AIR DISPERSION MODELING
Use of AERMOD for NAAQS Area Designations and State Implementation Plan Submittals

SPEAKER
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DATE
February 10, 2016
Presentation Objectives:

- Purpose for Air Dispersion Modeling
- Applications and regulatory uses for Air Dispersion Modeling
- Limitations of Air Dispersion Modeling using AERMOD
- Difficulty to demonstrate modeled compliance with 1-hr National Ambient Air Quality Standards (NAAQS)
PURPOSE FOR AIR DISPERSION MODELING
PURPOSE FOR AIR DISPERSION MODELING

Types Of Data Used

Predict future ambient air quality using:

- Past Meteorological Data
- Past Pollution Data from Ambient Air Monitoring Stations
- Stationary and/or Mobile Source Permitted Emission Limits
- Continuous Emissions Monitoring (CEMS) Data
- Surrounding Terrain and Topography Data
Air Dispersion Models:

• **Screen3 / AERSCREEN**
  - Simple estimation of air quality

• **AERMOD**
  - EPA’s preferred near field air dispersion model

• **CALPUFF**
  - Preferred model for assessing long range transport of pollutants and their impacts on Federal Class I visibility areas

• **SCIPUFF (Second-order Closure Integrated Puff)**
  - Very Sophisticated and Requires considerable time for input and data processing
Air Dispersion Models (continued):

- **SLAB**
  - Dense gas model used in RMP
- **PLUVUEII**
  - Atmospheric visibility degradation and discoloration
- **AUSTAL2000 (Germany)**
  - Official Dispersion Model used in the permitting of industrial sources in Germany
- **LOTOS-EUROS (Netherlands)**
  - Models dispersion of photo-oxidants, aerosols, and heavy metals for intercountry transport through Eurozone.
AIR DISPERSION MODELING
Applications & Regulatory Uses
Applications

- Design of Stacks
- Design of Air Pollution Control Equipment
- Emergency Planning for Accidental Chemical Releases

Regulatory Uses

- PSD/NSR Permitting
  - Evaluate Impact of a new pollution source(s)
  - Evaluation Impact of “Major Modifications” at Existing Stationary Sources
Regulatory Uses (continued)

• **Protection of Class I Visibility Areas**
  – Keep visibility pristine near:
    » National Parks > 6,000 acres
    » National Wilderness Areas > 5,000 acres
    » National Memorial Parks > 5,000 acres

• **National Ambient Air Quality Standards (NAAQS)**
  – $\text{SO}_2$, $\text{PM}_{10}$, $\text{PM}_{2.5}$, $\text{CO}$, $\text{NO}_x$, $\text{Pb}$
  – $\text{O}_3$ ($\text{NO}_x$ & VOC Precursors)
  – Selection of Ambient Air Monitoring Sites

• **State Primary and Secondary AAQS**
NAAQS NAA & Kentucky Class I Visibility Areas:

Counties Designated "Nonattainment" or "Maintenance" for Clean Air Act’s National Ambient Air Quality Standards (NAAQS) *

Legend**
- County Designated Nonattainment or Maintenance for 6 NAAQS Pollutants
- County Designated Nonattainment or Maintenance for 5 NAAQS Pollutants
- County Designated Nonattainment or Maintenance for 4 NAAQS Pollutants
- County Designated Nonattainment or Maintenance for 3 NAAQS Pollutants
- County Designated Nonattainment or Maintenance for 2 NAAQS Pollutants
- County Designated Nonattainment or Maintenance for 1 NAAQS Pollutants

Guam - Piti and Tanguisson Counties are designated nonattainment for the SO2 NAAQS

* The National Ambient Air Quality Standards are health standards for lead, carbon monoxide, sulfur dioxide, ground level ozone, and particulate matter (PM-10 and PM2.5). There are no nitrogen dioxide nonattainment areas.

