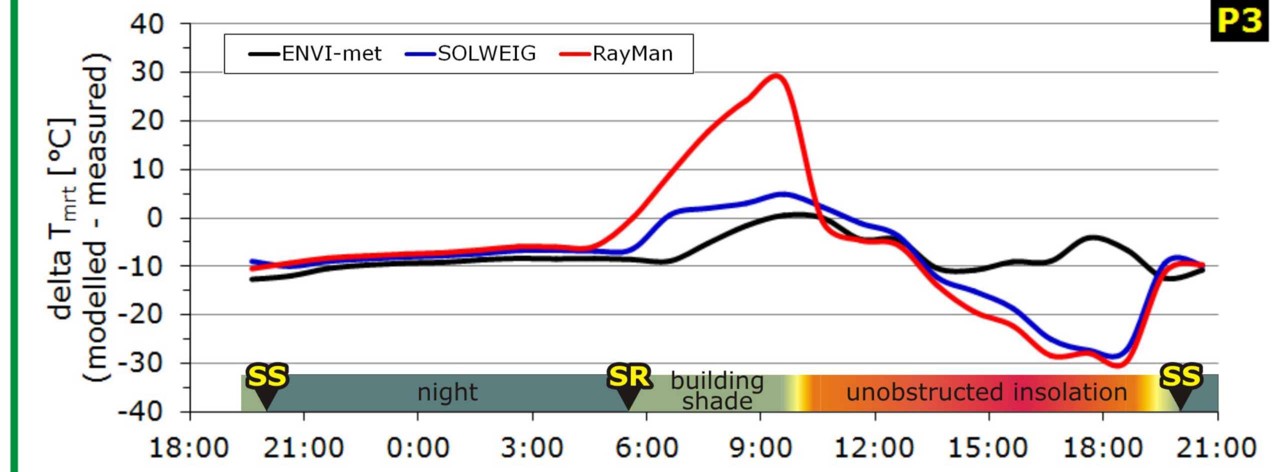
Observations Lead the Way

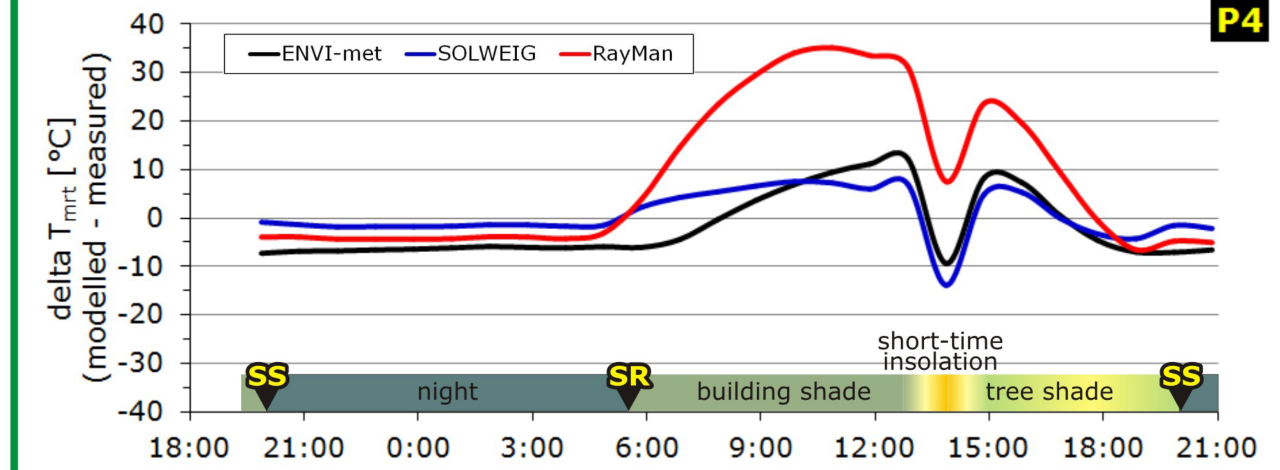
Several studies confirm that mean radiant temperature (T_{mrt}) is the main factor affecting human thermal comfort in outdoor places. Consequently, there is a growing need for affordable and mobile, but still accurate measurement techniques for determining T_{mrt} outdoors. This would not only lead to a better understanding of the thermal influences of various urban design features, but would also contribute to better numerical models indirectly. The measurement technique we regularly apply adopts net radiometers. It is regarded to be the most accurate method today. However, the sensors are expensive and the price of rescuing equipment costs that is to utilize one pair of pyrano- and pyrgeometers each, instead of tree pairs comes with increased labor input. The cheaper but more labor intensive process entails the continuous rotation of net radiometers along the three Cartesian axes. This exhaustive procedure hinders the measurement technique from being adopted wildly.

