Project: **1141**

Project title: **[UC]2 Urban Climate Under Change - 3DO+M**

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Report period: **2020-11-01 to 2021-08-31**

Global climate change has a high impact on the local urban climate. For example, heat waves or flash floods are often amplified within urban areas due to the high building density and sealed surfaces. Additionally, already more than 55 % of all humans live in metropolitan regions and large cities grow worldwide. For a successful climate adaption and design of worth living places, a profound knowledge about urban climate is essential. Consequently, advanced tools and technologies need to be developed to design sustainable and climate adapted cities according to the SDG No. 11 ("Make cities inclusive, safe, resilient, and sustainable, United Nations, 2015).

Thanks to the increased computational power, today's urban climate models are no longer restricted to idealised setups and can simulate realistic setups for large urban domains. The novel PALM-4U model (Maronga et al., 2019) allows for Large Eddy simulations at the urban scale with realistic forcing data. However, physical consistency and knowledge about the expected accuracy of the model are fundamental prerequisites for the physical meaningful application. For these reasons, a novel four-fold evaluation concept consisting of observations, wind-tunnel experiments and corresponding real and idealised PALM-4U simulations has been developed and applied. The requested computational resources have been and will be used for the PALM-4U evaluation. The focus is on the realistic forcing of the model and near-wall turbulence representation, to advance our knowledge and the model itself.

Two PALM-4U domains, the first centred around the Wettermast Hamburg supersite in the outskirts of Hamburg and the second around the inner-city location of the Geomatikum building are used for the evaluation of the realistic simulations. Each simulation is forced with realistic analyses of the COSMO-D2 weather prediction model. The resolution is 10 m in all directions and the size of the domains is 6400 x 6400 x 2400 m, which should be sufficient for an inner-domain development of local turbulence. The challenge of a realistic incoming solar radiation is solved by applying real measurement data and the static and dynamic input data is improved. In addition, an idealised PALM-4U setup with varying roughness lengths has been developed. This is used to analyse the turbulence properties close to walls and test fundamental assumptions of currently applied turbulence parameterisations and boundary conditions. Consistent boundary layer properties of the wind tunnel reference experiments are configured and the PALM-4U output is compared with it. The compiler and runtime options of all PALM-4U setups have been further optimised.

Already more than 60 days of July and August 2020 have been simulated for the Wettermast domain for the summer period. Moreover, various idealised PALM-4U simulations have been successfully accomplished and compared with wind tunnel reference data. Therefore, more than 150.000 node hours and 93 % of the granted nodes hours are already consumed by end of August and valuable results generated by this.

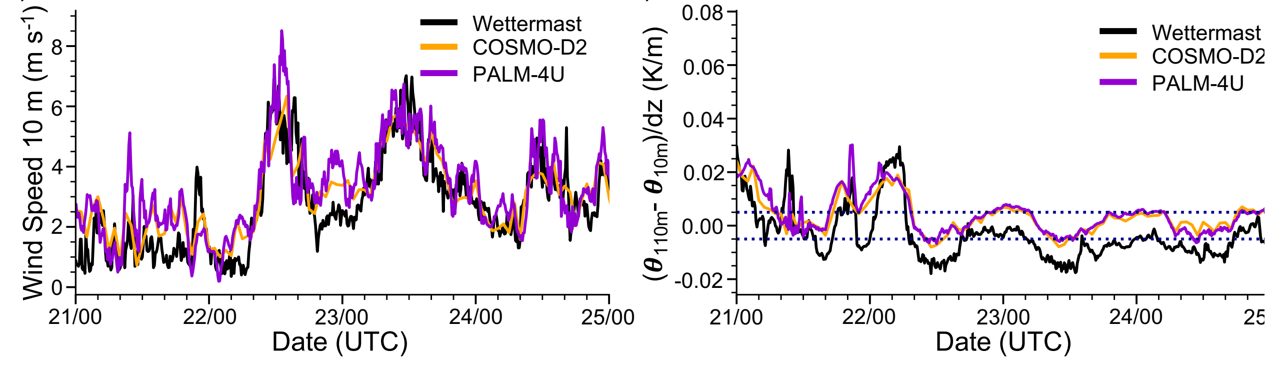

Figure 1: 10-m wind speed (a) and potential temperature gradient between 110 m and 10 m (b) at the location of the Wettermast Hamburg for 21-25 August 2020 for Wettermast (black), the forcing COSMO-D2 (orange) and realistic PALM-4U simulation (purple).

