NYSERDA's Environmental Monitoring, Evaluation and Protection (EMEP) Program

Overview of Accomplishments prepared for the September 19, 2006 EMEP Program Review

New York Energy Smart℠

EMEP

Environmental Monitoring, Evaluation, & Protection

NYSERDA's
Environmental Monitoring, Evaluation, and Protection (EMEP) Program

Overview of Accomplishments

Prepared for the 9/19/06 EMEP Program Review

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Section 1: Background

The primary mission of the **New York Energy $mart**[SM] Environmental Monitoring, Evaluation, and Protection (EMEP) Program is to support research to address environmental issues related to the generation of electricity. New York's electric utilities, individually and through associations, historically provided a stable funding stream for environmental research. However, with electric industry restructuring, the utilities are no longer in the generating business and thus, aren't obligated to sponsor environmental research. The **New York Energy $mart**[SM] Program employs System Benefits Charge (SBC) funds to ensure that critical energy-related environmental research programs continue through EMEP. EMEP provides scientifically credible, objective and policy-relevant research aimed at two primary goals:

- Enhancing understanding of the nature and characteristics of energy-related pollution and its impact on the environment and human health; and
- Characterizing sources of energy-related pollution and defining cost-effective policies to mitigate impacts and opportunities for emissions reduction.

The program focuses on electricity-related environmental issues in New York State. EMEP is currently supporting a diverse research portfolio in three areas:

- Ecosystem response to deposition of sulfur, nitrogen, and mercury;
- Air quality and related health research associated with particulate matter, ozone, and co-pollutants; and
- Crosscutting environmental science, technology, and policy projects.

Particular emphasis is placed on "environmental accountability" by establishing environmental baselines and evaluating changes in the environment as new emission control programs are launched. In addition, EMEP initiatives include elements focused on introducing its latest scientific findings into the policy arena through:

- Frequent meetings and conferences with analysts, policy makers and scientists;
- Translation of scientific studies into forms useful for a broad audience; and
- Provision of environmental data and scientific findings in a timely manner

EMEP has also supported a variety of research projects at various New York institutions and development and demonstration of better instruments for monitoring ambient air and water affected by pollution.

A Program Advisory Group comprising representatives from New York State and federal agencies, utility organizations, and other public interest organizations guides the EMEP

program.[1] A Science Advisory Committee, composed of university-based, federal, and non-profit researchers, assists EMEP in the development of its multi-year research plan and provides periodic review of critically important research.[2] The EMEP program reaches out extensively to these groups to provide external oversight throughout the development and progression of all research projects. All research proposals submitted to EMEP are rigorously peer reviewed and the principal investigators are required to present project updates to both program and science advisors – leading to very high scientific quality of EMEP-funded projects.

Key EMEP policy objectives include:

- Development and evaluation of the effectiveness of pollution control strategies for acid deposition, mercury, ozone and co-pollutants, and particulate matter including providing the scientific basis for a PM2.5 State Implementation Plan (SIP);
- Quantification of local sources versus regional transport of fine particles, ozone, ozone precursors, mercury, and acid deposition precursors to develop more equitable pollution control strategies;
- Assessment of the relationships between fine particles, ozone, and co-pollutants with health effects to support development of control strategies to effectively mitigate health impacts;
- Identification of alternative environmental protection and mitigation strategies to reduce the impacts of acidification and exposure to mercury in New York; and
- Development of emerging multi-media/multi-pollutant environmental protection strategies.

The scientific scope of potential research topics for EMEP is broad and includes:

- Biogeochemical cycling and ecosystems impacts of sulfur, nitrogen and mercury species;

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[1] **Current PAG members:** Alan Belensz, NYS Office of the Attorney General; Andrew Darrell, Environmental Defense; Richard Haeuber, Clean Air Markets Division, USEPA; Daniel Luttinger, NYSDOH; Sandra Meier, Environmental Energy Alliance of New York; Tina Palmero, NYSDPS; ST Rao, Atmospheric Sciences Modeling Division, USEPA & National Oceanic and Atmospheric Administration; Christina Dowd, Habitat Protection, NYSDEC; Gopal Sistla, Air Research, NYS Dept. of Environmental Conservation (NYSDEC); James Vickery, National Exposure Research Laboratory, USEPA; Ross Whaley, Adirondack Park Agency; Ronald Wyzga, Electric Power Research Institute. **Past PAG members**: James deWaal Malefyt/K. Bala/Peter Seidman, NYS Dept. of Public Service (NYSDPS); Ellen Baum, Clean Air Task Force; Rona Birnbaum, Clean Air Markets Division, USEPA; James Colquhoun/Steve Sanford, Bureau of Habitat, NYSDEC; Stacey Davis, Center for Clean Air Policy; Michael DiNunzio/Bernard Melewski/Radmilla Miletich, Adirondack Council; Lloyd Wilson/Edward Horn, NYS Dept. of Health (NYSDOH); Rashid Shaikh, New York Academy of Sciences; Edward Smeloff, Pace University School of Law; David Wooley, Pace University Energy Project; John Holsapple, Environmental Energy Alliance of New York.

[2] **Current Science Advisors:** Daniel Jacob, Harvard University; Praveen Amar, Northeast States for Coordinated Air Use Management (NESCAUM); Patrick Kinney, Columbia University School of Public Health; Stuart Findlay, Institute of Ecosystem Studies; William Fitzgerald, University of Connecticut; John Irwin, Retired, USEPA; George Hidy, Envair/Aerochem; Richard Schlesinger, Pace University. **Past Science Advisors**: Greg Lawrence, US Geological Survey; Scott Ollinger, University of New Hampshire.

- Factors limiting or promoting recovery of acidification;
- Relative environmental impacts of atmospheric deposition compared to other sources;
- Economic damage assessments and economic impacts of potential strategies;
- Characterization of atmospheric aerosols, co-pollutants and aerosol precursors;
- Fate and transport of primary and secondary particulate matter, ozone, ozone precursors and co-pollutants with respect to sources and receptors; and
- Relationship of atmospheric concentrations, compositions, and size to human health and other environmental concerns.

These research needs for New York State far exceed the funding available under EMEP. Therefore, program success requires coordination, collaboration, and leveraging with other state and federal agencies and co-funding of research projects. Synthesis and communication of research results is a key goal of the EMEP program (*i.e.*, the true test of success is the utilization of findings by policy makers to improve both environmental quality and human health). To achieve this goal, research findings are synthesized and translated into understandable formats, forums are provided for scientists and policy makers to discuss issues, and funding organizations are constantly seeking opportunities for collaboration. The EMEP program includes an aggressive communication and outreach policy to support this goal of science-policy integration to ensure that results from NYSERDA's EMEP research efforts are used.

For the purpose of this Peer Review, EMEP program activities have been grouped, where appropriate, into four distinct areas:

- Program Planning – including reviewing background research and convening research planning meetings with scientists, policymakers, analysts and other relevant stakeholders.
- Developing and Selecting Research Projects – including refining research focus areas for solicitation, developing and marketing solicitations, and reviewing and selecting proposal.
- Contracting with and Managing Collaborative Research Projects – including developing research contracts with scopes, budgets (including co-funding), and schedules; launching projects; evaluating progress; sharing interim findings; reviewing draft reports; and producing final NYSERDA project reports.
- Information Exchange – including preparing and disseminating summary reports and synthesis papers, sponsoring workshops and conferences, making data and information publicly available through the web, providing briefings, publishing NYSERDA reports and technical journal articles.

