Modelling of climate change induced urban climate with SURFEX land surface model

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1 Introduction

- At the Hungarian Meteorological Service (OMSZ) high resolution regional climate models are applied to estimate future climate change over a region or country in detail, and to serve as a fundamental basis for quantitative impact studies. Special attention is dedicated to investigate the effects of climate change in cities considering their vulnerability.
- Previously, in the framework of the Orientgate project, vulnerability assessment was conducted in Budapest and Veszprém county based on the future projections of ALADIN-Climate and REMO regional climate models (RCMs; Fig. 1).
- However, for such fine scale studies RCMs in themselves can only serve few information due to their coarse resolution and simplified parameterization scheme used over cities.

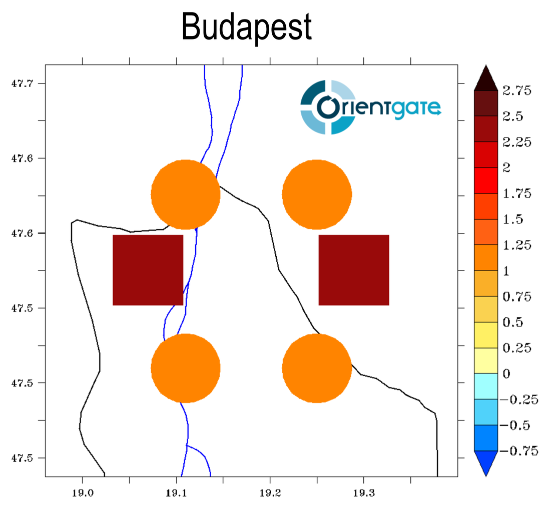
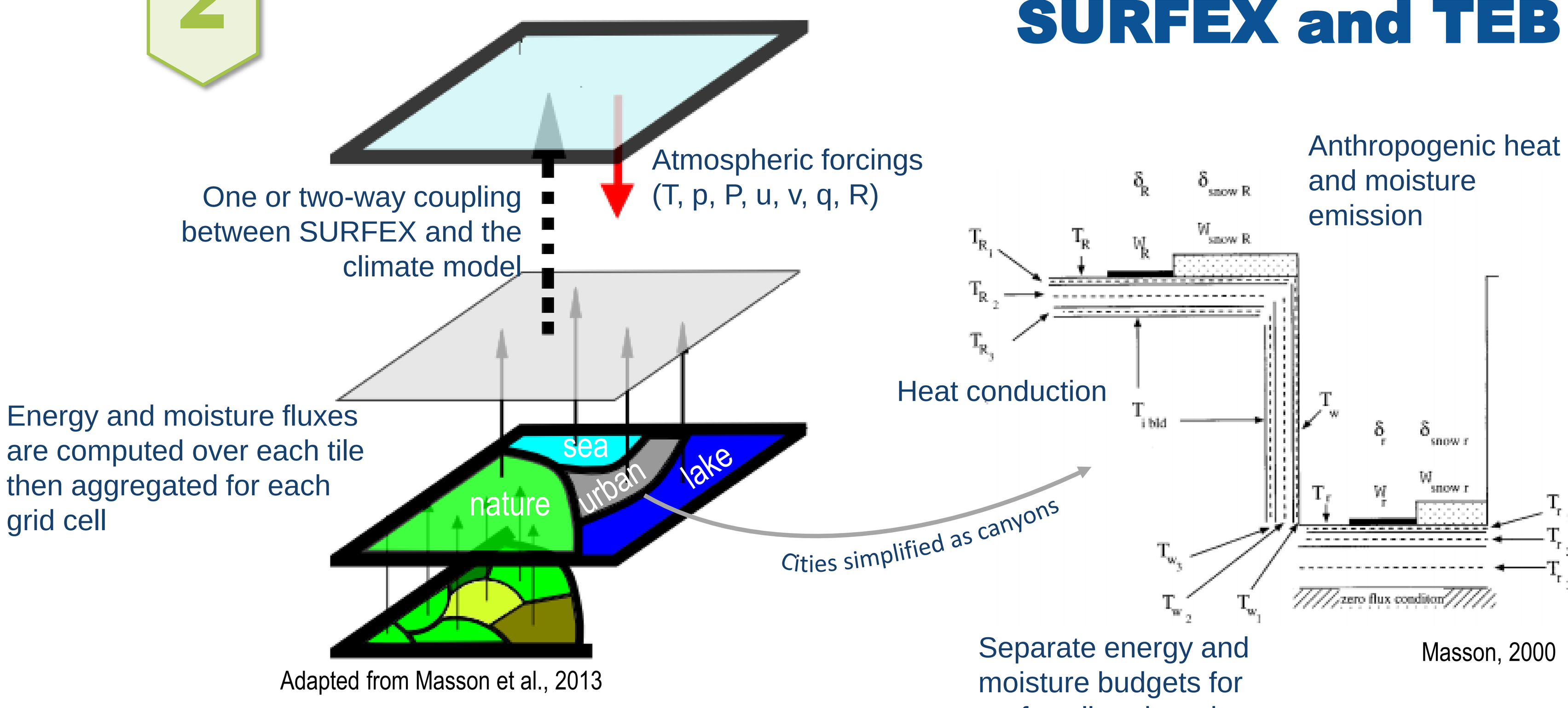


