PROJECT UPDATE

August 2005

New York Energy $mart℠ EMEP Environmental Monitoring, Evaluation, & Protection

New York State Energy Research and Development Authority

Environmental Monitoring, Evaluation, and Protection Program

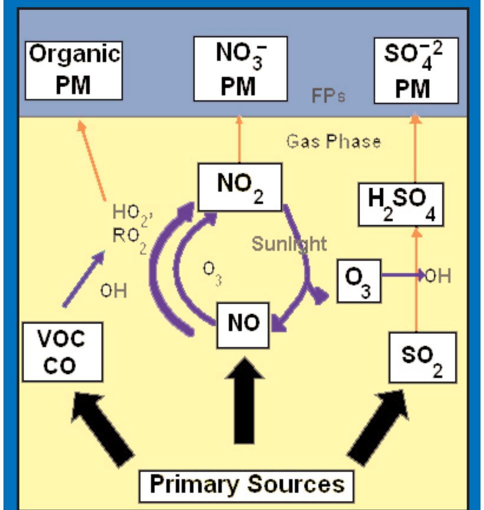
NYSERDA New York State Energy Research and Development Authority

Analysis of Ozone and Fine Particles in the Northeast

Principal Researcher

S. TRIVIKRAMA RAO

State University of New York at Albany



Ozone and fine particle production cycle

Contact Information

For more information on this project see:

http://www.nyserda.org/programs/environment/emep

or contact Mark Watson at: mw1@nyserda.org

Keywords

- Fine particulate matter ($PM_{2.5}$)
- Ozone (O_3)
- NAAQS
- Nitrogen oxides (NO_X)
- Trajectory analysis
- Volatile organic compounds (VOCs)

PROJECT FOCUS

This project aimed to improve our understanding of ambient ozone (O_3) and fine particulate matter ($PM_{2.5}$; diameter < 2.5 microns) pollution. Spatial and temporal factors that affect O_3 and $PM_{2.5}$ concentrations in rural and urban environments in the northeastern United States were investigated. Through air-quality modeling and data analyses, researchers examined the role of meteorological processes in the buildup and distribution of pollutant concentrations, impacts from local and more distant sources, and atmospheric conditions and relationships that induce high ozone and $PM_{2.5}$ levels in the Northeast.

The results are intended to assist policy makers and state regulatory agencies in designing optimal control measures for reducing ambient ozone and fine particulate pollution. In this and a related NYSERDA-funded project of the New York State Department of Environmental Conservation (NYS DEC), "Assessing the Effects of Transboundary Pollution on New York's Air Quality," methods were proposed for integrating observations and model predictions into an overall framework that draws on the strengths of both approaches while also providing a measure of the uncertainties involved. The analysis is an important advance toward increasing the reliability of modeling tools in the policymaking process.

CONTEXT

In July 1997 the U.S. Environmental Protection Agency (EPA) set new National Ambient Air Quality Standards (NAAQS) for O_3 and $PM_{2.5}$, pollutants that have major adverse consequences for human and ecosystem health and productivity. When these standards come into effect in 2004, they will likely be exceeded in several locations throughout New York State (NYS). Attaining compliance with the NAAQS will probably require new emissions regulations.

Combustion processes play an important role in the production of both O_3 and $PM_{2.5}$. Major sources include fossil-fuel electricity generation, industrial processes, industrial boilers, incinerators, and motor vehicles. $PM_{2.5}$ constituents include carbon, metals, nitrates, sulfates, and semivolatile organic compounds. These particles may be emitted directly into the atmosphere (primary particles) or formed in the atmosphere from precursor gases (secondary particles). Ambient ozone is produced from a series of chemical reactions in the lower atmosphere involving its precursors: nitrogen oxides (NO_x) and volatile organic compounds. The chemical processes whereby O_3 and $PM_{2.5}$ are generated in the atmosphere are linked in complex ways (see graphic).

While $PM_{2.5}$ and ozone and its precursors may be generated locally, they are also transported regionally, and therefore are subject to a number of spatial factors. Observed concentrations are also affected by temporal factors, ranging from the short-term effects of weather to the longer term effects induced by seasonal variations and environmental policies. Effective modeling and the evaluation of policy options for improving air quality require the careful use of data that reflect these factors.

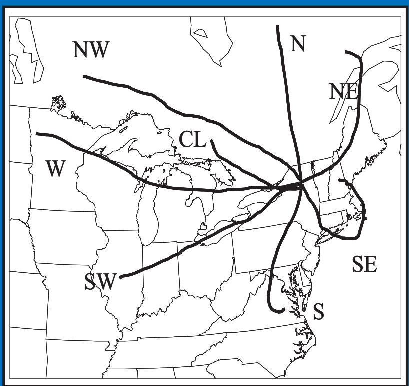
METHODOLOGY

The project relied on several years of air monitoring data from monitoring sites in NYS and the Northeast that included measurements of O_3, $PM_{2.5}$ components, and trace metals. Using statistical methods, trajectory models, and photochemical models to identify cause-and-effect relationships, research was performed in four major areas:

- Spatial and temporal features of ozone, $PM_{2.5}$, and trace metal data were analyzed to clarify the factors affecting the formation and accumulation of the pollutants. Using time-series analyses to assess trends or variations in data over time, the project team determined which portions of the observations were attributable to short-term weather-related factors, to seasonal factors, and to longer term climate and policy-related factors. In the process, the data were adjusted into a more useful form for trajectory and source analyses.
- Meteorological data were combined with the above results in order to analyze the trajectories, sources of the pollutants, and airshed for ozone $PM_{2.5}$ pollution in the Northeast. Trajectory models helped characterize the effects of sources located outside of NYS on pollutant concentrations measured in NYS.
- To clarify processes causing elevated ozone and $PM_{2.5}$ measurements, further analyses compared observations in urban and rural sites in the Northeast during the summer of 1995, when standards for these pollutants were exceeded.
- Modeling and analysis of ozone concentrations in the Northeast were conducted to develop methods for the improved use of photochemical models in regulatory policymaking.

