Evaluation of a novel city climate model

Evaluation of PALM-4U for big German cities against data from intensive observation periods

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In Short

- Extensive evaluation of a novel city climate model
- Comparison is based on data from very big measurement campaigns
- Target cities for evaluation are Berlin and Stuttgart

With the growing economical importance of cities, the peopleâs ânaturalâ 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. Urban climate models (UCMs) are the tool of choice to estimate effects of the city morphology (such as building density, degree of soil sealing, facade 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, a new modern and user-friendly UCM of unprecedented spatial resolution and computational performance has been developed. The highly parallelized and optimized large-eddy simulation (LES, turbulence-resolving) model PALM [4] served as the core of the new model PALM-4U (reads PALM *for you* and *for Urban applications*). PALM-4U is applicable on massively-parallel computers as well as on city plannersâ local PCs and workstations. Features that have been 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;
- an energy balance solver for all relevant urban surface types;
- an indoor climate and energy demand model for buildings;
- a full air 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 these 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 sources like satellite data, aerial imagery, and existing municipal data.

The main PALM-4U components as described above have been successfully developed by the end of 2019 [5] (see also former HLRN projekt **nik00060**). With the second phase of the $[UC]^2$ project (from September 2019 to August 2022) the BMBF is pursuing the goal of further developing PALM-4U into a product that meets the needs of municipalities and other practise users. At the same time, the model shall also be used for scientific research, and shall therefore be further developed and evaluated accordingly. One of the main goals is a further extensive evaluation of the model based on measurement campaigns conducted in the first phase within the cities of Berlin and Stuttgart. In total, four large simulations are planned for four different intensive observation periods, where different measurement strategies and systems were applied, including stationary tower measurements but also trajectory measurements with complicated pathways (see Figure 1). Comparisons will be performed with respect to various atmospheric and chemical properties (see e.g. Figure 2).

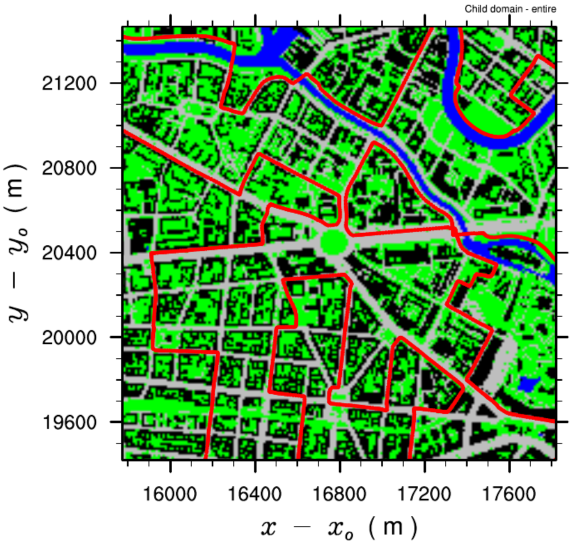

Figure 1: *Child domain for the Berlin winter IOP simulation. The domain is centred around Ernst-Reuter-Platz, Berlin. Black, blue, grey and green areas indicate building, water, pavement and natural surfaces, respectively. The red line indicates the pathway of a mobile measurement during the IOP.*

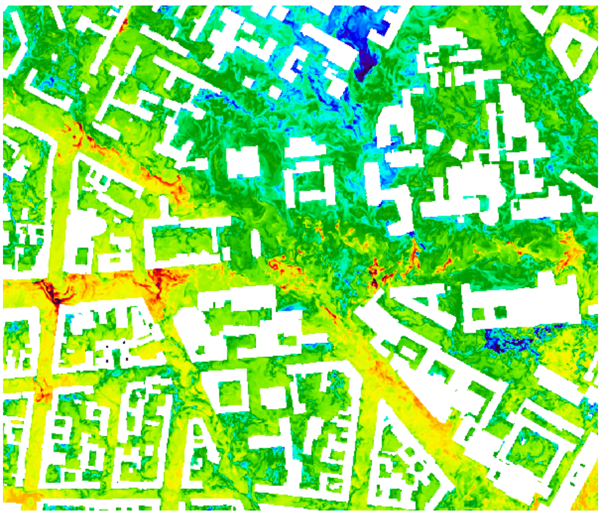

Figure 2: *Simulated PM10 concentration arount the Ernst-Reuter-Platz in Berlin for a winter observation period.*

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http://uc2-program.org/

More Information

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

[5] Maronga, B., Banzhaf, S., Burmeister, C., et al. *Geosci. Model Dev.* **13**, 1335–1372 (2020). doi:10.5194/gmd-13-1335-2020

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