Fig. 1. 2-m temperature change [in °C] in Budapest in 2071–2100 with reference to 1961–1990 under A1B emission scenario according to ALADIN-Climate (dots) and REMO (squares) models. The grid distance is 10 and 25 km for ALADIN-Climate and REMO, respectively.

- In order to improve such results and provide more solid impact assessments we adapted the SURFEX land surface model including a specific urban parameterization scheme, the TEB urban energy balance model (Masson, 2000).
- In these studies, we evaluate the added value of SURFEX and sensitivity of the results to SURFEX settings concentrating on analysis of 2-meter temperature results.

Masson, V., 2000. A Physically-Based Scheme For The Urban Energy Budget In Atmospheric Models. *Boundary-Layer Meteorology*, 94(3), pp.357–397.

2 SURFEX and TEB



Masson, V. et al., 2013. The SURFEXv7.2 land and ocean surface platform for coupled or offline simulation of earth surface variables and fluxes. *Geoscientific Model Development*, 6(4), pp.929–960.

3 Added value of SURFEX

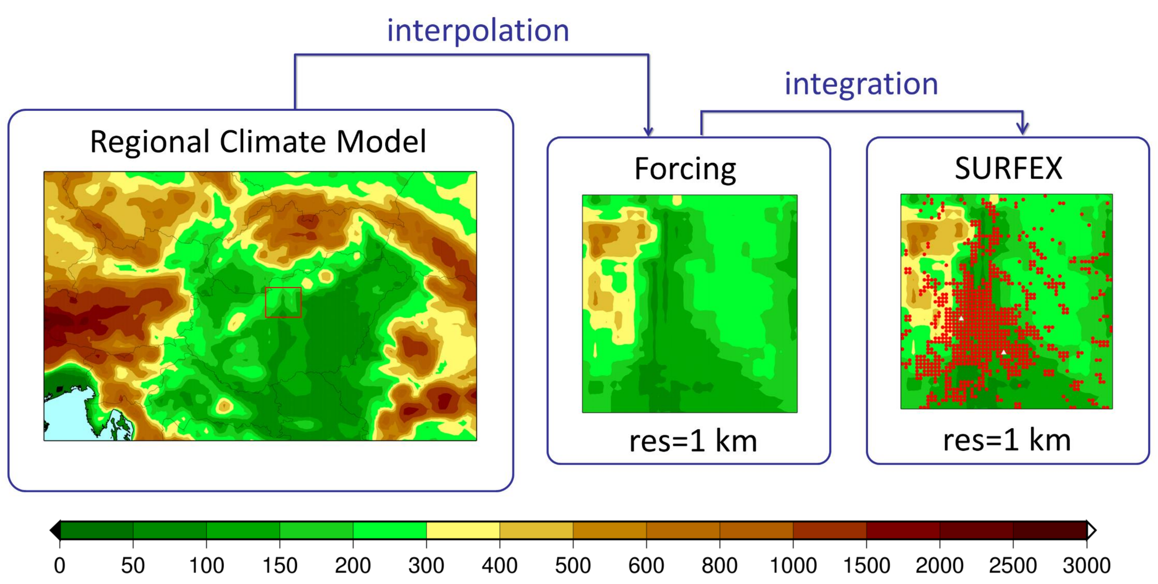


Fig. 4. Methodology to apply SURFEX for urban climate investigations. Atmospheric forcings provided by a RCM are interpolated to the target domains. Grid cells that include urban tile are marked with red dots.

