Comparison of MITRAS Microscale Model Results and Wind Tunnel Data

Contribution to subproject SATURN.

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Summary

As part of the evaluation of microscale model MITRAS, results from the numerical model are compared to reference data based on wind tunnel measurements. A number of simple test cases with obstacles has been chosen, including one quasi-2-dimensional case and four 3-dimensional cases. The rating is done using hit rates, estimated by a point-by-point comparison of the two and three velocity components, respectively. The evaluation is done according to a VDI (German Engineering Society) guideline, which is currently in preparation.

Introduction

Within the research project VALIUM, the microscale numerical model MITRAS is used as a part of the model system M-SYS which is currently developed for the prediction of air quality in urban areas (see contribution of Trukenmüller et al., 2002). One part of the evaluation of MITRAS is the comparison of results from numerical modelling with reference data taken from wind tunnel measurements. The reference datasets are based on the CEDVAL database hosted at the University of Hamburg (CEDVAL, 2001).

Objectives

The model system M-SYS consisting of the sub-models METRAS, MITRAS, MECTM and MICTM need to be based on extensively validated sub-models to ensure a satisfactory model performance for deriving concentration maps (Trukenmüller et al., 2002). This project aims on evaluating the microscale model MITRAS (Panskus, 2000; Schlünzen et al., 2002). Wind tunnel data are mainly used for this purpose. For further validation the measurements from the tracer experiments of the VALIUM field campaigns will be used (Bächlin, 2002).

Activities

For the comparison five different test cases have been selected from the database. One test case can be calculated with a quasi-2-dimensional model and four test cases employ the 3-dimensionality of the model:

- A beam lateral to the main flow direction; the beam width corresponds to the width of the modelling domain (quasi-2-dimensional),
- a cuboid with main flow direction perpendicular to the front plane,
- a cube with main flow direction perpendicular to the front plane,
- a cube with main flow direction 45° slanted to the front plane,
- an array of 7×3 cuboids, laterally bound by two walls.

Each test case is defined in detail depending on the configuration of the underlying wind tunnel measurements. For the numerical simulations the corresponding obstacle geometry, roughness parameter and stratification (neutral in all five cases) as used in the wind tunnel measurements are applied.

The rating of the model performance is done by the determination of hit rates. These are calculated with point-by-point differences of each velocity component for all wind tunnel measurement points and additionally for the near field around the obstacle. Each difference is compared to two deviation measures, the absolute difference r_{abs} and the relative difference r_{rel}, to distinguish 'hit' from 'missed'. The hit rate Q is calculated as follows

$$Q = \frac{\sum_{n=1}^{N} q_n}{N} \qquad \begin{cases} q_n = 1 \quad \text{if} \quad \left| w_n - m_n \right| \le r_{abs} \quad \text{or} \quad \left| \dfrac{w_n - m_n}{w_n} \right| \le r_{rel} \\ q_n = 0 \quad \text{otherwise} \end{cases}$$

Herein N is the total number of values to be compared, q_n is the individual hit rate at a single point, and w_n, m_n are the wind tunnel result and the model result at that point, respectively.

Results

Table 1 exemplarily shows the results of the quasi-2-dimensional test case and the deviation measures for this test case. The value r_{abs} is taken from the error of the wind tunnel measurements, while r_{rel} is an empirical value.

Obstacle Shape	Compared Section	Velocity Component	r_{abs}	r_{rel}	Number of 'hit'	Number of 'missed'	Hit Rate Q
beam	whole field	U	0.07	0.25	478	53	0.90
		W	0.07	0.25	430	101	0.81
	near field	U	0.07	0.25	234	53	0.82
		W	0.07	0.25	194	93	0.68

Table 1: Hit rates and deviation measures for the quasi-2-dimensional test case.

A hit rate $Q > 2/3$ is considered sufficient for the evaluation. For the test case shown in Table 1, most values are easily above this level. Only the vertical wind component in the near field is close to the level, but still fulfils the criterion.