** Partial counties, those with part of the county designated nonattainment and part attainment, are shown as full counties on the map.
AIR DISPERSION MODELING

Limitations of AERMOD
American Meteorological Society/Environmental Protection Agency Regulatory Model (AERMOD):

- Development began in early 1991 by AERMIC
- 4/21/2000 – AERMOD proposed by EPA to be the “Preferred Regulatory Model”
- 12/9/2005 – AERMOD promulgated as “Preferred Regulatory Model”
- AERMOD is a steady-state dispersion model designed for short-range (up to 50 kilometers) dispersion of air pollutant emissions from stationary industrial sources.
- AERMOD can only predict future ambient air quality; only quality assured monitoring data (e.g. direct measurement) can determine actual ambient pollutant concentrations.
American Meteorological Society / Environmental Protection Agency Regulatory Model (AERMOD):

- **AERMOD is a Steady-State, Straight-Line Plume Model**
  - Assumes uniform atmosphere across modeling domain for each hour
  - Limited to near-field (< 50 km) impact assessments
  - Area designations for NAAQS can be difficult to capture in single modeling domain

- **AERMOD can be used to estimate emissions from continuous releases**
  - Not valid for emergency release episodes
  - Limited methods to simulate intermittent process operations
  - Limited methods to simulate 30-day rolling total emission limits
  - Limited methods to simulate start-up and shutdown events
Air Dispersion Modeling (ADM) Limitations:

• ADM is complex and models cannot be used in all situations
• ADM must be conducted within the scope of its design capabilities
• ADM should not be used to evaluate instantaneous concentrations in space and time
  – AERMOD most accurate for annual pollutant concentration estimates
  – AERMOD least accurate for 1-hr pollutant concentration estimates
• ADM can only predict future ambient air quality
  – Only quality assured monitoring data (e.g. direct measurement) can determine actual ambient pollutant concentrations
Data Visualization
AIR DISPERSION MODELING
Demonstrating Modeled Compliance with a 1-hr NAAQS
Section 172 of the CAA [42 USC §7502(c)]

Requires States with areas designated as nonattainment for a NAAQS to submit a State Implementation Plan (SIP) detailing how the NAAQS will be attained as expeditiously as practicable.

- **§7502(c)(1) – In General**
  - Implement Reasonable Available Control Measures (RACM)
  - Implement Reasonable Available Control Technology (RACT)
  - 1994 EPA guidance states cost effectiveness should be $160 to $1300 per ton pollutant removed

- **§7502(c)(2) – RFP**
  - NAA SIP must demonstrate Reasonable Further Progress (RFP)
  - Annual incremental reductions of emissions of the relevant air pollutant for purposes ensuring attainment of the NAAQS by the attainment date
Section 172 of the CAA [42 USC §7502(c)]

- §7502(c)(3) – Inventory
  - Emissions Inventory for base year
  - Projected Emissions Inventory for attainment year

- §7502(c)(4) – Identification and Quantification
  - Identification and quantification of emissions allowed from the construction and operation of Stationary Sources

- §7502(c)(5): Permits for New and Modified Major Stationary Sources
  - Issue permits for New and Modified Major Stationary Sources
  - State must have Nonattainment NSR Permit Regulations

- §7502(c)(6): Other Measures
  - Includes enforceable emission limitations and control measures
Section 172 of the CAA [42 USC §7502(c)]

• §7502(c)(7): Compliance with Section 110(a)(2) of CAA
  – Air agencies must develop and maintain Air Quality Management Infrastructure Program

• §7502(c)(8): Equivalent Techniques
  – States may use equivalent modeling, emission inventory, and planning procedures that are equally effective in attaining the NAAQS
  – Weight of Evidence (WOE) Determinations

• §7502(c)(9): Contingency Measures
  – In the event that an area fails to make RFP or fails to attain the NAAQS, additional measures are not required but the control strategy must be implemented.
Difficult to Demonstrate Modeled Compliance with a 1-hr NAAQS

• SIP-required Modeling Demonstrations are typically performed by the designated Administrator (DAQ in Kentucky)

• Stationary Sources not involved in SIP Modeling Demonstrations in the same manner as required for Stationary Source PSD permitting