PROJECT UPDATE

August 2005



Group of eight clusters of average back-trajectories for receptor sites near Whiteface Mountain, NY. The clusters are labeled according to the origin of the airmass: Northwest (NW), North (N), Northeast (NE), Southeast (SE), South (S), Southwest (SW), West (W), and close regions towards the Northwest (CL). This figure is adapted from Brankov et al., "Identifying Pollutant Source Regions Using Multiply Censored Data", Env. Sc. Tech., Vol. 33, 2,273-2,277, 1999.

Project Status

- Initiated 1999
- Completed 2003

New York Energy Smart[SM]
Public Service Commission
NYSERDA

Since 1975, the New York State Energy Research and Development Authority (NYSERDA) has developed and implemented innovative products and processes to enhance the State's energy efficiency, economic growth, and environmental protection. One of NYSERDA's key efforts, the Environmental Monitoring, Evaluation Protection (EMEP) Program, supports energy-related environmental research. The EMEP Program is funded by a System Benefits Charge (SBC) collected by the State's investor-owned utilities. NYSERDA administers the SBC program under an agreement with the Public Service Commission.

PROJECT FINDINGS

Spatial and Temporal Features of Data

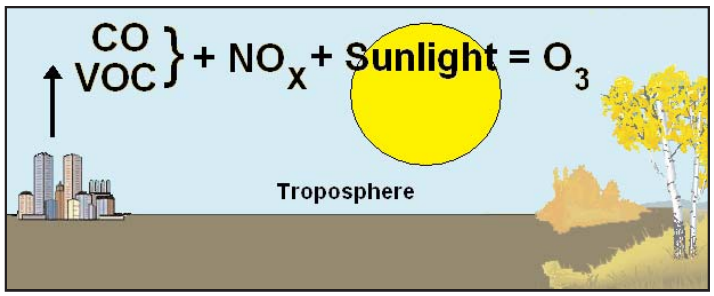
- Changes in data reporting practices can cause erroneous trend estimates to be derived from observational databases.
- Spatial and temporal features in pollutant data are sensitive to differences in the sampling procedures between the monitoring networks.
- Trace-element pollution is a regional-scale problem in the Northeast.

Pollutant Transport and Sources

- O_3 and $PM_{2.5}$ pollution in the Northeast is a regional, multistate, and even international issue.
- A high consistency in O_3 and $PM_{2.5}$ concentrations exists over the airshed, spanning a 600 km area. It is therefore difficult to distinguish regional from local effects using data collected at a few monitoring sites within an urban area.
- Daily, if not hourly, sampling of $PM_{2.5}$ and its species is necessary to evaluate pollutant transport patterns and identify source regions for pollutant levels measured in the Northeast.

Modeling and Analysis

- Current photochemical modeling systems are unable to capture the observed relationships between ozone and its precursors. The models tend to underestimate the efficiency of ozone production in the Northeast.
- Air-quality models capture the average concentration and its spatial pattern better than they do the peak concentration. The different meteorological, emission, and other data inputs of the model lead to large uncertainties in predicting daily maximum ozone concentrations on individual days. Uncertainties can be reduced by averaging the predicted daily maximum ozone concentrations over all episode days simulated, i.e., on timescales longer than one day.
- Observations and model predictions need to be integrated into a probabilistic framework to enable policymakers to assess the capability of a given emission control strategy to meet and maintain the relevant NAAQS. The probabilistic framework proposed in these studies, which aimed at integrating the spatio-temporal information provided by observations and model predictions, was applied to ozone concentrations for demonstration purposes. This methodology should be expanded to address multipollutant problems.



Ozone production.

PROJECT IMPLICATIONS

This project has contributed considerably to our understanding of the factors affecting ozone and $PM_{2.5}$ levels in NYS and to the optimal use of modeling results in the regulatory setting. The results will assist both researchers and policymakers in evaluating regulatory options for achieving compliance with air-quality standards. The findings, which essentially invalidate the previous regulatory practice of basing emissions management decisions on a small number of model predictions of the daily maximum ozone concentrations for individual days, have helped provide the technical basis for a recent U.S. Environment Protection Agency (EPA) modeling guidance. The EPA has indicated that for regulatory purposes, predicted daily maximum ozone concentrations averaged over all simulated episode days should be considered, instead of the peak predicted concentration at each site during an episode.

The statistical methods and modeling employed in this project underscore the fact that O_3 and $PM_{2.5}$ pollution is a regional, multistate, and even international issue. To adequately address this problem, NYS needs to seek regional air-management partnerships and the implementation of region-wide control strategies through approaches that cross industry boundaries. The project findings further indicate that the out-of-state versus in-state contributions of these reactive pollutants cannot be determined from data from a few monitoring sites within an urban area, owing to the interdependence of the pollutants among several states within the 600 km airshed. Hence, airshed-based emissions management strategies will be needed to meet and maintain the O_3 and $PM_{2.5}$ standards in NYS. This research also stresses the importance of a probabilistic interpretation of modeling results in the policy arena and the need for long-term high-resolution monitoring. The more reliable use of modeling is of paramount importance in the regulatory environment, for example, in gauging the probable benefits of controls affecting particular geographical areas or different polluting sectors, such as electrical utilities.