Validation of the microscale flow and dispersion model MISKAM in the framework of COST Action 732

Márton Balczó M.Sc.,

Department of Fluid Mechanics,
Budapest University of Technology and Economics
(COST 732 Management Comittee member 2008-)

István Goricsán Ph.D.,

Department of Fluid Mechanics (-2008)
Budapest University of Technology and Economics
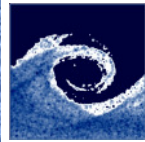(COST 732 Management Committee member
2006-2008)

Joachim Eichhorn Ph.D.

Institute for Atmospheric Physics,
Johannes Gutenberg University, Mainz
(developer of MISKAM)

ERCOFTAC Spring Festival | Budapest, May 4th, 2009

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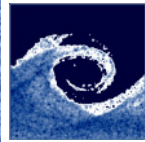*BME Department of Fluid Mechanics*

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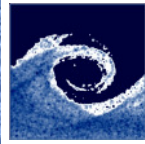
An introduction to the COST Action 732

- COST Action 732 "Quality Assurance and Improvement of Micro-Scale Meteorological Models" chaired by M. Schatzmann
- Models widely used in practice - lack of validation

Microscale flow and dispersion models

Model	CFD		Semi-Empirical	Empirical
Approach	LES	RANS, URANS	Surface roughness based Porosity type models	Diagnostic Analytical
Purpose	scientific studies	environmental impact assessment studies	urban air quality predictions	operational modelling emergency response
Computational power/runtime	high weeks / HPC	medium hours or days / PC		low (almost) real-time
User knowledge	deep knowledge in numerics and fluid dynamics/meteorology		fundamentals in meteorology and air quality	

- Model comparison exercises with dozens of CFD and non-CFD models
  - Rigorous harmonization and documentation of model inputs and setup
  - Exploratory result analysis
 - validation using metrics

COST Action 732 documents

- Action output: five documents, final versions to be published in June 2009
  - COST 732 homepage: http://www.mi.uni-hamburg.de/Home.484.0.html

[1] SCHATZMANN, M., BRITTER, R. (ed.): Proceedings, COST-ESF Workshop "Quality Assurance of Micro-Scale Meteorological Models", Hamburg, July 28/2, 2005

[2] BRITTER, R., SCHATZMANN, M. (ed.): Model Evaluation Guidance and Protocol Document 2007

[3] BRITTER, R., SCHATZMANN, M. (ed.): COST 732 Background and Justification Document to Support the Model Evaluation Guidance and Protocol. 2007

[4] FRANKE, J., HELLSTEN, A., SCHLÜNZEN, H., CARISSIMO B., (ed.): Best practice guideline for the CFD simulation of flows in the urban environment, 2007

[5] - : COST 732 Model Evaluation Case Studies: Approach and Results

- Excel validation datasheets with model results available
- COST 728/732 Mesoscale/microscale model inventory
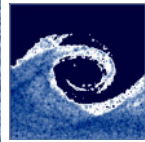
Selected validation data sets and models

- CFD: MISKAM, FLUENT, ADREA, STAR-CD, FINFLO, CFX, MITRAS, TSU/M2UE, VADIS, CODE_SATURNE

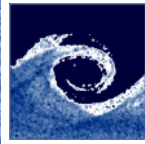- Non-CFD (Gaussian, puff models):, ADMS-URBAN, RAMS, OML, ESCAPE, CALPUFF, LASAT

Validation data sets

- Mock Urban Setting Test

- Joint Urban 2003 (Oklahoma City field measurement)

Problem: extreme variability of boundary conditions in the field ⇨ wind tunnel data
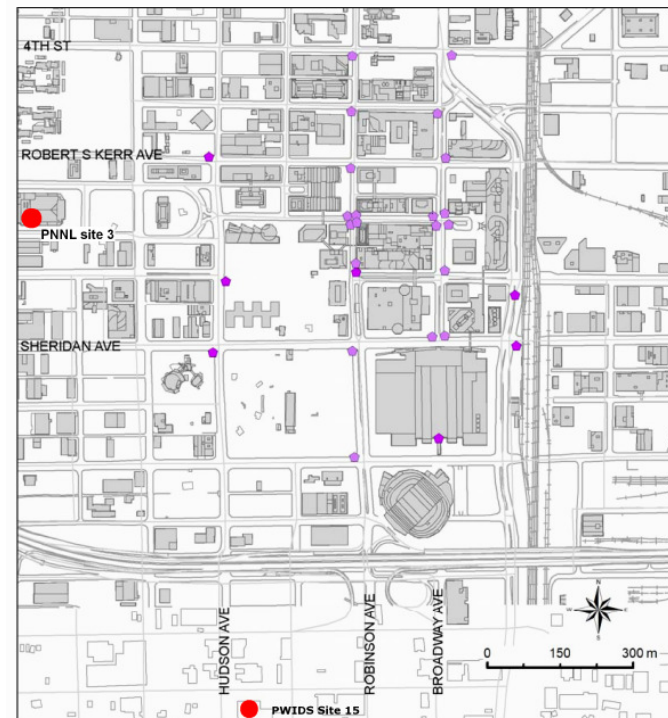

N

The Mock Urban Setting Test (MUST)