Table 1. Characteristics of the SURFEX simulations

Atmospheric forcings	ALADIN-Climate v4.5 (10 km res.)
LBC for RCM	ERA-Interim
Coupling height	30 m
Coupling frequency	3 h
Period of integration	2001–2010
Domain of SURFEX	Budapest

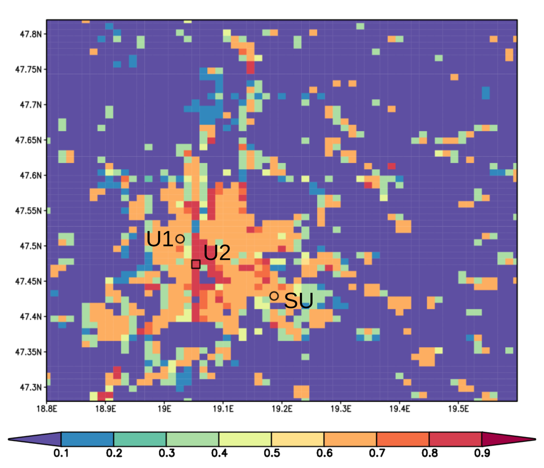


Fig. 5. Fraction of urban tiles in gridpoints according to ECOCLIMAP land surface database. Closest gridpoints to station measurements are marked.

- Budapest: urban climate and the influence of topography interacts. Investigating the impact of the forcings is essential.
- SURFEX is able to simulate the magnitude and daily cycle of UHI (Fig. 6, 7).

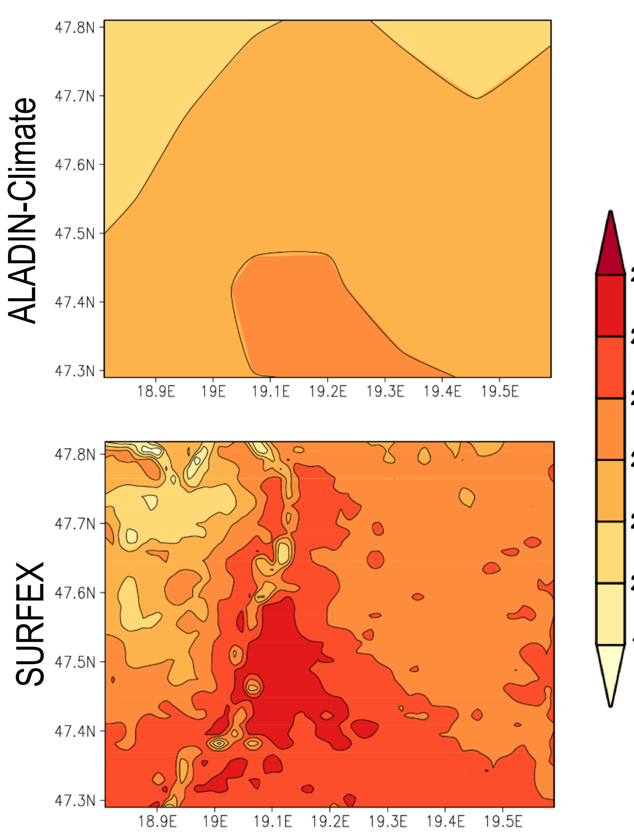


Fig. 6. Mean summer 2-m temperature [°C] over Budapest in ALADIN-Climate and SURFEX in 2001–2010.

