PROJECT UPDATE

August 2005

New York State Energy Research and Development Authority

Environmental Monitoring, Evaluation, and Protection Program

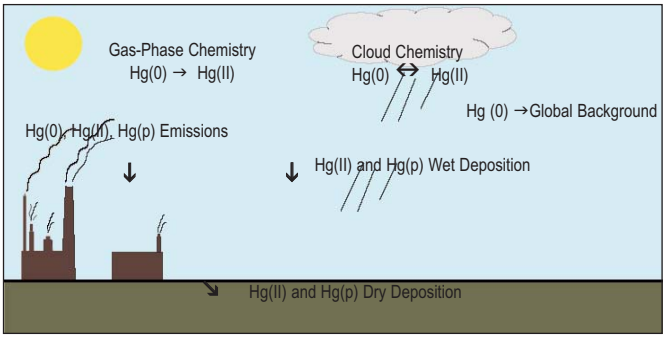
Atmospheric Transport and Fate of Mercury in New York State

PROJECT FOCUS

This project developed a speciated mercury (Hg) emissions inventory available for Hg modeling and analysis. The inventory was incorporated in two state-of-the-science atmospheric mercury pollution models to simulate the transport, transformation, and deposition of mercury in the Northeast region of the United States, with a focus on New York State (NYS). These simulations allowed the project team to compare the two models, evaluate model calculations against observed deposition levels, and estimate in-state and out-of-state contributions to Hg deposition in New York. Through "influence function" analyses, the contribution of particular point sources or source areas on Hg deposition at specific sites in NYS was evaluated.

CONTEXT

Mercury cycles in the environment as a result of both natural and human activities. The major contributors to atmospheric mercury include emissions from the combustion of mercury-containing fuels or materials and industrial processes. Recent inventories indicate that approximately 150 tons of mercury are emitted from anthropogenic sources each year in the United States. The mercury transported through the air is deposited in water and on land, where human and wildlife exposure may occur. While pollution prevention programs exist to remove mercury from the environment and various products, mercury emissions from coal-burning power plants, the largest source (approximatetly 30% of total emissions), are currently unregulated.



Atmospheric Fate and Transport of Mercury Species

Mercury is present in the atmosphere in several forms – gaseous elemental mercury (Hg[0]), gaseous divalent mercury (Hg[II]), and particulate divalent mercury (Hg[p]) – with different atmospheric lifetimes. Conversions between these forms occur in the atmosphere, particularly in the presence of clouds. The potential impacts of atmospheric mercury emissions depend on the Hg species involved, meteorological processes (e.g., wind and precipitation), and chemical transformations.

METHODOLOGY

Emissions inventory. The inventory was generated by consolidating information on mercury emissions sources gathered by the U. S. Environmental Protection Agency (1996 data), Canadian authorities, and the Electric Power Research Institute. Mercury emissions reported were classified by chemical forms, as Hg(0), Hg(II), and Hg(p).

Model simulations. The emissions inventory was incorporated in two regional-scale atmospheric mercury models developed at the University of Athens: RAMS and SKIRON/Eta. The use of two models allowed comparison of the results and clarification of discrepancies in our current knowledge of atmospheric processes affecting Hg pollution. The models simulated a 13-day summertime episode in eastern North America (14–26 August 1997) for which mercury concentration and deposition data are available. Model calculations of Hg deposition were assessed for two different emission scenarios, including:

- All Hg emissions in eastern North America. This scenario allows evaluation of the models' performance through a comparison of model calculations with actual wet deposition measurements. Deposition measurements are available from several locations in the Northeast upwind and downwind of NYS only; no measurement sites were located in NYS during this time period.
- All Hg emissions in eastern North America except those of NYS. This scenario allows an estimate of the relative contributions of NYS and out-of-state sources to Hg deposition in NYS and contributes to the evaluation of the efficacy of state-level mitigation efforts.

"Influence function" analyses. Analyses were conducted to identify the recent transport history of the air masses arriving at specific locations, indicating the upwind regions influencing Hg concentrations at these sites during specific time periods.

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Study Region

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

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Keywords

- Emissions inventory
- Influence function analysis
- Mercury speciation
- Mercury transport
- Modeling

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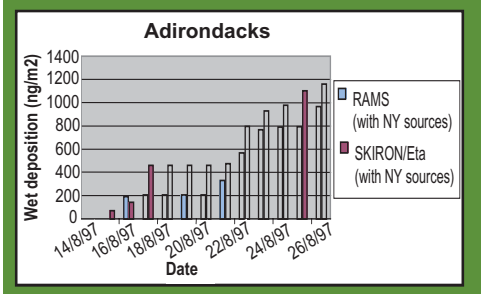
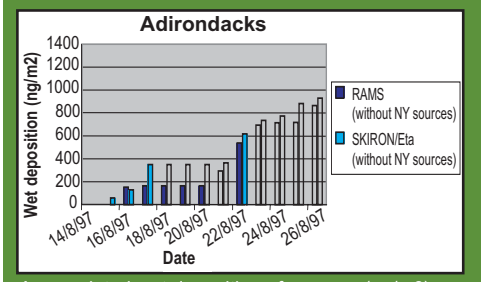




Accumulated wet deposition of mercury (ng/m2) calculated from RAMS and SKIRON/Eta models with (top) and without (bottom) NYS emissions at a location in the Adirondacks, 14-26 August 1997.

