Weather and climate modeling possibilities using local climate zone concept and observation network in Szeged, Hungary

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Introduction

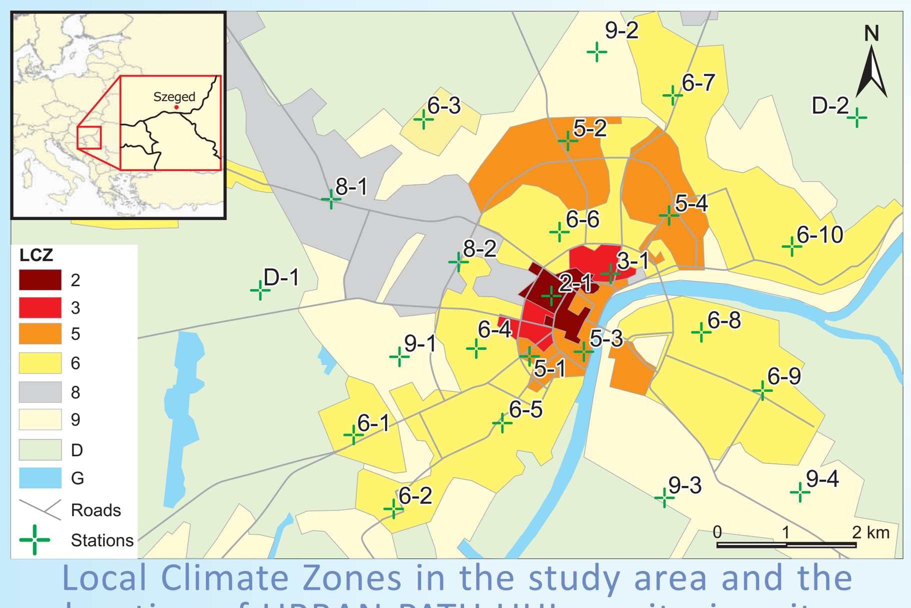
In the field of urban climatology Local Climate Zone (LCZ) classification is widely accepted as a representation of urban land use. Application of this system for climate modeling is advantageous because the classification is based on the thermal characteristics thus it is an ideal way to represent the effect of the urban surface for the urban heat island (UHI) development.

The aim of this study is to present the different urban climate modelling initiatives in the case of Szeged, Hungary. We applied the widely known Weather Research and Forecasting model and MUKLIMO model developed by the German Meteorological Service. In the city data from a 23-element measurement network (Lelovics et al, 2014) is available for validation, it makes the city an ideal testbed model validations.

Study area and measurements

Szeged is located in the Pannonian Plain . The urbanized area covers about 30 km^2. Tisza River is the axis of the town and the city has a regular avenue-boulevard structure. In this areas numerous surface database are available from previous studies (building database, SVF, albedo, NDVI, etc.) In addition the Local Climate Zones (developed by Stewart and Oke 2012) was also evaluated using different methodologies (Bechtel method, Lelovics-Gál method).

In 2014 a 24- element measurement network was deployed. It means ~1 station/2 km^2. The station locations are representative of their local climate zone.



Local Climate Zones in the study area and the location of URBAN-PATH UHI monitoring sites

WRF

In case of Weather Research and Forecasting (WRF) model (Skamarock et al, 2008) experiment we aimed to apply the Local Climate Zone system as the land use input data. For the experiment we applied single layer canopy scheme and GFS as forcing.

