Flow and Dispersal Simulations of the Mock Urban Settings Test

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Outline

– MISKAM – version 5.x → 6
– Evaluation
– Model setup for MUST simulations
– Flow simulations
– Dispersal simulations
– Discussion
MISKAM – up to version 5.x

- threedimensional non-hydrostatic flow model
- $k-\varepsilon$ turbulence closure, modified as suggested by Kato & Launder (1993) and Lopez (2002)
- simple numerical procedures, runs on standard PC
- ~ 100 implementations in Europe
MISKAM – version 6

– optional: use of predictor corrector advection scheme \((MacCormack, 1969)\) for momentum transport
– optional: use of corrected upstream scheme \((MPDATA, Smolarkiewicz, 1989)\) for transport of scalars \((k, \varepsilon)\)
– minor bug fixes
Evaluation following VDI guideline

– first results (MISKAM 6 beta2) presented at Harmo11, Cambridge
– two bugs fixed in the meantime → MISKAM 6 beta3
– repetition of evaluation process gives irritating results in some cases
## Comparison to wind tunnel data - near field

<table>
<thead>
<tr>
<th>Test case C4, 223°</th>
<th>Hit rate %</th>
<th>(required according to guideline: 66)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>u</td>
<td>v</td>
</tr>
<tr>
<td>MISKAM 5.02</td>
<td>74</td>
<td>67</td>
</tr>
<tr>
<td>MISKAM 6 beta2</td>
<td>76</td>
<td>68</td>
</tr>
<tr>
<td>MISKAM 6 beta3</td>
<td>75</td>
<td>67</td>
</tr>
</tbody>
</table>
Comparison to wind tunnel data - near field

MISKAM 5.02  MISKAM 6 beta2  MISKAM 6 beta3

'right for the wrong reason'?
Comparison to wind tunnel data - near field

An explanation?

– turbulence energy inaccurate near building walls (wall functions, grid resolution)
– flaw ‘preserved‘ by refined MPDATA advection scheme
– beta 2 erroneously did not use MPDATA scheme

Discard latest version?

– overall, no significant changes of evaluation results → NO
Model setup for MUST simulations

- Wind direction:
  - 0 degree
  - -45 degree

- Source position:
  - At -45 degrees

- Cell size:
  - 0.5x0.5x0.5m
Model setup for MUST simulations

Flow simulations:
– grid size 400 x 400 x 30 cells
– grid resolution 0.5 – 2 m
– surface roughness length 2 cm
– building roughness length 2 mm

Dispersal simulations:
– point source at lowest grid level
– continuous emission
Model setup for MUST simulations

Inflow profiles:
- good agreement between computed and observed wind profiles
- computed TKE too low ($z_0$ too low?)
Flow simulations - positions of vertical profiles

0°

-45°
Flow simulations – 0° case

Profiles in the wake of containers:

- profiles of MISKAM 5.x and 6 almost similar, fine grid better
- U: lower velocities than in wind tunnel
- W: downstream flow component at container height not resolved
Flow simulations – 0° case

Profiles in the longitudinal „streets“:

- profiles of MISKAM 5.x and 6 almost similar, fine grid better
- U: lower velocities than in wind tunnel
- W: both in WT and simulation around 0
Flow simulations – -45° case

- profiles of MISKAM 5.x and 6 differ remarkably in some cases
- simulation results of W again more problematic than those of U
Dispersal simulations – -45° case

MISKAM 5 results:
- plume direction in simulation different from the experimental one
- larger values of concentration near the source
- MPDATA scheme: thinner and longer plumes
Dispersal simulations – -45° case

MISKAM 6 results:
- plume direction in simulation overlapping with the measurement
- near-source concentrations lower than in MISKAM 5
- MPDATA scheme: again thinner and longer plumes
Dispersal simulations – -45° case

Significant improvement of MISKAM 6 results in comparison to version 5.x
Dispersal simulations – -45° case

Horizontal profiles of $C^*$
Dispersal simulations – -45° case
Dispersal simulations – -45° case

Horizontal profiles of C*
Dispersal simulations – -45° case

Horizontal profiles of C*

- Wind tunnel measurement
- 5.01 upstream scheme
- 5.01 MPDATA scheme
- 6 beta3 upstream scheme
- 6 beta3 MPDATA scheme
### Statistical evaluation of dispersal results

<table>
<thead>
<tr>
<th>Metric</th>
<th>NMSE</th>
<th>R</th>
<th>FAC2</th>
<th>FB</th>
<th>Hit rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceptance criteria</td>
<td>&lt; 4</td>
<td>&gt; 0.8</td>
<td>&gt; 0.5</td>
<td>-0.3 &lt;…&lt; 0.3</td>
<td>&gt; 0.66</td>
</tr>
<tr>
<td>MISKAM 5.01 coarse grid</td>
<td>23.29</td>
<td>0.54</td>
<td>0.40</td>
<td>-0.88</td>
<td>0.5</td>
</tr>
<tr>
<td>MISKAM 5.01 fine grid upstream scheme</td>
<td>6.26</td>
<td>0.76</td>
<td>0.53</td>
<td>-0.32</td>
<td>0.62</td>
</tr>
<tr>
<td>MISKAM 5.01 fine grid MPDATA scheme, 2 steps</td>
<td>9.21</td>
<td>0.71</td>
<td>0.45</td>
<td>-0.37</td>
<td>0.53</td>
</tr>
<tr>
<td>MISKAM 6 beta3 fine grid upstream scheme</td>
<td>0.53</td>
<td>0.96</td>
<td>0.60</td>
<td>-0.02</td>
<td>0.77</td>
</tr>
<tr>
<td>MISKAM 6 beta3 fine grid MPDATA scheme, 2 steps</td>
<td>1.18</td>
<td>0.92</td>
<td>0.50</td>
<td>-0.02</td>
<td>0.66</td>
</tr>
</tbody>
</table>
Hit rates for flow variables and concentrations

Calculated for all measurements of the 0° and -45° MUST case (up to 3462 measurement points) with allowed deviation D of 25% and threshold W according the table.

W

<table>
<thead>
<tr>
<th>Variable</th>
<th>W</th>
</tr>
</thead>
<tbody>
<tr>
<td>U/U_{ref}</td>
<td>0.008</td>
</tr>
<tr>
<td>V/U_{ref}</td>
<td>0.007</td>
</tr>
<tr>
<td>W/U_{ref}</td>
<td>0.007</td>
</tr>
<tr>
<td>k/U_{ref}^2</td>
<td>0.005</td>
</tr>
<tr>
<td>C*</td>
<td>0.003</td>
</tr>
</tbody>
</table>
Discussion

− improvements of model code not exactly reflected by evaluation results
− MPDATA scheme reveals possible problems of turbulence closure
− significant improvement of dispersal results based on refined advection schemes in flow model
− as a whole, MISKAM 6 beta3 is a clear improvement compared to previous versions
Discussion

- revision of turbulence model is expected to improve flow simulations
- additional simulations of the MUST setup are planned
  - refined grid resolution at container height
  - higher inlet turbulence