Project Status

- Initiated 2001
- Completed 2005

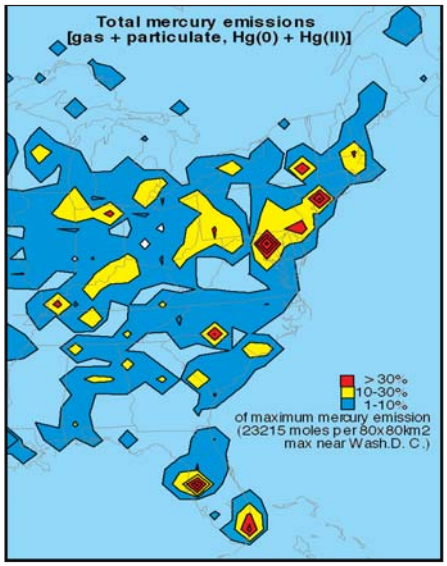
New York Energy Smart℠

PUB

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

The emissions inventory indicates the source areas of highest Hg emissions in eastern North America to be just west of Washington D. C., near New York City (NYC), and two locations in Florida. These are associated with individual point sources, such as a cement production facility west of Washington, D.C., several large municipal waste incinerators just to the east of NYC, and waste incinerators in the Tampa and Miami, FL areas. However, Hg emissions are spread widely throughout eastern North America. Some localized emission peaks are also located in the Ohio River Valley; others are associated with urban areas.



Credit: Chris Walcek

Spatial distribution of Hg (gaseous and particulate) emissions in eastern North America.

Comparison between the two Models:

- Agreement between the models on calculated total deposition is quite good, indicating that they are reasonably consistent and can be used as tools for assessing longer term impacts of concentration and deposition.
- Discrepancies between the two models are related to differences in how they treat cloud physics, cloud processes, and wet deposition, suggesting a need for further evaluation and refinement of atmospheric mercury models. This is a key area of uncertainty that strongly influences our ability to accurately simulate mercury pollution and its impacts.
- Calculated mercury impacts are extremely sensitive to how cloud processes are simulated in the models, which is highly variable and uncertain in current modeling systems for air pollution.

Comparison of Model Results with Observations:

- Simulated Hg wet deposition showed reasonable agreement with available wet deposition data, although both models tended to overestimate wet mercury deposition. The overestimation is within acceptable limits, considering the uncertainties, possible errors, and limitations in the observations, as well as how the individual models treat the physics of convection and precipitation.
- Data on Hg deposition are too sparse and intermittent to allow robust conclusions about the accuracy of the models. Accurate assessments of model performance would require considerably higher resolution data and longer term comparisons between model simulations and measurements.

In-State vs. Out-of-State Contributions:

- NYS emissions contributed ~11–21% of total accumulated wet deposition of mercury to the Adirondacks during the study period, indicating the considerable influence of out-of-state sources on NYS deposition.
- The relatively low in-state contribution to NYS mercury deposition results from the extremely long residence time of mercury pollution in the atmosphere, a feature that renders mercury pollution a global phenomenon.

Influence of Point Sources:

Hg transport within and around NYS, and consequently the effects of individual point-source emissions on Hg deposition in NYS, are strongly influenced by small-scale meteorological features. As a result, fairly high-resolution modeling of the air flows in NYS would be needed in order to accurately assess the impacts of point sources of mercury on deposition in NYS.

PROJECT IMPLICATIONS

These results underscore the fact that mercury is a global problem that requires control strategies that function on the national and international levels. In efforts to address the problem, models of atmospheric mercury constitute an essential tool for estimating Hg concentrations and deposition resulting from anthropogenic emissions, and for assessing the relationship between undesirable impacts and controllable emissions. Accurate quantification of mercury emissions for use in air quality models is necessary for developing effective environmental policies, both to reduce the release of mercury in the environment and to monitor progress over time. However, despite improved modeling capabilities and understanding of mercury as an air pollutant, critical gaps remain in our understanding of the atmospheric transport and fate of mercury. Not least, the assessment of model performance would benefit from considerably higher resolution data and longer term comparisons between model simulations and measurements.

This research effort initiated an international collaboration between the Atmospheric Modeling group at the University of Athens and the NYS Department of Environmental Conservation air pollution modeling group. The information from this project will be helpful in evaluating the different policy proposals currently under discussion as well as in gauging the effectiveness of regulations implemented in the future.