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Geoscientific Model Development Discussions

Interactive comment on "Validation of the Dynamic Core of the PALM Model System 6.0 in Urban Environments: LES andWind-tunnel Experiments" *by* Tobias Gronemeier et al.

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Answers to the general comments

We would like to thank the anonymous referee for his/her comments on our manuscript. It was commented that changes between the old and the new PALM version were just mentioned as "drastic" but not further described. The changes between PALM4.0 and PALM6.0 (version 5 does not exist) are manifold. A detailed description to the current state and the changes between both versions are given by Maronga et al. (2020). However, we agree that the reader should at least get an overview on the changes re-

garding the dynamic core of the model. The most significant changes within the code are more related to code structure and less to the physics. With the introduction of the land-surface and building surface models, the internal treatment of surfaces changed significantly. Several one-dimensional Fortran data structures were introduced to handle surface treatment. This also includes treatment of surfaces were neither the land-surface model nor the building-surface model is used as it is the case in our study. Also, further modularization of the code, i.e. reordering code parts like boundary treatment or turbulence closure into separate modules changed the overall code structure of the PALM model also affecting the model core. These changes should ideally have no effect on the simulation results but in reality might have small changes due to changes in computational order and rounding errors or even have changes due to fixed bugs which might have been not even noticed. Further changes which might have an effect on the results are the optimization of the multigrid solver which is also described by Maronga et al. (2020) and the calculation of the constant-flux layer which uses the Monin-Obukhov similarity theory (MOST) which was also used in previous versions of PALM but was also completely reworked for version 6.0. New code features, which were introduced in version 6.0 and which were used within this study, include the y-shift method and the virtual measurements module both of which we mentioned within our manuscript. We are going to modify our manuscript in order to briefly mention the changes between the old and the new PALM version.

The second general commend made was regarding the inflow condition. It is mentioned that although the approaching flow shows clear differences between PALM and the wind-tunnel data, profiles are said to match well for stations 2 and 3 which are positioned close to the windward edge of the analysis area. Differences between the approaching flow are due to the different setup of the upwind area between both experiments. While roughness elements are present within the wind-tunnel experiment, there was only a flat surface present within the PALM simulation as discussed in Sect. 2.2 in the manuscript. A more detailed analysis of the development of the wind profile with distance to the upwind area is only possible for the PALM simulation as there are no further measurements available from the wind-tunnel experiment. We analyzed the development of the profile of the u component at varying distances to the upwind area at y=1400m which is close to station 3. Profiles are depicted within the annotated figure. The building area starts at x=3500m where the surface was raised from z=-5m (lowest height within the simulation) to z=0m which is in accordance to the wind-tunnel experiment. Profiles are shown until x=3800m which corresponds to the x coordinate of station 3. We assume that the PALM profiles match to the wind-tunnel profiles at x=3800m as measurements show at station 3. The depicted profiles do not change significantly from x=3600m onward. Hence, we conclude that the wind flow between both experiments should also not vary anymore starting from this point further downwind. The differences of the approaching flow are therefore limited to the first about 100m of the building area (i.e. from x=3500m to x=3600m) at least close to the ground surface. Figure 2 also shows that the differences between both experiments are only small within the lower 100m and become larger at levels above 100m height. Further analysis of the wind field at heights above 100m were, however, not possible due to the lack of reference data at these heights. It is however likely that differences between PALM and wind-tunnel results would have been larger closer to the upwind area than to the downwind area.

Answers to the specific comments

- L7: Indeed we did not present any proof for our recommendations in how to reduce differences between measurements and simulation results. However, we discuss how differences might be reduced. We therefore rephrase the sentence: "In the end, we discuss how these differences might be reduced using already implemented features of PALM."
- L27: See answer to general comments.

