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EXTENDED ABSTRACT

Application of lagrangian models in urban area for exposure assessment in the vicinity of medical and industrial facilities –challenges and lessons learnt (Project EXPO-URB, Part 3)

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Abstract. The following study was conducted in the frame of the research Project EXPO-URB, initiated from the Federal Office for Radiation Protection in Germany (BfS) dealing with the application of atmospheric long-term dispersion models in urban areas. Main focus in the project was to improve exposure assessment near medical and industrial facilities. The planned research and development activities aim to support the realistic calculation of individual exposure in the population due to the release of radioactive substances from medical and industrial facilities and plants by using lagrangian particle models.

The study deals with the challenges appearing by the model input preparations and especially by the harmonization of the model input requirements, particularly when aiming to be generally applicable on a wide spectrum of numerical dispersion models. Key aspect is the preparation of the building data in a format suitable to be applied independent from the specific model of choice, without additional adaptations. Depending on the intended application of a model or a model chain, specific model characteristics have different influences on the quality of the application-specific simulation results. The calculation of personal exposure to air pollutants requires, among other things, sufficient simulation accuracy in the areas where people are present. As demonstrated in the study, the different dispersion models offer varied approaches, each with distinct input requirements, strengths, and limitations. While this diversity allows for custom solutions, it also introduces inconsistencies in results interpretation, model validation, and overall comparability across the studies. A harmonization in the modelling approaches and tools can improve the effective exposure assessment in urban areas. This could support by decision-making for urban planning and public health but also poses challenges for cross-study evaluations and policy development.

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Keywords: Lagrangian Particle Models, Wind Tunnel Experiments, Release in Built Environment, Model Intercomparison

INTRODUCTION

The primary aim of the project is to assess the performance of lagrangian dispersion models in estimating long-term radiation exposure within urban environments. A range of experimental datasets has been gathered and analyzed using comprehensive boundary layer wind tunnel simulations, measuring the wind flow and tracer dispersion within a scaled model of a typical European city. The geometry model was created with various buildings density, inclusive one with slanted roofs. Various measurements scenarios were defined, incorporating changes in wind direction, urban geometry complexity, and the positioning of the emission sources. Based on these scenarios model simulations with the following models: TalDia-ARTM, MISKAM-LASAT, GRAL-system and MicroSwiftSpray were conducted. The resulting concentrations were then compared with experimental data.

Preparation of the model geometry data

In general, any complex numerical system requires different input formats and has varying restrictions and adaptions. These circumstances making it almost impossible to create an 'unified' dataset which guarantees perfectly comparable results among diverse evaluation methods. The following example provides an overview on what difficulties might appear when comparing different numerical models with laboratory data. The "City" used in this study has been artificially generated and 3D printed for the wind tunnel. One big challenge arises when trying to use these input data within a wind field model or dispersion program, since most of these systems, including the ones used in this study, are not capable of using the provided .STL files (Figure 1) as they are. But simply converting the input into some other format is also not sufficient, since the models generally also do not share a common datatype. This leads to time consuming procedures of converting datasets into multiple different formats, a significant increase in the uncertainty but also to the general question if it is sufficient to provide one single base dataset for future projects or public use. In this study, some models needed the buildings to be given as footprint shapes with one mean height while others were able to process complete 3D shape files. Presumable, this will be impacting the results and all comparisons of the models, especially when using a configuration with different roof types (Figure 1, right).
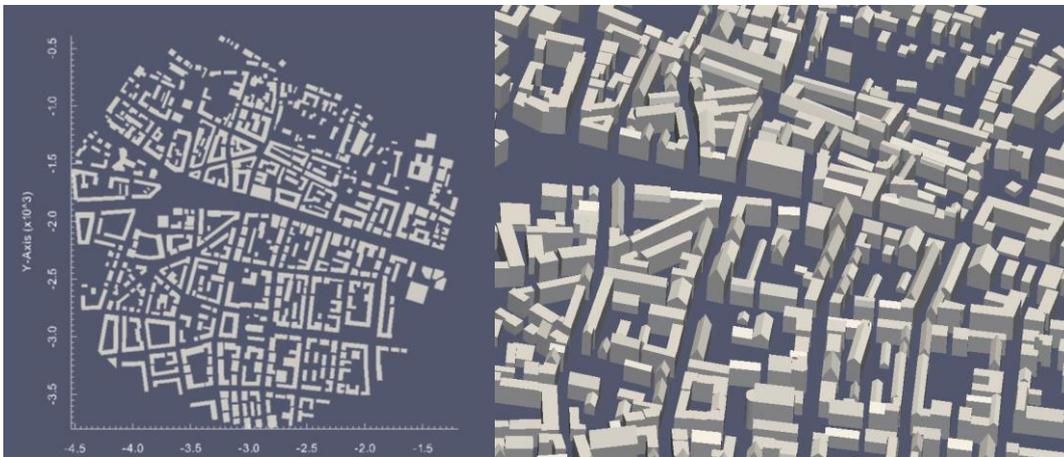
Figure 1: 3D visualisation of the building geometry; dense configuration with flat roofs (left) and with the slanted roof forms (right).

For the comparison scenarios four different geometries have been provided. Three of them are with different building densities (Figure 2) and one with slanted roofs using also the 'densest' geometry. Each one needed to be converted, scaled and adapted according to the restrictions of each system, before being applied on more than 20 individual dispersion scenarios dealing with different source locations, grid resolutions and sizes, but also wind conditions and release momenta.