• Administrators don’t always have the time or resources for a thorough analysis:
  – Eliminate “double counting” of air emissions from background concentrations and stationary sources.
  – Administrators don’t have to live with the business consequences of their modeling demonstrations.
Double Counting Emissions

Background Concentrations vs Source Modeling

Legend
- 50 km Radius
- AAQ Monitor 1
- AAQ Monitor 2
- Modeling Domain Border
- SO2 Source - 137 TPY
- SO2 Source - 187 TPY
- SO2 Source - 258 TPY
- SO2 Source - 29,945 TPY
- SO2 Source - 3,010 TPY
- SO2 Source - 476 TPY
- SO2 Source - 7,824 TPY
40 CFR §50.11 – NAAQS for oxides of Nitrogen (NO₂ as Indicator)

B. 100 ppb, 1-hour average concentration, measured in the ambient air as nitrogen dioxide.

F. Met when the three-year average of the annual 98th percentile of the daily maximum 1-hour average concentration is less than or equal to 100 ppb.

[75 FR 6531, February 9, 2010]
**AIR DISPERSION MODELING**
Demonstrating Modeled Compliance with a 1-hr NAAQS

**40 CFR §50.11 – NAAQS for oxides of Nitrogen (NO₂ as Indicator)**

Modeling Data Interpretation of Standard:
The 1-hour primary standard is met when the three-year average of the annual 98th percentile of the daily maximum 1-hour average concentration is less than or equal to 100 ppb, as determined in accordance with appendix S of this part for the 1-hour standard.

<table>
<thead>
<tr>
<th>Meteorological Data Period</th>
<th>Number of 1-hr Time Intervals Modeled</th>
<th>Number of Daily Maximum 1-hr Values</th>
<th>Annual 99th Percentile Daily 1-hr Maximum Concentration</th>
<th>3-Year Averaging Periods</th>
<th>Number of 1-hr Time Intervals Used For NAAQS Design Value</th>
</tr>
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<tbody>
<tr>
<td>1/1/2008 through 12/31/2013</td>
<td>43,800</td>
<td>1,825</td>
<td>8th Highest Value in Calendar Year</td>
<td>A) 2008 - 2010</td>
<td>3</td>
</tr>
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40 CFR §50.17 – NAAQS for sulfur oxides (sulfur dioxide)

a) 75 parts per billion (ppb, which is 1 part in 1,000,000,000), measured in the ambient air as sulfur dioxide (SO$_2$).

b) Met at an ambient air quality monitoring site when the three-year average of the annual (99th percentile) of the daily maximum 1-hour average concentrations is less than or equal to 75 ppb.

c) The level of the standard is measured by a reference method or by a Federal Equivalent Method (FEM).

[75 FR 35592, June 22, 2010]
40 CFR §50.17 – NAAQS for sulfur oxides (sulfur dioxide)

Modeling Data Interpretation of Standard:
The 1-hour primary standard is met at an ambient air quality monitoring site when the three-year average of the annual (99th percentile) of the daily maximum 1-hour average concentrations is less than or equal to 75 ppb, as determined in accordance with appendix T of this part.

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EPA Modeling Guidance leads to conservative emission estimates

Stationary Sources are modeled at the worst case emission rate:

- 1970’s emission standards for “Existing Sources” are significantly higher than 40 CFR Part 63 NESHAP emission standards

- Sources subject to current/upcoming MACT Standards which are not listed in a federally enforceable operating permit are not incorporated in modeling demonstrations

- Modeled conditions are not representative of typical operating conditions
EPA Modeling Guidance leads to conservative emission estimates

1-Hr NAAQS Design values based on the worst case meteorological conditions

• Three (3) 1-Hr periods out of 43,800 modeled time intervals = Model Design Value

• Background pollutant concentration values further overestimate emissions

• NWS meteorological data best suited for aviation safety, not for air dispersion modeling

• Low wind speeds not measured accurately at Air NWS monitoring stations
  – Low/calm wind speeds lead to overestimation of emissions by AERMOD
Modeling Guidance for SIP submittals often released late in the Designation Process