- Mock Urban Setting Test – 120 containers arranged in Utah desert, flow and dispersion measurements

- Wind tunnel tests (University of Hamburg) - controllable environment 0° and -45° wind direction

- ~ 3700 points - vertical profiles, horizontal planes | u,v,w, k, c
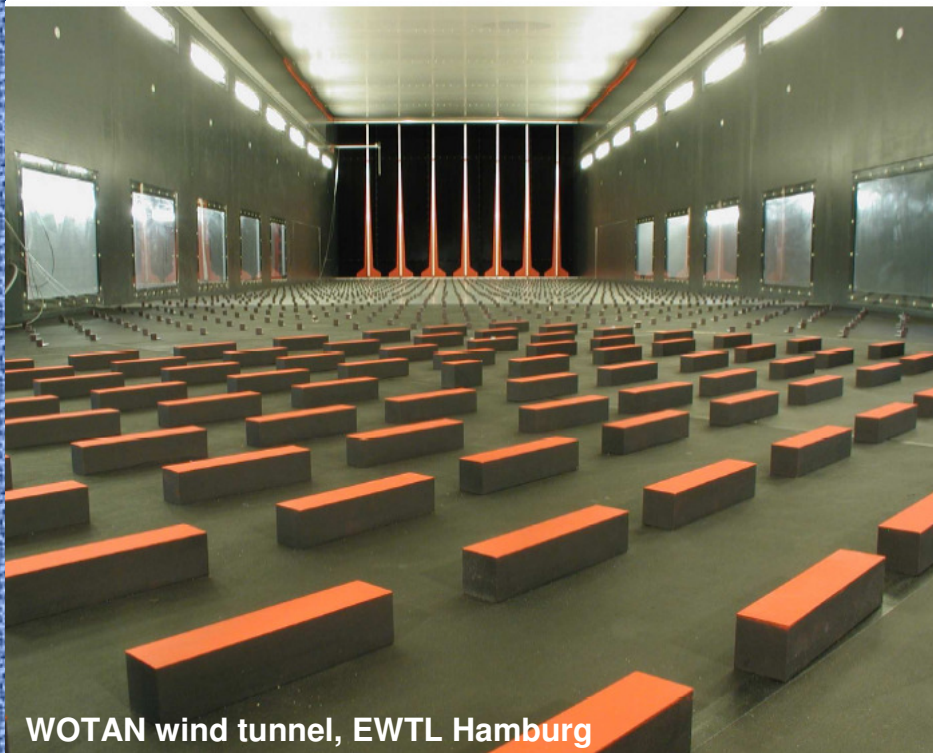

WOTAN wind tunnel, EWTL Hamburg

-45 deg

ground source

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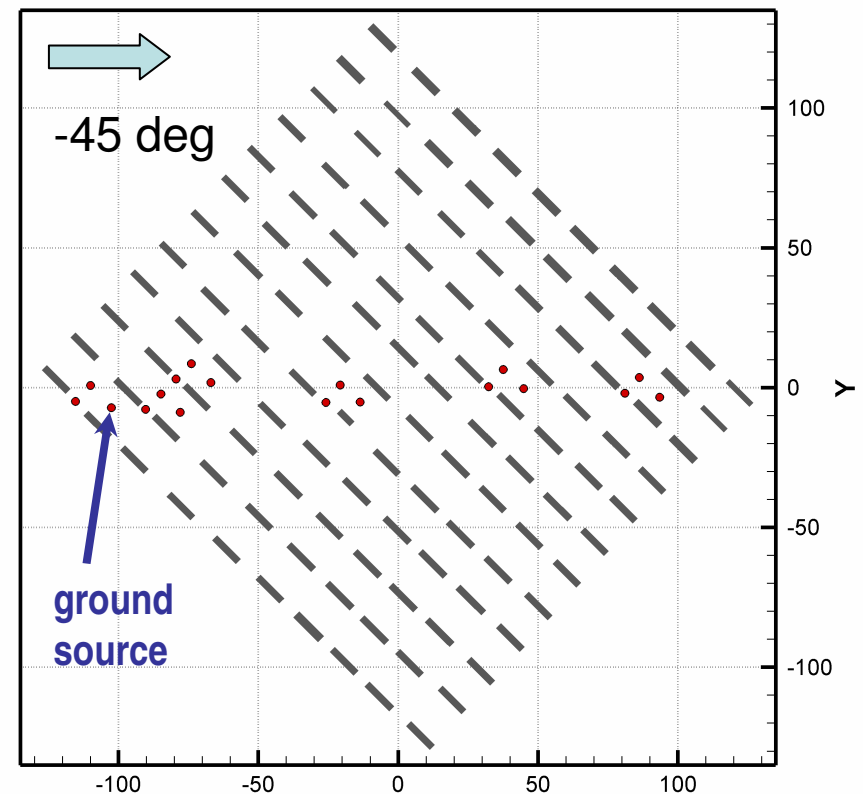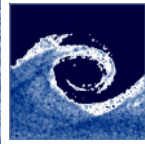
Code applied - MISKAM 5 & 6

- MISKAM: flow and dispersion model for urban environment

- RANS with k-ε turbulence closure, modified as suggested by Kato & Launder (1993) and Lopez (2002) on Arakawa-C Cartesian grid

