Near-Road Modeling Research

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Wind Tunnel Simulation - Six Lane Roadway
Near road impact assessment priority research area for ORD

– Over 36 million people in this country live within 100 meters of a four-lane or larger highway. A number of health studies have identified increased risks of adverse health effects for populations spending significant time near major roads.

– Emission inventories reveal that mobile sources significantly contribute to local and national concentrations of a number of air pollutants.

– Air quality monitoring studies have measured elevated concentrations of pollutants emitted directly by motor vehicles near large roadways, adding to the public health concern for adverse health effects resulting from exposures to motor vehicle emissions.

– EPA’s Clear Air Research multi-year plan increases the emphasis on research to better understand the linkages between sources and health outcomes.

– A Near-Road Action Plan has been developed to integrate all of EPA/ORD’s ongoing and planned activities addressing near-road issues.
Environmental Issue

► Need to further understand the atmospheric transport and dispersion of emissions within the first few hundred meters of the roadway, a region often characterized by complex flow (e.g. sound barriers, road cuts, buildings and vegetation).

► Therefore, new studies of near-road emissions, and field and laboratory measurements of concentration distributions are necessary.

► To simulate potential exposures, an improved algorithm is needed for modeling roadway dispersion.
Research Objectives

The ORD near-road research program’s overall goal is to understand the source-to-health outcome continuum for roadway pollutants. The sub-objectives related to AMAD’s work include the following:

► Characterization of the spatial variability of traffic-related pollutants near roadways using wind tunnel, computational fluid dynamics (CFD) and tracer and year-long field studies of roadway dispersion. The resulting data bases will be used for the development and evaluation of applied modeling tools.

► Assessment of how roadway design, meteorology, topography, and surrounding structures and vegetation affect near-road air quality.

► Assessment of inadequacies in applied dispersion models and development of improved modeling tools for linking traffic emissions to population exposures for use in regulatory decision-making, for evaluation of mitigation techniques and for transportation planning.
Research Approach

The overall approach to understanding the spatial distribution of traffic-related pollutants and for improving our tools for simulating the effects of roadside structures includes:

1) **Examining existing tools** - reviewing and evaluating existing models and data bases related to near road dispersion;

2) **Developing measurement methods** - developing methods for measuring near-road concentration distributions in both the laboratory and in actual urban situations;

3) **Performing new studies** - collecting and analyzing field, tracer, and wind tunnel measurements, as well as CFD results to understand the basic structure of flow and dispersion;

4) **Improving algorithms and modeling methodologies** - developing and evaluating improved algorithms and incorporating them into a selected near-field modeling platform (e.g. AERMOD) and as a subgrid algorithm within CMAQ.
1) Examining existing tools

An exhaustive review of 21 available dispersion models that simulate line-type sources was completed (Report EPA/600/R-09/001). Based on the findings and recommendations of this report, AERMOD, was chosen as the best platform for further development for roadway scenarios. AERMOD is the current near-field and urban scale model recommended by the EPA for regulatory assessments.

2) Developing meas. Methods

A methodology has been developed as part of this program to use mobile platform measurements over an urban area to characterize air-toxic concentration distributions (Isakov, et al. 2007). Successfully demonstrated on fine particulate and formaldehyde measurements in Wilmington, DE, the use of a mobile platform provides several advantages over fixed monitoring networks by providing measurements on a quick response basis over a large part of an urban area. This methodology was adopted by EPA and is currently being applied with the GMAP mobile sampling vehicle in a series of intensive field studies examining the impact of roadside barriers on local air quality and their potential use for mitigation purposes.
3) Performing new studies

An important tool for examining near road dispersion is the EPA’s meteorological wind tunnel where the flow and dispersion around roadway scenarios (e.g. barriers, road cuts) have been examined.
Complementing the wind tunnel studies, in particular to examine atmospheric stability, is a tracer study of line-source emissions upwind of a single 6 meter high barrier simulating a typical road-side noise barrier.