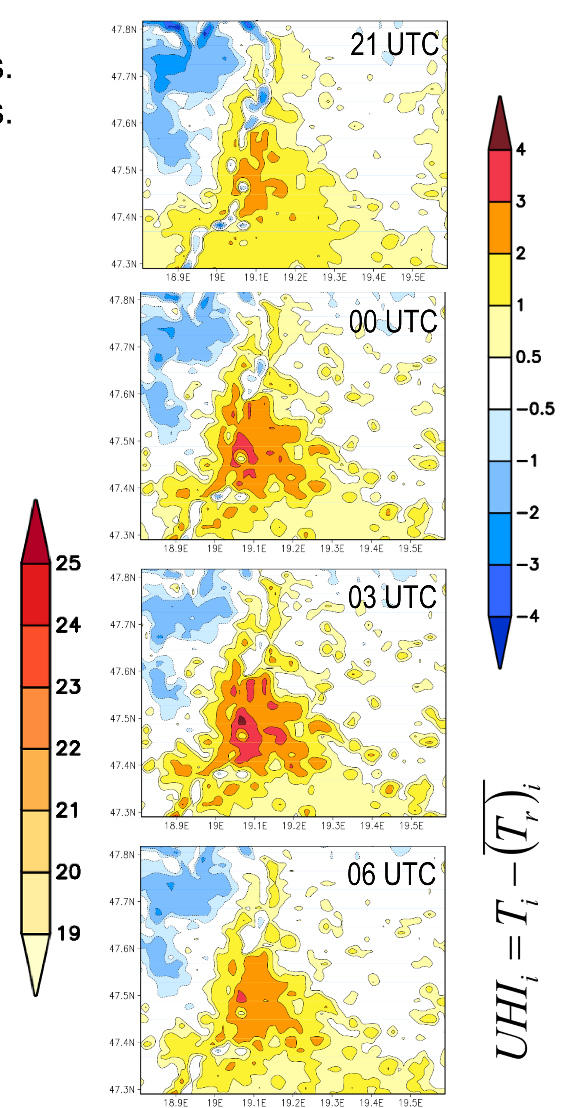


Fig. 7. Summer nocturnal UHI intensity [°C]. UHI is computed as the difference between the temperature in each gridpoints and the mean temperature of the rural gridpoints.

4 Validation with station data

- Traditional tools for validation of spatial and temporal characteristics of model performance are insufficient for our purposes. The available gridded, observational database has 10 km resolution and does not show the influence of urbanized areas. Few observational stations are in- and outside of the city, some of them provide short time series or locate unfavourably.
- Partly due to the complex topography of Budapest, spatially diverse bias in ALADIN results (Fig. 8).
- ALADIN underestimates the 2-m temperature with 1-2 °C over the great part of the domain, while in summer the model is slightly too warm (Fig. 8). SURFEX adds extra heat to the ALADIN results on the entire domain.

