5.29 LAGRANGE VERSUS EULERIAN DISPERSION MODELING COMPARISON FOR INVESTIGATIONS CONCERNING AIR POLLUTION CAUSED BY TRAFFIC

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INTRODUCTION

In Germany, the subject of ambient air quality is regulated by a special guideline, the "TA Luft". With the renewal of the TA Luft, a Lagrangian dispersion model has been introduced as standard method for dispersion modelling.

Traffic-related air pollution is a growing issue in the European Community (Air quality directive 1999/30/EG). The most affected areas are the inner-city streets, surrounded by complex building clusters. Therefore, the dispersion modeling should be performed with high grid-resolution, otherwise, flow and turbulence around buildings and within street canyons cannot be calculated accurately.

This can be a strict limitation to the use of Lagrangian models, because in areas of more than $500 \cdot 500$ m^2, an hourly calculation of a whole year's cycle using a grid spacing of 5 meter might not be finished in suitable computer time. Therefore, a method has to be established, which allows a full high-resolution 3D-simulation of such phenomena.

SCHEMES AND APPLIED MODELS

An Eulerian dispersion model solves a conservation equation for gaseous or aerosol materials, which can be expressed formally very easy and which can be transformed into a very fast numerical code. On the other hand, Eulerian dispersion modeling is often rejected because of the appearance of artificial diffusion.

Using the Lagrangian approach, trajectories of several thousands of particles have to be calculated in small consecutive time steps. Every particle carries a certain amount of gaseous or aerosol mass. The movement of the particle is determined by average wind velocity components and turbulence conditions. The latter is described mathematically by a Markov process. Concentration is calculated by counting particles or time-intervals of particles within the grid volumes. Artificial numerical diffusion does not occur by using this method, but, since statistic accuracy is important, usually a vast number of particle-trajectories have to be calculated, which may lead to very time-consuming simulations, especially, when low mesh width correspond with a large model domain.

The Lagrangian Particle model used in this study is **LASAT** (**LA**grange **S**imulation of **A**erosol **T**ransport, e.g. Janicke 1983), which satisfies the requirements of the TA Luft and the VDI-Guideline 3945/3. The model with the Eulerian scheme is **ABC** (**A**irflow around **B**uilding **C**lusters, according to VDI 3710/10, e.g. Röckle et al. 1995). Both models use diagnostic flow modules as dynamic part of the calculation.

EXPERIMENTS

Note, that this is not strictly a classic comparison of two formal dispersion-model-approaches, where all other parameters like e.g. the used grid are held identical. Here, both models, ABC and LASAT, were operated according to their applicability in expert opinion's experience. With respect to computer time, that leads to a horizontal grid resolution of 10 m for LASAT and 3 m for ABC.

Three different sceneries have been examined (see also Fig. 1):

1) a simple line source (street) without any buildings
2) the same street with surrounding small and large buildings
3) similar to 2), with an additional network of streets and a city-like building environment.