<u>Results To-Date/Outlook for the Future:</u> Through these activities, NYSERDA's EMEP program has developed a Research Plan that reflects a common understanding of energy-related environmental research needs which, if addressed will support informed decision-making in New York State, the region and nationally. In addition, the EMEP program

has effectively identified and implemented a portfolio of research projects specifically designed to meet high priority research needs within this Plan. A number of individual projects have been completed (or are in various stages of completion) and are: successfully achieving key research objectives; resulting in high quality and in-demand reports, briefing materials, technical journal articles etc.; advancing scientific and policy-relevant knowledge; enhancing the exchange of important environmental research information among scientists and policy-makers; strengthening New York State's research infrastructure; and contributing to the formulation of effective and equitable energy-related environmental policies and resource management practices.

Looking forward, the program has been renewed for another five years, with funding of $3.5 million per year from 2006 through 2011. The main research focus areas launched under EMEP will continue and some new focus areas will be added, including global climate change and assessing and mitigating the environmental impacts from alternative energy resources.

The input provided from this review effort will help NYSERDA in developing future EMEP programs.

For more information on the EMEP program, see
www.nyserda.org/programs/environment/EMEP

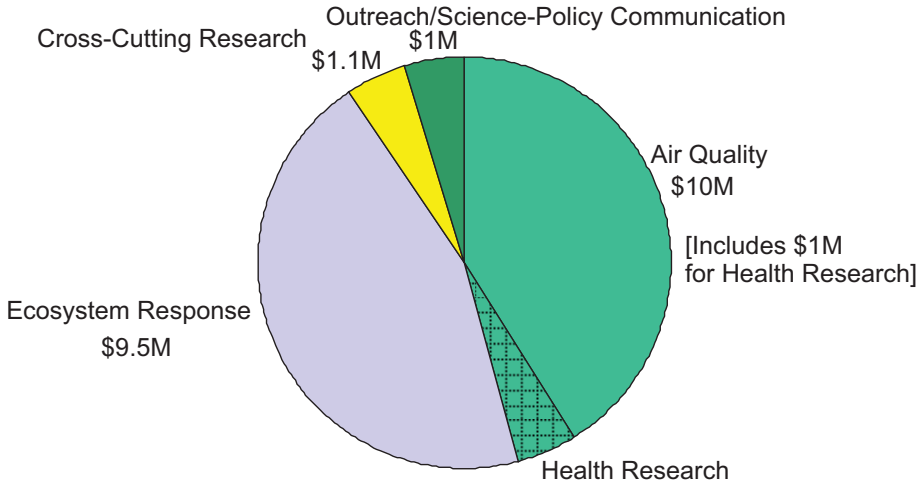
Section 2: EMEP Program Resources

Table 1 in this section lists the funding levels, funding partners, and contractors associated with solicitations issued through the EMEP program from 1998 through 2006. NYSERDA staff and other resources made available to this program are also described.

The pie chart in Figure 1 illustrates the allocation of resources by program area.

Figure 1. Current EMEP Portfolio

$21.6 million NYSERDA/$44 million total



46 research projects (16 completed, 30 active)

Table 1: Summary of Resources Committed Through the EMEP Program

Contract ID	Projects Identified in the Public Service Commission SBC1 Order*	Program Opportunity Notice (PON) 444	PON 446	PON 497	PON 540	PON 586	PON 682	PON 839	Unsolicited/ Sole-Source Projects
Number of Contractors	6	2	3	1	6	8	12	8	8
Start Date	1998	Feb-99	Jun-99	Oct-99	Oct-00	Jul-01	Jan-03	Jul-04	N/A
NYSERDA Funding	$3,165,917	$456,557	$1,159,875	$450,000	$850,780	$4,195,434	$5,298,703	$2,563,719	$3,557,326
	PON 594 consisted of two outreach contracts totaling $611,243 in NYSERDA funds.								
Estimate of NYSERDA staff resources used for project	NYSERDA has dedicated approximately 2.5 full-time equivalent (FTE) staff since 1998 supporting these research efforts. Specific responsibilities for support of this program include defining research needs; developing and managing research solicitations; evaluating proposals; contracting projects; reviewing work statements for funding; reviewing project reporting and invoicing; reviewing project final reports; production and dissemination of outreach materials, including Web materials and newsletters, as appropriate; and participating in technical/policy and project-related meetings.								

*These were ongoing projects identified in the 1998 Public Service Commission System Benefits Charge (SBC) Order as critical to policy formulation in New York State. They were transferred from ESEERCO to NYSERDA after technical review.

Section 3: Knowledge Creation from the EMEP Program

This section identifies intermediate performance indicators and knowledge creation associated with the EMEP program. An illustration of the NYSERDA performance goals/targets, broader public benefits/outcomes, and performance indicators associated with the various elements of the EMEP program is presented in Appendix A and provides the evaluation framework for the material in the following sections.

3.1 Program Planning

In 2001 NYSERDA initiated a comprehensive planning effort to provide direction for environmental research in New York State over the next five years, with a focus on pollution associated with the generation of electricity. Potential users of the plan include NYSERDA, other New York State/regional/national research funding organizations, the scientific community, public benefit organizations, and policy makers. The goal and philosophy of this effort was to identify critical research that:

- is policy-relevant;
- is inter-disciplinary/multi-media;
- will be useable for New York State—not just for NYSERDA's EMEP program; and
- takes advantage of related national research plans and programs to address regional/state needs.

Within the plan, prioritized key research areas were identified that were suitable to be addressed through the EMEP program, as well as in collaboration with other funding organizations

NYSERDA convened working groups of science and policy experts to help develop the plan. Policy objectives were identified to guide the research scoping process so that the research would be most useful and applicable to environmental management challenges facing New York State. Potential priority research areas were identified and presented at the EMEP conference in Albany, NY, to over 200 participants for additional input. The draft plan was distributed to the EMEP Program Advisory Group for final review. All of the EMEP PONs issued since 2002 have been guided by the Research Plan. In addition, the EMEP plan has been cited by others in developing/identifying research needs (e.g., *Acid Rain and the Adirondacks: A Research Summary*, prepared in 2005 by the Adirondack Lakes Survey Corporation). Over 1200 copies of the EMEP Research Plan have been downloaded from NYSERDA's website.

This plan is a work in progress. As research findings become available and policies are implemented, it will be necessary to continually revisit and revise this plan to ensure that it effectively addresses the current and future environmental issues of concern. The plan is scheduled to be updated in late 2006. The plan in its current form can be found in Appendix B.

3.2 Research Project Development and Selection Activities

EMEP solicitations were issued to target research needs identified in the EMEP research plan. Program Opportunity Notices (PONs) were advertised broadly and sent directly to potential researchers. NYSERDA's process to evaluate and select research projects includes numerous internal controls and input from program, legal, contract, communications and evaluation staff. Technical evaluation panels include more external (non-NYSERDA) reviewers than NYSERDA staff. Recommendations from the panel were reviewed and approved by senior management prior to awarding contracts.

The attached "Team Memos" [Appendix C] describe the process followed for each of the 7 EMEP solicitation issued to date. Appendix C identifies the targeted research areas in each solicitation.

3.3 Funding and Management of Collaborative Research Projects

Table 2 displays the portfolio of EMEP research projects, including both completed and ongoing projects. For more information on these projects, see Appendix D. Appendix D contains a 2-page summary for each project including preliminary project findings and implications.

To date, EMEP has funded 46 research projects, 16 of which have been completed. The distribution of the research projects in the focus areas is as follows:

- Air quality and related health research associated with particulate matter, ozone, and co-pollutants (18 projects, $9.9 M NYSERDA, $22 M total project cost);

- Ecosystem response to deposition of sulfur, nitrogen, and mercury (21 projects, $9.6 M NYSERDA, $20 M total project cost);

- Crosscutting environmental science, energy, technology, and policy projects (7 projects, $1.1 M NYSERDA, $1.6 M total project cost).