- advective diffusion equation for dispersion

- simple numerical procedures, fast grid generation, runs on PC

- Used in environmental assessment etc.   ~100 users in Europe

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In the MUST exercise: MISKAM 5.01 and MISKAM 6 compared

- **New schemes** in MISKAM 6 instead of upstream scheme:

    - predictor corrector advection scheme (MacCormack, 1969) for momentum transport

   - use of corrected upstream scheme (MPDATA, Smolarkiewicz, 1989) for transport of scalars (k, ε)
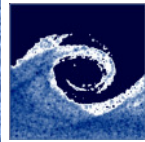
# MISKAM model setup

No	version	grid	comment
1	5.02	coarse	1m resolution
2	5.02	fine	0. 5m resolution
3	**6 b3**	**fine**	**0. 5m resolution**
4	**6 b3**	**refined**	**0.25m resolution**
5	**6 b3**	**fine**	**modified inlet TKE**
6	**6 b3**	**refined**	**modified inlet TKE, 0.25m resolution**

- Coarse, medium and fine grids showed grid dependency

- good agreement of inlet wind profiles, but computed TKE too low
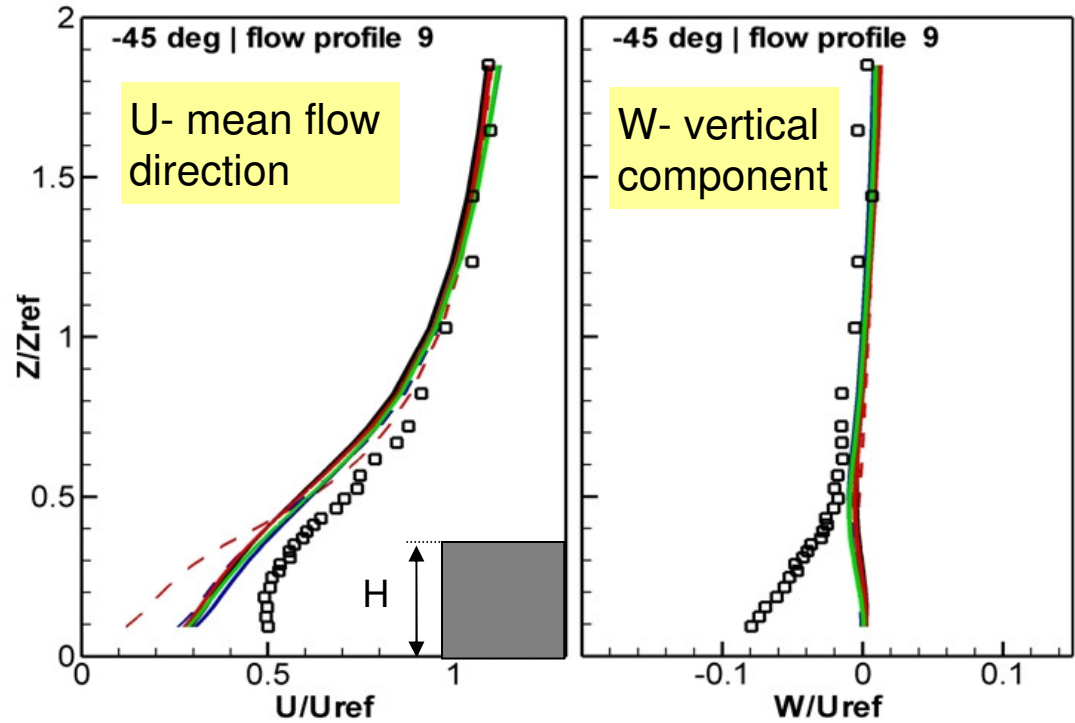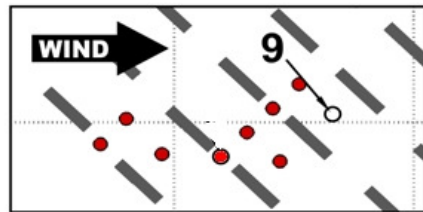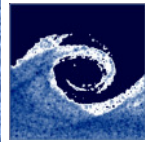
⇨ **modified profile**
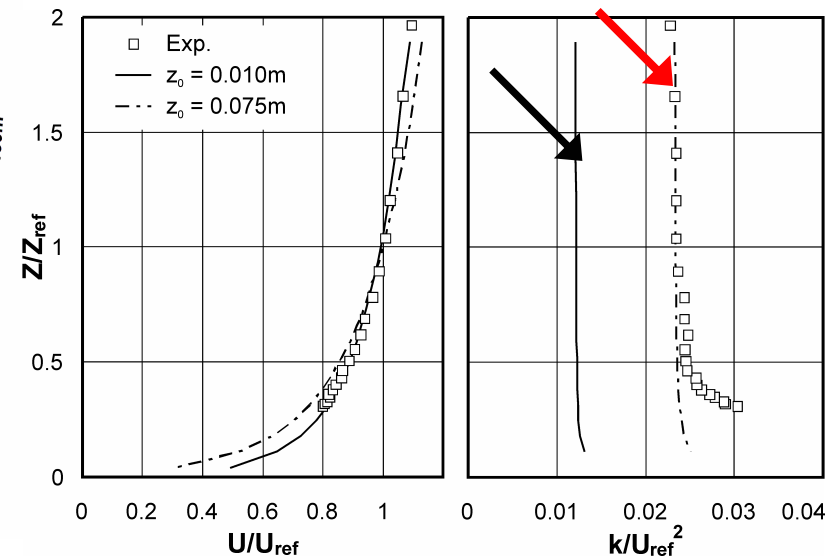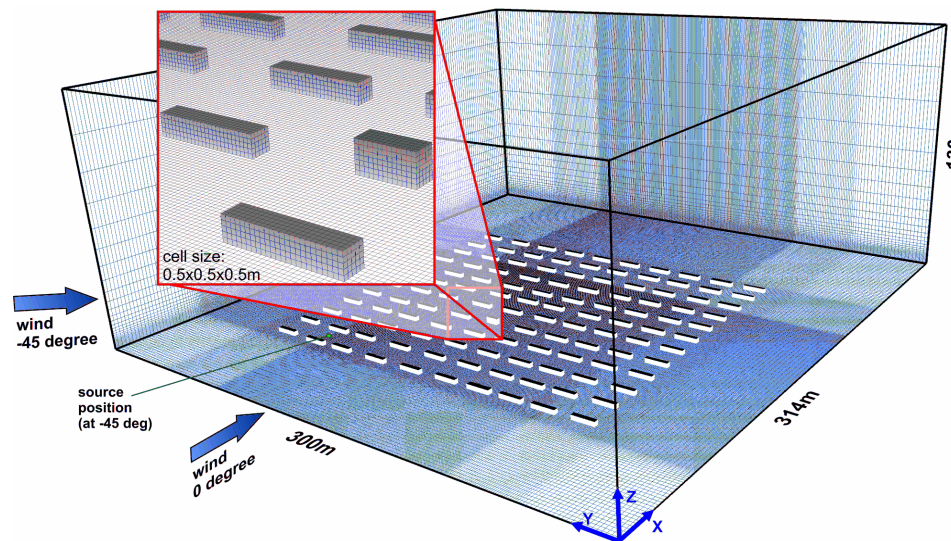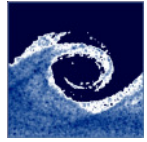
Wind field analysis