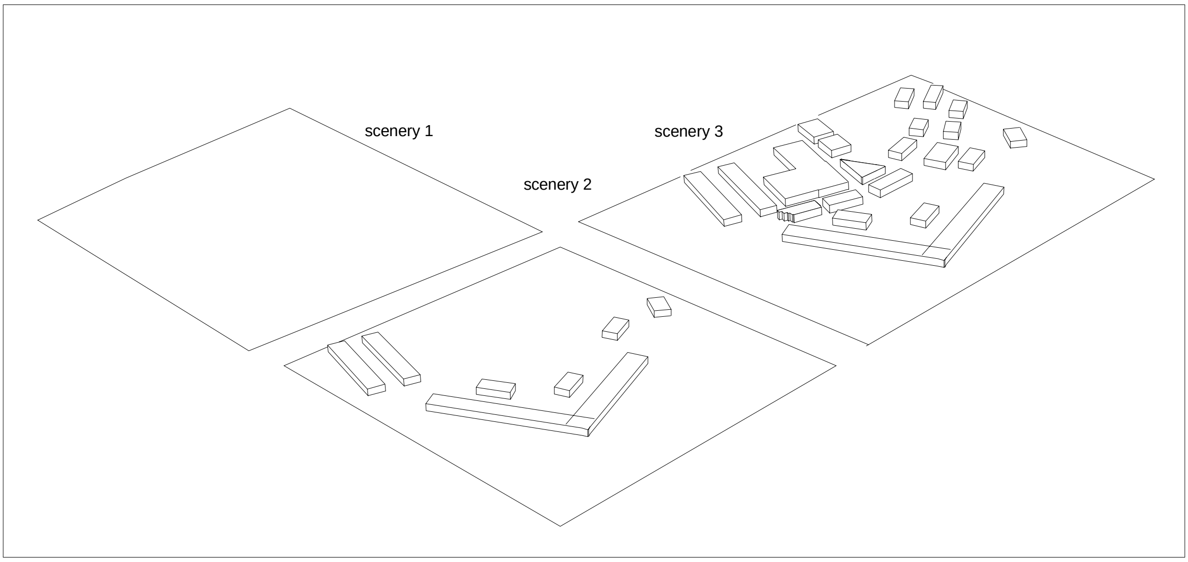

Figure 1. Bird's eye view of the 3 experimental sceneries: A street without any buildings (case 1, left), same street with some buildings (case 2, middle) and a city-like building-environment with a network of streets (case 3, right).

FURTHER INPUT DATA

The vertical grid spacing is 3 m in the near-surface level, particle emissions in LASAT have been set to the lowermost grid volume to describe traffic induced turbulence and, furthermore, to obtain comparable results (The Eulerian approach distributes the emissions in the lowest volume right from the source, a point which is sometimes criticized as well). Roughness length in the flat terrain is 0.1 m, buildings are simulated explicitly.

A time series of Stuttgart Airport serves as meteorological input data (hourly measurements). The anemometer height is 10 m above ground, the anemometer position is located at x=250 m and y=250 m (see results, Figures 2 to 4)

Traffic emissions were set to artificial values and had been identically applied to both models.

RESULTS

The results of all three cases show at first glance a satisfying conformity of the Eulerian method with the Lagrangian approach. In case 1, where no buildings are present and therefore horizontally homogenous flow and turbulence develops in both models, the agreement is quite well when both models develop a well mixed atmosphere near the surface.

With the terrain becoming more complex, differences occur (Fig. 2), which have to be attributed to the more accurate modeling of the higher resolution model ABC. As can be seen in Fig. 3, the higher resolution allows a far more accurate description of recirculation areas around buildings. In general, the calculated concentrations by ABC are a bit higher than in the Lagrangian simulation, which is acceptable with respect to the established strategy of trying to be rather slightly on the pessimistic side of reality with model simulations.

In the city-like building environment with a streets-network, this effect becomes even more observable (Fig. 4). The general level of concentration is comparable in both models, and so is the overall spatial structure of the concentration field. But going into detail, e.g. into building edges or street canyons, visible differences occur. They are caused by the fact that the three-dimensional flow and turbulence structure is much better in the high resolution grid of 3 m grid-spacing (ABC) than in the coarser one of 10 m (LASAT).

