An Overview of Recent Research and Development on Building Downwash

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Summary of EPA Research and Development
Wind Tunnel Study

Building Geometry

<table>
<thead>
<tr>
<th>H x W</th>
<th>H = 15 cm</th>
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<tbody>
<tr>
<td>1 x 2</td>
<td>1 x 4</td>
</tr>
<tr>
<td>1 x 8</td>
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(L = H)

Source Height and Location

h_s = 1.2H, 1.5H, 2H, 3H, 4H

Wind Angle

Θ = 0°, 15°, 30°, 45°, 60°

Model Scale 1:150

Embedded LES Approach

- LES zone subgrid-scale model
  - WALE (Wall-Adapting Local Eddy viscosity)
- RANS zone:
  - Shear-Stress Transport k-ω model
  - Schmidt number = 0.7
- Interface treatment:
  - Vortex method

3D Computational Mesh (x-z slice)
~ 6 million grid cells in domain
Wind Tunnel & LES

1x2, hs = 1.5H, DM0, 0deg, y/H = 0

FLUENT (LES)
How PRIME works:

• Defines near & far wake boundaries
• Deflects the plume centerline based on building-affected streamlines
• Partitions the plume: Primary, Cavity & Re-emitted
• Adjusts plume growth rate in wake based on wake turbulence
Ground-level concentration for a 1x2x1 building and a 1.5H stack
Three proposed model enhancements:

• Fix mismatch in plume width at transition between cavity and far wake
Proposed Enhancement 1

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• Fix mismatch in plume width at transition between cavity and far wake
• Use effective wind speed for primary plume (currently using stack height wind speed)
Three proposed model enhancements:

• Fix mismatch in plume width at transition between cavity and far wake
• Use effective wind speed for primary plume (currently using stack height wind speed)
• Adjust cap on ambient turbulence level
Performance with Proposed Enhancements

Ground-level concentration for a 1x2x1 building and a 1.5H stack
Wind Tunnel Based Model Evaluation

Wind direction – 0°

Stack location:
o: DM0, ✗: UM0; ♦: UC-;
★: DC+.

Measurement location:
Open symbols: \( x = 3H \);
Closed \( x = 10H \).

Bldg size (symbol size):
Small – 1:1:2;
Medium – 1:1:4;
Large – 1:1:8
Wind Tunnel Based Model Evaluation

**Wind direction – 45°**

Stack location:
o: DM0, ✺: UM0; ♦: UC-; ★: DC+.

Measurement location:
Open symbols: $x = 3H$;
Closed $x = 10H$.

Bldg size (symbol size):
Small – 1:1:2;
Medium – 1:1:4;
Large – 1:1:8
Proposed Update to BPIP

4th Enhancement for non-perpendicular winds:
BPIP – AERMOD’s building pre-processor

Long building at 45° to wind

BPIP creates substitute building based on extremities of footprint

Test alternative based on along-wind length of building cross section
• Wind tunnel study
  • Journal article – Perry et al., 2016, *Atmos. Env.*, 142, 286-295
  • Examined building aspect ratio, source location, source height, and wind direction

• Analysis & comparison with AERMOD/PRIME
  • Journal article – Monbureau et al., 2018, *Atmos. Env.*, 179, 321-330
  • Proposed three changes to building downwash algorithms (wake turbulence, sigma matching, effective wind speed), plus a change to BPIP building pre-processor

• Embedded Large Eddy Simulations
  • Journal article – Foroutan et al., *Atmos. Env.*, available online
ORD Building Downwash – Next Steps

• Lateral plume shift in cavity with oblique wind angles
• Examination of the boundary of far wake region
• Reviewing PRIME2 contributions
PRIME2 coordination update
Coordination with PRIME2 Committee

• February 2018, EPA hosted the PRIME2 Committee for a day-long “Downwash Summit”
• Primary focus on cross-review of technical work
  • Identify areas of overlap between ORD and PRIME2 efforts
  • Particular focus on proposed BPIP changes
• Discussed path forward on sharing proposed code updates
  • PRIME2 committee working to refine code updates to share with EPA
  • ORD shared BPIP code updates with PRIME2 committee
EPA’s planned path forward
EPA’s planned path forward

• PRIME updates to be released as alpha options
• Updates from ORD and PRIME2 likely to be separate “sets”
  • Each of the changes proposed by groups likely to be individual options in each set, similar to the new LOW_WIND approach
• Planned as part of next year’s model release (19xxx)
• Key model evaluation needs
  • Model evaluation targeted at individual “pieces” of proposed updates and the composite effect
  • Need to determine if existing databases are sufficient