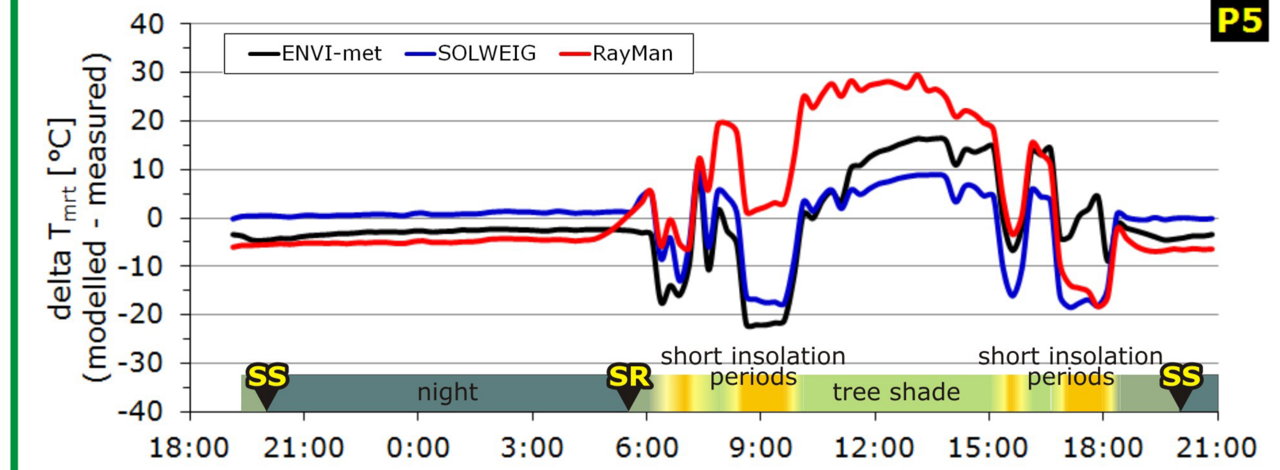
MODELL VALIDATION











Statistical Analysis

		Delta Mean	Delta Range	Delta Std	MAE	RMSE	Index of Agreement
P1	ENVI-met	-0.3703	10.4090	5.1154	6.6810	7.6735	0.8867
	SOLWEIG	1.2815	11.4390	4.4423	4.9998	5.9225	0.9250
	RayMan	6.3969	9.0646	8.0618	10.2570	14.5680	0.6760
P2	ENVI-met	-6.0517	1.8225	0.7322	8.2693	9.9439	0.9263
	SOLWEIG	-3.9431	-0.3791	0.2844	6.0269	7.1463	0.9601
	RayMan	-2.9757	-4.1761	-0.7124	7.5872	8.7285	0.9352
P3	ENVI-met	-7.7077	-0.9273	0.4582	7.8474	8.5602	0.9592
	SOLWEIG	-8.4831	-5.0005	-3.1513	9.5765	12.0570	0.9041
	RayMan	-6.4947	-8.2338	-3.5226	12.5320	15.3330	0.8300
P4	ENVI-met	-1.8462	-3.2202	2.9504	6.4533	6.9408	0.7995
	SOLWEIG	0.5587	-11.9760	-0.6140	3.7387	4.8019	0.8412
	RayMan	7.9472	14.7970	10.3110	12.4650	17.0090	0.4799
P5	ENVI-met	-1.0208	2.6792	2.3751	6.6660	8.8972	0.8246
	SOLWEIG	-0.6918	-15.8580	-2.9795	4.5759	7.0882	0.8075
	RayMan	2.8569	9.7271	7.2601	10.1410	13.3040	0.7297

STUDY OUTCOMES AND CONCLUSIONS

Our measurements indicated:

- During clear summer days exposed locations (P2, P3) can reach extreme radiation load (T_{mrt} = 65–75°C).
- Shade trees (P4, P5) are however effective solutions against this burden (they can mitigate T_{mrt} to 30–35°C).
- Shading of SE-, S- and SW-exposed building facades and sidewalks is extremely important to avoid heat stroke and improve human comfort conditions (outdoors and indoors as well).

Recently, planning directives of the European Union emphasize to use more **nature-based solutions** in urban planning. They may help re-naturing cities and several times they are more cost-effective than conventional planning concepts. Our field survey demonstrated that besides shading of the surrounding buildings, planting and management of trees can be considered a good solution against heat stress.

The small-scale model validation demonstrated:

- Among the evaluated models, SOLWEIG and ENVI-met predicted the radiative conditions better in complex urban environments.
- At night all models underestimated T_{mrt}. The best nighttime performance was achieved by SOLWEIG, in locations where shade trees were present.
- During the day all models overestimated T_{mrt} in shaded locations, however, they frequently underestimated T_{mrt} when observation points became irradiated.
- Some of the extreme errors are the results of coarse model resolutions.

Models are simplifications of reality and thus they introduce a certain degree of idealization. For example, trees are never as perfectly shaped or have a homogeneous crown ransmissivity and leaf area index (LAI) in the reality, neither do surface parameters are as uniform as frequently assumed by models. Additionally, the numerical simulation discrepancies observed during the night and in shaded conditions indicate that the simplified approaches estimating the impact of materials with high thermal mass is still in need of improvements.

However, through adequate parameterization obtained via accurate measurements the investigated expert modeling tools can be suitable for the purpose of urban green space planning.

Acknowledgement

Authors are grateful for the invaluable assistance of Gábor Horváth and Zsuzsa Győri during the 26 hour-long observations. The presented study is connected to the Nature4Cities project which has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 689817.

European Commission

THE FRAMEWORK PROGRAMME FOR RESEARCH AND INNOVATION
HORIZON 2020