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EXTENDED ABSTRACT

Application of the Lagrangian particle model in PALM in an urban area for exposure assessment in the vicinity of medical and industrial facilities (Project EXPO-URB, Part 2)

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Abstract
The EXPO-URB research project aims to improve exposure assessment near medical and industrial facilities using long-term atmospheric dispersion simulations. A key focus is the evaluation of the Lagrangian model ARTM in complex urban environments, validated through wind tunnel experiments. Additionally, the PALM model, including its Lagrangian Particle Model (LPM), was tested using reference scenarios and compared with experimental wind tunnel data. The project establishes a comprehensive reference dataset, combining laboratory measurements and dispersion statistics, to validate various microscale models (e.g., ARTM, MISKAM-LASAT, GRAMM/GRAL and MicroSwiftSpray) for future practical applications in urban exposure and risk assessment. In contrast to the modelling of accidental releases, the calculation of the radiation exposure is generally based on the dose and requires sufficient simulation accuracy in the areas where people are present.

Keywords: *Dispersion modelling, PALM Model, Release in Built Environment, Model Intercomparison*

Introduction

Within the project, the practical application of the PALM model was tested. The PALM model for the simulation of urban atmospheric boundary layers has been mainly developed and maintained by the PALM-group at the Institute of Meteorology and Climatology (IMUK) of Leibniz University Hannover, Germany. Currently, the main application of the model is the practical city planning related to urban microclimate and climate change. PALM modelling system provides an increasing number of embedded models. In this study the Lagrangian particle model (LPM) was considered, additionally to the LES calculations. Some model runs, based on the reference scenario in the project were conducted and preliminary results are shown.
The PALM model setup follows the approach of Gronemeier et al. (2021) for comparison of LES model simulations for neutrally stratified urban environment with wind tunnel experiments. Additionally, a Lagrangian module was tested and the results are prepared for comparison with wind tunnel measurements performed within the EXPO-URB project.

Input data: Model geometry data

Building geometry data were provided within the EXPO-URB project in the ESRI shape Format (*.shp). In the reference simulation, the shape file for scenario “Dense” with dense building and flat roofs is used (Figure 1). The shape file contains multi polygons with 802 features.

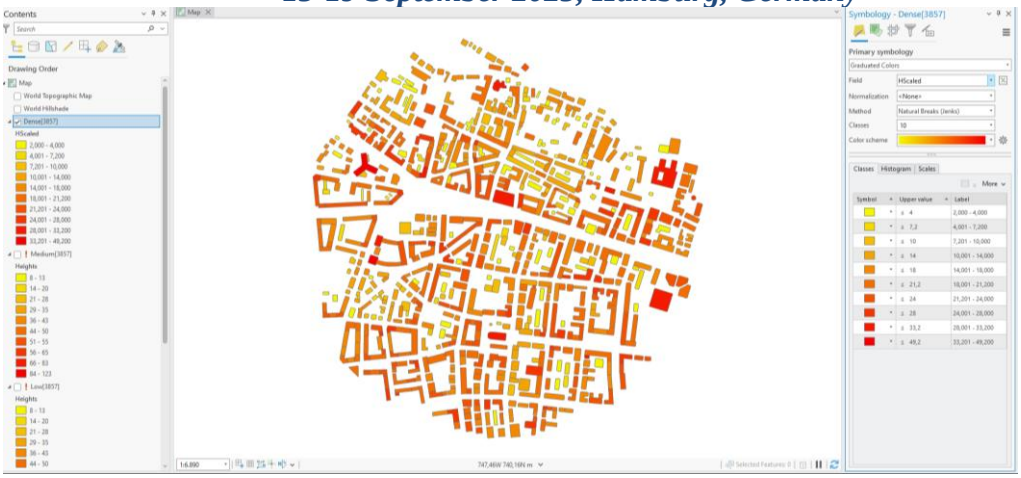

Figure 1. Building footprints and height for the use case with dense buildings and flat roofs visualised in ArcGIS Pro.

Model configuration

Table 1 shows the model configuration parameters as defined in the project EXPO-URB. The parameters such as domain extent, spatial resolution, etc. were adjusted for the PALM model application.

Model parameter	Settings
model version	*PALM v23.04*
model domain	*1440 m x 1440 m x 300 m*
horizontal resolution	*3 m x 3 m*
vertical resolution	*3 m*
height of the vertical layers	*300 m*
number of the grid cells	*480 x 480 x 100*
reference points (centre)	0,0
highest building in the domain	49.2 m above ground
minimal distance between model border and buildings	*10* grid cells
simulated time (hours/days/year)	15 hours
z_o	0.6 m
reference wind	Logarithmic profile
reference wind height	100 m
reference wind speed	10 m/s
stability	neutral

Table 1. Model configuration as specified in the EXPO-URB project. PALM specific parameters are given in cursive.

Source term

The properties of the particle source are defined in the EXPO-URB project (Table 2).

