AERMOD Version 13350 Low Wind Options: Sensitivity Analysis and Evaluation Update

Study conducted on behalf of:

- API for sensitivity analysis
- Lignite Energy Council for evaluation update
Outline of Presentation

• Purpose and objectives of this study for AERMOD low wind options

• Sensitivity Study Funded by API
  – Model Options Tested
  – Source Types Modeled for Flat and Complex Terrain
  – Results of Sensitivity Analysis

• Evaluation Study Funded by Lignite Energy Council
  – Models and Options Tested
  – Database Tested to Date
  – Results of Evaluation Tests to Date
Purpose and Objectives: Sensitivity Analysis

• Explore the sensitivity of the AERMOD low wind speed options for predicted impacts in both flat and complex terrain

• Tested for a variety of emission sources of interest to the American Petroleum Institute and their members

• 11 different source types were examined, ranging from tall buoyant point sources to low-level fugitive sources

• Examined types of sources significantly affected by use of the low wind options in AERMET and AERMOD

• NO$_2$ was the pollutant selected → assumed full conversion of NOx to NO$_2$

• Model setup was based on hypothetical locations, but used input parameters and building downwash (when applicable) from real model applications
Model Configurations and Options for Sensitivity Analysis

- AERMET/AERMOD Versions 13350 and 14134

- Three model configurations were run
  1. AERMET/AERMOD all default
  2. AERMET (Beta u*) / AERMOD (default)
  3. AERMET (Beta u*) / AERMOD (LOWWIND2)

- Each model configuration was run for each source in both flat and complex terrain

- Results from AERMOD versions 13350 and 14134 were the same
## Model Inputs: Source Types

<table>
<thead>
<tr>
<th>Source ID</th>
<th>Source Description</th>
<th>Stack Height (m)</th>
<th>Stack Temp (K)</th>
<th>Stack Vel. (m/s)</th>
<th>Stack Diameter (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FCC</td>
<td>Source 1: a tall buoyant point source indicative of an FCC (fluid catalytic cracking) refinery source (including building downwash)</td>
<td>54.0</td>
<td>561.0</td>
<td>49.1</td>
<td>2.0</td>
</tr>
<tr>
<td>FLARE</td>
<td>Source 2: a tall buoyant point source representing a flare (pseudo temp and velocity modeled to conserve buoyancy flux)</td>
<td>75.6</td>
<td>1273.0</td>
<td>20.0</td>
<td>1.1</td>
</tr>
<tr>
<td>REGENHTR</td>
<td>Source 3: a tall buoyant point source indicative of a CCR (continuous catalytic regenerative reformer) refinery source (including building downwash)</td>
<td>104.2</td>
<td>450.0</td>
<td>12.2</td>
<td>3.7</td>
</tr>
<tr>
<td>GASTURB</td>
<td>Source 4: a buoyant point source indicative of gas turbine at a compressor station (including building downwash)</td>
<td>13.7</td>
<td>777.0</td>
<td>41.6</td>
<td>1.2</td>
</tr>
<tr>
<td>DIESENG</td>
<td>Source 5: a short-stack horizontal release point source indicative of a diesel generator (including building downwash)</td>
<td>9.1</td>
<td>697.0</td>
<td>0.001</td>
<td>0.60</td>
</tr>
<tr>
<td>DRILLRIG</td>
<td>Source 6: a buoyant point source indicative of a drill rig (e.g., used at a fracking site, including building downwash)</td>
<td>6.1</td>
<td>665.0</td>
<td>45.0</td>
<td>0.3</td>
</tr>
<tr>
<td>LNGTURB</td>
<td>Source 7: a combustion turbine source indicative of drilling or LNG facility operations.</td>
<td>13.7</td>
<td>777.0</td>
<td>30.0</td>
<td>3.0</td>
</tr>
<tr>
<td>PNTTANK</td>
<td>Source 8: a non-buoyant point source located on a tank (including downwash)</td>
<td>14.6</td>
<td>ambient</td>
<td>0.001</td>
<td>0.001</td>
</tr>
<tr>
<td>COMPRSTA</td>
<td>Source 11: buoyant point source associated with a compressor station at a coal bed methane drilling site (including downwash)</td>
<td>14.3</td>
<td>449.8</td>
<td>22.8</td>
<td>1.8</td>
</tr>
<tr>
<td>AREA</td>
<td>Source 9: a ground-level area source</td>
<td>Release Height (m)</td>
<td>X-Dim. (m)</td>
<td>Y-Dim. (m)</td>
<td>Initial Sigma-Z (m)</td>
</tr>
<tr>
<td>ROADVOL</td>
<td>Source 10: a volume source representing roadway traffic</td>
<td>Release Height (m)</td>
<td>Initial Sigma-Y (m)</td>
<td>Initial Sigma-Z (m)</td>
<td></td>
</tr>
</tbody>
</table>
Model Inputs: Receptors

- 50 meter spacing out to 500 meters
- 100 meter spacing out to 1,000 meters
- 200 meter spacing out to 2,000 meters
- 500 meter spacing out to 5,000 meters
- 1,000 meter spacing out to 10,000 meters
- 2,000 meter spacing out to 20,000 meters

- Additional receptors placed in complex terrain areas
- AERMAP was used to calculate elevation and critical hill heights for all receptors
Model Inputs: Meteorology

- Two meteorological databases used in the study
  1. Flat Terrain - 2007-2011 from Pascagoula, Mississippi
  2. Complex Terrain - 2008-2012 from Page, Arizona

