Building-Resolved Urban Dispersion Models Evaluated with MID05 Data


Background

The Urban Dispersion Program (UDP) was a collaborative research program involving a number of national laboratories, federal agencies, and universities. Research activities under this program were conducted from 2004 through 2007, and comprised several major elements:

- Limited-scale dispersion study in the vicinity of Madison Square Garden in New York City ( MSG05 )
- Large-scale dispersion study in Midtown Manhattan in New York City ( MID05 )
- Permanent meteorological network and web-accessible observations for emergency response
- Modeling of MSG05 and MID05 cases to improve urban dispersion modeling

Overview

It is vitally important that models are evaluated against field data to identify the strengths and weaknesses of the models. This assessment of the model output guides improvements to modeling systems and informs users on the limitations of the model output.

In this study, six building-resolved urban dispersion modeling systems were evaluated using data from the MID05 field experiment. The models that were evaluated accounted for urban geometries when calculating wind and concentration fields, and are therefore useful tools for emergency planning and response and long-term recovery.

The primary objective of this study was to evaluate the performance of the science building-resolved models that are available for application in addressing national homeland security needs. A secondary objective was to identify critical technical gaps in urban dispersion modeling and to recommend future research needed to fill these gaps. The concept for this evaluation study was to examine the effectiveness of the modeling system as a whole in simulating the cases that were presented. Staff at Pacific Northwest National Laboratory (PNNL) served as the model evaluation team. Five modeling groups used unique computational fluid dynamic (CFD) codes, while one group used a semi-empirical building-resolved model.

Table 1. Model Evaluation Study Participants

<table>
<thead>
<tr>
<th>Participant</th>
<th>Model</th>
<th>Turbulence Model</th>
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<tbody>
<tr>
<td>CFD Research Corporation (CFDRC)</td>
<td>CFD-Urban</td>
<td>RANS k- * with “ABL” coefficients</td>
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<tr>
<td>GasCon</td>
<td>FLACS</td>
<td>RANS standard k-</td>
</tr>
<tr>
<td>National Oceanic and Atmospheric Administration (NOAA/DEAP)</td>
<td>EPA-Fluent</td>
<td>RANS realizable k-</td>
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<tr>
<td>Lawrence Livermore National Laboratory (LLNL)</td>
<td>FAST3D-CT</td>
<td>RANS similarity closure</td>
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<tr>
<td>Navy Research Laboratory (NRL)</td>
<td>QUIC</td>
<td>Local gradient &amp; non-local mixing</td>
</tr>
<tr>
<td>Los Alamos National Laboratory (LANL)</td>
<td>GexCon</td>
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</tbody>
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The model evaluation team, in cooperation with the modeling groups, developed a model evaluation plan:
- Simulate four tracer experiments from the MID05 study
- Each simulation consisted of a 30-minute long tracer release from up to 3 locations.
- Each simulation was a 2-hour period starting at the beginning of the tracer release.
- The model evaluation team provided necessary data to the modeling groups including:
  - Building geometry
  - Meteorological measurements (starting with the hour preceding the simulation period)
  - Tracer release rate and location
  - Boundary conditions
  - Sensitivity studies

Results

A rigorous evaluation of the model performance was conducted, comparing concentrations paired in time and space.
- Hour1 was generally simulated well, while Hour2 simulation performance was not as strong.
- Concentrations differ due to differences in approach flow conditions rather than differences in fundamental model formulations
- No appreciable differences in the model performance between the setup and blind cases

The best Hour1 model performance features:
- Predominantly 70% of the observed plume
- Predominantly 10% of predicted plume concentrations were false negatives
- 80% of the observed plume
- 20% of the predicted plume concentrations were false positives
- 90% of predicted concentrations were within a factor of 2 of observations
- 40% of predicted concentrations were within a factor of 2 of observations

Statistical Evaluation

- BOPT code (Chang and Hanna, 2005)
- Fractional bias, normalized root mean square error, geometric mean, FAC2, FAC10, etc.
- Aggregate model performance score

Graphical Evaluation

- Horizontal contour plots of observed and predicted tracer concentrations at 3m AGL
- Vertical contour plots of predicted tracer concentrations (for a selected case)

Acknowledgments

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- We also acknowledge the contribution of Dr. Chris Doran (PNNL). His involvement, particularly in the planning phases of this project, was integral to its success.
- GexCon's participation in this study was voluntary and at their own expense.
- FLUENT-ERA efforts were supported by NOAA, US EPA, and DOE-ERA Interagency Agreement (JAG, RY-89-0220701). FLUENT-ERA computations would not have been possible without the use of the Argonne National Laboratory and Univ. of North Carolina at Chapel Hill clusters. Additionally, support from the US EPA Environmental Modeling and Visualization Laboratory, and in particular Matt Freeman and Wei Tang, is greatly appreciated.


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