Table 3 summarizes the research target areas identified in the Research Plan and identifies the EMEP projects that were funded to address these needs. As can be seen in Table 3, the majority of high-priority research needs identified in the EMEP planning process are now being addressed by specific EMEP research projects.

Section 3.4 (Knowledge Synthesis) summarizes the knowledge gained from these research projects and highlights how these projects have advanced the state-of-science in key policy relevant areas.

Table 2: New York Energy $mart[sm] Environmental Monitoring, Evaluation, and Protection Program Project Portfolio					
Contract #	Title	Principal Investigator and Research Organizations	Site	Total Project Cost	NYSERDA Cost
Air Quality and Related Health Research associated with Fine Particles, Ozone and Co-Pollutants					
4913	*Clinical Studies of Exposure to Ultrafine Particles	Dr. Mark Utell, Univ. of Rochester Medical Center	Rochester (clinical)	$817,141	$480,851
4914	*Analysis of Ozone and Fine Particles in the Northeast	Dr. S.T. Rao, SUNY-Albany	Statewide (modeling)	$547,749	$547,749
4918	Enhanced Measurements of Oxidants, Fine Particles and their Precursors	Dr. Kenneth Demerjian, SUNY-Albany	Whiteface Mtn, Pinnacle St. Park, NYC/Queens	$9,584,586	$3,879,617
5060	*Development and Demonstration of Continuous Ambient Particulate Monitor (R&P 6400 series)	Dr. Harvey Patashnick, Rupprecht & Patashnick Co., Inc.	Albany (lab work), field site	$122,078	$49,880
6083	Impact of In-and Out-of-State Power Plants on Semivolatile Pollutants in New York	Dr. Philip Hopke, Clarkson University	Stockton, Brockport (NYS northwest border)	$1,538,980	$1,143,118
6084	Source Apportionment of Fine Particles in New York City	Dr. George Thurston, NYU Medical Center	New York City, Tuxedo	$801,432	$489,358
6085	*Assessing the Effects of Transboundary Pollution on New York's Air Quality	Dr. S.T. Rao, NYS Dept. of Environmental Conservation	Canadian-NYS border, statewide (modeling)	$661,169	$387,919
6183	*Development and Demonstration of Innovative Instrument for Ambient Particulate Matter Mass Measurement Standard	Dr. Harvey Patashnick, Rupprecht & Patashnick Co., Inc.	Albany (lab work), field site	$1,328,580	$450,000
6230**	*Fine/Ultrafine Particulate Emissions Profiles	Dr. Paul Drayton, Gas Technology Institute; Dr. Glen England, GE-EER	New York State, California, others	$2,113,599	$198,000
6484	Fine Particle Constituents and Acute Asthma in Urban Areas	Dr. Daniel Luttinger, Health Research Inc./NYSDOH	New York City	$239,238	$184,965
6820	*Monitoring Particle Size Distribution in Rochester	Dr. Philip Hopke, Clarkson University	Rochester, NY	$246,555	$165,783
7607	*Workshop on Incorporation of Receptor Models into PM and Adverse Health Effects Study	Dr. Phil Hopke, Clarkson University	Statewide	$41,461	$30,112
7616	Chemical Composition of Fine Organic Particles from Urban Regional Background Locations in New York State	Dr. Monica Mazurek, Rutgers University	New York City, Pinnacle State Park, NYSDEC Testing Lab	$1,101,849	$678,890
7618	Formation and Transformation of Particles in Motor Engine Exhaust	Dr. Fangqun Yu, University at Albany	Statewide	$176,576	$100,000

Table 2: New York Energy $mart[sm] Environmental Monitoring, Evaluation, and Protection Program Project Portfolio					
Contract #	Title	Principal Investigator and Research Organizations	Site	Total Project Cost	NYSERDA Cost
7919	Analysis of PM Data in NY Using Advanced Source Apportionment Methods	Dr. Philip Hopke, Clarkson University	Statewide	$716,830	$200,000
8641	Assessment of Carbonaceous Fine Particle (PM2.5) for New York and the Region	Dr. Phil Johnson, NESCAUM	Statewide and Region	$491,477	$352,974
8643	Physical and Chemical Characterization of Laboratory-Generated Secondary Semi-volatile Organic Particles	Dr. Kenneth Demerjian, SUNY Albany	Albany, NY	$504,777	$299,998
8650	Ultrafine Particles and Cardiac Responses: Evaluation in a Cardiac Rehabilitation Center	Dr. Mark Utell, Univ. of Rochester Medical Center	Rochester, NY	$946,255	$300,000
Total number of Fine Particle and Ozone research projects: 18				**$21,980,332**	**$9,939,214**
Ecosystem Response to Deposition of Sulfur, Nitrogen and Mercury					
4915	Long-Term Monitoring Program for Evaluating Changes in Water Quality in Adirondack Lakes	Karen Roy. Adirondack Lakes Survey Corporation (ALSC)	52 Lakes in Adirondacks	$10,067,076	$3,845,443
4916	Mercury in Adirondack/Catskills Wetlands, Lakes and Terrestrial Systems	Dr. Ronald Munson, Tetra Tech, Dr. Charles Driscoll, Syracuse University	Sunday Lake (Adirondacks) & various sites in the Catskills	$1,193,597	$727,684
4917	Evaluation of the Recovery from Acidification of Surface Waters in the Adirondacks	Dr. Myron Mitchell, SUNY College of Env. Science and Forestry - Syracuse	Arbutus Pond, Hunt. Wildlife Forest, Statewide modeling	$1,200,896	$962,517
6086	*Effects of Atmospheric Deposition of S, N, Hg on Adirondack Ecosystems	Dr. Dudley Raynal, SUNY College of Environmental Science and Forestry	Adirondack Region	$413,385	$282,598
6485	*Contributions of Global and Regional Sources to Mercury Deposition in New York State	Dr. Christian Seigneur, Atmospheric & Environmental Research, Inc.	Statewide (modeling)	$203,903	$96,805
6486/6490	*Integrated Assessment of the Recovery of Surface Waters from Reduced Levels of Acid Deposition in the Catskills and Adirondacks	Dr. Douglas Burns, US Geological Survey, Dr. Gary Lovett, Institute of Ecosystem Studies	Adirondack and Catskill Regions (modeling and assessments)	$277,186	$245,506
6487	*Status and Effects of Nitrogen Pollution in North Eastern United States	Kathy Fallon Lambert, Hubbard Brook Research Foundation	Statewide	$379,440	$149,320
6488	*Atmospheric Transport and Fate of Mercury in New York State	Dr. Chris Walcek, Research Foundation of SUNY	Statewide (modeling)	$139,099	$102,828
6818	Mercury Deposition Monitoring in the Catskills	Dr. Mike McHale, U.S. Geological Survey	Neversink area, Catskills	$179,738	$116,363

