An Improved Version of the Microscale Flow Model MISCAM - Evaluation according to VDI Guideline 3783/9

Joachim Eichhorn[1] and Anke Kniffka[2]

[1] Johannes Gutenberg University, Mainz, Germany

[2] University of Leipzig, Germany

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

UNIVERSITÄT LEIPZIG

Introduction

There is an increasing demand on meteorological expertise based on numerical modeling. Therefore, a detailed quantitative validation of the models in use is mandatory.

Since 2005 an evaluation guideline (VDI 3783/9) for obstacle resolving microscale models is available. Recently, the model MISCAM has successfully undergone the complete evaluation procedure (Eichhorn and Kniffka, 2007)

The current study discusses the question whether or not an improvment of the numerical schemes adopted in MISCAM is reflected by better results of the evaluation.

The Model

MISCAM is a non-hydrostatic three-dimensional flow model which solves the eqations of motion on a rectangular Cartesian grid. Turbulence is handled by a standard k-ε-model adopting modifications by Kato and Launder (1993) and Lopez (2002).

Up to version 5 advection of momentum and turbulence quantities has been solved numerically by a simple upstream scheme. This scheme is known to be fast and stable but inaccurate due to ist severe numerical diffusion. Therefore, following a suggestion of Mendez-Nunez and Caroll (1995), version 6 uses a predictor-corrector scheme (MacCormack, 1969) for momentum advection and the MPDATA scheme (Smolarkiewicz, 1989) for scalars such as turbulence energy or dissipation.

Although the revised advection schemes require additional computational effort, the overall increase of CPU time of approximately 15 – 20 % is still manageable.

Summary of the Guideline

The guideline consists of five parts:

- First, the general evaluation (model documentation, publications, comprehensibility of the model) is addressed.
- The second part (scientific evaluation) specifies the necessary model equations and parameterisations as well as boundary and initial conditions.
- Part 3 of the guideline describes a number of test cases, either designated to check the consistency of the model results or to compare simulated wind fields to wind tunnel data.
- Part 4 summarises the results of the procedure in an evaluation record.
- Finally, measures of quality assurance are specified which have to be taken by the end user of the model.

For brevity, this study will solely be concerned with results of the third part of the guideline. Model results are validated quantitatively using point-by-point comparisons with reference data.

For each test case, hit rates q (in %) are computed from normalised model results P_i and normalised reference values O_i and the number of comparison values n according to

$$q = \frac{100}{n} \cdot \sum_{i=1}^{n} N_i$$

where

$$N_i = 1 \quad for \quad \left| \frac{P_i - O_i}{O_i} \right| \leq D \quad or \quad \left| P_i - O_i \right| \leq W$$

$$N_i = 0 \quad else$$

Values for the allowable absolute deviation W and the allowable normalised deviation D are specified within the guideline. For a successful evaluation, the hit rate must not fall below the threshold values given in the guideline for any of the test cases.

Correspondig author:

Joachim Eichhorn

Institute for Atmospheric Physics
Johannes Gutenberg University
Becherweg 21
D 55128 Mainz
Germany

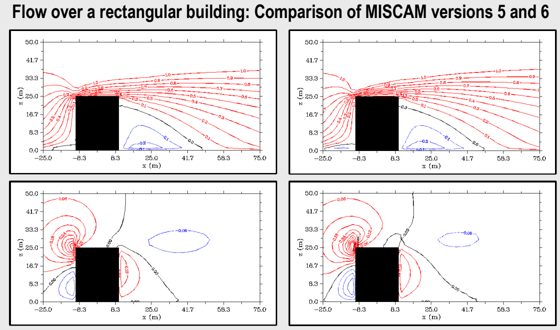
Phone +49 6131 3922866
Fax +49 6131 3923532
email eichhorn@uni-mainz.de

Results

The figures to the right compare qualitatively results of both model versions for the flow over a cuboid, which is one of the test cases specified in the guide-line. Deviations between both versions are small, allowing the assumption that the evaluation results will not be heavily altered due to the changes of the model code.

