Towards future-oriented urban climate modeling

MOSAIK: Model-based city planning and application in climate change

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In Short

- City planning in the scope of climate change and densification of cities gains importance.
- A new modern, efficient and user-friendly urban climate model will be developed for that purpose.
- The PALM model system is the base for the new urban climate model PALM-4U.
- PALM is a highly efficient code for the simulation of atmospheric and oceanic flows.

With the growing economical importance of cities, the people's "natural" environment for working, accommodation and recreation is an urban settlement. A growing city population is associated with a replacement of nature spots, a concentrated consumption of resources, a high energy demand, and increased air pollution. The interactions between urban areas and the atmosphere have received growing attention in urban climate research in the last decades [1]. The main challenges in the 20th century were the urban heat island problem [2] and urban air quality issues [3], both affecting human health and comfort. It is therefore necessary to include these aspects in sustainable and future-oriented city planning, especially under consideration of local and regional impacts of climate change, leading to increased threats of heat waves and declining air quality [4]. Urban climate models (UCMs) are the tool of choice to estimate effects of the city morphology – such as building density, degree of soil sealing, façade greening, etc. – on air quality and thermal/wind comfort for urban residents.

Within the joint research project MOSAIK – as part of the three-year nation-wide program "Urban Climate Under Change" ($[UC]^2$) funded by the German Federal Ministry of Education and Research (see Fig. 1) – a new modern and user-friendly UCM of unprecedented spatial resolution and computational performance will be developed. The highly parallelized and optimized large-eddy simulation (LES, turbulence-resolving) model PALM [5] will serve as the core of the new model PALM-4U (reads PALM "for you" and "for Urban applications"). PALM-4U shall be applicable on massively-parallel computers as well as on city planners' local PCs and workstations. Features that will be added to the PALM core in order to make PALM-4U a full UCM are:

- Reynolds-averaged-Navier-Stokes (RANS) type turbulence parameterizations for fine and coarse spatial resolution;
- grid nesting to allow forcing by larger-scale models, and self-nesting to enable a magnifying-lens function that allows planners with limited computer resources to perform high-resolution studies for specific areas of interest, e.g. small city quarters, embedded into a coarse-resolution larger city domain (see Fig. 2);
- an energy balance solver for all relevant urban surface types;
- an indoor climate and energy demand model for buildings;
- an urban chemistry model;
- a multi-agent system (MAS) for studies of environmental effects on large groups of people.

With its LES core, PALM-4U is the first UCM with LES mode, allowing for a direct quantification of turbulence-induced fluctuations (e.g. peak concentrations or wind gusts). PALM-4U will be able to provide maps of urban climate and bio-climate standard products including physiological equivalent temperature (PET) and universal thermal climate index (UTCI), but in addition the MAS will also help to identify areas for humans with high stress potential based on the individual characteristics of the agent, such as the walking path and speed, age, clothing, etc.. These hotspots cannot be determined from standard maps, because they do not take into account peoples' behavior.

The new model requires local surface information with very high resolution of building topography, vegetation, soil moisture etc., which can be derived from

Figure 1: *Logos of the MOSAIK project and the German Federal Ministry of Education and Research, the funding agency of this project.*

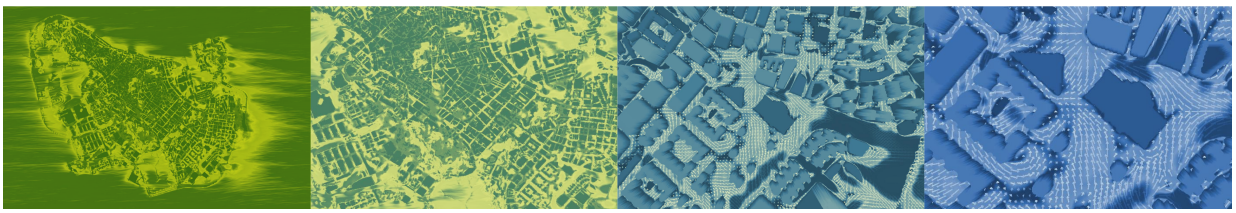

Figure 2: *Illustration of the capabilities of PALM-4U: considering meso-scale to micro-scale atmospheric and land-surface processes (frames from left to right) within one and the same simulation, at affordable costs.*

sources like satellite data, aerial imagery, and existing municipal data. A special focus will be the data input/output formats and data interfaces to PALM-4U in order to support standards of (future) city planning. Data will be stored in an online data management system in a consistent format, including a standard data catalog for typical weather and climate scenarios as well as for high-risk situations such as rainfall extremes and heat waves. An intuitive web-based user interface will allow to define input data and model setups, to carry out the simulations, and to analyze and assess model output data.

WWW

http://uc2-program.org/

More Information

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[4] IPCC WGII, *Fourth Assessment Report*, 23 pp. (2007). http://www.ipcc.ch/SPM13apr07.pdf

[5] B. Maronga, M. Gryschka, R. Heinze, et al., *Geosci. Model Dev.* **8**, 2515-2551 (2015). doi: 10.5194/gmd-8-2515-2015

Funding

MOSAIK is funded by the German Federal Ministry of Education and Research (BMBF) under grant 01LP1601A within the framework of Research for Sustainable Development (FONA; www.fona.de).