Table 2: New York Energy $mart[sm] Environmental Monitoring, Evaluation, and Protection Program Project Portfolio					
Contract #	Title	Principal Investigator and Research Organizations	Site	Total Project Cost	NYSERDA Cost
6819	*Monitoring Deposition and Effects of Air Pollution in the Hudson Valley	Dr. Gary Lovett, Institute of Ecosystems Studies	Millbrook, NY	$133,333	$100,000
7605	Assessment of Extent to Which Intensively-studied Lakes are Representative of the Adirondack Mountain Region	Dr. Timothy Sullivan, E&S Environmental Chemistry, Inc	Adirondack Region	$2,531,415	$710,787
7606	Potential Recovery of Water Chemistry and Stream Biota from Reduced Acid Deposition at a Sensitive Watershed in the Catskills	Dr. Doug Burns, U.S. Geological Survey	Catskill Region	$63,552	$25,216
7608	Long-term Monitoring and Assessment of Mercury Based on Integrated Sampling using the Common Loon, Prey Fish, Water, and Sediment	Dr. Nina Schoch, Adirondack Cooperative Loon Program/Wildlife Conservation Society	Adirondack Region	$729,090	$380,914
7612/7716	Strategic Monitoring of Mercury in New York State Fish	Dr. Howard Simonin, NYSDEC, Karen Roy, ALSC	Statewide	$714,837	$487,226
7613/7717/ 7718	Assessment of Chemistry and Benthic Communities in Streams of the Oswegatchie-Black River Basins	Dr. Greg Lawrence, U. S. Geological Survey, Karen Roy, ALSC, Dr. Sophia Passy, Univ. Texas	Adirondack Region	$818,575	$476,000
8152	Mercury Deposition Monitoring in the Adirondacks	Dr. Charles Driscoll, Syracuse University	Newcomb, NY	$162,649	$142,658
8644/8739	Regional Forest Health and Stream and Soil Chemistry Using a Multi-scale Approach and New Methods of Remote Sensing Interpretation, Catskill Mountains, NY	Dr. Peter Murdoch, U.S. Geological Survey; Dr. Richard Hallet, USDA Forest Service	Catskill Region	$408,630	$256,553
8646	Assessment of Nitrogen and Acidic Deposition Impacts to Terrestrial and Aquatic Ecosystems of Tug Hill	Dr. Myron Mitchell & Dr. Gregory McGee, SUNY ESF	Tug Hill Region	$167,329	$123,762
8649	Assessing the Sensitivity of New York Forests to Cation Depletion	Dr. Ruth Yanai, SUNY ESF	Statewide	$210,132	$166,043
9059	Wind Power/Wildlife Interaction Project Services ($5,000 EMEP funds, $159,847 SBC Renewables)	Abby Arnold, RESOLVE, Inc	Statewide	$164,847	$164,847
PO-8142	Mercury Matters–General Interest “Science Links” Publication	Hubbard Brook Research Foundation	Northeast	$250,000	$10,000
Total number of Acid Deposition and Mercury research projects: 21				**$20,408,709**	**$9,573,070**

Table 2: New York Energy $mart[sm] Environmental Monitoring, Evaluation, and Protection Program Project Portfolio					
Contract #	Title	Principal Investigator and Research Organizations	Site	Total Project Cost	NYSERDA Cost
Projects Crosscutting the Topics of Air Quality, Health, Ecological Response, and Energy					
6681	*New York City Regional Heat Island Mitigation	SAIC (R. Slosberg), Columbia University (C. Rosenzweig), Hunter College (W. Solecki)	New York City	$134,010	$134,010
7609/8183	Quantifying Atmospheric Nitrogen Sources with New Stable Isotope Techniques	Dr. Carol Kendall, U.S. Geological Survey/Dr. Elizabeth Boyer, SUNY-ESF	Statewide	$649,806	$411,986
7610	*Multi Pollutant Policies for the Electricity Sector and Environmental Quality in the Empire State	Dr. Karen Palmer, Resources for the Future	Statewide	$312,345	$234,261
7615	Analysis of New Pollution Control Strategy Utilizing Emission Reduction Credits and Small Scale Combined Heat and Power Units	Navigant Consulting	Statewide	$101,890	$79,535
7617	Quantifying the Environmental Benefits of Increased Deployment of Combined Heat and Power Technologies in NY State and the Impact of Proposed Emissions Standards for Small Distributed Generation	Navigant Consulting	Statewide	$300,438	$171,863
8642	Ambient Gaseous Ammonia: Evaluation of Continuous Measurement Methods Suitable for Routine Deployment	Dr. James Schwab, SUNY Albany	Albany, Pinnacle State Park, and Addison, NY	$116,671	$89,430
PO-8055	A Synthesis of Climate Change Research	Ecologic: Analysis & Communications	Northeast	$14,000	$14,000
Total number of Crosscutting research projects: 7				**$1,629,160**	**$1,135,085**
Total Funds Committed				**$44,018,201**	**$20,647,369**
Total number of research projects: 46					

*Project complete; project report peer-reviewed and published
**Includes Non-SBC Statutory R&D funds

TABLE 3. EMEP Projects Initiated to Address Research Needs Identified in the EMEP Research Plan

Importance: 1 = critical/extremely important; 2 = important; 3 = moderately important

A. Atmospheric Deposition of Sulfur, Nitrogen, and Mercury, and Ecosystem Response

Research Target	Importance for NYS	Research Projects Underway (Includes completed projects, noted by *)		
		Contract #	Title	P.I.
1.0 Baseline Monitoring/Characterization/Surveys				
1.1. Characterize current conditions with respect to baseflow and episodic stream chemistry in sensitive watersheds Statewide to assess the extent and severity of effects, and to establish a baseline from which to assess future recovery.	1	4915	Long-Term Monitoring Program for Evaluating Changes in Water Quality in Adirondack Lakes	Roy
		7613 / 7717 / 7718	Assessment of Chemistry and Benthic Communities in Streams of the Oswegatchie-Black River Basins	Lawrence , Roy, & Passy
		4917	Evaluation of the Recovery from Acidification of Surface Waters in the Adirondacks	Mitchell
		8646	Assessment of Nitrogen and Acidic Deposition Impacts to Terrestrial and Aquatic Ecosystems of Tug Hill	Mitchell & McGee
1.2. Characterize current soil conditions to assess effects and recovery potential of sensitive soils, and develop a soil database that supports other terrestrial and aquatic effects studies. Use historic soil data, where possible, to evaluate long-term changes in soil chemistry.	1	7605	Assessment of Extent to Which Intensively Studied Lakes are Representative of the Adirondack Mountain Region	Sullivan
		8649	Assessing the Sensitivity of New York Forests to Cation Depletion	Yanai
1.3 Develop a strategic monitoring and assessment program on long term trends of mercury deposition and effects, Statewide, to understand the health and environmental consequences of mercury deposition.	1	4916	Mercury in Adirondack/Catskills Wetlands, Lakes, and Terrestrial Systems	Munson & Driscoll
		6818	Mercury Deposition Monitoring in the Catskills	McHale
		8152	Mercury Deposition Monitoring in the Adirondacks	Driscoll
		7612 / 7716	Strategic Monitoring of Mercury in New York State Fish	Simonin & Roy
		7608	Long-Term Monitoring and Assessment of Mercury Based on Integrated Sampling Using the Common Loon, Prey Fish, Water, and Sediment	Schoch
1.4. Monitor biota to evaluate recovery of aquatic food webs from plankton to piscivorous birds.	1	4915	Long-Term Monitoring to Evaluate Changes in Water Quality in Adirondack Lakes	Roy
		7608	Long-Term Monitoring and Assessment of Mercury Based on Integrated Sampling Using the Common Loon, Prey Fish, Water, and Sediment	Schoch
		7612 / 7716	Strategic Monitoring of Mercury in New York State Fish	Simonin & Roy
		6086*	Effects of Atmospheric Deposition of S, N, and Hg on Adirondack Ecosystems	Raynal