The consistency checks (Steady state, scalability, homogeneity, independance of grid resolution and orientaton) yielded identical results for both versions except for the check of steady state, which required a revision of the stationarity criterion for version 6. This was due to the fact, that obviously the upstream scheme accelerated the convergence towards a steady state solution.

Flow over a rectangular building: Comparison of MISCAM versions 5 and 6



Contours of horizontal wind component u (upper) and vertical wind component w (lower figures, both in m/s) for neutral flow over a cuboid. Vertical cross sections in the plane of symmetry. Left: upstream scheme; right: revised advection schemes.

Comparison of hit rates for MISCAM versions 5 and 6

	Hit rates (%) for Version 6 (5)			passed ☺ / failed ☹
Test case	u	v	w	
C1 (Beam)	86 (87)	./.	96 (95)	☺
C3 (Cube, 270°)	94 (93)	98 (97)	93 (93)	☺
C4 (Cube, 225°)	85 (84)	76 (76)	81 (81)	☺
C5 (Cuboid)	77 (77)	90 (88)	87 (86)	☺
C6 (Array of cuboids)	92 (93)	68 (67)	81 (81)	☺

Hit rates for comparisons of MISCAM results and wind tunnel data, see VDI (2005) for detailed specifications of test cases. Values for version 5 are given in brackets. The threshold value to pass a test case is 66 %.

As can be seen from the table gathering results of the comparisons with wind tunnel data, in most cases the hit rates for version 6 are slightly higher then those for the former version. The small differences between the hit rates, however, do not allow one model version to be preferred to the other.

At some points the results give rise to further discussion:

An unexpected deviation from symmetry bet-ween hit rates for u and v for case C4 could be traced back to a rotation of the wind tunnel inflow profile.

Comparatively small rates for v for case C6 might also be caused by a non-symmetry of the wind tunnel data.

Remarks

Both model versions fulfill the requirements as specified in the guideline. The comparisons with wind tunnel data also revealed some uncertainties within the data sets.

For the next revision of the guideline, additional data sets representing complex and realistic set-ups should be included, e.g. the wind tunnel and field data from the VALIUM campagne at Göttinger Straße, Hannover.

Conclusions

The VDI guideline 3783/9 serves as a useful tool to locate coding errors as well as to check quantitatively the model‘s performance in comparison to measure-ments.

A decision in favour of one of the model versions, however, must be based on additional reasoning since the evaluation results do not differ significantly.

References

Eichhorn, J. and A. Kniffka, 2007: Application of a new evaluation protocol to the numerical flow model MISCAM. Submitted to *Meteorol. Zeitschr*. Ÿ MacCormack, R.W., 1969: The effect of viscosity in hypervelocity impact cratering, *AIAA Paper,* 69 – 354. Ÿ Mendez-Nunez, L. R. and J. J. Carroll, 1993: Comparison of leapfrog, Smolarkiewicz, and MacCormack schemes applied to nonlinear equations. Mon. Wea. Rev., **121**, 565–578 Ÿ Schlünzen, K.H., W. Baechlin, H. Brünger, J. Eichhorn, D. Grawe, R. Schenk, C. Winkler, 2004: An evaluation guideline for prognostic microscale wind field models. – 9th International Conference on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes, Garmisch-Partenkirchen, 2–4 June 2004. Ÿ Smolarkiewicz, P.K., 1990: The multidimensional positive definite advection transport algorithm: nonoscillatory option. *J. Comput. Physics*, **86**, 355 – 375. Ÿ Verein Deutscher Ingenieure (VDI), 2005: Environmental Meteorology: Prognostic microscale wind field models – Evaluation for flow around buildings and obstacles. VDI 3738, Part 9; Kommission Reinhaltung der Luft im VDI und DIN, Beuth Verlag GmbH, Berlin, Germany.