M-SYS - A Model System for Evaluating Air Quality in Different Detail

Contribution to subproject SATURN

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Summary

A model system (M-SYS) for evaluating air quality in different spatial detail is being developed. The system is based upon the 3-dimensional meteorological microscale model MITRAS (Panskus, 2000; Schlünzen et al., 2002), the mesoscale model METRAS (Schlünzen, 1990; Schlünzen et al., 1996) and the respective chemical transport models MICTM and MECTM (Lenz et al., 2000). M-SYS shall generate air quality maps with different horizontal resolution ranging from several kilometres down to a few metres within street canyons. These air quality maps represent statistics of air concentrations as required by the European Framework Directive on ambient air quality assessment and management and its daughter directives.

Aim of the research

As one contribution to the AFO2000-project VALIUM (Development and Validation of Tools for European Air Quality - Entwicklung und **Val**idierung von **I**nstrumenten zur **Um**setzung der europäischen Luftqualitätspolitik), a model system (M-SYS) will be developed and evaluated. M-SYS will generate maps of air quality statistics as required by the European directives on ambient air quality assessment and management. The basic approach is to nest an obstacle-resolving microscale model (MITRAS) into a mesoscale model (METRAS), and similarly the microscale chemical transport model MICTM into the mesoscale MECTM (Figure 1). A special challenge for the modelling approach stems from the fact that some of the percentiles required by the European directives are very high, even exceeding 99 %. To meet these requirements with available computing capacities, meteorological and emission input into the system is derived by a two-step cluster analysis (Figure 1) by Schaller (2001): synoptic-scale meteorological and concentration data will be processed with cluster analysis techniques to define short episodic (ca. 1 day) mesoscale situations (clusters); in a second step, quasi-stationary microscale situations (clusters) will be derived by cluster analysis from output of the mesoscale model.

Activities during the year

The VALIUM project, which is scheduled until 31 March 2004, started in January 2001. The M-SYS model system has been outlined (Figure 1) and the models to be included (METRAS, MITRAS, MECTM and MICTM) have been tested. Results of the obstacle resolving microscale model were compared with the CEDVAL (2001) wind tunnel data using the comparison method described in VDI (2002).

A mesoscale and a related microscale model domain have been set up and runs have been performed on both scales based on preliminary meteorological data. Different resolutions were used to study its effect and the effect of domain size on the model results. The harmonisation of the mesoscale and microscale meteorological and chemical models is in progress. For supporting the preparation of the VALIUM field campaigns, the flow field simulated for the measurement side Göttinger Straße in Hannover was visualised.

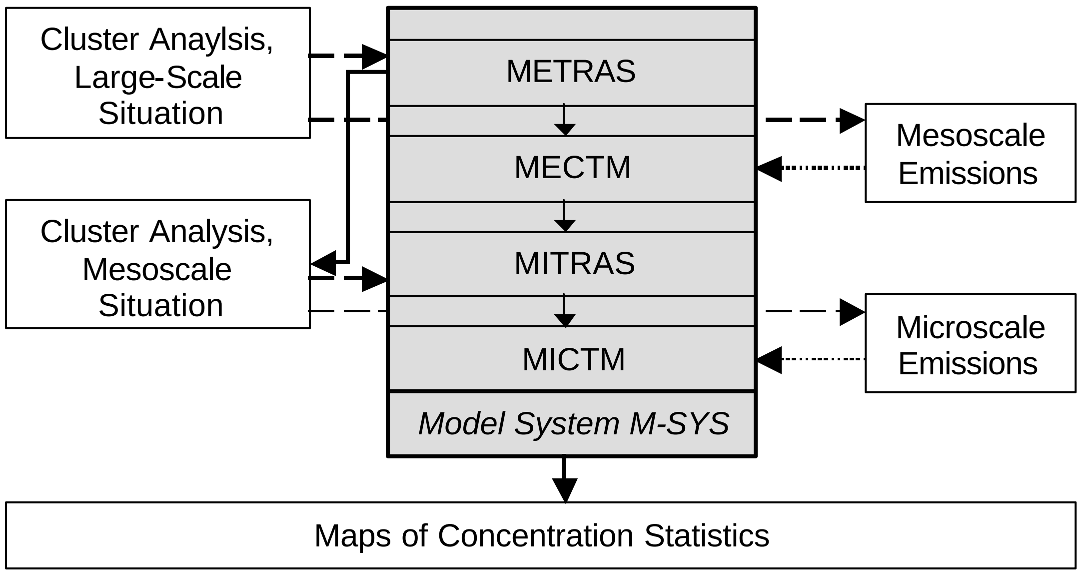

Figure 1. Structure of the model system M-SYS (shaded box), its input and output.

Principal results

Results of the microscale model MITRAS as part of model system M-SYS have been compared with wind tunnel data. According to quantitative evaluation criteria the agreement is satisfactory. Figure 2 shows for each MITRAS simulated value of the u-component the corresponding wind tunnel reference value. Most values are close to the bisecting line and within the deviation measures $r_{abs} = 0,07$ and $r_{rel} = 0,25$. A notable deviation can be seen for negative values. Predicted values are too low in this section compared to the wind tunnel data. That means, the re-circulation of the flow at the lee side of the obstacle is slightly over-estimated in the model result.