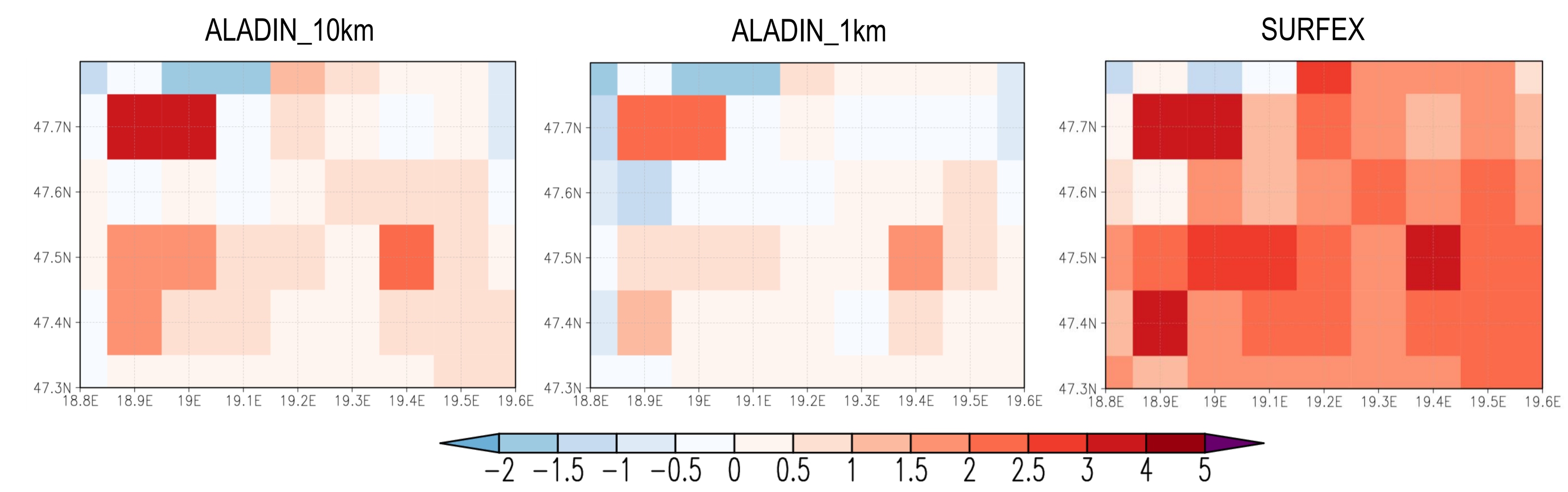


Fig. 8. Summer mean temperature bias [in °C] of the 10-km resolution ALADIN-Climate, the interpolated ALADIN-Climate and SURFEX with reference to CARPATCLIM gridded observational dataset.

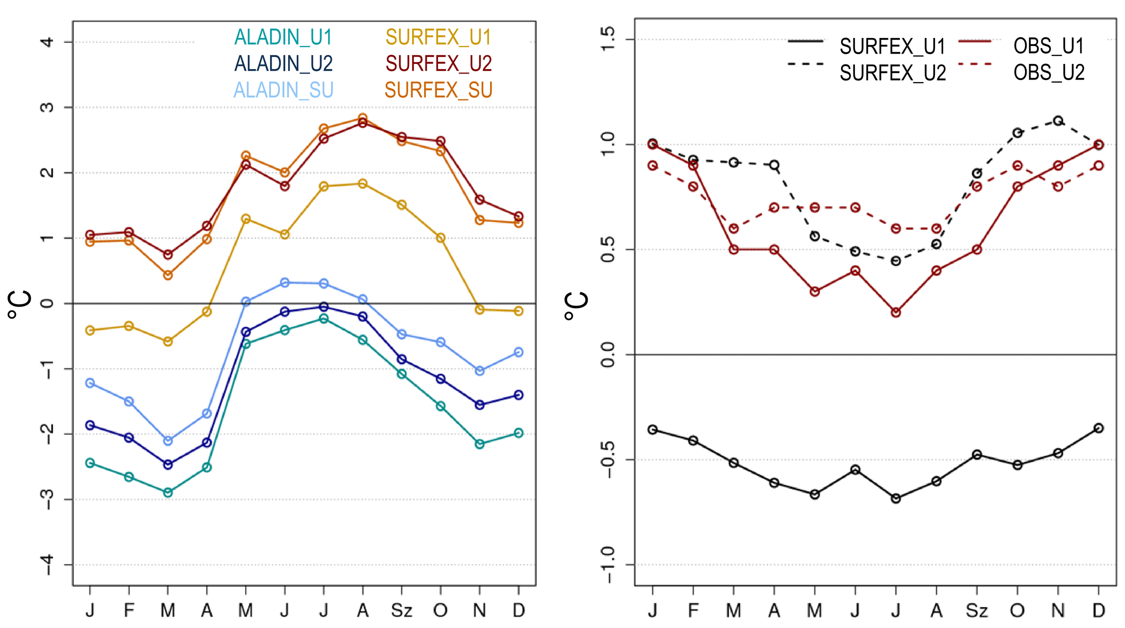


Fig. 9. Monthly mean temperature bias (left) and UHI intensity (right) [°C] in two urban and a suburban point with reference to station measurements.

- Two urban (U1 and U2) and a suburban (SU) gridpoints close to station measurements were selected for UHI validation (see map on the left). Note that U1 and SU gridcells have the same cover type (Fig. 5).
- The larger urban tile fraction leads to larger heat load in U2 than in SU resulting in similar temperature bias of SURFEX (left panel of Fig 9).
- Orography effect and the wrong land cover characterisation cause negative UHI in U1 (right panel of Fig. 9).
- Small summer underestimation and winter overestimation in U2 (Fig 9).