- Both meteorological databases feature a fairly large percentage of low wind speed hours
  - Winds < 1.5 m/s at least 25% of the time
  - Winds < 2.5 m/s at least 60% of the time

- The location of the hypothetical sources in complex terrain was strategically positioned near (and upwind of) a major terrain feature
Flat Terrain Wind Rose and Frequency Distribution

Wind speeds < 2.5 m/s over 60% of the time
Complex Terrain Wind Rose

Wind speeds < 2.5 m/s over 60% of the time
Model Relative Sensitivity Results: Flat Terrain

Relative AERMOD Peak and 1-hour NO2 Design Concentrations - Flat Terrain

Legend:
- Downwash = D or blank
- Low Wind (< 1.5 m/s) = L or blank
- Stability = Stable, Unstable, Neutral

*modeled as horizontal release

- Default Design Conc.
- Beta u* Design Conc.
- LW2 Design Conc.
- Default Maximum Conc.
- Beta u* Maximum Conc.
- LW2 Maximum Conc.

gray shading indicates modeled concentrations are insensitive to LW Options
AERMOD Low Wind Sensitivity – Flat Terrain

- Tall buoyant stacks (FCC, FLARE, REGENHTR) were insensitive to the LW options - max impacts occur during unstable conditions

- Short buoyant stacks with downwash (DRILLRIG, COMPRSTA) insensitive to LW options - max impacts did not occur under light winds

- Short stacks without either momentum or buoyancy with downwash (DIESENG, PNTTANK) and fugitive sources are sensitive to LW options resulting in lower concentrations
  - max impacts occurred under light wind stable conditions
  - beta u* increase mechanical mixing and vertical dispersion

- LNGTURB (short buoyant non-downwashing) source experienced a high wind “side effect” of the LW options
  - max impacts occur under high wind neutral conditions
  - use of beta u* causes higher turbulence and plume touch down closer to the stack

- Low-level sources have peak impacts at low terrain near fenceline in complex terrain case as well
Model Relative Sensitivity Results: Complex Terrain

Relative AERMOD Peak and 1-hour NO2 Design Concentrations - Complex Terrain

Legend:
- Terrain Type = Complex or Flat
- Downwash = D or blank
- Low Wind (< 1.5 m/s) = L or blank
- Stability = Stable, Unstable, Neutral

Concentration Relative to Default Modeled Maximum

* modeled as horizontal release

gray shading indicates concentrations occur in flat terrain
AERMOD Low Wind Sensitivity – Complex Terrain

- Tall buoyant stacks (FCC, FLARE, REGENHTR) are sensitive to the LW options in complex terrain
  - For default options, max impacts occur under light wind speed stable conditions
  - Use of beta u* increases effective wind speed, mechanical mixing, vertical dispersion, and plume rise; reduces predicted concentrations
  - Use of LowWind2 also increases lateral dispersion and lower concentrations

- LNGTURB (short, non-downwashing) is sensitive to LW options
  - For default options, max impacts occur under light wind stable conditions
  - Use of beta u* increases mechanical mixing height and vertical dispersion

- COMPRSTA (short, downwashing) responds to LW options
  - For default options, max impact occurs under stable conditions (downwash)
  - Lower max impact for beta u* option occurs in downwash during high wind unstable conditions
Lignite Energy Council Evaluation of AERMOD Low Wind Options for Tall Stack Releases

North Dakota Evaluation Study Layout

Legend
- Monitoring Stations
- EGUs
- GPSP

0 2.5 5 10 Kilometers
Terrain Contours for SO$_2$ Monitors Used in the ND Study

(10-m contour interval)
## Preliminary AERMOD Evaluation Results* with Actual Hourly Emissions for North Dakota 4-year Database (07-10)

<table>
<thead>
<tr>
<th>Monitor</th>
<th>Obs. Conc. 4-yr Avg</th>
<th>AERMOD 14134 with default options: Pre/obs ratio</th>
<th>AERMET with beta u*, default AERMOD: Pre/obs ratio</th>
<th>AERMET with beta u*, AERMOD with LOWWIND2 with min sigma-(v = 0.5) m/s: Pre/obs ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>DGC #12</td>
<td>91.52 µg/m(^3)</td>
<td>1.28</td>
<td>1.28</td>
<td>1.05</td>
</tr>
<tr>
<td>DGC #14</td>
<td>95.00 µg/m(^3)</td>
<td>1.45</td>
<td>1.45</td>
<td>1.05</td>
</tr>
<tr>
<td>DGC #16</td>
<td>79.58 µg/m(^3)</td>
<td>2.00</td>
<td>2.00</td>
<td>1.58</td>
</tr>
<tr>
<td>DGC #17</td>
<td>83.76 µg/m(^3)</td>
<td>2.07</td>
<td>1.49</td>
<td>1.29</td>
</tr>
<tr>
<td>Beulah</td>
<td>93.37 µg/m(^3)</td>
<td>1.31</td>
<td>1.31</td>
<td>1.01</td>
</tr>
</tbody>
</table>

* Note: assumes \(\text{SO}_2\) background of 10 µg/m\(^3\)
Conclusions

• This study reports sensitivity and field evaluation results for low wind options in AERMET/AERMOD

• Sensitivity was tested for 11 different source types

• In flat terrain, this option is important for low-level, non-buoyant source types, and not for tall, buoyant stacks

• In complex terrain, this option is very important for tall, buoyant stack releases

• Low wind speed evaluations are underway for real-world field databases featuring tall, buoyant stacks: ND, Gibson

• For the North Dakota database, low wind options lead to better AERMOD performance, especially for the elevated terrain monitor. SCICHEM does well for this database.