Figure 1 shows each value of the u-component of the MITRAS results against its wind tunnel reference value. Most values are close to the bisecting line and therefore within the deviation measures. 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 leeside of the obstacle is slightly overestimated in the model result. This gives a clue for the comparatively low hit rates in the near field of the obstacle and is a hint for future model improvements.

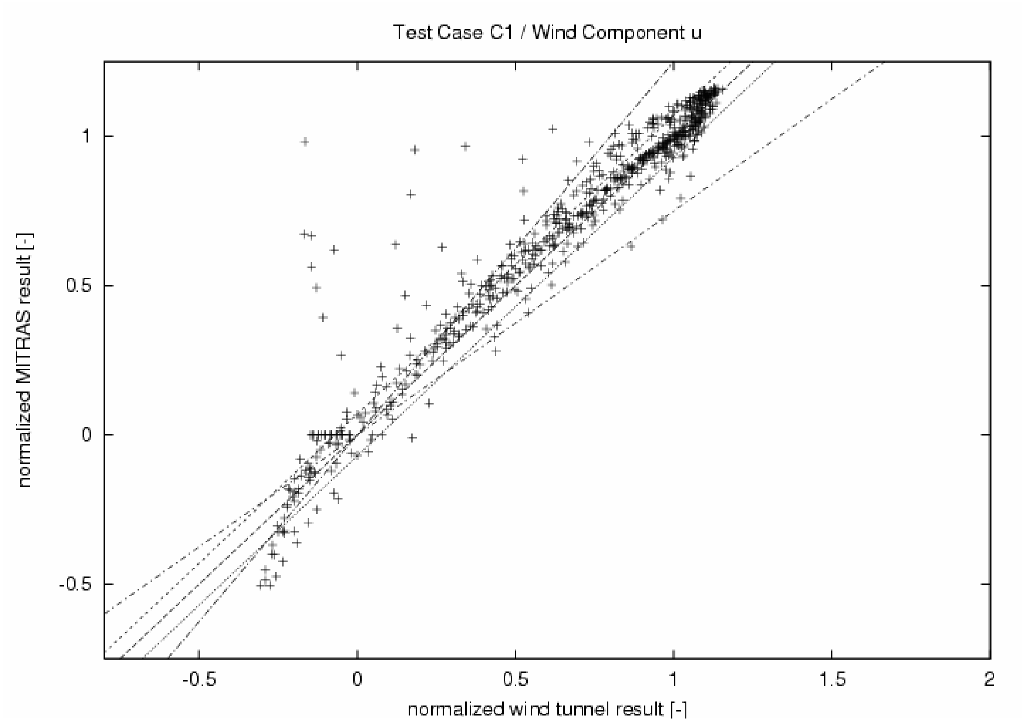

Figure 1: Scatter plot of the MITRAS results against the wind tunnel results for the u-component. Short dashed and dashed-dotted lines show the deviation boundaries r_{abs} and r_{rel} for the hit rate, respectively. All values are normalised with the undisturbed flow.

Conclusions

The comparison for the beam has shown a good agreement of MITRAS results and wind tunnel data. First evaluations of the other four test cases show similar model performance, but the flow field close to the obstacles remains the critical simulation part. Therefore the treatment of the walls within the model and the turbulence parameterisation will be reviewed again.

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Aims for next year (i.e. 2002)

Validation of MITRAS, application to the VALIUM field campaigns; simulation of street canyon chemistry.

List of publications in 2001

Schlünzen, K. H. and H. Panskus, 2001: Evaluierung atmosphärischer Modelle für die Berechnung von Strömungsfeldern. *Österreichische Beiträge zu Meteorologie und Geophysik, Nr. 27, Deutsch-Österreichisch-Schweizerische Meteorologen-Tagung, Vienna, Austria, September 18-21 2001.*

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