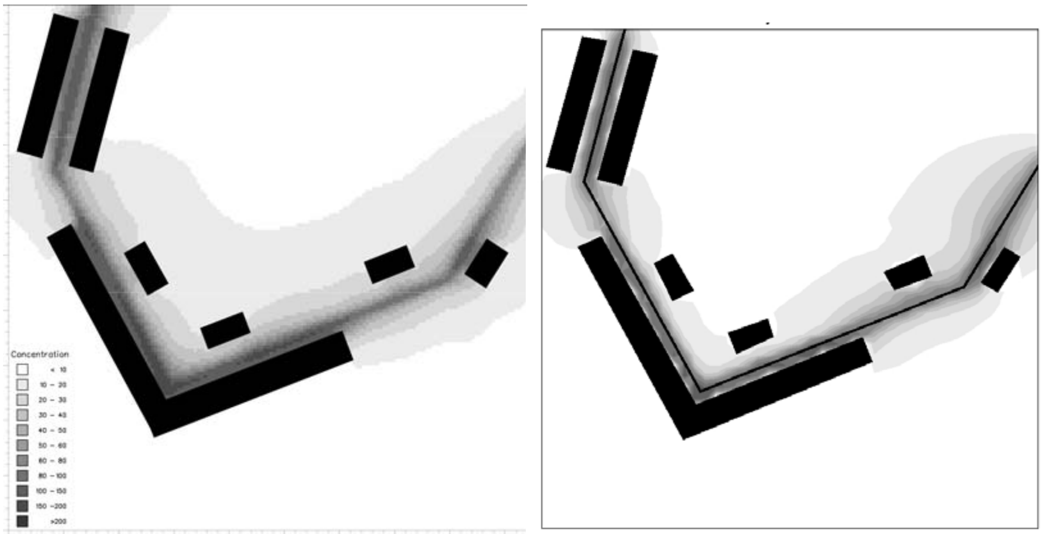

Figure 2. Near surface concentration fields. Left: ABC (Eulerian), right: LASAT (Lagrange) Case 2 (one street, some buildings).

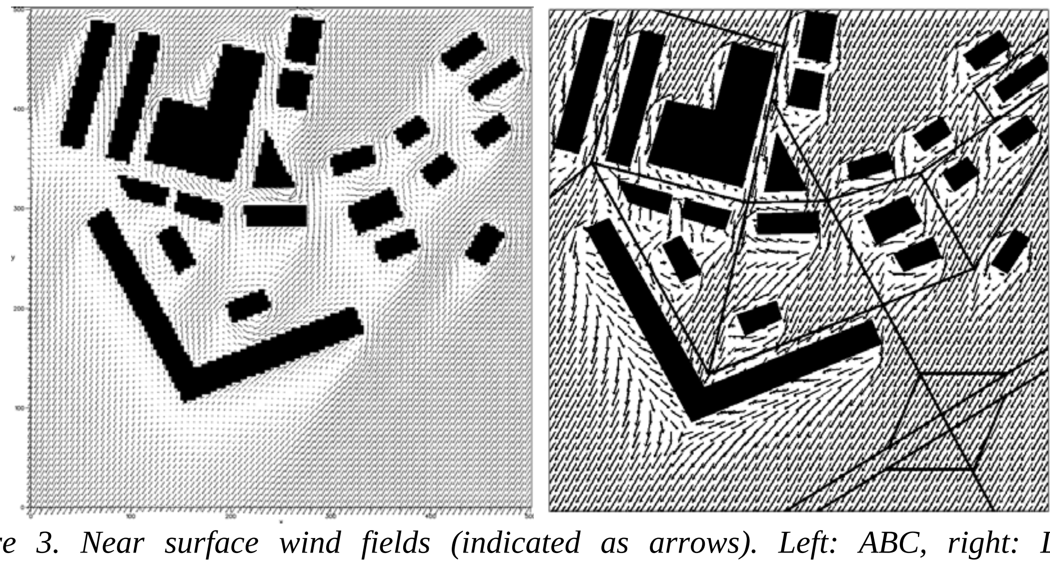

Figure 3. Near surface wind fields (indicated as arrows). Left: ABC, right: LASAT. Case 3 (network of streets, inner-city like assembly of buildings).