Example: one typical profile of velocity of a MISKAM 6 run
(from the 39 measured vertical profiles)

- Above-roof flow modelled correctly
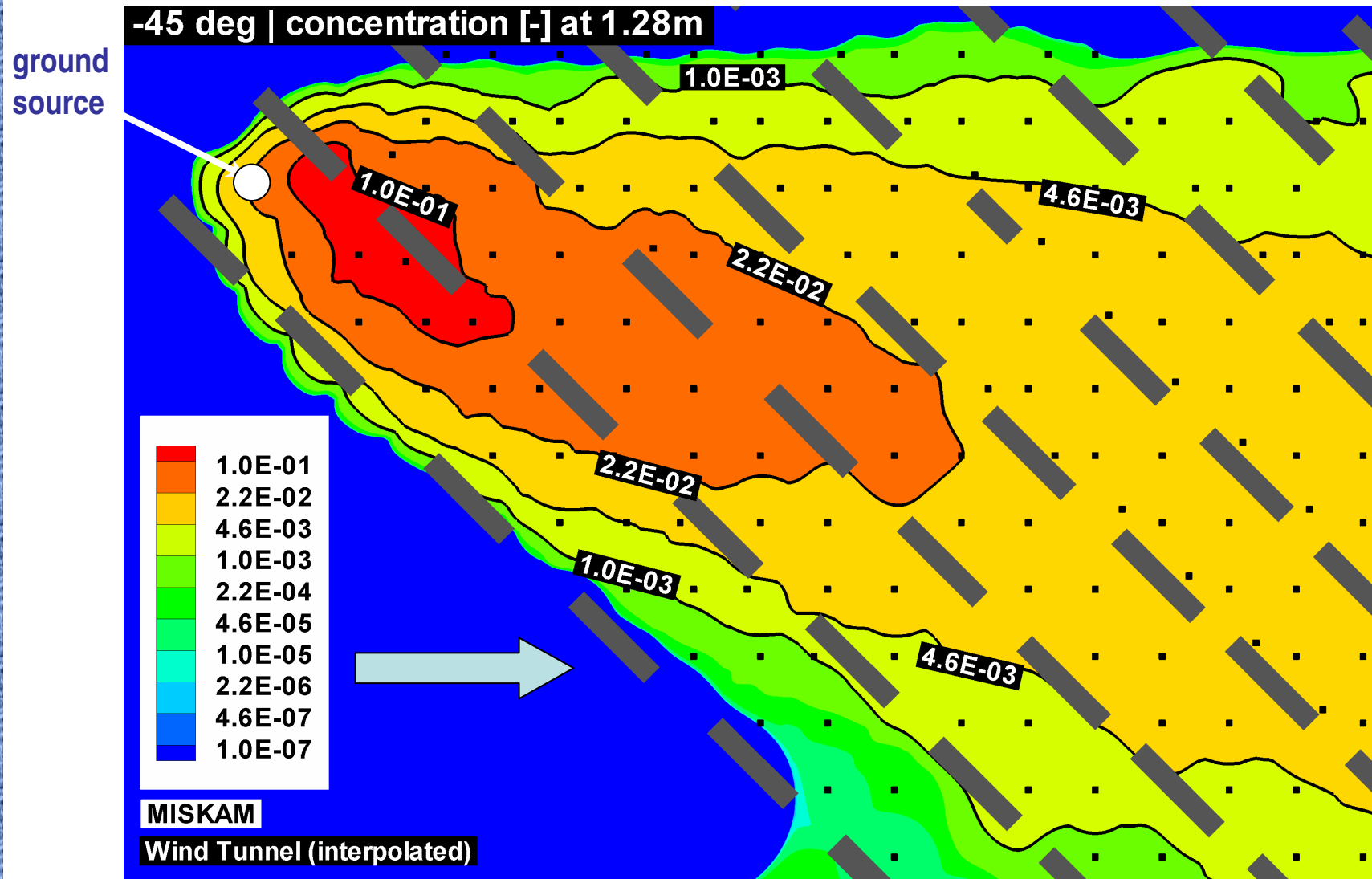
- Moderate improvement in U compared to 5.02
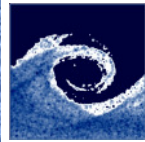
- Problem in W around buildings

