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Simulation of Critical Urban Climate Load Situations in Augsburg, Southern Germany, using PALM-4U

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Introduction

As part of the 2nd phase of the research programme "Urban Climate Under Change [UC]^2 (e.g. Scherer et al. 2019) the research project "Strategies for Reduction of Critical Urban Climate Load Situations in Augsburg" aims at the application of the LES model PALM-4U (Parallelized Large-eddy Simulation Model for Urban Applications) (e.g. Maronga et al. 2020) to the medium-sized city of Augsburg and its surroundings. It focuses on the analysis of situations with adverse thermal conditions and poor air quality.

Objectives

1. Model evaluation and application to the city of Augsburg
2. Investigation of factors and mechanisms influencing the spatio-temporal evolution of situations with critical thermal load and particulate matter (PM) concentrations
3. Simulation, development and evaluation of short- and long-term methods for the minimization of these critical situations
4. Investigation of possible side-effects of these measures

Study region

- Located in Bavaria, Southern Germany (48.37°N; 10.90°E), 485m a.s.l.
- Climatic conditions: warm temperate, humid throughout the year
- City structure to some extent entangled with surroundings of the city: forested area expanding sector-like into the city (Fig. 1)
- Observed mean urban heat island intensities of up to 5°C in summer for nocturnal situations with clear and calm weather (Beck et al. 2018)

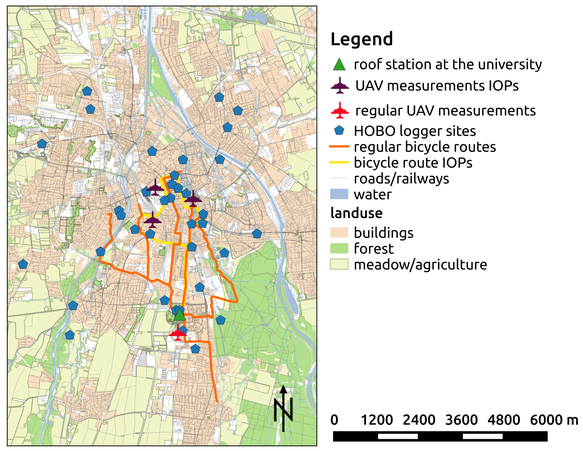

Figure 1: Study area with overview of measurements available for model evaluation

Materials and methods

- Meteorological and PM data for model evaluation (Fig. 1)
  - Network of stationary measurement sites (HOBO logger)
  - Regular mobile ground based measurements (bicycle)
  - Regular measurement flights with unmanned aerial vehicles (UAV)
  - Stationary measurements at the University
  - German Weather Service (DWD) station in the rural surroundings
  - Intensive measurement campaigns (IOP) in the city
- Static PALM-4U input data
  - Gridded digital elevation model with horizontal resolution of 1m
  - Building height information
  - land cover (Open Street Map): vegetation, water, sealed area

Pre-study: heat wave in July 2019

- Simulation of 48 h, site: part of the university campus
- Domain: 400 x 400 m, resolution: 5 m, height: 600 grid cells
- Modules: radiation (RRTMG), land surface, urban surface
- Very idealized settings, e.g. initialization with constant profiles of wind and potential temperature (surface values taken from DWD station)
- 4th day in a row with maximum air temperatures exceeding 30°C

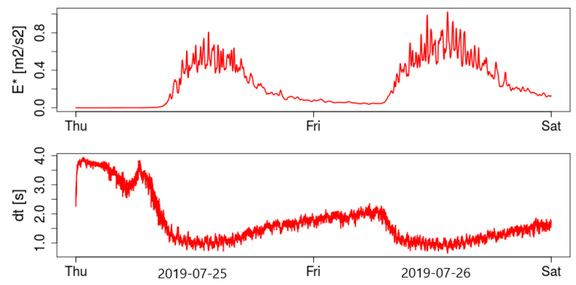

Figure 2: Time series of resolved-scale turbulence kinetic energy of the flow (E*, above, 3D domain average), and the time step width (dt, below)

- During day, E* reaches considerable magnitudes, indicating that the simulation resolves most of the turbulence and therefore can be indeed called a large eddy simulation (Fig. 2)
- At night, E* is near 0, thus, in order to resolve the nocturally reduced turbulence and to meet the criteria of a large eddy simulation a higher spatial resolution would be necessary.
- After the first night, dt exhibits a distinct reduction, indicating that the spin-up time of 30 h was not sufficient
- Consequently, only the 2nd half of the run (July 26th, 2019) is suitable for further analysis

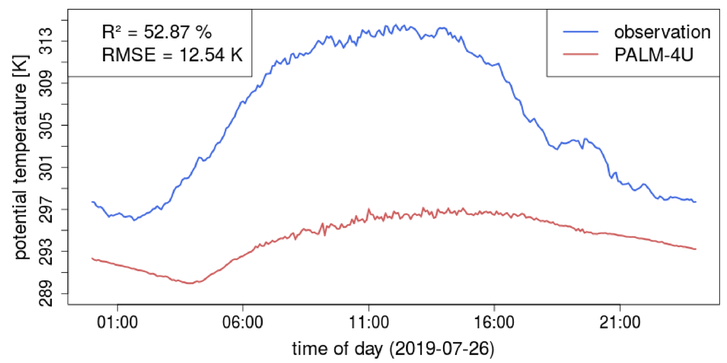

Figure 3: Comparison of T_{pot} at the university measurement station with model results

- Exemplary comparison of this first model run with observations (Fig. 3) shows general agreement of the daily cycle of potential temperature (T_{pot}) with an explained variance (R^2) of 52.87 %
- Clear underestimation of the absolute values throughout the day due to the very idealized setup with a high root mean square error (RMSE)
- Such results from idealized runs can serve as benchmark for the evaluation of more realistic model setups (see below)

Next steps towards a more realistic setup

- Improvement of static input: inclusion of 3D building model, differentiation of soiltype, inclusion of further data (e.g. street type)
- Pre-processing of COSMO-D2 model data (from DWD) with INIFOR (Mesoscale Interface for Initializing and Forcing PALM-4U) and inclusion as dynamic mesoscale meteorological forcing
- Simulation of a larger domain, including a nested domain
- Inclusion of further PALM-4U modules, e.g. chemistry, plant canopy

References

[1] C. Beck et al., "Air temperature characteristics of Local Climate Zones in the Augsburg urban area (Bavaria, Southern Germany) under varying synoptic conditions", *Urb. Clim.* 25, 2018.

[2] B. Maronga et al., "Overview of the PALM model system 6.0", *Geosci. Model Dev.* 13, 2020.

[3] D. Scherer et al., "Urban Climate Under Change [UC]^2 A National Research Programme for Developing a Building-Resolving Atmospheric Model for Entire City Regions", *Meteorol. Z.* 28 (2), 2019.

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