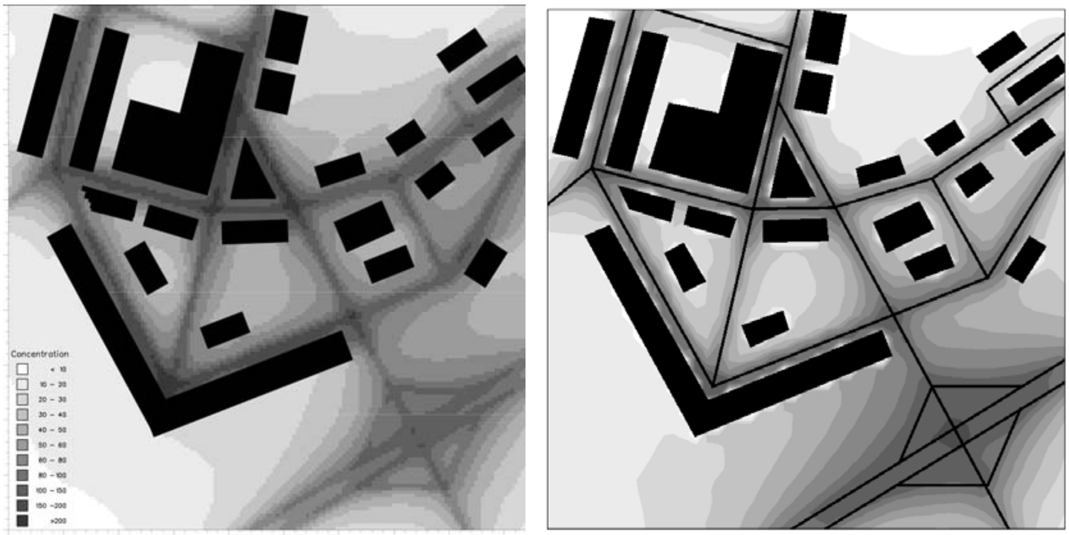

Figure 4. Near surface concentration fields. Left: ABC (Eulerian), right: LASAT (Lagrange). Case 3 (network of streets, inner-city like assembly of buildings).

CONCLUSIONS

In spite of using two completely different numerical approaches to calculate air pollution caused by traffic, there is not much difference in the general concentration level or the overall spatial structure of concentration fields in the results of both models. Differences occur when the focus is set on small scale features within the building-influenced zone. There, the calculated concentrations by ABC are a bit higher than in the Lagrangian simulation, which is acceptable with respect to the established strategy of trying to be rather slightly on the pessimistic side of real conditions with model simulations.

The disadvantage of artificial diffusion in the Eulerian approach is in case of air pollution caused by traffic not prominent, which might be due to the line-character of the sources. Since it seems obvious that a higher resolution to describe flow and turbulence more accurately in many cases is desirable, the use of an Eulerian model with higher grid accuracy can be recommended as well as (and probably even in favour of) a Lagrangian model.

REFERENCES

Janicke, L., 1983: Particle simulation of inhomogeneous turbulent diffusion. Air pollution modeling and its application II (Ed. Weber). Plenum Press, N.Y., 527-535.

Röckle, R., and C.-J. Richter., 1995: Ermittlung des Strömungs- und Konzentrationsfeldes im Nahfeld typischer Gebäudekonfigurationen – Modellrechnungen. Forschungsbericht FZKA-PEF 136. Forschungszentrum Karlsruhe.

Röckle, R, Kost, W.-J., Janicke, L., 1995: Modeling of motor vehicle immissions in a street system by combination of lagrange models and surface wind field simulation in complex city structures. In Wind Climate in Cities, Kluwer Academic Publishers, Series E: Applied Sciences, Vol. 277, Ed. Cermak, Davenport, Plate, Viegas, p. 547-553

Röckle, R., Richter, C.-J., Salomon, Th., Dröscher, F., Kost, W.-J., 1998: Ausbreitung von Emissionen in komplexer Bebauung – Vergleich zwischen numerischen Modellen und Windkanalmessungen. Projekt Europäisches Forschungszentrum für Maßnahmen der Luftreinhaltung, Forschungsbericht FZKA-PEF, September 1998, Förderkennzeichen: PEF 295002