Geosci. Model Dev. Discuss.,
https://doi.org/10.5194/gmd-2020-126-AC2, 2021

Geoscientific Model Development Discussions

Interactive comment on "Sensitivity analysis of the PALM model system 6.0 in the urban environment" *by* Michal Belda et al.

Michal Belda et al.

michal.belda@mff.cuni.cz

Received and published: 14 February 2021

General comments

The sensitivity of the LES model framework PALM-4U to selected surface parameters and to a combination of surface properties representing potential planning scenarios are evaluated. While the study reveals some nice details on the capabilities of such LES modelling of a real urban environment, the study design could be clearly improved. - It is not clear why the scenarios are chosen in this particular way. For example, several planning scenarios appear rather unrealistic. - Further, scenarios discussed in full in the main manuscript should be reduced to only reveal the most important aspects of the modelling capabilities and urban planning assessment. Currently, it is

very difficult for the reader to keep track of all the scenarios being discussed. This may also be related to the rather high number of figures which could be reduced to give a better overview to the reader. - A major drawback of the scenarios aiming to assess model sensitivity to certain input parameters is that no reference measurements are presented to determine model performance. So how do the SA scenarios really differ from the SB scenarios? - Finally, the analysis should really highlight the added value from the LES model setup, i.e. the spatial variability in meteorological indicators. Most of the "average" conclusions drawn (e.g. contrary impact on human thermal comfort and ventilation) can be expected from lower resolution modelling – there is a clear lack of references to e.g. evaluation of urban surface scheme.

We would like to use this opportunity to thank the reviewer for many helpful suggestions. We added more discussion on the issues raised by the reviewer(s) throughout the manuscript and believe that the revised manuscript version is considerably improved and answers all the reviewers' comments. Some text was reformulated to be more comprehensible by the readers, namely, we attempted to make it more clear, why the two scenario types were employed, how they differ and what kind of questions they are designed to answer. We also added more discussion of the "non-average" model response, bearing in mind the need to keep the manuscript as concise as possible, we tried to find a compromise between highlighting the interesting results and not overwhelming the reader with descriptions of every single analysis point.

The present manuscript tries to really focus on the sensitivity analysis, for systematic validation against measurements we refer the readers to the accompanying manuscript under review for the same special issue (https://doi.org/10.5194/gmd-2020-175).

Minor comments

P2, l50: PM10 defines particle up to diameter of 10 μm P3,

corrected

l66: Why are two radiation models listed? What are they doing, respectively?

The Rapid Radiative Transfer Model for Global models (RRTMG, see Clough et al., 2005) is a one-column radiation model which calculates the global downward incoming radiation. The radiative transfer model (RTM, see Krč et al., 2020) takes these global radiation values and calculates explicit interactions of shortwave and longwave radiation with urban surfaces like terrain and buildings (shading, absorption, reflection, emission) and plant canopy (partial shading, absorption, emission). It provides temporally and spatially resolved radiative fluxes for the land and building surface models and plant canopy model for calculation of the surface and ground heat fluxes and plant canopy sensible and latent heat fluxes. The RTM also calculates detailed spatial and temporal structure of the mean radiant temperature (MRT) and provides it to the biometeorological module. We updated the formulation to better distinguish these two models.

P4, l87: How are the boundary conditions defined for the pollutants? Spatial variations in surface emissions? Horizontal advection and long-range transport?

The boundary conditions for pollutants are set to zero. We decided to study air pollution sensitivities to pure transport without chemistry as this makes these sensitivities easier attributable and thus more useful. As we study the sensitivity (differences of scenarios) and we concentrate only to traqnsport of the pollutant, the boundary conditions do not influence these differences. Note that we use boundary conditions from CAMx in the validation study GMD-2020-175 (currently under review), as well as in practical urbanistic studies. Emission is distributed spatially to particular streets and transport flow lines, crossroads,... according to the traffic census. Horizontal advection is carried by the PALM dynamic and chemistry module. The long-range transport, as much as it is important for weather and air quality forecasts, does not influence the sensitivity (differences) as far as it is considered the same in all scenarios.

P4, l93: Why is there no urban scheme used in WRF? How does this impact the

boundary conditions provided in the nesting (e.g. wind profiles, boundary layer height, . . .)? Are there relevant studies that should be cited here?

This analysis is focusing on the model sensitivity in realistic conditions, not necessarily real conditions. Additionally, for this particular case study, no detailed measurements are available against which the WRF model simulation could be perfected for the particular location. The reason for using this case study is to stay comparable to our previous study (Resler et al., 2017).

