Linking Local-Scale and Regional-Scale Models for Exposure Assessments

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Environmental Issue

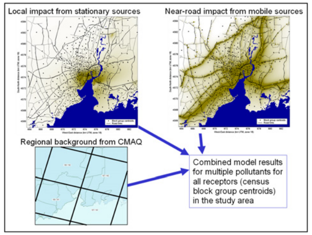
- Epidemiological studies require detailed air quality and exposure information in assessing the likelihood of adverse health effects that could result from exposure to air pollutants.
- Ambient monitoring data from centrally-sited monitoring stations have been used historically in epidemiological studies. Concentrations measured at a single monitor, or averaged from a few nearby monitors, are assumed to be representative of exposure for the population of interest over a broad area. This is not always the case, especially for air toxics.
- Many toxic pollutants have large concentration gradients especially near large sources such as major roadways and require data from many closely-spaced monitors to approximate community impacts. These and other limitations make it problematic to use ambient observations as the sole source of information in investigating health effects due to either the short-or long-term exposures to toxic air pollutants.
- Since air quality models are among the main tools that can be used to evaluate the impacts from emissions changes, they can be used to provide detailed ambient outdoor concentrations in the analysis of health data. However, regional air quality models such as CMAQ cannot provide adequate spatial resolution needed for exposure assessments. Therefore, a new approach is needed to enhance spatial resolution in air quality modeling.
- While air quality modeling is a preferred approach to provide air pollutant concentrations, it does not account for the relative contributions of air pollutants in microenvironments of concern to human exposures. Therefore, linking air quality with exposure models is necessary to account for human mobility and exposure issues.

Research Objectives

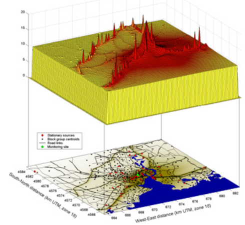
- Detailed information on air quality is needed for air pollution related environmental health studies. Air quality modeling estimates should include local-scale features, long-range transport, and photochemical transformations. Therefore, a hybrid air quality modeling approach is needed to combine results from a grid-based chemical-transport model with a local plume dispersion model to provide spatially and temporally resolved air quality concentration estimates as required by human exposure models.
- The main objective is to develop a new methodology for combined air quality and exposure modeling that can be used in environmental health studies.
- To demonstrate how this approach may be used in future community health studies, results are presented from a linked air quality/exposure approach in a feasibility study being conducted in New Haven, CT, examining the cumulative impact of various air pollution reduction activities (at local, state, national level) on changes in air quality concentrations, human exposures and potential health outcomes in the community.

Modeling Approach

The hybrid modeling approach combines concentrations from a grid-based chemical-transport model and a local plume dispersion model to provide the contribution from photochemical interactions and long range (regional) transport and details due to local-scale dispersion. In the New Haven feasibility study, we used the AERMOD dispersion model, which treats individual road links as area sources to simulate hourly concentrations of various pollutants near the road. AERMOD also simulates near-source impacts from stationary sources. Contributions to photochemical interactions were provided as background concentrations from CMAQ, a regional grid model.



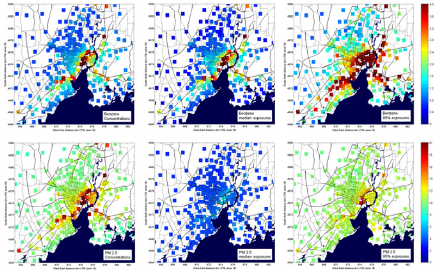
The hybrid modeling approach provided spatially and temporally resolved air quality concentration estimates at the census block group level, necessary for linking with human exposure models. The combined air quality concentrations were used as inputs to two different exposure models developed by the U.S. EPA: the Stochastic Human Exposure and Dose Simulation (SHEDS) model and the Hazardous Air Pollutant Exposure Model (HAPEM).



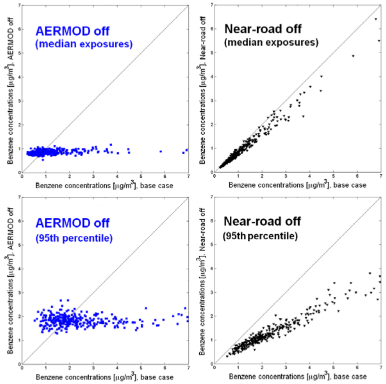
The use of linked hybrid air quality and exposure modeling results was explored as part of a feasibility study to assess public health impacts of emission reduction activities in New Haven, CT. New Haven is the site of one of EPA's Community Air Toxics projects as well as the site of an ongoing Community Actions for a Renewed Environment (CARE) project. Through the CARE project, New Haven has implemented several voluntary air pollution reduction programs. Baseline results were modeled for the year 2001, and projections were based on planned air pollution reduction activities for 2010, 2020, and 2030 for multiple criteria and toxic air pollutants. The hybrid air quality modeling results were then used as inputs to the SHEDS and HAPEM exposure models. The New Haven project is seeking to foster collaborations and partnerships with state and local agencies including the federal and state governments, academia, and the New Haven community.

Results and Discussion

The results show differences between modeled concentration and exposure, both in magnitude and spatial patterns. To illustrate these differences, spatial distributions of annual average concentrations and exposures (median and 95th percentile) for benzene (top panel), and $PM_{2.5}$ (bottom panel) are shown below.



In order to investigate the relative importance of several exposure modeling features, such as spatial resolution and near-road impact, we conducted a series of sensitivity tests: with and without the use of AERMOD and with and without the use of a near-road algorithm.



These sensitivity tests show that modeled exposures are much higher and have a wider range when based on the hybrid approach than when based on CMAQ alone, for both the median and 95th percentiles of the exposure distribution. This clearly suggests that providing spatially-resolved concentrations in air quality modeling is very important for exposure modeling. The results also indicate the importance of developing suitable line-source algorithms to characterize near-roadway concentration gradients in estimating human exposure.

Summary

The variability in spatial and temporal concentration gradients near large point sources and roadways, as shown with this research, is especially important given the growing body of literature on the potential adverse health effects associated with elevated concentrations that can occur near these sources. We have developed a hybrid modeling approach that combines the advantages of both regional and near-field dispersion models that provides higher spatial resolution than can be obtained from either model alone. These hybrid modeled concentrations were then used in two different exposure models, HAPEM and SHEDS. The local detail provided by this hybrid modeling approach can enhance the analysis of spatially and temporally resolved exposure within a community.

Future Directions

- Improve the near-road component of AERMOD as a part of the hybrid modeling approach (see Poster 3.2).
- Evaluate the hybrid modeling approach with spatially-resolved monitoring data; collaborate with other organizations to try to obtain such monitoring data.
- Conduct air quality modeling using the hybrid approach to support two environmental health studies (Baltimore and Atlanta) as a part of cooperative research agreements with University of Washington and Emory University.

Impact

The models provided in this study are serving as prototypes for air quality and exposure assessments for community air pollution health studies. The air quality models can be used to provide the baseline air quality for future assessments of impacts due to regional or local scale air pollution control measures. These same models can also be used to project air quality and exposures for future years, due to air pollution reduction activities or to the addition of new sources in a community. Projected future air quality and exposure model results can then be used to estimate the likely impact of air pollution control measures on human exposures and health in the community, such as that carried out in the New Haven air accountability feasibility project. Although this study has targeted one city, application of the information collection activities will have broad application to other areas within the United States. Finally, the techniques developed and the information derived from this research can be used as part of air accountability research (see Poster 3.3).

Contributors/Collaborators

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