Research Target	Importance for NYS	Research Projects Underway (Includes completed projects, noted by *)		
		Contract #	Title	P.I.
1.5. Assess the extent of effects of deposition on forest health in geologically sensitive areas of New York State.	1	4917	Evaluation of the Recovery from Acidification of Surface Waters in the Adirondacks	Mitchell
		8646	Assessment of Nitrogen and Acidic Deposition Impacts to Terrestrial and Aquatic Ecosystems of Tug Hill	Mitchell & McGee
		6487*	Status and Effects of Nitrogen Pollution in North Eastern United States	Lambert
		6819*	Monitoring Deposition and Effects of Air Pollution in the Hudson Valley	Lovett
		8644 / 8739	Regional Forest Health and Stream and Soil Chemistry Using an Multi-Scale Approach and New Methods of Remote Sensing Interpretation, Catskill Mountains, NY	Murdoch & Hallet
		8649	Assessing the Sensitivity of New York Forests to Cation Depletion	Yanai
1.6. Develop methodologies to improve accuracy of dry deposition measurements.	1			
2.0 Process-level Studies/Fate and Transport/Ecosystem Cycling/Modeling/Effects				
2.1. Conduct assessments of the effects of acid deposition and Hg on biota and food webs; examine the effects of food web structure on elemental transfers to document biological effects of acid deposition.	1-2	7608	Long-Term Monitoring and Assessment of Mercury Based on Integrated Sampling Using the Common Loon, Prey Fish, Water, and Sediment	Schoch
		7606	Potential Recovery of Water Chemistry and Stream Biota from Reduced Acid Deposition at a Sensitive Watershed in the Catskills	Burns
2.2 Identify multiple sources (including sources outside of NYS) and relative contributions of mercury; determine mercury ecosystem fluxes, transformation and transport, to assist in source reduction initiatives.	2	4916	Mercury in Adirondack/Catskills Wetlands, Lakes, and Terrestrial Systems	Munson & Driscoll
		6485*	Critical Gaps in Research on Mercury in NY State	Seigneur
		6488*	Atmospheric Transport and Fate of Mercury in NYS	Walcek
2.3. Examine interaction of biogeochemical cycles of nutrients (N, S, C, P, Ca) to identify potentially important but indirect effects of acid deposition.	2	6487*	Status and Effects of Nitrogen Pollution in North Eastern United States	Lambert
		6486 / 6490*	Integrated Assessment of the Recovery of Surface Waters from Reduced Levels of Acid Deposition in the Catskills and Adirondacks	Burns & Lovett
		6086*	Effects of Atmospheric Deposition of S, N, and Hg on Adirondack Ecosystems	Raynal
3.0 Synthesis/Integration Studies				
3.1. Investigate landscapes as integrated ecological units by (1) describing linkages among their physical components; (2) examining approaches to extrapolating from small watershed or plot scales to larger units; (3) determining whether the small number of well-studied sites in some parts of New York are representative of larger areas.	1		Assessment of Extent to Which Intensively Studied Lakes are Representative of the Adirondack Mountain Region	Sullivan
3.2. Synthesis and assessment of current	1-2	6487*	Status and Effects of Nitrogen Pollution in North Eastern United States	Lambert

Research Target	Importance for NYS	Research Projects Underway (Includes completed projects, noted by *)		
		Contract #	Title	P.I.
information and study site data regarding key issues related to the effects from acid rain and mercury.		6486 / 6490*	Integrated Assessment of the Recovery of Surface Waters from Reduced Levels of Acid Deposition in the Catskills and Adirondacks	Burns & Lovett
3.3. Comprehensive, state-of-science synthesis of acid rain and mercury impacts in New York State.	3	4915	Long-Term Monitoring Program for Evaluating Changes in Water Quality in Adirondack Lakes	Roy
		PO-8142	Mercury Matters–General Interest "Science Links" Publication	Hubbard Brook RF
4.0 Other (Mitigation, Policy/Economic Assessments, Technology Transfer)				
4.1. Conduct modeling to determine critical and target loads.	1-2			
4.2 Assess the effectiveness of cross-sector pollution control strategies in reducing ecological impacts and enhancing recovery.	1-2			
4.3. Assess the economic value of natural resource improvements (aquatic and terrestrial) associated with air pollution control.	2			
4.4. Demonstrate techniques for accelerated recovery.	1-2			

B. Air Quality and Related Health Research: Particulate Matter, Ozone and Co-Pollutants

Research Target	Importance for NYS	Research Projects Underway (Includes completed projects, noted by *)		
		Contract #	Title	P.I.
1.0 Ambient Monitoring and Evaluation				
1.1. Develop and integrate improved measurement technologies, including technologies for higher time-resolution composition measurements into network design (2-3 key locations).	2	5060*	Demonstration of Continuous Ambient Particulate Monitor	Patashnick
		6183*	Demonstration of Innovative Instrument for Ambient Particulate Matter Mass Measurement Standard	Patashnick
		8642	Ambient Gaseous Ammonia: Evaluation of Continuous Measurement Methods Suitable for Routine Deployment	Schwab
		6820*	Monitoring Particle Size Distribution in Rochester	Hopke
		6083	Impact of Power Plants on Semivolatile Pollutants and Fine Particles in New York State	Hopke

Research Target	Importance for NYS	Research Projects Underway (Includes completed projects, noted by *)		
		Contract #	Title	P.I.
		NYSERDA is supporting several other research projects to address this goal, including the following: development of ultrafine particle monitor at Clarkson, development of a continuous PM speciation monitor with x-ray optical. However, these projects are not funded by EMEP.		
1.2. Develop coarse particle (PM10-PM2.5) monitoring data and source-receptor relations for to help New York State comply with likely course particle standard.	2-3			
1.3. Analyze long-term archived PM filter samples to establish long-term trends, baselines, support source apportionment and transport assessments.	3			
2.0 Fate and Transport				
2.1. Develop, apply and interpret PM/Ozone models and data analysis methods to support policy formulation for PM and ozone management.	1	6083	Impact of Power Plants on Semivolatile Pollutants and Fine Particles in New York State	Hopke
		6084	Source Apportionment of Fine Particles in New York State	Thurston
		4918	Enhanced Measurements of Oxidants, Fine Particles, and Precursors	Demerjian
		7919	Analysis of Particulate Matter Data in New York Using Advanced Source-Apportionment Methods	Hopke
2.2. Improve understanding of the role of primary & secondary organics in PM in New York State.	1	6083	Impact of Power Plants on Semivolatile Pollutants and Fine Particles in New York State	Hopke
		4918	Enhanced Measurements of Oxidants, Fine Particles, and Precursors	Demerjian
		8641	Assessment of Carbonaceous PM2.5 for New York and the Region	Johnson and Graham
		8643	Physical and Chemical Characterization of Laboratory-Generated Secondary Semivolatile Organic Particles	Demerjian
		7616	Chemical Composition of Fine Organic Particles from Urban and Regional Background Locations in New York State	Mazurek
2.3. Improve understanding of transport phenomena, specifically aloft and at night.	1			
2.4. Explore co-pollutant interaction and multi-pollutant effects related to pollution control.	2			

Research Target	Importance for NYS	Research Projects Underway (Includes completed projects, noted by *)		
		Contract #	Title	P.I.
2.5. Explore feasibility of alternative air quality management strategies on different time scales (e.g., forecasting and real-time control).	2-3			
3.0 Health Effects				
3.1a. Support the integration and analysis of relevant PM Supersite/network data with exposure/health effects studies.	1			
3.1b. Support the integration of source attribution methods of PM into exposure/health effects studies (methods development, technology transfer) [relates to 2.1].	1	6484	Fine Particle Constituents and Acute Asthma in Urban Areas	Luttinger
		7607*	Workshop on Incorporation of Receptor Models into PM and Adverse Health Effects Studies	Hopke
3.2. Explore feasibility of a targeted cohort study to examine exposure and health effects to “line exposure” from mobile sources.	1			
3.3. Better understand the patterns of, and factors influencing, dose and human exposures to pollutants of ambient origin.	1-2	8650	Ultrafine Particles and Cardiac Responses: Evaluation in a Cardiac Rehabilitation Center	Utell
3.4. Support critical research to identify causal components in PM.	2	4913*	Clinical Studies of Exposure to Ultrafine Particles	Utell
3.5. Develop long-term data for black carbon as surrogate for diesel exposures/Develop exposure data for diesel PM urban environments.	3			
4.0 Source Emissions, Technology and Policy Analysis				
4.1. Support method development and characterization of sources of primary and secondary PM emissions impacting NYS.	1	6230*	Fine/Ultrafine Particulate Emissions Profiles	Drayton & England
		7919	Analysis of Particulate Matter Data in New York State Using Advanced Source Apportionment Methods	Hopke
		NYSERDA is supporting several other research projects to address this goal, including: characterization of emissions from ferries, buses, and the construction sector. However, these projects are not funded by EMEP.		
4.2. Integrated assessment of PM in NYS to	1	4918	Enhanced Measurements of Oxidants, Fine Particles, and their Precursors	Demerjian