Another manuscript, also under revision for this special issue (https://doi.org/10.5194/gmd-2020-175), describes a validation experiment with similar settings. It also discusses the reasoning why no urban parameterization was used. Briefly, in our extensive preliminary testing within the local URBI PRAGENSI project (http://www.urbipragensi.cz - only in Czech), the WRF quite surprisingly performed better without urban parameterization in comparison to background synoptic stations in Prague and mainly in terms of the temperature vertical profiles which are fundamental for providing boundary conditions to PALM (in contrast to surface values).

P4, l108: so albedo and emissivity are independent of material category?

reformulated

P4, l110: define symbols at first occurrence

Added definitions

P4, l150: Give some details on the building database. This a vector dataset? What is the level of detail?

Added reference to Prague OpenData portal (description only available in Czech language) and basic information about the dataset.

P5, l132: replace 'housing' by 'residential' or remove the word.

corrected

P5, l144: what are 'non-impervious' anthropogenic surfaces?

simplified

P6, Figure 1: include reference to Resler et al. (2017),in figure caption as this defines the 'old domain'

Reference added

P6, l151: provide reference for ABL height maximum in summer.

Added references with a more accurate estimate of the ABL height in Europe in summer.

P7, l160: why adding a flat buffer zone? How does this impact the flow? Provide a reference where readers can find more information on this aspect.

With the mesoscale nesting we prescribe boundary value at the lateral and top model boundaries inferred from a mesoscale model, which is WRF in this case. However, since the modelled WRF flow does not necessarily reflect the flow in the LES, adjustment effects occur. These include, for example, an acceleration/deceleration of the flow behind the inflow boundary as well as on the outflow boundary to maintain mass conservation in the model caused e.g. by different effective roughness. The flat buffer zones in this setup aim to allow for undisturbed adjustment to give the model more flexibility. Here, we refer to Kadasch et al. (2020) where these effects are discussed in detail. The exact size of the buffer zones were chosen according to prior numerical experiments as well as experience. Without adding such buffer zones the flow will be accelerated/decelerated even stronger since the mesoscale flow would immediately hit the buildings, which in turn would create strong up- and downwind areas. With adding buffer zones we aim to relax this effect, though we have to say that we do not fully get rid-off it.

P8, l177: where were the meteorological measurements conducted? Within the study area? What height above roof level?

Added station location. It is 4km away from the study area, slightly further away than another professional meteorological station (Praha-Klementinum), on the other hand, it is in an urbanistically similar part of the city.

P8, l180: Maybe more appropriate to present results in local time rather than UTC?

We opt to use UTC for compatibility with other studies. We provide information on local time in the text where appropriate.

P8, l183: add reference for importance of traffic emissions. What fraction of PM10 in the area is from local traffic emissions? What is the role of other sources? What is the role of regional transport and local scale advection?

We extended the emission description paragraph (2.6) with the information on the traffic emissions ratios in comparison with the total emissions. Based on calculations using the regional chemical transport model (not published) the regional background is 50-60

P11, Table 2: some scenarios are rather unrealistic. Maybe provide some reasoning why these were tested? i.e. changing all roads to grass but then not changing vehicle emissions is a scenario that can not be translated to reality.

This less realistic approach was adopted to separate the effects of UHI mitigation techniques that are at the forefront of urban planning now. Changing vehicle emissions too would make it difficult to distinguish the meteorological effects on air quality.

P12, l222: that's the reason why spin-up time is usually excluded from analysis. Please clarify you comment.

The spin-up period itself is not included in the analysis as it does not represent the real simulated conditions (the whole dynamics of the model is parameterized). The spin-up technique is used for bringing the temperature of the ground/wall layers closer to the reality and thus avoid the strong balancing in the first simulation hours which would significantly affect the simulation results. Some influence may still persist in the first hours of the "real" simulation after the spin-up. Given the enormous computational costs, it was not feasible to extend the simulation for another day. However, as the results show, for most of the scenarios, the differences between respective simulations show up mostly after the sunrise, which gives the model enough time. Therefore, we think this approach is correct.

Added some clarification in the text.

P12, l228: please clarify. All indicators at 2m height above ground. What distance from the buildings? Which surface temperature is used as the indicator?

Surface temperature = material skin layer temperature (results of energy balance equation calculation).

The distance from the buildings is given by the respective measurement point (see the map), where point measurements are analyzed. The model itself does not calculate influence only of the one nearest surface but it considers and calculates the impact of all surfaces in the model on conditions at the given evaluation point.

P12, l229: what is meant by 'where necessary'? please explain.

Removed the sentence, the only other variable that was used was the net radiation for discussion of albedo scenarios.