□ Wind Tunnel Data
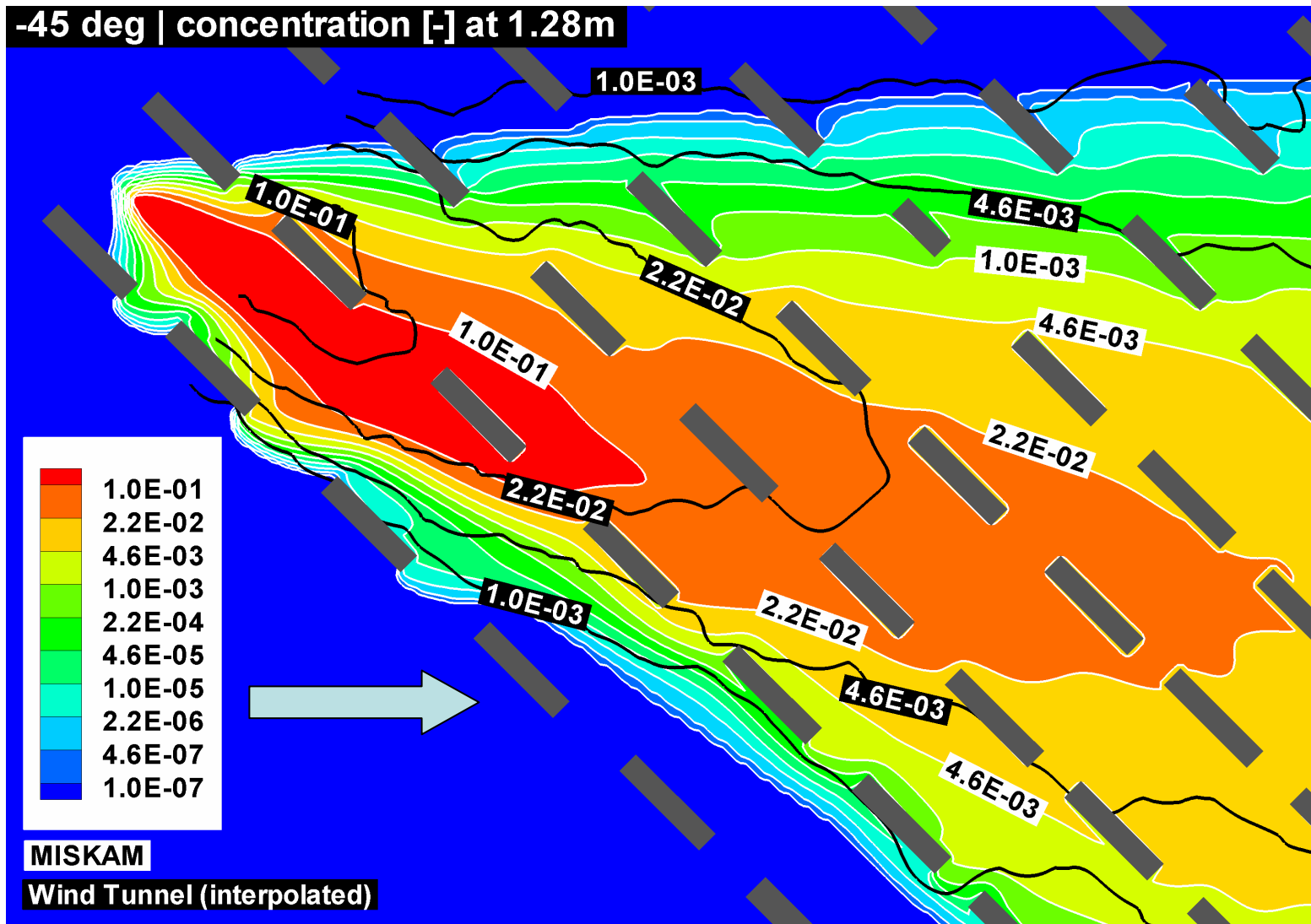- - - - - (1) 5.01, coarse grid
- - - - - (2) 5.01, fine grid
——— (3) 6 Beta 3, fine grid
——— (4) 6 Beta 3, refined grid
——— (5) 6 Beta 3, fine grid, modified profile
——— (6) 6 Beta 3, refined grid, modified profile