Source parameter	Settings
coordinates	N: 430.4 m E: 2.4 m
height	20 m
diameter of the source	2 m
shape of the source	circle
height of the source above building	2 m above flat roof level
stacks: yes/no	yes
emission rate	2 g/s
exit temperature	20°C
exit velocity	2 m/s

Table 2. Source PALM model configuration used in wind and Lagrangian model application.

Initialization and boundary conditions

The model application uses initial wind as defined in the EXPO-URB project with logarithmic profile that has 10 m/s wind speed at 100 m height from North direction (Figure 2). The lateral boundaries are set to "cyclic" conditions at the East-West boundary and "cyclic" or "dirichlet/radiation" at North-South boundary. The top boundary is set to "dirichlet" conditions. In this application, the default values for creation of disturbances are used. Comparisons of the wind profiles applied in MISKAM und PALM is shown on Figure 2.

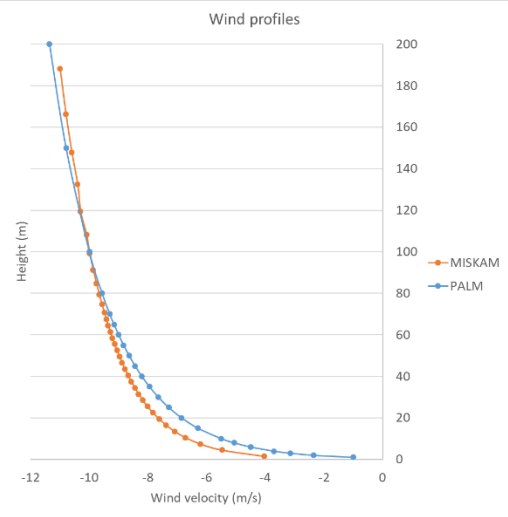

Figure 2. Wind profiles used in PALM and MISKAM model.

Model output

Model output is saved as NetCDF files containing 1D and 2D data. The 2D output includes variables: 3-wind components (u, v, w), measure for turbulence (ti), wind speed (wspeed) and particle concentration (pc). The output is saved on prescribed horizontal and vertical transects. The horizontal transects are chosen as the model vertical levels nearest to the height of wind measurements. This corresponds to:
Height [m]: 2, 5, 12, 15, 20, 25, 30, 40, 50, 60, 80, 100
Model z-level: 1, 2, 4, 6, 7, 9, 11, 14, 17, 21, 27, 34

Particle dispersion

The particle concentration follows the wind field pattern and is the strongest near the emission source (Figure 3). The spread of particles in East-West direction is relatively narrow and accumulation of particles at the bottom layer near buildings can be detected.

