3D Radiation in urban climate models

3D Radiation and coarse-grid simulation techniques in building resolving urban climate models

***M. Salim, S. Schubert**, Geography department, Humboldt-Universität zu Berlin*

In Short

- Implementing 3D radiation scheme into the PALM model system
- Support the immersive boundary condition for radiation interactions
- Incorporating precipitation parametrization in DCEP-PALM model

Three-dimensional (3D) radiation effects in urban environments are parameterized in the model system PALM 6.0 [1] for urban applications (PALM-4U) using a radiative urban canopy model (URTM) [2], which is coupled to the radiation model, e.g. the RRTMG [3]. This model considers the interactions of longwave and shortwave radiation between the urban elements (surfaces, buildings, urban vegetation, etc.) based on the so-called view factors approach, using ray tracing methods. The model can be used in complex urban geometries for different spacial scales starting from a street canyon to a city, Fig. 1.

While this coupled radiation model is a surface-to-surface base, some 3D radiation related processes are not well captured, e.g. the longwave divergence within the urban canopy. Within the project MOSAIK-2 [4], we will develop an alternative 3D radiation scheme to realistically describe the cooling of air in a city during nighttime. To this end, we will couple the 3D radiative transfer model TenStream [5] to PALM-4U as an alternative to the RRTMG-URTM coupled system. Additionally, this scheme considers the interactions with atmospheric constituents in the urban canopy layer and above, such as water vapour, fog, and clouds.

This scheme is expected to require a considerable amount of computer resources since we will solve the 3D system of the radiation interactions rather than the current surface-to-surface view factor interaction.

PALM-4U explicitly resolves the buildings within the 3-D model domain by a blocking approach, in which the wind velocity components vanish at the building boundaries. All buildings are treated to fit the grid so titled surfaces are approximated to the grid structure. During the project MOSAIK-2, the concept of the mask method [6] will be employed in PALM-4U to enhance the buildings representations based on the immersed boundary method [7]. This will allow for flow simulation of complex geometries that do not conform on Cartesian grids. We will also update the URTM to support the immersive boundary conditions to allow for the tilted urban surfaces in order to better map the realistic buildings and orography in the urban domains. This involves the modification of the ray-tracing and the calculation of the view factors taking the real surface orientations into account.

The Double Canyon Effect Parameterization scheme (DCEP) [8] was implemented in PALM-4U in the first phase of MOSAIK project. DCEP is a multi-layer city parameterization scheme for non-building resolution simulations. Here we enhanced the scheme to consider the effect of precipitation on urban surfaces, in particular the surface cooling by runoff, which is not considered usually by urban parameterization schemes. DCEP as implemented in PALM-4U will be updated and optimized accordingly. The updated PALM-4U in RANS mode with DCEP will be evaluated for Berlin (Germany) with measurements.

WWW

https://www.geographie.hu-berlin.de/en/Members-en/dr-sebastian-schubert

More Information

[1] B. Maronga et. al, *Geosci. Model Dev.* **13**, 1335-1372 (2020). doi:10.5194/gmd-13-1335-2020

[2] J. Resler et. al, *Geosci. Model Dev.* **10**, 3635-3659 (2017). doi:10.5194/gmd-10-3635-2017

[3] S. Clough et. al, *J. Quantitative Spectroscopy and Radiative Transfer* **91**, 233-244 (2007).

[4] MOSAIK project https://palm.muk.uni-hannover.de/mosaik

[5] F. Jakub, and B. Mayer, *Geosci. Model Dev.* **4**, 1413-1422 (2016). doi:10.5194/gmd-9-1413-2016

[6] M. Briscolini, and P. Santangelo, *J. Comput. Phys.* **4**, 1413-1422 (2016). doi:10.1016/0021-9991(89)90181-2

[7] R. Mittal,and G. Iaccarino, *Annu. Rev. Fluid Mech.* **37**, 239-61 (2005). doi:10.1016/0021-9991(89)90181-2

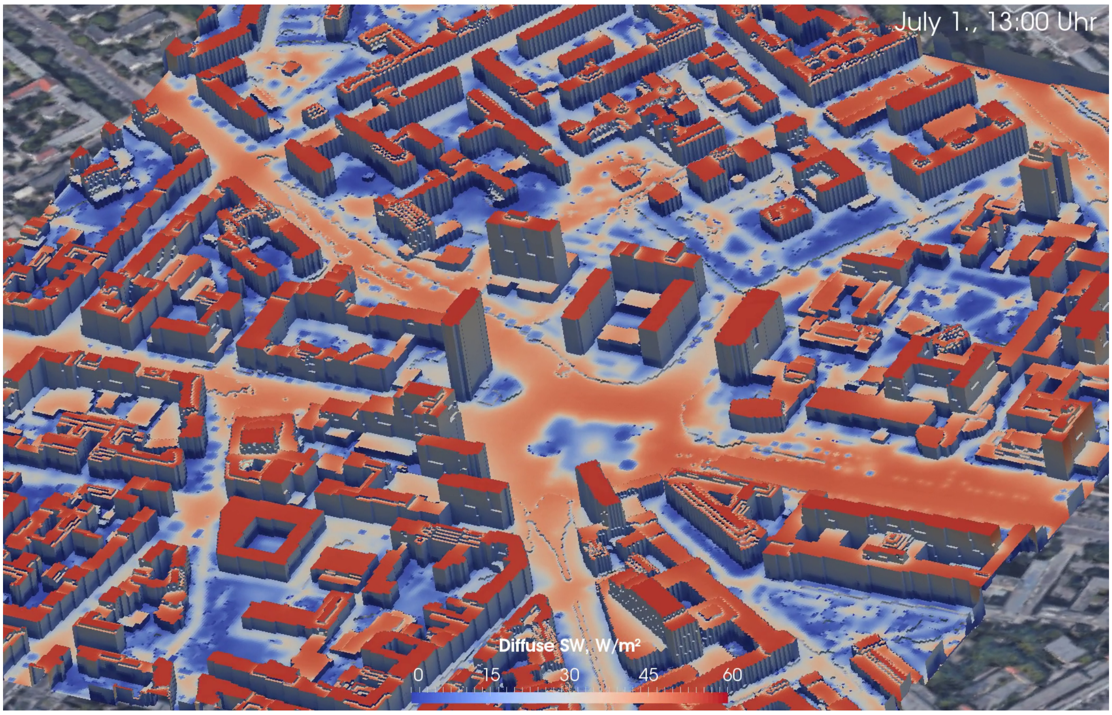

Figure 1: *Example of radiation calculations using URTM in the model PALM-4U: Distribution of incident diffuse short-wave radiation from the sky at Ernst-Reuter-Platz at 13:00 on 1. July (local time) under clear-sky conditions*

[8] S. Schubert, S. Grossman-Clarke and A. Martilli, *Boundary-Layer Meteorology* **145.3**, 439-468 (2012). doi:10.1007/s10546-012-9728-3

Funding

BMBF