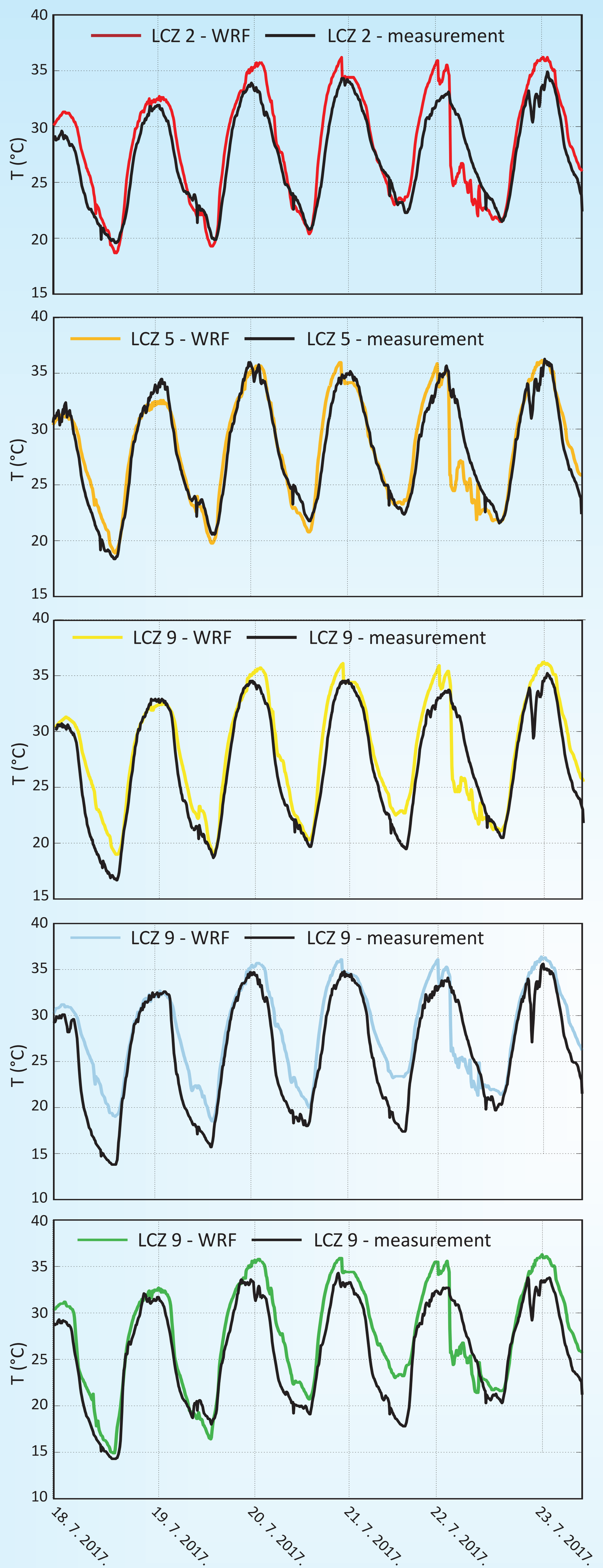
In order to be sure that the urban landforms will be represented correctly we calculated the necessary input parameters based on the available datasets. In case of definition of thermodynamic parameters detailed field survey was carried out.