Concentration field analysis

- Measurement (interpolated) : plume direction different from inlet flow direction

-45 deg | concentration [-] at 1.28m

ground source

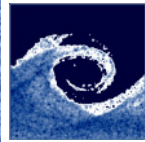|	
1.0E-01	
2.2E-02	
4.6E-03	
1.0E-03	
2.2E-04	
4.6E-05	
1.0E-05	
2.2E-06	
4.6E-07	
1.0E-07	

MISKAM
Wind Tunnel (interpolated)
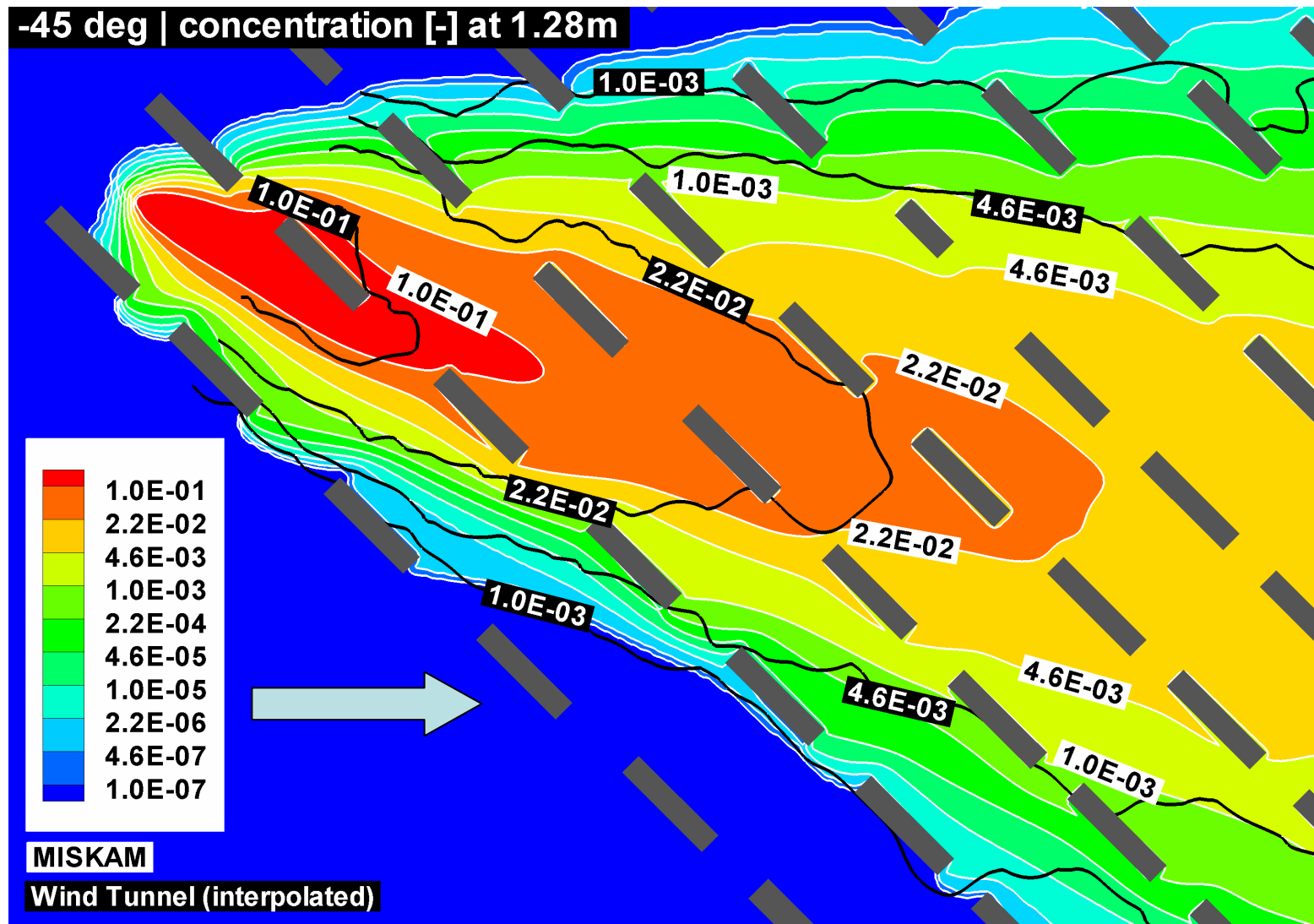
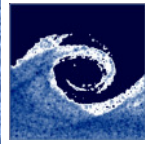# Concentration field analysis