5 Different coupling strategies

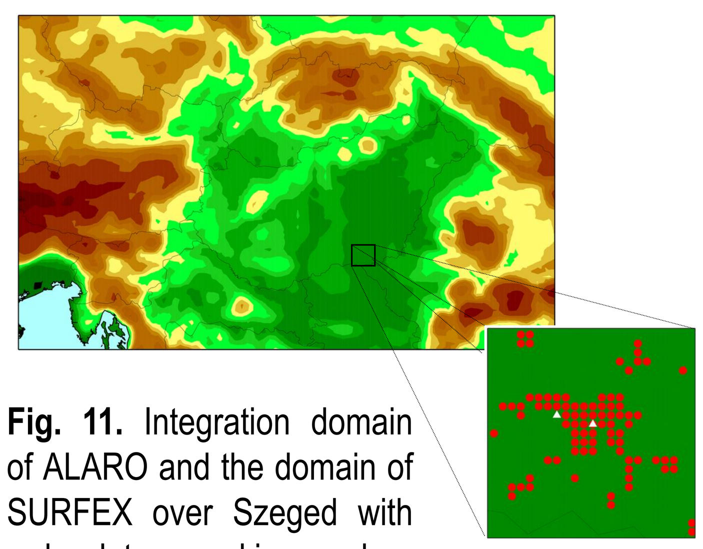


Fig. 11. Integration domain of ALARO and the domain of SURFEX over Szeged with red dots marking urban gridcells and white triangles marking selected reference points.

- Aim is to study the effect of different coupling strategies on the performance of UHI.
- SURFEX run on 1 km resolution with different settings for one summer day in 2010 over Szeged (Table 2; Szeged has flat area and dry climate, suitable to test the performance of SURFEX).
- Forcings provided by ALARO short-range model driven with ERA-Interim on 10 km resolution.
- Result: 1-hourly in stead of 3-hourly forcing update leads to stronger UHI early morning and evening when the incoming solar radiation changes rapidly (Fig. 12).

Table 2. Characteristics of the SURFEX simulations.

Atmospheric forcings	ALARO (10 km res.)	
LBC for RCM	ERA-Interim	
Coupling height	30 m	
Coupling frequency	3 h	1 h
Integration time	15. 07. 2010.	
Domain of SURFEX	Szeged	

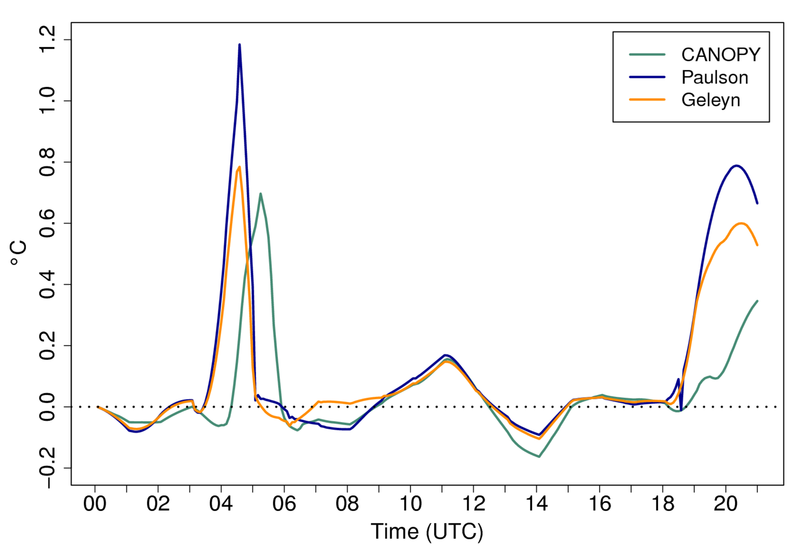


Fig. 12. Difference [in °C] between UHI on 15 July 2010 derived from two simulations with 1 h and 3 h forcing update. UHI was calculated between the two reference gridpoints. Different curves indicate simulations with different computation method in SURFEX for 2-m temperature.

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Conclusions

- SURFEX including the TEB urban energy scheme is able to simulate the pattern and diurnal evolution of UHI over Hungarian cities.
- Coarse gridded observational dataset and only few station measurements inside the city are available which limit the exact model validation. New validation methods (e.g. using satellite data) is planned.
- Result of the short sensitivity study suggested that updating atmospheric forcings more frequently improves the SURFEX results.

- Future plans: continue the sensitivity study on longer time scale and its extension on other model setting. Special attention will be put on the achieved improvements in function of computational and data storage need. Our far goal is to use SURFEX for future urban impact studies.