Calculated input parameters in the different LCZs for WRF model

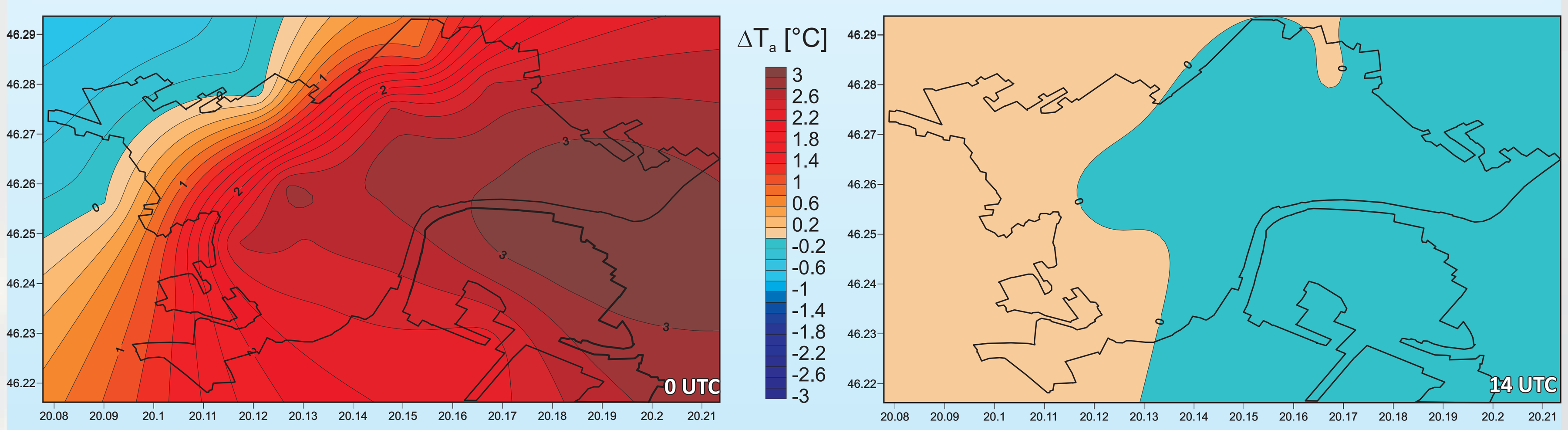
	Compact midrise	Compact low-rise	Open midrise	Open low-rise	Large low-rise	Sparsely built
Urban fraction	0.9	0.82	0.58	0.66	0.75	0.25
Vegetation fraction	0.1	0.18	0.42	0.34	0.25	0.75
Building height [m]	13.6	7.9	15.4	5.4	6.6	5
Road and roof width [m]	5.1	4.3	5.3	3.2	5.5	2.9
Surface albedo of road, roof, walls	0.15	0.14	0.12	0.16	0.16	0.17
Thermal conductivity of road [$Jm^{-1}s^{-1}K^{-1}$]	0.7	0.7	0.7	0.7	0.7	0.7
Thermal conductivity of roof [$Jm^{-1}s^{-1}K^{-1}$]	1.04	1.01	1.2	1.01	1.24	1.01
Thermal conductivity of walls [$Jm^{-1}s^{-1}K^{-1}$]	1.02	1.01	1.1	1.02	1.2	1.01
Heat capacity of road [$Jm^{-3}K^{-1}$]	$1.95\cdot10^6$	$1.98\cdot10^6$	$1.95\cdot10^6$	$1.98\cdot10^6$	$1.94\cdot10^6$	$1.98\cdot10^6$
Heat capacity of roof [$Jm^{-3}K^{-1}$]	$1.97\cdot10^6$	$1.97\cdot10^6$	$1.97\cdot10^6$	$1.97\cdot10^6$	$1.97\cdot10^6$	$1.97\cdot10^6$
Heat capacity of walls [$Jm^{-3}K^{-1}$]	$1.63\cdot10^6$	$1.62\cdot10^6$	$1.72\cdot10^6$	$1.62\cdot10^6$	$1.86\cdot10^6$	$1.61\cdot10^6$
Emissivity of road	0.93	0.93	0.93	0.93	0.93	0.93
Emissivity of roof	0.91	0.92	0.87	0.92	0.86	0.92
Emissivity of walls	0.92	0.93	0.9	0.93	0.87	0.93

Our results shows that the daily cycle of temperature estimated reasonably well. At daytime WRF simulation is more accurate, however nocturnal UHI is also appears. The most problematic phenomena is the early nocturnal cooling process.

It is a clear advantage that the system could be applied for operational UHI forecast after some optimization and corrections in the land use datasets.



Comparison of observations and WRF prediction of air temperature in a heat wave period (18-23[th] July 2017)



Mean UHI intensity for the modelled period (18-23[th] July 2017) at 0 UTC and 14 UTC (2 and 16h in local time)

MUKLIMO

MUKLIMO_3 is a non-hydrostatic micro-scale model (Sievers, 1990). It is a much simpler model than the WRF therefore we concentrated to a heat wave period without any disturbing weather effect. The forcing data was obtained from ALARO model. The input parameters was defined based on detailed calculations in the study area.