- MISKAM 5.02

Concentration field analysis

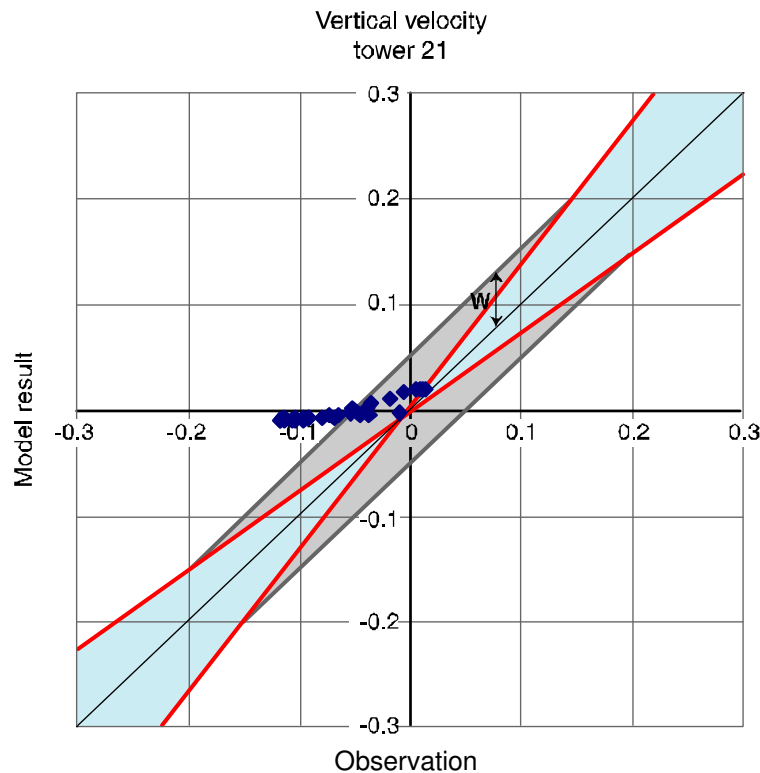- MISKAM 6 b3 with modified TKE profile: shorter plume

Validation metrics

- **Hit rate:** O – observation M- model result

- We have a hit, if: $\left| M_i - O_i \right| \leq W$ or: $\left| \dfrac{M_i - O_i}{O_i} \right| \leq D$

  allowed absolute deviation :   W (e.g. measurement error)
  allowed relative deviation: D   (+/-25%)

- Hit rate above 66% proposed as acceptance criterion

Vertical velocity tower 21

Graphical representation of hit rate from [5]

[6] VDI 3783, Blatt 9: Environmental meteorology - Prognostic microscale windfield models - Evaluation for flow around buildings and obstacles. Beuth-Verlag, Berlin, Germany (2005)

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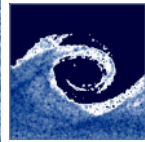
Validation metrics

Hit rate of different MISKAM runs at 45 deg wind dir.

- Acceptance limit reached only for some variables
- MISKAM 6 performs better
- Grid resolution, input parameters have an influence