Figure 2: Different buildings geometries (dense, medium, low) as applied in the models.
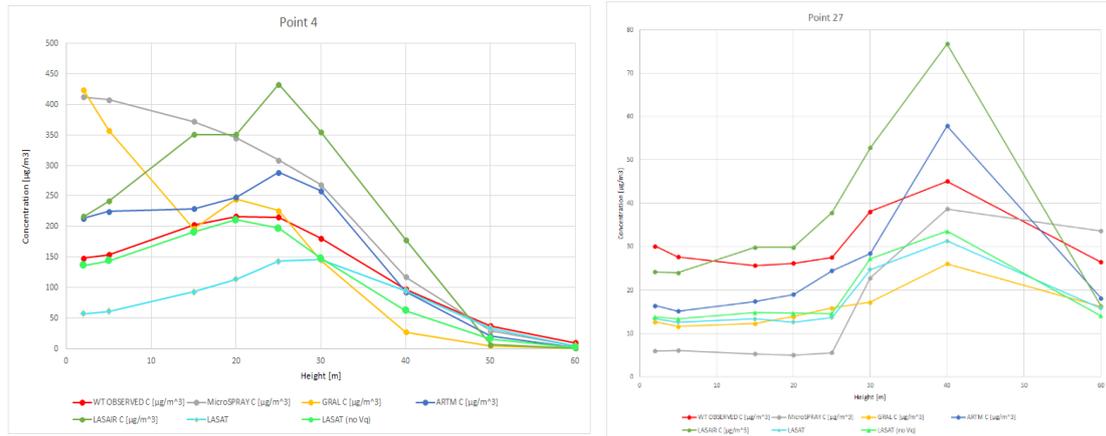
Model comparison

Whenever comparing dispersion models with real measurements another challenge arises. Actual measurements can only be given on single points, while models provide field data, as output. In a complex urban setup like the one presented here, the gradient of the concentration can be quite steep, especially close to the source (Figure 3). It is obvious that any differences in the setup of the model configuration, the chosen grid or stack as well as the resolution of the buildings within the systems can lead to expressive disagreement in any direct point comparison. In order to reduce this issue a large set of measurement points (72), including 2 vertical profiles, is used. Nevertheless, as can be seen in Figure 4, the results can vary significantly at any point of interest. The challenging part in such a case is to distinguish between numerical or methodical differences within the models and the uncertainties caused by the different treatment of the input, as described above.
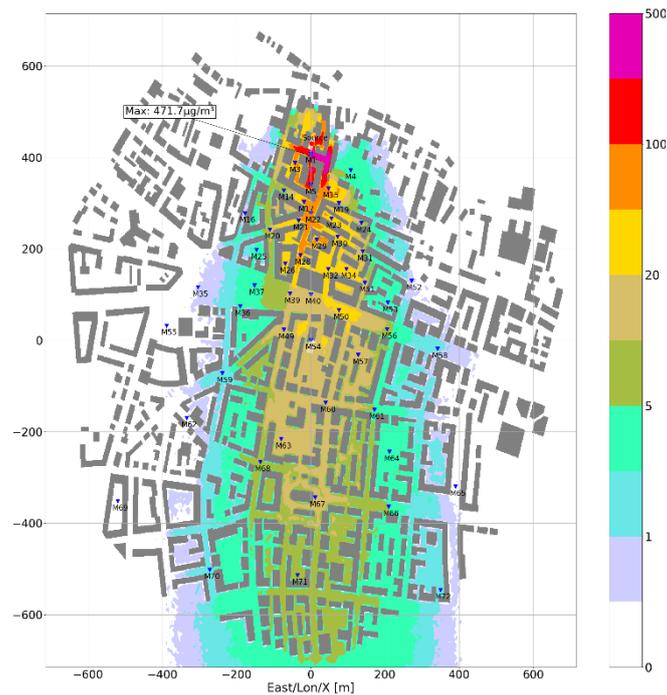
Figure 3: Example dispersion field for 'dense' geometry with wind coming from north. Concentration close to the source can vary by magnitudes within a few grid cells. Measure points are denoted by blue triangles and numbers.

Additionally, we noticed a significant sensitivity with respect to the release velocity in the models. The background here is, that in an urban environment, any release is assumed to come from ventilation systems which typically have flow speeds around 2m/s while the wind tunnel uses a passive dispersion, with neglectable release momentum, The impact of this discrepancy is currently under investigation, but an evidence for its impact can be seen in Figure 4 when comparing the light green and the light blue lines with the measurements (red). The light blue lines represent a 'realistic' release with 2m/s source current while the light green one uses a passive release and is therefore in better agreement with the measurements (Figure 4, left). Further away from the source (Figure 4, right) this change in the initial conditions has less influence on the results.

Figure 4: Model comparison for the measurement points 27 and 4 (vertical profiles).

Conclusions:

Urban environments present unique and complex challenges for air dispersion modelling, due to the intricate interplay between meteorological conditions, building configurations, and emission sources. As demonstrated in the study, different dispersion models offer varied approaches, each with distinct input requirements, strengths, and limitations. This diversity needs a common solutions, it could also introduces inconsistencies in results interpretation, model validation, and overall comparability across studies. A harmonized framework for dispersion modelling and tool application would address these challenges by standardizing methodologies, aligning input data requirements, and promoting consistent validation practices and validation datasets. Such harmonization would enhance model interoperability, improve the reliability and transparency of simulation results, and ultimately support more informed and coordinated strategies for air quality management and public health in urban settings.