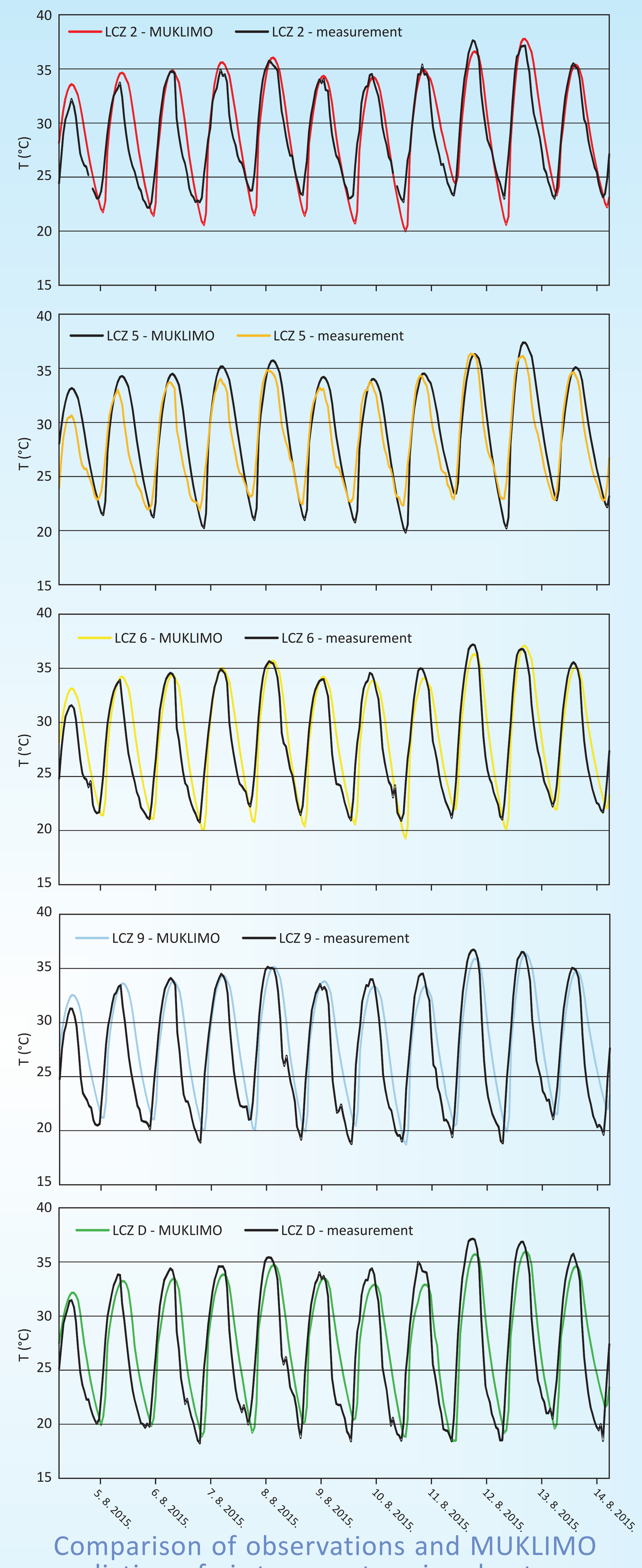
Calculated input parameters in the different LCZs for MUKLIMO model

	Compact midrise	Compact low-rise	Open midrise	Open low-rise	Large low-rise	Sparsely built	Low plants
fraction of built area (Δ_b)	0.45	0.45	0.3	0.3	0.4	0.15	0
mean building height (h_b)	16.5	9.2	18.6	6.5	6.8	8.5	0
wall area index (w_b)	3.42	2.4	4.4	2.1	2	2.1	0
fraction of pavement of the non-built area (v)	0.7	0.4	0.45	0.4	0.8	0.45	0
fraction of tree cover (Δ_t)	0	0	0	0	0	0	0
fraction of low vegetation of the remaining surface (Δ_c)	0.9	0.8	0.8	0.7	0.8	0.8	1
tree height (h_t)	0	0	0	0	0	0	0.2
height of the low vegetation (h_c)	0.1	0.1	0.1	0.1	0.1	0.1	0.5