Research Target	Importance for NYS	Research Projects Underway (Includes completed projects, noted by *)		
		Contract #	Title	P.I.
provide scientific foundation for SIP development.		8641	Assessment of Carbonaceous PM2.5 for New York and the Region	Johnson & Graham
4.3. Develop standard test method for particle size distribution for mobile sector emissions: test stand and in-use	2			

C. Research Needs Crosscutting the Topics of Air Quality, Health, and Ecosystem Response

Research Target	Importance for NYS	Research Projects Underway (Includes completed projects, noted by *)		
		Contract #	Title	P.I.
1. Assess adequacy of existing monitoring networks as they relate to (i) source attribution, (ii) determining transport, (iii) evaluating health and environmental effects, and (iv) verifying the impacts of changes to pollution controls strategies on air quality.	1	EMEP did not pursue this area in SBC2, given ongoing federal evaluation of monitoring networks.		
2. Evaluate Environmental Effects and Strategies for Mitigating Impacts of Electricity Generation	1	7610*	Multi-Pollutant Policies for the Electricity Sector and Environmental Quality in the Empire State	Palmer
3. Evaluate the environmental and energy implications of the distributed generation of electricity in New York State.	1	7615	Analysis of New Pollution Control Strategy Utilizing Emission Reduction Credits and Small Scale Combined Heat and Power Units	Greene
		7617	Quantifying the Environmental Benefits of Increased Deployment of Combined Heat and Power Technologies in NYS and the Impact of Proposed Emissions Standards for Small Distributed Generation	Navigant
4. Maintain and initiate, where necessary, measurements of fine particulates/precursors, wet and dry deposition of sulfur and nitrogen, and base cations at specific long-term study sites, building on assessment in C1 above.	1	4915	Long-Term Monitoring Program for Evaluating Changes in Water Quality in Adirondack Lakes	Roy
		4918	Enhanced Measurements of Oxidants, Fine Particles, and their Precursors	Demerjian

Research Target	Importance for NYS	Research Projects Underway (Includes completed projects, noted by *)		
		Contract #	Title	P.I.
5. Identify multiple sources and relative contributions of fixed nitrogen, including ammonia, to NYS ecosystems; examine watershed retention of nitrogen, to assist in source reduction initiatives; improve understanding of the sources of ammonia and role in aerosol formation in NYS - including inventory development and exploration of mitigation options.	1	6487*	Status and Effects of Nitrogen Pollution in North Eastern United States	Lambert
6. Develop evaluation protocols to verify the impacts of pollution control strategies.	2			
7. Assess the feasibility and cost effectiveness of multi-pollutant control strategies for existing generation infrastructure in NYS.	2	7610*	Multi-Pollutant Policies for the Electricity Sector and Environmental Quality in the Empire State	Palmer
8. Evaluate potential effects of emissions trading (e.g., Hg, PM precursors) on local/regional impacts.	3	7610*	Multi-Pollutant Policies for the Electricity Sector and Environmental Quality in the Empire State	Palmer
9. Evaluate the environmental impacts of biodiesel in NYS	2	EPA completed a study to address this topic. It was not pursued under EMEP.		

As discussed at the beginning of Section 3, the Program Advisory Group and Science Advisory Committee are pivotal components of the EMEP process. Table 4 displays the meetings that were held with the two groups to define research needs, develop solicitations, review proposals, and discuss and evaluate progress in EMEP research.

Table 4: Program/Science Advisory Meetings

Date	Purpose
1998	Evaluate six research projects identified in the SBC1 Public Service Commission Order started by the Empire State Electric Energy Research Corporation (ESEERCO) and transferred to EMEP. Provide recommendations for funding.
May 24, 1999	- Develop agenda for the next fall EMEP conference - Convene Technical Evaluation Panel (TEP) for Program Opportunity Notice (PON) 446 - Develop future strategies for EMEP peer review and science/policy integration
December 9, 1999	- Review project portfolio
August 7, 2000	- Convene TEP for PON 540
September 26-27, 2000	- Review project portfolio
March 1, 2001	- Finalize PON 586 - Identify future research target areas and solicitations - Develop strategies for assistance with science/policy communication - Develop agenda for the next fall EMEP conference
June 21, 2001	- Convene TEP for PON 586
September 26, 2001	- Review draft EMEP research plan
June 5, 2002	- Convene TEP for PON 594
October 16-17, 2002	- Review Acid Deposition and Mercury projects
December 11, 2002	- Convene TEP for PON 682
March 18-19, 2003	- Review Fine Particle & Ozone projects
October 9, 2003	- Discuss future EMEP solicitations and planning for the year ahead
June 22, 2004	- Convene TEP for PON 839
December 9-10, 2004	- Review outreach and science policy communication strategies - Explore planning for the future of EMEP - Discuss the structure and function of the PAG/SAC

3.4 Knowledge Synthesis: Highlights of Findings from EMEP Research

The EMEP Program is sponsoring a wide range of energy-related environmental research consistent with the Research Plan. Findings and implications of each project are presented in the individual Project Updates found in Appendix D.

Appendix E presents a *synthesis*, prepared by EMEP staff, of the findings from these projects pertaining to the three EMEP focus areas:

- Air quality and related health research associated with particulate matter, ozone, and co-pollutants;
- Ecosystem response to deposition of sulfur, nitrogen, and mercury; and
- Crosscutting environmental science, energy, technology, and policy projects.

The following boxes highlight some of the key findings from the EMEP program and illustrate where EMEP has advanced the state-of-the-science in key policy relevant areas.

Figure 2: Highlights from EMEP-Supported Projects Related to Air Quality and Health Effects

HOW CAN WE IMPROVE MEASUREMENT OF $PM_{2.5}$ AND ITS COMPONENTS?

- Fine-particle instrument development such as the Sample Equilibration System (SES) Differential Tapered Element Oscillating Microbalance (TEOM) and the Filter Dynamics Measurement System (FDMS) are improving continuous PM measurement by resolving issues with adsorption and evaporation of collected samples. Improved monitors provide a detailed time-series of PM mass that more closely represents fine particles found in the ambient air.

- Field comparisons of the Federal Reference Method (FRM) with the FDMS and beta-attenuation monitor (BAM) show the FRM to be significantly lower than the BAM and FDMS, raising serious questions about the representativeness of the FRM to ambient PM. The designation of the FRM as the mass measurement standard for the “true” ambient PM mass is now being challenged.

- Continuous PM sulfate measurement technologies (R&P 8400S and Thermo 5020) show promise for routine network deployment. PM sulfate measurements are in good agreement with collocated instruments and consistently recover about 80% as much sulfate as 24-hr Speciation Trends Network (STN) filters. Operational and maintenance issues with some systems remain to be resolved.

- Continuous PM nitrate measurement technology (R&P 8400N) shows promise for routine network deployment, but measured PM nitrate levels are significantly lower (30-40%) than other collocated semi-continuous instruments and 24-hr STN filters.

