[UC]^2 Urban Climate Under Change – 3DO+M

Worldwide, more than half of the world's population is living in urban areas, estimated by the United Nations (2016). In Germany, already 75 % of all citizens were living in cities in 2014, which is expected to increase to 83 % by 2050 (Schön and Müller, 2016). This illustrates the importance of profound knowledge about the influencing environmental factors on human well-being and air quality in urban areas under a changing climate for a successful climate adaption. Large cities and their surrounding areas are in addition very sensitive to severe weather conditions like storms, weak wind situations, heat and cold waves, heavy rainfall and combinations of those due to their high building density, sealed surfaces and few natural areas (Smith et al., 2014). Therefore, an in-depth understanding of the relevant processes and new modelling tools are highly relevant for the development of new city quarters and the transformation of existing cities towards sustainable and climate-adapted places according to the United Nations SDG No. 11 ("Make cities inclusive, safe, resilient and sustainable', United Nations, 2015).

The Parallelized Large-Eddy Simulation Model (PALM-4U, Maronga et al., 2019) model was developed within the first phase of the national "Urban Climate Under Change" [UC]^2 project, funded by the Federal Ministry of Education and Research (BMBF). This novel Large Eddy Simulation (LES) model provides city planners, municipalities, researchers and related users an excellent tool to investigate the environmental conditions of urban areas as well as to plan new places. Nevertheless, an in-depth evaluation of the PALM-4U model, crucial to ensure physical consistency as well as to advance the model itself, is so far still missing.

The increased computational power and numerical advances of recent years allow nowadays for large area LES runs with realistic forcing data in the application field and research. The ICON LES simulations (Dipanker et al., 2015) are a breakthrough in the field of cloud research, whereas PALM-4U is one of the leading models for the simulation of urban areas. Evaluation concepts for idealized LES simulations using wind tunnel data are available (Schatzmann und Leitl, 2012) and widely used (Hertwig et al. 2017a,b, Tolias et al., 2018). In contrast, the evaluation of realistic LES in cities using field measurements is a novel topic in research and could benefit from concepts of the cloud research community (Heinze et al., 2017).

Daily 24-hour long PALM-4U simulations are planned for two domains in Hamburg with a domain size of 1000 x 1000 x 1000 m and a spatial resolution of 1 m to gather long-term statistics as well as to perform sensitivity experiments to advance the model. The first domain is planned around the supersite of the Hamburg Wettermast at the outskirts of Hamburg and the second domain around the 21-level high Geomatikum building in the city-center, which will especially be equipped with vertical flux measurements at the frontage.

The planned PALM-4U LES simulation will address the following three scientific questions for an overarching evaluation of the model and further model development:

1.) How accurate can PALM-4U simulate the urban wind field and the related transport phenomena, especially regarding severe conditions (wind gusts, strong and weak wind situations)?

2.) What's the impact of the model setup and boundary conditions (size of model area, meteorological forcing data, inflow and outflow conditions) on the simulation results?

3.) How accurate are the momentum- and energy exchanges represented within the urban surface layer, especially at tilted walls and how can these approaches be advanced?

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