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Sensitivity analysis of the PALM model system input parameters

MOSAIK

Simone Pfau[1], Günter Groß[1]

[1] *Leibniz Universität Hannover*

Introduction

The PALM-6.0 model system is capable of simulating the physical processes within urban environments. Within the framework of the UC² project, it has been further developed, evaluated and applied. However, the sensitivity of the model results to the input parameters was not sufficiently addressed. With the presented study the quality of the input parameters and the required accuracy of the model results are investigated and a systematical sensitivity analysis is carried out for the input parameters required for PALM simulations of the urban enironment. This allows for the estimation of the input parameters, for which extensive data acquisition is worthwhile and necessary and for obtaining reliable model results.

Data accuracy and model setup

For an application of PALM in urban areas, input data concerning land use, road surfaces, soil type, buildings and vegetation are required. They can be obtained from various sources like municipal data, Open Street Map, satellite data or aerial imagery to name a few. However, Heldens et al. (2020) summarized that quality and availability of input data are very heterogeneous, which results in uncertain input parameters, which are transferred to the model results. For the latter, required accuracies are defined based on VDI guidelines (*) and assumptions:

model result	permissible deviations	
	absolute	relative
wind speed (*)	0.5 m/s	10 %
air temperature (*)	0.5 K	0.2 %
indoor temperature	0.5 K	0.2 %
surface temperature	0.5 K	0.2 %
UTCI	3 K	1.2 %

Tab. 1: Permissible deviatons for the model results.

Setup for the main area of investigation:

- reference scenario and multiple further scenarios with variations, summer
- building resolving simulation
- self nested PALM simulation with coarser-gridded parent and finer-gridded child domain
- grid resolution 10 m and 1 m in parent and child domain, respectively
- energy-balance model applied to natural an building surfaces
- radiative transfer model to account for shading and reflections
- plant canopy model to accout for evapotranspiraion an tree shading