P13, Figure 4: Some odd model results should be discussed. This includes: very high LST in small gaps between buildings. Are these realistic? Where do they come from? Why do they not translate into high MRT? Also, Why are the PM10 concentrations only relevant in the two cross-roads? According to Figure 3 there are also emissions for the roads closer to the domain edges. Also, make sure symbols and variable names are defined and sued consistently. E.g. in the text and figure caption you use 'surface temperature' without defining the term 'LST' that appears in the Figure.

Ad LST) We agree with the reviewer that these striking high land-surface temperatures should be discussed in the text (the issue was alluded to in the model limitations section in the discussion of pollutant concentrations, temperature was added in the revised

version). Indeed, this is a well-known issue for the PALM developers that within narrow structures quite high values of air and surface temperature can occur. This is a numerical artefact and is attributed to the topography formulation in PALM in conjunction with the nature of LES and the numerics. Within such narrow geometries, the flow is not well resolved on the numerical grid and largely affected by numerical dispersion errors, forming stationary numerical oscillations within such geometries. As the turbulent mixing is almost not resolved there, no turbulent eddy can penetrate into these geometries, so that almost no mixing with the air above happens. Geometries that are represented by only one grid point are filtered in the initialization, but larger (though still narrow) geometries remain. We do not observe such high temperatures all the time, only at some times and also not within each narrow geometry.

Here, we also note that this is only an issue for the prognostic variables that are solved on the numeric grid. The MRT, however, is a diagnostic quantity that results from radiation reflections from various horizontal and vertical walls and thus the effect of high surface temperatures at single surface partly cancels out.

Ad PM) Regarding the PM concentrations (formerly PM10, changed to PM2.5 in the new version, see other comments), the original Figure 3 confusingly showed all emissions in the domain and the closest streets. However, the model inputs included only emissions from the two crossing streets (Dělnická and Komunardů). We supplied a new version of Figure 3 with only those emissions actually included in the inputs.

P13, l154: Explain. Why is the importance of window fraction changing throughout the day?

Our hypothesis, supported by the daily cycle (chaotic behaviour during the high sun period of the day and more systematic changes in the late afternoon and through the night) is that the reason for this lies in the different heat storage by the windows and the wall. Simply put: lower window fraction = more walls = more heat storage = higher temperature and vice versa. We extended the discussion in the text accordingly.

P13, l152: rephrase 'opposite behaviour to the air temperature in terms of the sign of the changes with higher absolute values'. Not clear.

Rephrased, an example is shown in the following sentences.

P18, l278: It is actually more interesting to see the spatial variability in impact of different scenarios. While average impact can be expected simply according to simple model physics and are in accordance with low-resolution simulations, the added value of the LES approach are the new insights into the spatial variability. This should be highlighted more clearly. But where are the analysis points marked that are shown e.g. in Figure 11? More detailed discussion could be nice.

All points and averaging areas are shown in the supplement figures S01-S09. We extended the discussion of the "non-average" model response by adding more examples of the spatial variability at the end of this section, in the discussion of the influence on concentrations and also in the Discussion.

P19, Figure9: combine with Figure 10 to reduce the number of figures and make analysis more compact.

Accepted.

P21, l330: Provide some interpretation. What explains the decrease in particle concentrations?

The decrease of concentrations in the Komunardů street (see maps in the supplement) is in fact only concentrated in and in the vicinity of the crossroad, no significant changes are evident further away from the crossroad. The maps of the wind speed can suggest an explanation. The wind over the roofs runs approximately from the east. In the basecase, this causes the air flow is running almost freely through the Delnicka street (west-east oriented street) and it creates quite a nicely pronounced anticlockwise eddy in the Komunardu street (north-south street) which is broken in the area of the crossroad by the east-west stream from Delnicka street. Planting a tree alley only in

the Delnicka street (scenario SB13 and SB14) has two consequences. The first is that the air flow in Delnicka street is slowed down which allows the manifestation of the air buoyancy near the south-facing wall caused by radiative heating of this wall during the day. This causes an increase of the concentrations in the north half of the street and a modest decrease of them in the south parts of the street canyon. The second consequence affects the area of the crossroad. The obstruction in the Delnicka street has the effect that the area of the crossroad behaves as a part of the north-south street canyon which leads to partial creation of the eddy similarly to other parts of the Komunardu street. This increases the transport of the crossroad emission from transportation to the space above the roofs and leads to decrease of the concentrations in the crossroad area. While the statistics for particular streets are done over all their surface including the crossroad area, the average concentration in Komunardu street decreases. This situation also suggests how complex the relations of the quantities in the urban canopy are and how difficult it is to find any generalized rules of them. We added a shorter version of this rather long explanation in the text.

Interactive comment on Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2020-126, 2020.