- L71: Wind tunnel experiments were carried out long before corresponding numerical simulations took place. The choice of measurement locations in the wind tunnel was based on considerations regarding area coverage, location of observation stations as well as the investigated effect of building structure on near ground ventilation and pedestrian wind comfort. They were not specifically chosen with respect to average values of measurements covering the entire area of interest because this would have been too time consuming regarding the laboratory experiments. This approach was decided to be appropriate because the basic flow dynamics core in PALM had been evaluated successfully before already.
- L76: Crucial differences between PALM version 4.0 and version 6.0 are now mentioned within Sect. 1 of the updated manuscript. See also our answer to the general comments.
- L96: We agree that the wind speed of 1.54m/s is a rather weak wind speed which originated from a former misinterpretation of wind-tunnel results by the simulation team of our group. However, we think that our results still lie within an area of high Reynolds numbers and are therefore mostly independent from the actual wind speed value.
- L158, L167: The reference height was defined by qualified laboratory experiments to be representative for the measured canopy flow and is expected to be well within the height range for which a scaled neutrally stratified atmospheric boundary layer wind flow could be modeled most accurately. Despite the fact, that the reference height could have been changed when comparing numerical results with wind tunnel data, we decided not to introduce additional uncertainty in data comparison by translating reference conditions to a different height range based on common assumptions on the vertical structure of the ABL. For a neutrally stratified and fully turbulent near-ground ABL flow, the flow dynamics and

statistics of turbulence perfectly scales with the chosen reference wind speed and non-dimensional flow and turbulence data do not change within the bounds of experimental uncertainty. As a part of quality assurance of experimental data, this behavior is mandatory to be checked and documented before systematic experiments are carried out in a proper boundary layer wind tunnel experiment.

- L170: We tried to not add another layer of uncertainty to the results by interpolating them to different heights. Hence, we compared the non-interpolated values and accepted a small mismatch in measurement heights. Interpolation of results at greater heights might have been possible, however, closer to the ground, the uncertainty introduced by interpolation might have been as high as not interpolating the results at all. Therefore, we decided to not interpolate the results to different heights.

- L240: The local wind speed differs between PALM results and the wind-tunnel measurements at rooftop height at both stations as shown in Figs. 11 and 12. However, at higher levels, wind speeds agree between both experiments. Hence, we concluded that the mismatch is caused by differences within the building layout and surface roughness. This will then also result in a mismatch of local horizontal wind speed. As in both experiments the building heights are exactly the same in the close vicinity of stations 4 and 11, the differences must occur from the brick-like representation resulting in smooth walls being significantly more rough by the introduction of additional corners. Additionally, the mentioned mismatch of z0 between both experiments, where in PALM z0 was of higher value than in the wind-tunnel experiment, also leads to higher surface roughness within the PALM simulation and results in higher turbulence intensity and a shift of the turbulence spectra to higher wave numbers. As the overall wind speed is about similar within both experiments, the local wind speed is then reduced due to the higher roughness which can be observed in Figs. 11 and 12.

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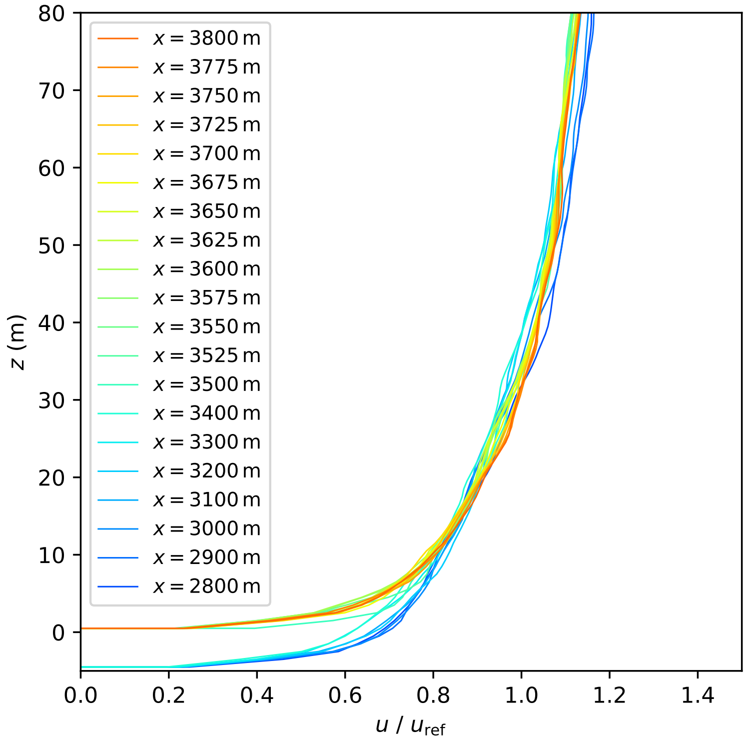

Fig. 1. Time averaged vertical profiles of the normalized u component from the PALM simulation at several x coordinates at y=1400m.