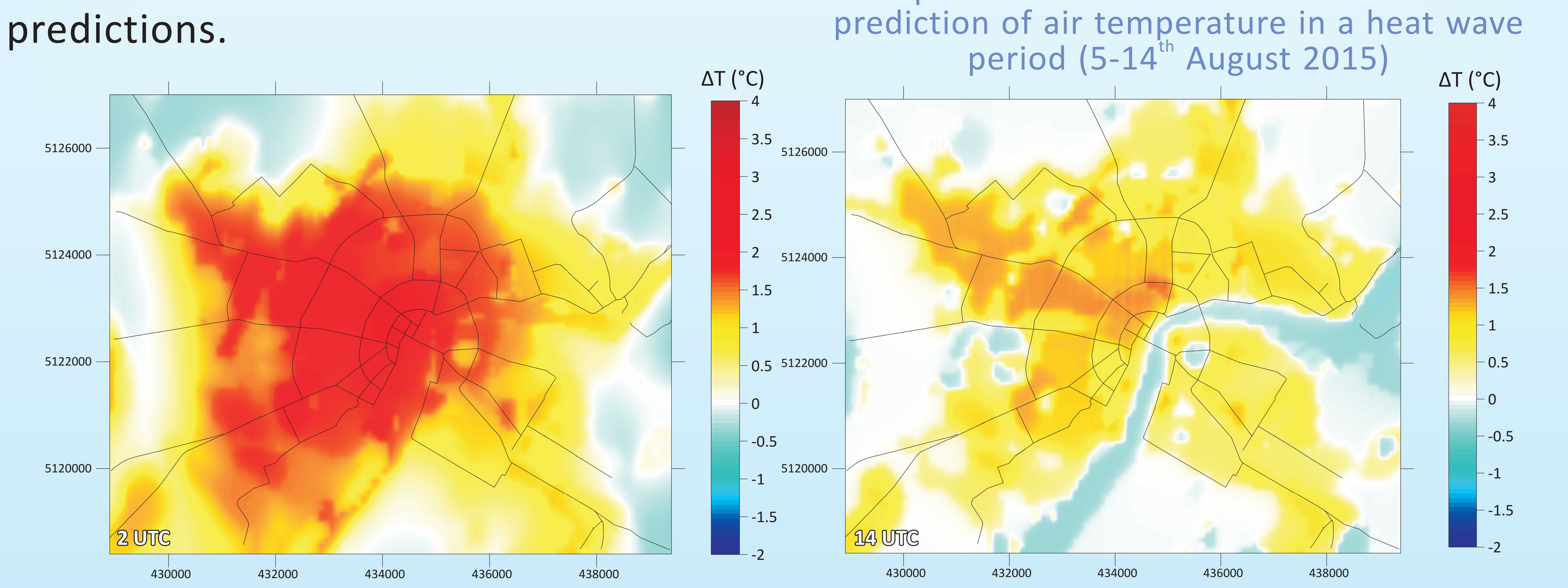
This model applies different concept than the WRF. Changing the concept from infinite urban canyon into a porous 3D urban surface is a significant step forward if we evaluate the results and consider the less detailed physical background of the model.

The result shows that the daily cycle of the temperature is captured correctly, the spatial distribution of the nocturnal UHI is correct. In case of daytime the model partly overestimates the temperature.

It is a clear advantage of this model that it can be used for the proper estimation of climate parameters (summer days, tropical nights) based on climate predictions.



Comparison of observations and MUKLIMO prediction of air temperature in a heat wave period (5-14[th] August 2015)



Mean UHI intensity for the modelled period (5-14[th] August 2015) at 2 UTC and 14 UTC (4 and 16h in local time)

Conclusions

The results show that both of the applied model is capable to estimate UHI. Our previous results prove the importance of time period near sunset in the role of nocturnal cooling process and the development of UHI. This cooling process could be described properly using the Sky View Factor (SVF), unfortunately it is not implemented as an input parameter in models. The use of SVF and a new physical parametrization would be an important step forward in the field of UHI modelling.

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This work has been supported by OTKA K-111768 and NKFI 120346. The first author was supported by the ÚNKP-17-4 New National Excellence Program of the Ministry of Human Capacities.

10[TH] INTERNATIONAL CONFERENCE ON URBAN CLIMATE
14[TH] SYMPOSIUM ON THE URBAN ENVIRONMENT
6-10 AUGUST 2018, NEW YORK