- Continuous PM carbon measurement technology (Sunset Labs-Elemental Carbon/Organic Carbon (EC/OC)) shows promise for routine network deployment, indicating good agreement with collocated instruments and 24-hr STN filters and aerosol mass spectrometer - OC measurements. R&P 5400 EC/OC tracks total relative carbon well, but is not quantitative, as it does not provide comparable EC/OC with 24-hr STN filters.

- Dilution source sampling can be an effective method of measuring PM2.5 emissions from stationary sources. Measurement of PM2.5 emissions is highly method dependent. Emissions tests using different methodologies (e.g., dilution vs. filterable + condensable methods) can produce significantly different results and emission factors. In tests with gaseous fuels (refinery gas and natural gas), filterable + condensable methods yielded PM2.5 emission factors that were one to two orders of magnitude greater than determined using dilution methods. In field and pilot tests with No. 6 fuel oil, conventional stack sampling of filterable + condensable PM2.5 produced PM2.5 emission factors that were between 25% and 60% less than those determined using dilution sampling methods. These tests underscore the need for a consistent measurement method for PM2.5 – established at the national level - combined with a concerted effort to improve PM2.5 emissions inventories and emission factors.

WHAT IS IN $PM_{2.5}$ IN THE NEW YORK REGION?

- The PM Technology Assessment and Characterization Study in New York (PMTACS-NY or "Supersite") research program has measured the temporal and spatial distribution of the $PM_{2.5}$/co-pollutant complex. The findings show that for the annual composition of PM in NYC, the largest fraction is carbon (36%), followed by sulfate (30%), nitrate (15%), and ammonium (15%), with 5% of trace metals/water.

- Composition of $PM_{2.5}$ at NYC (average of New York Botanical Garden, South Bronx, and Queens College measurements), Rochester, Pinnacle State Park, and Whiteface Mountain showed they all have the major components of carbon, nitrate, sulfate, and ammonium but there is a systematic change in the distribution of these components from the urban to the rural and remote locations. Carbon is proportionally highest in the NYC area and lowest in the rural and remote areas indicating an important local component. Nitrate is proportionally highest in the large urban (NYC) and small urban (Rochester) sites, and significantly lower in the rural and remote locations. Sulfate is proportionately highest at Pinnacle State Park, presumably due to its proximity to the Ohio River Valley source region.

- PMTACS also found that the composition of PM changes with season. During summer, wind is generally from the southwest, a region with many coal sources. PM collected during summer has high amounts of sulfate (28%) and organic PM (45%), and lower nitrates (5%). In winter, when there is less photochemistry, the wind is generally from the northeast, an area of fewer regional sources relative to the southwest. During this season, there is less $PM_{2.5}$ mass but it has a higher proportion of nitrate (17%) and higher mass of nitrate.

- PM mass, composition and particle size can vary with day of the week and time of day, revealing important sources and processes. PM mass is greatest in NYC during the morning (6-8 a.m.). Sulfates show almost no diurnal pattern due to transported component. In contrast particle nitrate has peak between 6-7 a.m. Organic PM shows a peak at 5-8 a.m. and again at 3-6 p.m. due to both traffic-related particles and photochemically produced organic PM.

WHAT ARE THE SOURCE REGIONS AND SOURCE TYPES CONTRIBUTING TO PM2.5 IN NEW YORK?

- The geographically separated sites of Queens College, Whiteface Mountain and Pinnacle State Park have similar concentrations of sulfate due to long-range transport of aerosols impacting all three sites similarly. Air mass trajectory analysis

for Queens College, Whiteface Mountain and Pinnacle State Park indicate the Ohio River Valley and area around the Great Lakes as source regions transporting high sulfate concentrations.

- Several different EMEP studies indicate that a large fraction of PM and particulate sulfate is transported into NYC and is not from local sources.

    - While these studies reveal a range in the transported contribution to particulate sulfate (44 to 95%), studies generally agree that more than half of the ambient particulate sulfate in NYC is transported into the region.

    - Studies suggest that on an annual basis approximately 31 to 75% of ambient PM2.5 in NYC is transported into NYC from upwind sources.

    - The transported contribution to PM2.5 and particulate sulfate in NYC can vary depending on season and photochemistry; and the specific quantitative determination of this transport component will be affected by methodological assumptions (e.g., spatial definitions, background reference point.)

- Source apportionment studies for NYC and Upstate New York locations identified secondary sulfate, and the Ohio River Valley as the major source contributing to PM. Soil, secondary nitrate, wood smoke, zinc smelter, copper smelter, nickel smelters, spark ignition vehicles, diesel vehicles, oil combustion, and sea salt were also identified depending on the technique and data sets used.

- Results of Positive Matrix Factorization (a type of source apportionment) using particle number concentrations and size distributions were able to identify major source types and processes including primary industrial emissions, traffic, nucleation. In addition this approach was able to separate residential and commercial heating from other sources such as diesel vehicles.

- Chemical speciation of 63 molecular markers in organic aerosol samples collected upwind, down wind and within New York City have identified three important source types of organic PM. Motor vehicles, using hopanes as the molecular marker are highest in urban areas, and lowest in rural areas. Cooking oil, a less emphasized source type in air quality planning, and identified by n-alkanoic acids, are highest in urban areas during the winter. Photochemical oxidation products identified by C2-C10 diacids are highest in urban areas during spring and summer.

- Estimates of summertime PM production based on OH + VOC measurements suggest that approximately 40% of the PM organic carbon (which can account for close to 20% of PM) can be generated by photochemical oxidation processes (most likely of local origin).

- Estimates of summertime PM sulfate photochemical-production and reaction kinetics of OH + SO_2 indicate that some of the PM sulfate observed at Queens, NY (~15-60%) can be generated by photochemical oxidation processes (most likely of local origin).

- The major source types of PM identified by source apportionment techniques do not have good agreement with the EPA Emissions Inventory for Primary PM, indicating that there may be some problems with the Emissions Inventory for Primary PM in New York City, especially in the soil-related PM component.

ARE THERE SPECIFIC COMPONENTS IN THE PM2.5/CO-POLLUTANT COMPLEX CAUSING ADVERSE HEALTH EFFECTS?

- Clinical health studies on the effects of ultrafine particles (UFP) inhalation showed high pulmonary deposition rates of UFP that increased with exercise, and a number of cardiac effects such as alteration of cardiac repolarization.

- Ultrafine particle (UFP) measurements in Rochester, NY identified diurnal patterns of UFP associated with the morning rush-hour and with afternoon photochemical activity in the spring and summer.

- An analysis of asthma emergency department (ED) visits found $PM_{2.5}$, SO_2, and NO_2 had a statistically detectable impact on acute asthma ED visits in a community with a relatively high baseline rate of acute asthma exacerbations. It is of particular interest that the more robust health impacts were associated with the daily maximum $PM_{2.5}$ concentrations compared to the 24-hour mean, suggesting that peak exposures may have larger health impacts. These associations of the three pollutants with health effects in the Bronx occurred at ambient air levels that are below the current short-term NAAQS.

WHAT ARE THE IMPLICATIONS FOR AIR QUALITY MANAGEMENT OF $PM_{2.5}$ AND OZONE?

- The measured reactions of OH (an indicator of the oxidative strength of the atmosphere) with SO_2 and VOCs, suggest that oxidant control strategies will have a direct benefit in mitigating warm season PM production, underscoring the need for multipollutant control strategies to reduce ambient ozone and PM.

- Summertime photochemical oxidation experiments indicate that local/regional reductions of VOCs (which are gas phase/semivolatile precursors to PM) may be an effective strategy for reducing the organic component of PM2.5, which can be significant in NYC.