Model domain and exemplary results

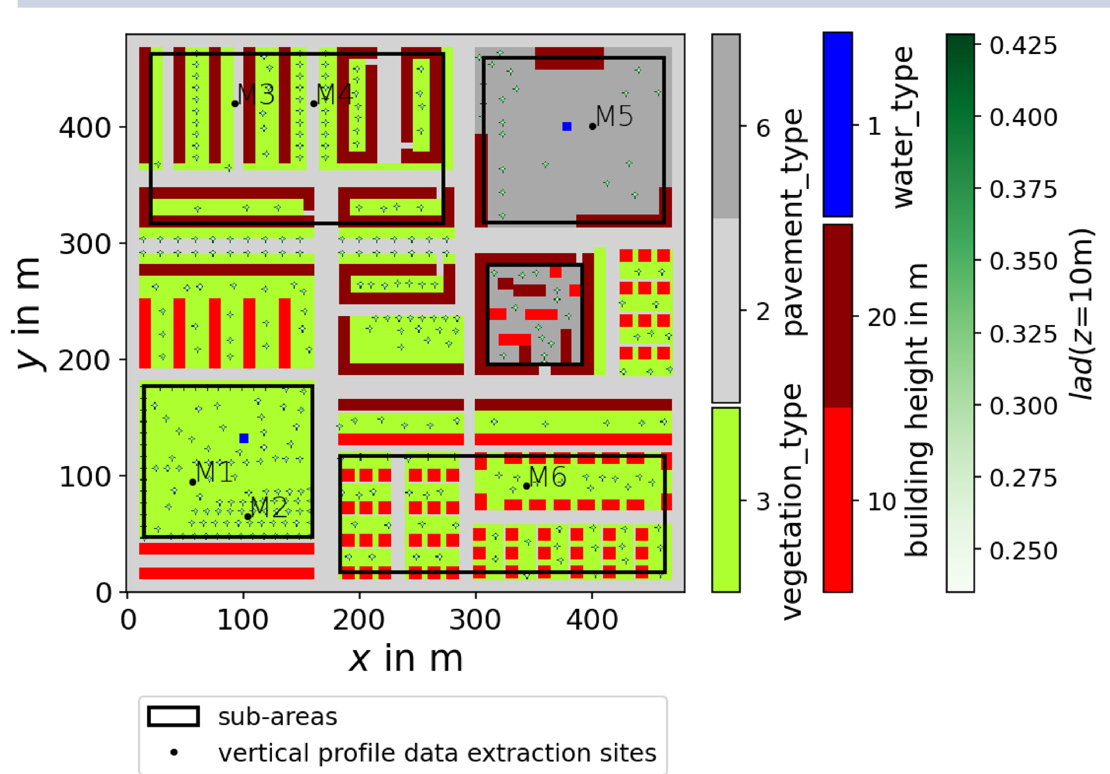

Fig. 1: Visualization of the main area of investigaton.

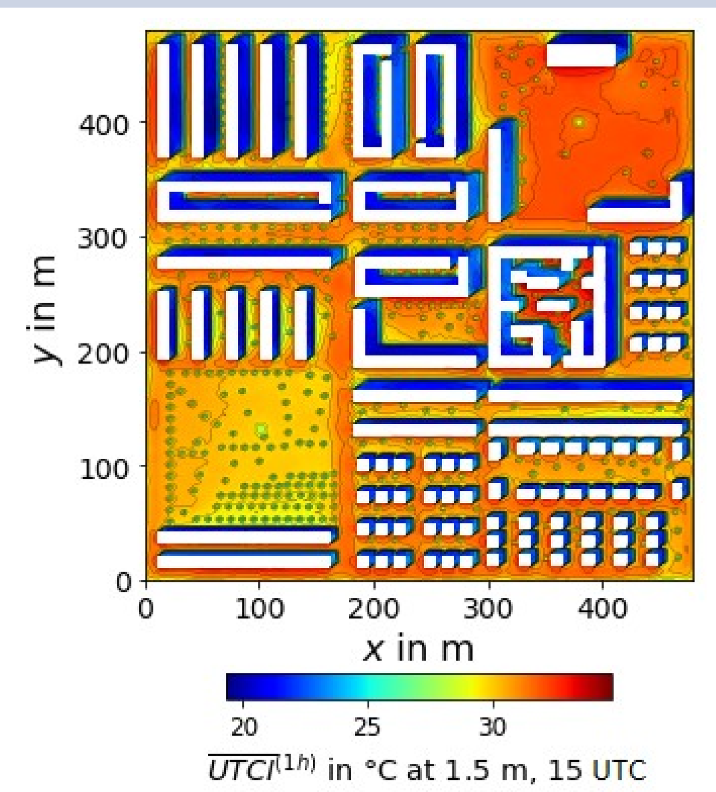

Fig. 2: Horizontal cross section of the modeled hourly averaged UTCI at 15 UTC 1.5 m above ground level.

- heterogeneity of UTCI in urban environments
- effect of different surface properties (vegetation, pavement), shadowing visible
- during day, moderate heat stress occurs in the non shadowed areas