The mesoscale 10-minute and small-scale turbulent quantities are evaluated for the realistically forced PALM-4U simulations by the Wettermast Hamburg observations up to 280 m. The 10-m wind speed and difference of the potential temperature between 110 m and 10 m, representing the atmospheric stability, is exemplarily illustrated in Fig. 1 for the period between 21-25 August 2020. The PALM-4U simulations almost only reproduce the 10-m wind speed of the forcing COSMO-D2 model and add some additional variability. Similar, the potential temperature gradient of PALM-4U follows the COSMO-D2 output and deviates from the measurements. Both models underestimate the diurnal amplitude and are most of the time too stable. There is so far no added value identified by the higher resolution of 10 m of PALM-4U compared to the 2.8 km of COSMO-D2, which is important to be considered at the application of the model. Most probably the PALM-4U domain is too small for an inner-domain development of mesoscale quantities. A PALM-4U simulation for a larger region and coarser resolution is planned as a case study to analyse if the mesoscale quantities would benefit from the explicit simulation of the city.

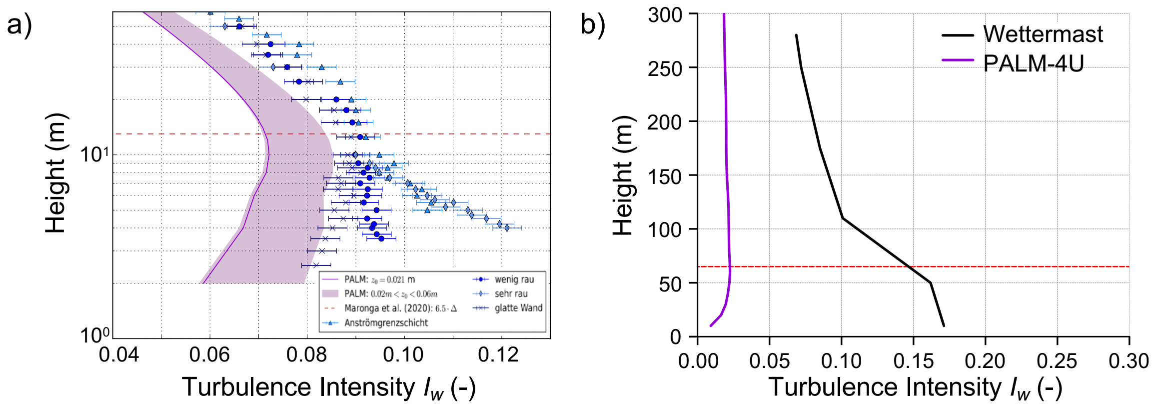

Figure 2: Mean turbulence intensity of vertical wind component *w* for idealised PALM-4U (a) with different roughness lengths (purple), wind tunnel reference data (blue dots) and realistic PALM-4U simulation (b, purple) with 20 Hz Wettermast Hamburg measurements (black line).

The added value of the PALM-4U simulations is especially expected for small scale turbulent quantities because of the explicit simulation of large parts of the turbulence spectrum. Among others, the turbulence intensities of all three wind components are analysed in detail for the realistic and idealised PALM-4U simulations. The idealised simulations are compared with wind tunnel reference data (Fig. 2a) and the realistic simulation of the 22/08/2020 with Wettermast observations up to 280 m (Fig. 2b). The turbulence intensity of the wall-normal / vertical wind component *w* is substantially underestimated for the idealised and realistic PALM-4U simulations, while other flow measures (mean wind and turbulent fluctuations parallel to surfaces) meet the measurements. The underestimation is consistent for both independent PALM-4U setups and highlights the advantage of the four-fold evaluation approach to derive robust evaluation results. First attempts of simulations with 1 m resolution indicate for improvements and a still insufficient resolution of the 10 m.

Consequently, further PALM-4U simulations with the very computationally intensive 1 m resolution are planned as well as the remaining seasons and Geomatikum domain. The impact of for example balconies on the turbulence will be investigated in the wind tunnel, real-world measurements and by corresponding realistic and idealised PALM-4U simulations for which the computational resources for the next period are requested.

References:

Maronga, B., G. Groß, S. Raasch, S. Banzhaf, R. Forkel, W. Heldens, F. Kanani-Sühring, A. Matzarakis, M. Mauder, D. Pavlik, J. Pfafferott, S. Schubert, G. Seckmeyer, H. Sieker, K. Trusilova, 2019: Development of a new urban climate model based on the model PALM - Project overview, planned work, and first achievements. Meteorologische Zeitschrift (in press). DOI: 10.1127/metz/2019/0909.

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