Major components:
1. roadside barrier,
2. time-integrated tracer gas bag measurements,
3. mobile fast response analyzer tracer gas measurements,
4. turbulence measurements by sonic anemometers, and
5. tracer gas line source release.
Field measurements have been conducted along an eight-lane expressway in Raleigh, NC, examining the concentration gradient in a clearing and behind a noise barrier. The barrier influence is substantial. These data are critical for model development and evaluation.
March 2008: Pilot study along I-85 in Durham, NC

Fall 2008: Roadside barrier study at 3 sites in the Triangle Region

Carbon monoxide downwind of road
Cook et al. (2008) describe an approach for developing detailed highway emission inventories based on emission factors and traffic inventories for individual road links. This approach was applied with a hybrid model in New Haven, CT. Substantial spatial gradients were observed near roadways.

Applying a line-source model of Venkatram et al. (2007), the eight-lane expressway in the Raleigh 2006 field study was simulated for an area with no terrain changes or obstructions to the flow. The concentration gradient for benzene was matched well.

Results of EPA wind tunnel studies provide initial indications that for distances beyond the cavity zone of the barrier, the effects of noise barriers can be simulated with a no-barrier model by adjusting the effective source location upwind by a distance of 5 to 10 barrier heights (Heist et al., 2007).
Local topography, roadway design, and roadside features affect the transport and dispersion of traffic emitted pollutants away from the road. These features may be used by urban and transportation planners to mitigate population exposures near roads.

*Wind tunnel simulations of varying roadway designs indicate that cut sections and noise barriers may reduce near-road pollutant concentrations.*
Depressed Roadway Algorithm*

*preliminary work based on surface-coal-mine algorithm currently in AERMOD

Based on previous wind tunnel studies (Perry et al., 1994), an algorithm has been developed for inclusion into AERMOD for simulating the influence of depressed roadways. The figure at right compares the modeled concentration gradient with newly-collected independent wind tunnel data.
Next Steps

► Continued improvement of line-source type algorithms for the AERMOD for regulatory applications.
► Further wind tunnel studies and possible tracer studies to examine additional roadway configurations, wind direction and atmospheric stability influences.
► Collaboration with other EPA laboratories and the FHWA on field campaigns in Las Vegas, Detroit, and Raleigh to better understand the relationship between traffic emissions and roadway-related air pollution concentration gradients.
► Computational fluid dynamics modeling of near-road dispersion to complement wind tunnel and tracer studies.
► Use of the improved near-road dispersion models to support planned environmental health studies in Atlanta during 2009. This is an integral part of the "Air Pollution Exposure and Health Cooperative Agreement" between EPA/NERL and Emory University.
EPA-Emory/GA Tech Cooperative Agreement Hypotheses:

– Accounting for finer spatial resolution in ambient concentrations in epidemiologic analyses will yield estimates of pollutant exposures that differ substantially from estimates based on ambient monitoring data alone

– The use of these refined estimates will provide greater power to detect epidemiologic associations of interest, particularly for heterogeneous, traffic-related pollutants

Requirements of Air Quality Models: It’s all about exposure

– Regulatory models, e.g., for permitting, applied to predict the peak of the concentration distribution, unpaired in time and space, for comparison to AQ standards (i.e., maximum exposed individual)

– Air quality models used for exposure and risk assessments require skill at predicting concentration distributions paired in time and space (i.e., population exposure/risk)

– Growing need for integrated exposure and risk-based approaches to health and environmental impact assessments places higher demands on photochemical and dispersion model skill
Research is building block for successful exposure/risk studies

– Need continued emphasis on improving our atmospheric models through support of our basic research & development

– Rigorous testing and evaluation are critical for necessary improvement in model inputs and science, e.g.,
  • Challenges with meteorology at fine scales
  • Complex urban environments
  • Improvements in local scale emissions inventories
  • Need more resolved local emissions
  • Modeling science to improve chemistry and physical processes at fine scales

– Better understanding and characterization of model uncertainty/variability at fine scales

– Evaluation/comparison of techniques across projects, e.g.,
  • Atlanta, NYC, Cleveland, Detroit, Houston are possibilities
Research and Application Roles: NERL & OAQPS

NERL

Atmospheric Chemistry Data & Models → CMAQ Model Development & Testing → Base Year Model Evaluation → Future Baseline & Control Case Applications

OAQPS

R&D → Testing & Evaluation → Applications/Reg Assessment

NERL/OAQPS

AERMIC

Research Data & Algorithms → AERMOD Model Development & Testing → Performance Evaluation & Consequence Analysis → Model Applications & Guidance

OAQPS
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