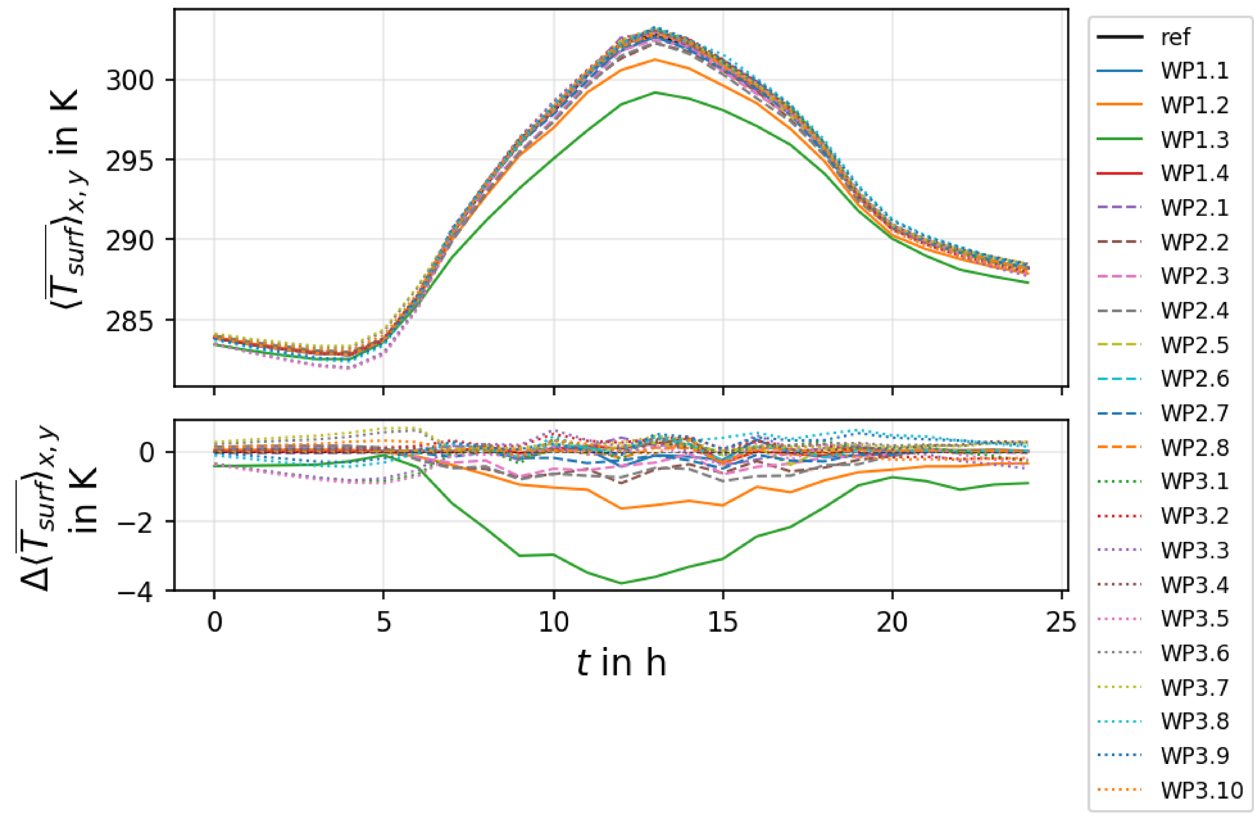

Fig. 3: Time series for hourly and spatial averaged surface temperature for the different scenarios and the respective differences to the reference run. The averaging domain includes single houses.