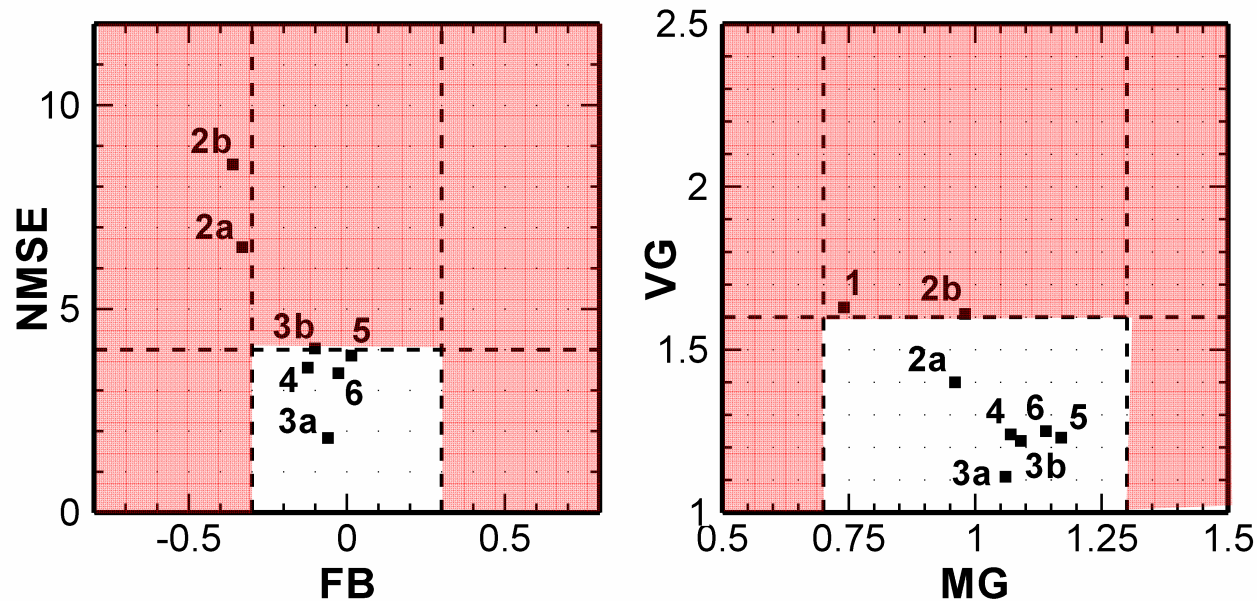|	V.	comment
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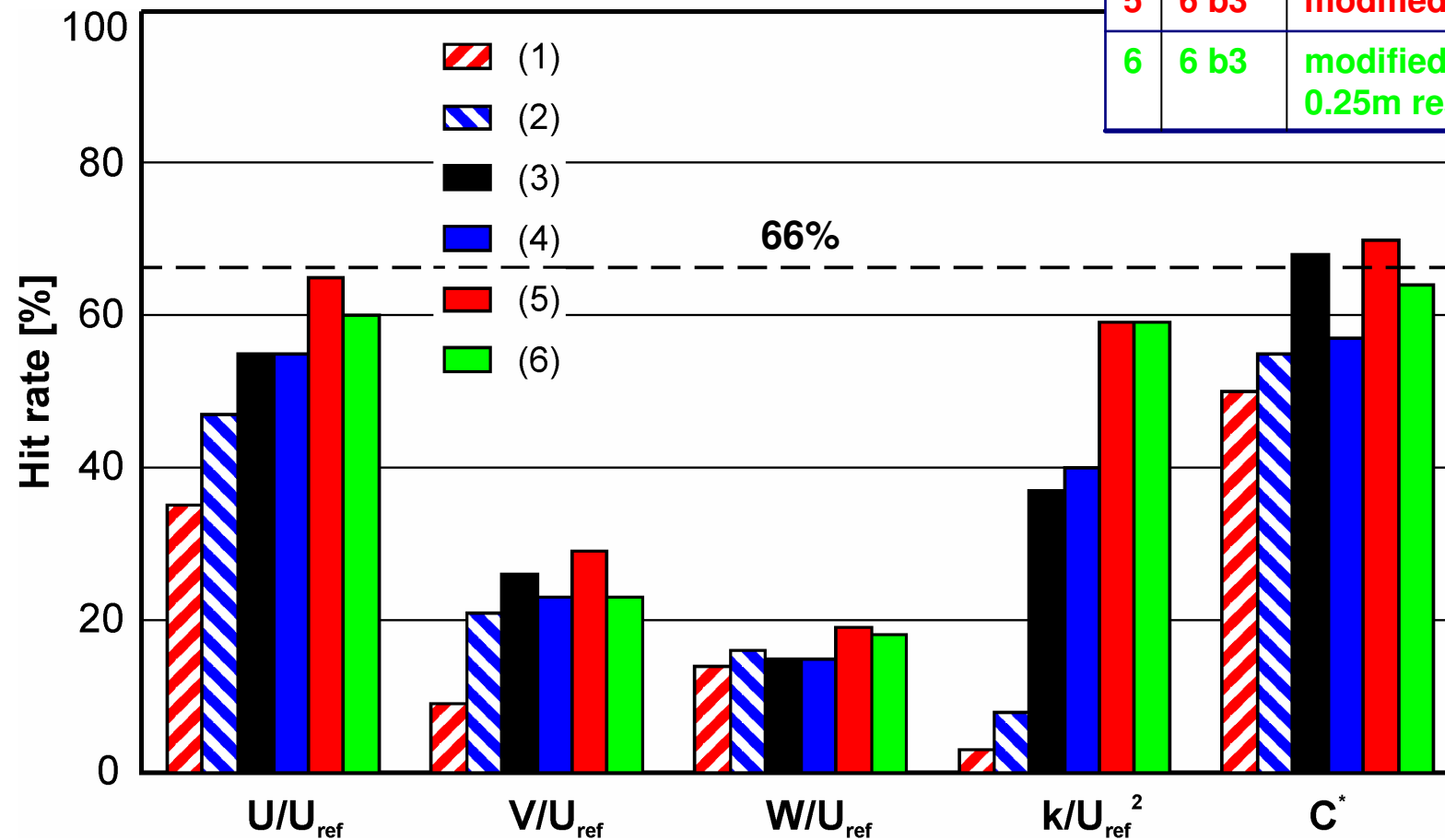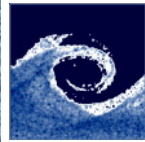
Validation metrics

For non-negative scalars (concentration) further metrics used in COST 732:

- Normalized mean square error (NMSE), fractional bias (FB), geometric mean bias (MG) and geometric variance (VG) *

  - Acceptance criteria defined *

	V.	comment
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6	6 b3	modified inlet TKE 0.25m resolution

[7] CHANG, J.C. AND HANNA, S.R.: Air quality model performance evaluation -Meteo. Atmos. Phys. 87 (2004) 167-196.
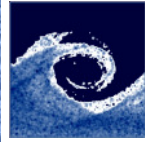
Conclusions

About the MISKAM model

- New schemes of MISKAM6 ⇨ improvements in results
  - Main flow features resolved well
  - Smaller flow structures around containers not resolved properly
  - Concentration field although acceptable

- Advices to MISKAM users on model setup

Regarding COST 732

- Multiple check of input geometry, parameters, measurement locations necessary

- Data visualization and exploratory analysis is essential before applying validation metrics
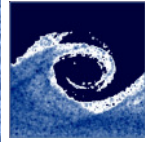
THE END

Thank you for your attention!

COST 732 homepage
http://www.mi.uni-hamburg.de/Home.484.0.html