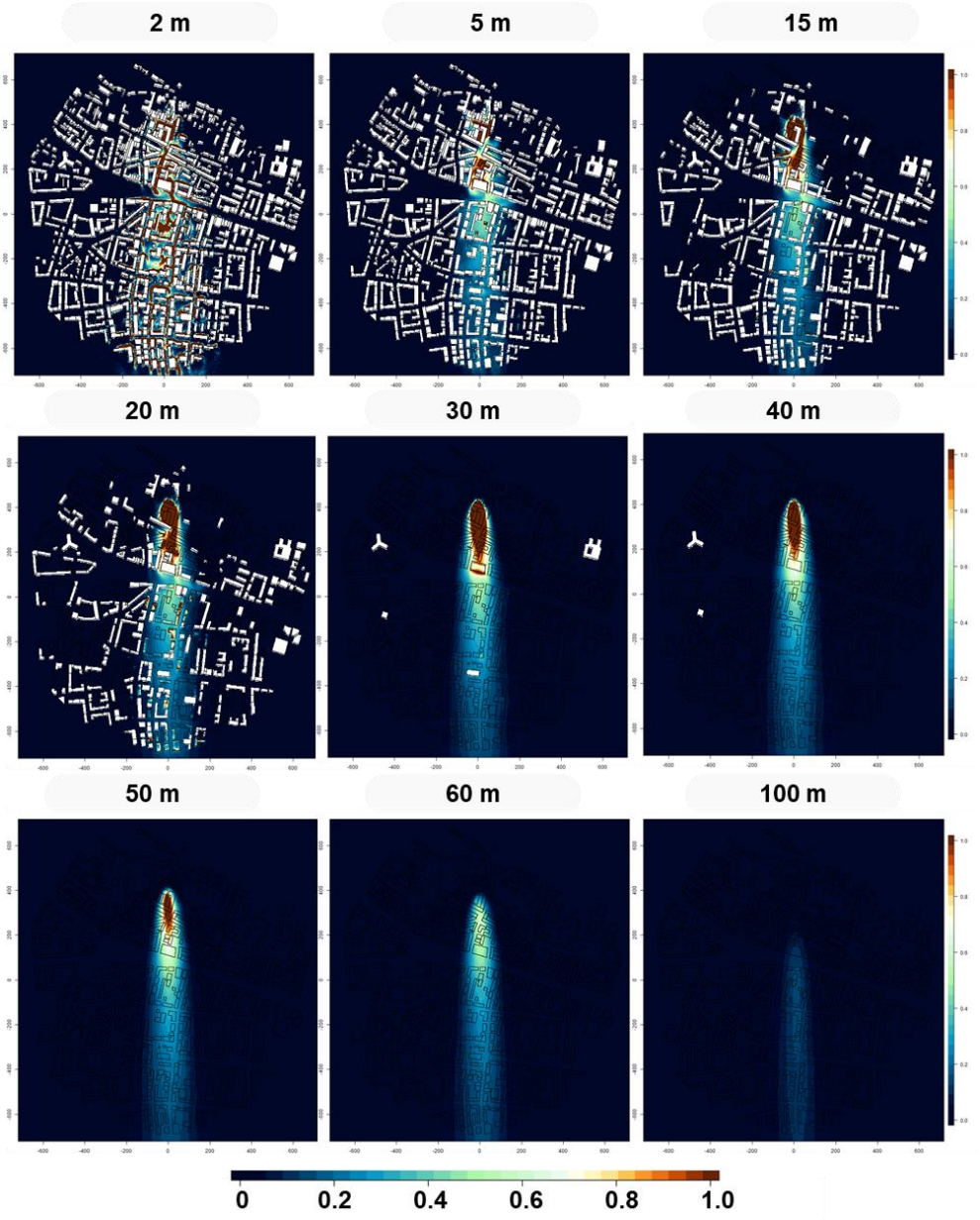

Figure 3. Particle concentration per grid box at different heights averaged over 4 h for the simulation v1.1.

Since the emission rate, as defined in EXPO-URB project, could not be exactly specified in the PALM configuration input file, in the experiments v1.0 and v1.1 are compared distributions of particles given different emission rate of particles per point. The reference of 1000 particles per point (v1.1) is reduced to 350 particles per point, which corresponds to surface of source with 2 m diameter (3.14 m2), compared to area of one grid point with size of 3 m (9 m2). The results for particle concentration were multiplied by factor 10 to be in range of concentration simulated in other models in EXPO-URB project. The results show that increasing emission rate increases particle concentration and lateral spread of particles, as expected (Figure 4).

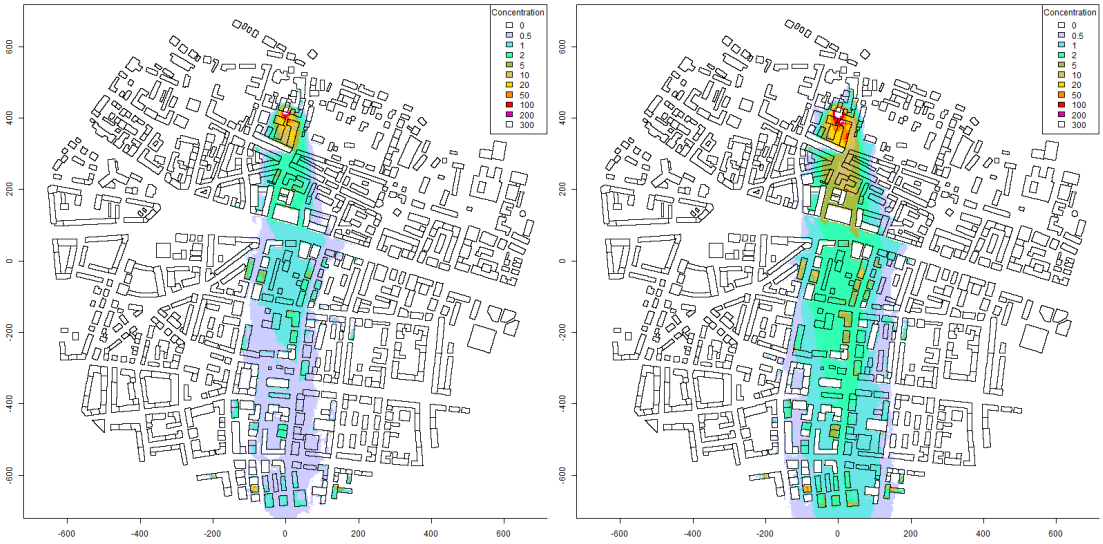

Figure 4. Average particle concentration at 20 m after 4 hours of simulation with increased number of particles released per point. On the left: 350 particles (v1.0) and on the right: 1000 particles (v1.1). Total number of particles is multiplied by factor 10.

Conclusions

The challenges in the PALM model input preparation and the configuration adjustments for the query, including the immense computing capacities required for the simulations and the analysis are presented and discussed in the project. The practical application of the model PALM for dispersion modelling in urban areas and radiation exposure assessment near medical and industrial facilities was considered as less suitable, given the current development stage. Nevertheless, recommendations for further investigations in the field were identified.

References

Gronemeier, T., Surm, K., Harms, F., Leitl, B., Maronga, B., & Raasch, S. (2021). Evaluation of the dynamic core of the PALM model system 6.0 in a neutrally stratified urban environment: comparison between LES and wind-tunnel experiments. Geoscientific Model Development, 14(6), 3317-3333.