Administrators have limited time to develop “case-by-case” modeling demonstrations for NAA:

- SO$_2$ NAAQS Final Rule – 4/12/2010
- SO$_2$ NAA Identified by EPA – August 2013
- SO$_2$ Modeling Guidance Memo Released – 4/23/2014
- SO$_2$ NAA SIP Submittals Due - 4/03/2015
- NAA to Reach Attainment by October 2018
Modeled Emissions Exceed Actual Monitoring Measurements

Low wind speed (calms) time intervals lead to artificially high ground level concentrations

Combined low wind speed and building downwash issues

\[
C(x, y, z) = \frac{Q}{2\pi\sigma_y\sigma_z U} \exp\left[-\frac{y^2}{2\sigma_y^2}\right]\left[\exp\left[-\frac{(z-h_s)^2}{2\sigma_z^2}\right] + \exp\left[-\frac{(z+h_s)^2}{2\sigma_z^2}\right]\right]
\]

- \( Q = \) Emission Rate (g/s)
- \( U = \) Surface Friction Velocity (m/s)
  [Influenced by Wind Speed (m/s)]
Modeled Emissions Exceed Actual Monitoring Measurements

Older Stacks which exceed GEP stack heights now modeled at GEP

- AERMOD underestimates the actual dispersion characteristics of existing stacks.

40 CFR §51.100(hh) Dispersion Techniques:

- Prohibits modeling techniques which increase final exhaust gas plume rise by manipulating source process parameters, exhaust gas parameters, stack parameters, or combining exhaust gasses from several existing stacks into one stack.
  - Exceptions:
    - Can increase final exhaust gas plume rise where the resulting allowable emissions of SO₂ from facility do not exceed 5,000 tons/yr
    - Reheating gas stream, following a control device, for the purpose of returning the gas to the pre-control device discharge temperature
Modeled Emissions Exceed Actual Monitoring Measurements

“Regulatory Default” (Tier 1) method overestimates NO\textsubscript{x} to NO\textsubscript{2} conversion

- Alternate NO\textsubscript{x} to NO\textsubscript{2} conversion estimation methods exist but not always used in modeling demonstrations
  - Multiply Tier 1 Results by empirically derived NO\textsubscript{2}/NO\textsubscript{x} ratio
    \[0.80 = \text{national default ratio for hourly NO}_2\]
- Tier 3 Method:
  - Ozone Limiting Method (OLM). (Cole and Summerhays, 1979)
  - Plume Volume Molar Ratio Method (PVMRM). (Hanrahan, 1999)
- Tier 3 methods require administrator approval for use in modeling demonstrations
Modeled Emissions Exceed Actual Monitoring Measurements

“Rural Source” vs “Urban Source” in AERMOD for SO$_2$

- Stationary Sources in rural areas which have large sources of radiant heat have increased atmospheric turbulence during nighttime hours not captured by AERMOD evaluating pollutant dispersion over rural land.
  - Cement kilns
  - Refinery process heaters
  - Observed ground level temperature differences up to 4 °F

- SO$_2$ decay coefficient (pollutant half life) hard coded in AERMOD for Urban Sources but not for Rural Sources.
The SIP Process has Changed

For a NAA to reach attainment designation:
- Areas must submit a **Modeling** and **Monitoring** attainment demonstration for NAA SIP
- Only certified monitoring data can change the attainment status of an area, but modeling is required for an approvable plan prior to redesignation.

What happens if an area lacks data completeness for Ambient Air Monitoring stations?
- WOE Determinations lack the necessary quality assured data:
  - Cannot use Coal-fired EGU Shutdowns and correlated background pollutant concentration reductions to demonstrate future attainment with a NAAQS

What happens if an area shows attainment with a NAAQS based on recent monitoring data but does not show modeled attainment?
- Is it reasonable to require a source to implement controls greater than RACT/RACM if it will not advance the attainment date?
- Lawsuit?
QUESTIONS?

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