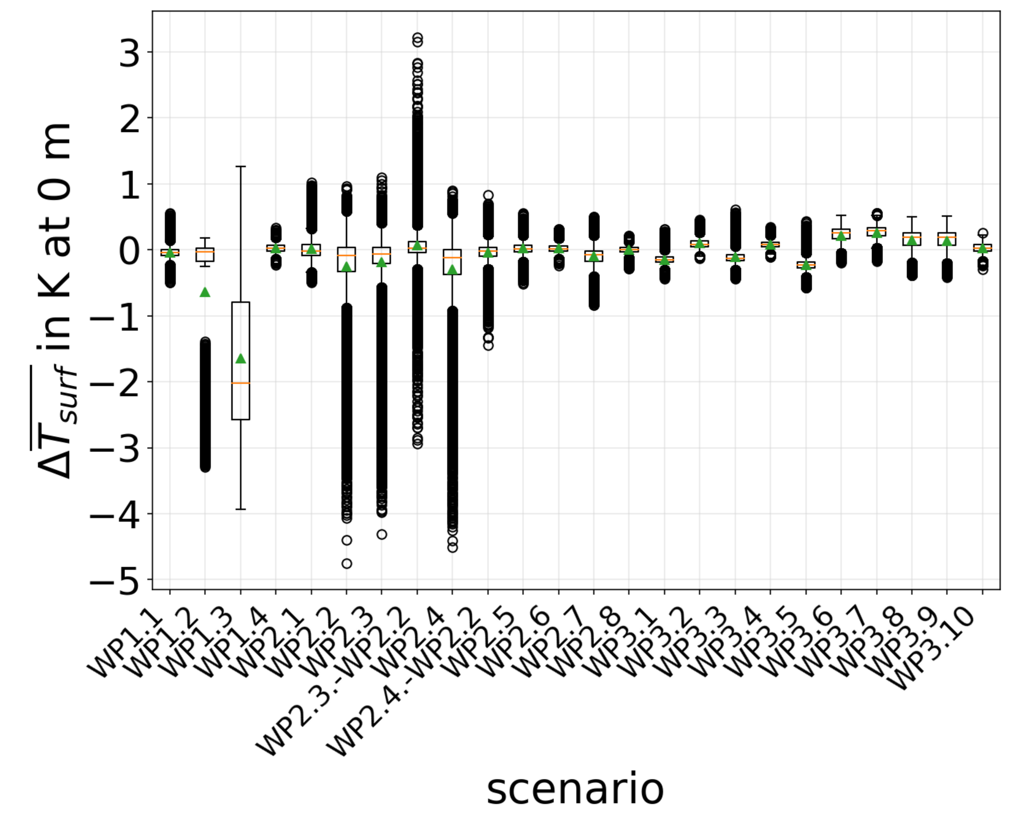

Fig. 4: Bandwidth of local differences between diurnal averaged scenario and reference surface temperature for the domain with single houses.

model result	varied input	averaging domain	deviation from reference result
$\overline{T_{surf}}^{(1h)}_{max}$	pavement type	single houses	-1.5 K
	pavement type	street canyons	-1.5 K
	pavement type	court yard	-0.8 K
	pavement type	open place	-0.8 K
	vegetation type	park	-5.1 K
	vegetation type	single houses	-3.6 K
	vegetation type	street canyons	-2.4 K
	tree type	park	-1.8 K
	tree type	court yard	-0.9 K
	tree type	single houses	-0.5 K
	tree type	street canyons	-0.5 K
	tree shape	park	0.8 K
	crown diameter	park	-0.5 K
	no tree	open place	0.5 K
	wall albedo	park	-0.8 K

Fig. 5: Exceedances of the permissible deviations for the example of the hourly averaged surface temperature maximum.

- WP1: land-surface parameters, WP2: vegetation parameters, WP3: building parameters
- A vegetation type (LAI, albedo!) change results in a surface temperature change (WP1.3)
- A pavement type (albedo!) change results in a local effect on the surface temperature (WP1.2)
- Uncertainties in tree height, crown diameter, tree shape lead to uncertain surface temperature due to shadowing (WP2.2-4)

Lessons learned

The performance of the PALM model system depends on the available input data.
The use of a wrong building type leads to an exceedance of the permissible deviations for surface, indoor and air temperature and wind. The energetic properties should be available and a classification via age and use is not sufficiant due to the lack of information on renovation.
To accurately model surface and 2 m air temperature and UTCI, the tree shape should be known in addition to tree height and crown diameter which are available from LiDAR data. Missing or wrong information on crown height-widht ratio and the drag coefficient result in uncertainties of the wind.
Missing information on the vegetation type result in an exceedance of the permissible deviations for surface temperature and near surface wind. Especially LAI, albedo and rouhness length are required.
Missing informations on the pavement type result in an exceedance of the permissible deviations for surface temperature. Especially the albedo should be known.
For other parameters like e.g. soil parameters, more automatable, area-wide available data can be used.

References

Heldens et al.: Geospatial input data for the PALM model system 6.0: model requirements, data sources, and processing, Geoscientific Model Development, Vol. 13, 5833–5873, 2020.
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Leibniz Universität Hannover

palm

MOSAIK web page:
uc2-mosaik.org

Contact: pfau@meteo.uni-hannover.de