A flow field visualisation has demonstrated the difference of the wind directions above and below the urban canopy (Figure 3): while the mean wind direction above the canopy is from right to left, various wind directions are observed in the street canyon, and the prevailing wind direction at the ground is from left to right. The flow pattern depends on the specific geometry of obstacles and their orientation with respect to the mesoscale wind field. 3-dimensional modelling is required to account for the distribution of pollutant concentrations under these conditions

Main conclusions

The mesoscale model METRAS and the microscale model MITRAS, which are largely based on common parameterisations and equations, together with the respective chemical transport models MECTM and MICTM are well suited to implement a model system which fulfils the requirements of the new European directives on ambient air quality assessment. A special advantage of these models with respect to the directives is their non-uniform grid, which allows to zoom down to horizontal resolutions of 1 km in the mesoscale and a few metres in the microscale while at the same time covering a sufficiently large domain. Even such closely related models require further harmonisation in order to comprise a self-consistent model system. Special attention is given to an interface using the cluster analysis results and to experimental evaluation.

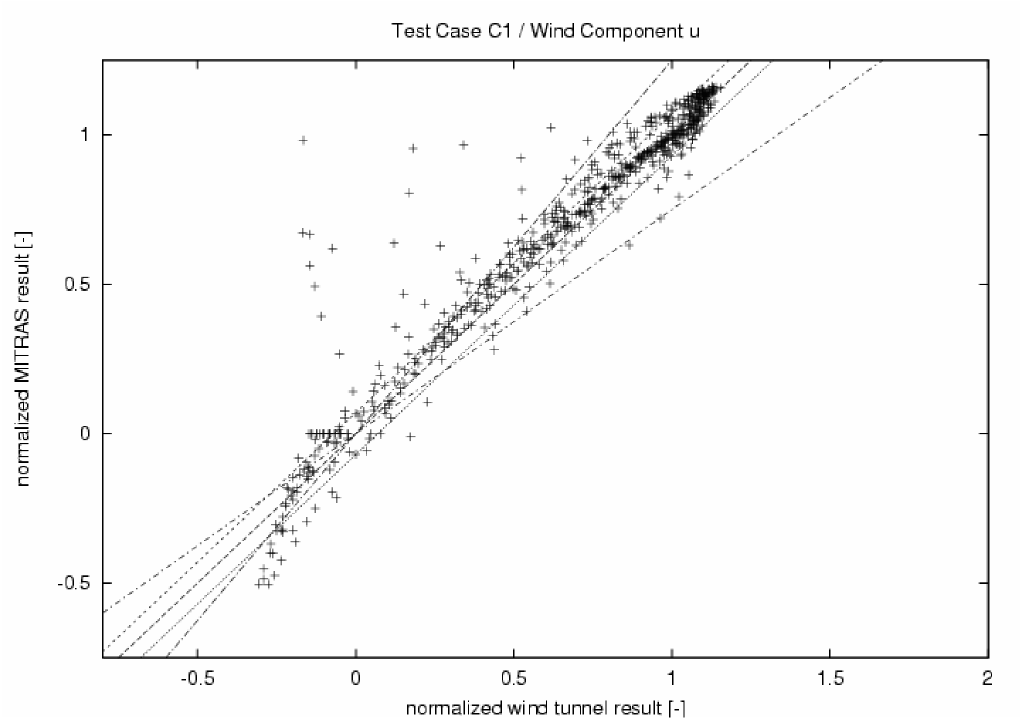

Figure 2. Scatter plot of the MITRAS results against the wind tunnel results for the u-component. Short dashed and dashed-dotted lines show the deviation boundaries r_{abs} and r_{rel}, respectively. All values are normalised with the undisturbed flow.

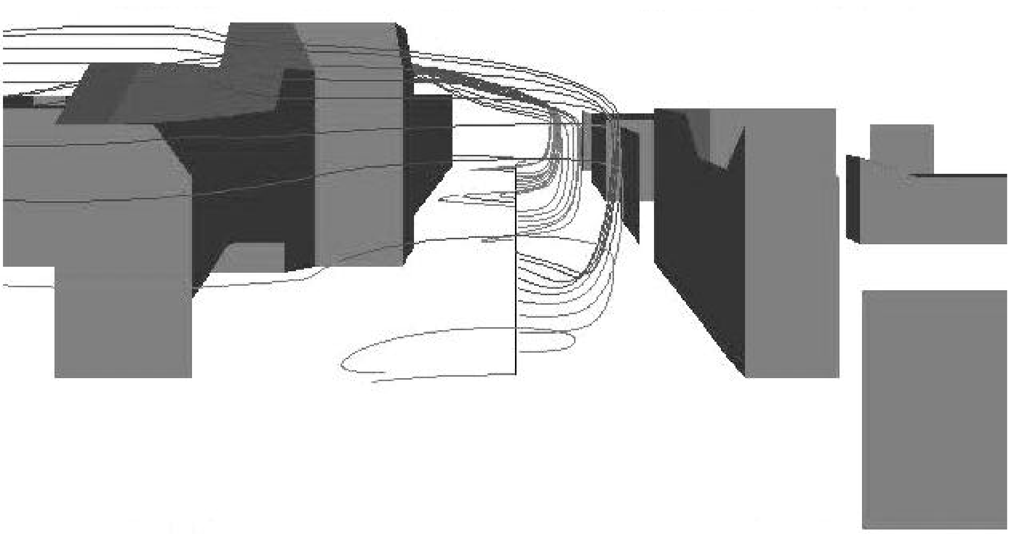

Figure 3. Simulation of a tracer experiment in an urban street canyon (Göttinger Straße, Hannover). Buildings are indicated as shaded blocks. The tracer is released at a line source in the centre of the street. Advection of the tracer is visualised by streamlines. Above the urban canopy, the wind is blowing from right to left.

Aims for the coming year

Extension, harmonisation and nesting of METRAS/MITRAS and MECTM/MICTM. Model simulations with the system components for clustered meteorological situations.

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