- While a large fraction of the annual PM sulfate (44-95%) is transported into NYC - and will therefore necessitate national/regional emission reductions - photochemical oxidation experiments show there is sufficient OH in the summertime to oxidize local SO_2 to PM sulfate (contributing up to 15-60% of PM sulfate in some cases). This suggests that reductions of local SO_2 emissions in the NYC region could potentially further reduce ambient PM2.5.

- Diesel-particulate-filter (DPF) equipped diesel buses and compressed natural gas (CNG) buses show significant reduction in PM emissions as compared to standard diesel buses. CNG-powered buses have methane and formaldehyde emissions that may have to be addressed. In addition, DPF-equipped diesel buses have changed NO_2/NO_x ratios that may have to be addressed. The studies demonstrate that a multi-pollutant approach, combined with appropriate field/in-use testing, is important to avoid unintended consequences with emerging control technologies.

- The findings of “airshed” models underscore that no state in the Northeast can adequately address pollutant problems alone until region-wide control strategies are implemented for ozone and $PM_{2.5}$. The probabilistic framework recommended by these EMEP studies – aimed at integrating the spatiotemporal information of observations and model predictions, and applied to ozone concentrations for demonstration purposes – should be expanded to address multipollutant problems within the “one atmosphere” approach.

Figure 3. Highlights From EMEP-Supported Projects Related to the Deposition of Sulfur, Nitrogen, and Mercury

How have reduced emissions of sulfur and nitrogen resulting from the Clean Air Act Amendments impacted New York State ecosystems?

- Surface waters in New York State affected by acid deposition are slowly improving due to reduced levels of acid precipitation, but additional improvements may require reductions in SO2 and NOx emissions greater than were mandated under the 1990 CAAA. The most recent data from the Adirondacks shows that the rates of improvement have slowed, and the region continues to be at risk.

- The rates of improvement in acid neutralizing capacity in Adirondack lakes are small and slow, suggesting it will take decades at current deposition rates to reach 50 meq/L, a level suitable for aquatic biota.

- Episodic acidification is extremely damaging to Adirondack lake and stream ecosystems. High acidity during snowmelt and high flow events causes aluminum levels to rise, which has been well documented to cause widespread fish mortality. An ongoing EMEP-funded study has found that over 50% of western Adirondack streams have aluminum levels during high flow events that were sufficiently elevated to cause fish mortality.

- Adirondack soil acid-base chemistry has been continuing to deteriorate in most of the acid-sensitive watersheds. It appears that this deterioration in soil condition may have occurred even while lake chemistry was getting better. Such an effect would be expected to restrict the extent to which lakes will be able to recover in the future from acidification and might contribute to future adverse impacts on forest vegetation. Watershed soil is clearly the key to determining the extent to which Adirondack lakes will recover.

- In the Hudson Valley region, fertilized plots show signs of significant increases in foliar and litterfall nitrogen, and nitrate leaching. The surprisingly high nitrate leaching indicates that nitrogen saturation may occur at this site much earlier than expected based on other studies, suggesting that the ecosystem is susceptible to nitrogen saturation.

- While the widespread recovery of streams in the Catskills is as yet unconfirmed, recent data do suggest that recovery may be under way in waters with ANC values in the range of 30–70 ìeq/L. The potential early improvements in stream chemistry may eventually result in the recovery of acid-intolerant biota in affected streams.

What is the role of nitrogen and what are our control options?

- Reactive nitrogen originates from numerous sources and has complex relationships with other pollutants. It therefore requires integrated management strategies and policies addressing multiple rather than individual sources. The assessment of nitrogen pollution in the Northeast region conducted in 2002/2003 shows that the CAAA had not yet had a substantial effect on airborne nitrogen emissions. Together with efforts to reduce SO2, CO2, and other pollutants, nitrogen in the Northeast can be further decreased through a number of strategies: reducing power-plant nitrogen emissions, improving wastewater treatment to remove nitrogen from effluent, reducing the use and increasing the efficiency of

nitrogen fertilizers, and creating and restoring natural nitrogen sinks in wetlands and floodplains.

- Isotopic trace analysis of wet deposition samples shows that the isotopic composition of nitrogen is spatially variable with a gradient from the Midwest (highest isotopic enrichment of ^{15}N) to the Northeast (lowest isotopic enrichment of ^{15}N). The isotopic enrichment is correlated with nitrate, sulfate and pH. These findings, although preliminary, may provide further insight into control strategies for reducing nitrogen loading into the ecosystem.

WHAT HAVE WE LEARNED ABOUT MERCURY EMISSIONS, TRANSPORT AND DEPOSITION?

- Computer modeling conducted in 2001 showed U.S. emissions (non-NYS) to be the largest source of total Hg deposition in New York State. Dry deposition was dominated by NYS and U.S. emissions, while wet deposition showed a much greater contribution from sources outside North America.

- 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.

WHAT HAVE WE LEARNED ABOUT THE FORMS OF MERCURY AND THEIR IMPACT ON NEW YORK STATE?

- The dynamics of Hg studied within forest plots at an Adirondack watershed showed that the flux of Hg to the forest ecosystem was dominated by dry deposition, which was estimated as throughfall (water that falls to the ground following interaction with the forest canopy) plus litter fall. These inputs accounted for 70% of total deposition. Current data on mercury dry deposition are extremely limited, underscoring a significant gap in the ability to assess the effectiveness of mercury control strategies.

- A monitoring project measuring reactive gaseous mercury, particulate Hg, and Hg in wet deposition has begun characterizing the forms of Hg in New York's ambient air and its sources. This initial project and its instrument comparison will become the basis of New York's future Hg monitoring network.

IS MERCURY AFFECTING WILDLIFE IN NEW YORK STATE?

- 18% of the loons sampled in the Adirondacks are estimated to be at risk for harmful effects from mercury contamination.

- Fish and water samples collected from 131 lakes across New York State has resulted in the addition of numerous waterbodies, including all waters of the Adirondacks and Catskills, to the NYS Department of Health has fish consumption advisories.

Figure 4. Highlights From Completed EMEP-Supported Projects Crosscutting the Issues of Air Quality, Health, Ecological Response, and Energy

How will planned national and regional proposals to reduce emissions from the electricity sector affect New York State and the nation?

- In 2004 an assessment was conducted of several proposed regional and national emission control strategies to reduce SO2, NOx, and mercury including: (i) the Clean Air Interstate Rule (CAIR) combined with a mercury cap; (ii) CAIR combined with a mercury cap and seasonal SIP NOx policy; (iii) CAIR plus a tighter mercury control using Maximum Achievable Control Technology (MACT); and (iv) CAIR plus a tighter mercury standard with trading. The study concluded that the benefits to the nation and to New York State significantly outweigh the costs associated with the proposed reductions in SO_2, NOx, and mercury. All policies evaluated showed dramatic *net* benefits underscoring the rationale for further national/regional reduction in emissions from power plants.

- Contrary to EPA's initial findings, CAIR as originally proposed by itself would not keep summer emissions of NOx from electricity generators in the SIP region below the current SIP seasonal NOx cap. [In the final CAIR, EPA added a seasonal NOx cap to address seasonal ozone problems.] CAIR with the seasonal NOx cap produces higher net benefits.

- The study also illustrated that the manner in which mercury emissions are regulated will have important implications not only for the cost of the regulation, but also for emission levels and emission locations for SO_2 and NOx. The evaluation of scenarios with tighter mercury emission controls shows that the net benefits of a maximum achievable control technology (MACT) standard exceed the net benefits of a cap and trade approach.

Are there options for mitigating the urban heat island effect in New York City?

- Significant reductions in New York City's near-surface air temperature can be achieved by implementing heat island mitigation strategies.

    - Street trees—which involve redevelopment of impervious surfaces—have the largest cooling potential per unit area, followed by living roofs, light-colored surfaces, and open-space planting.

    - Taking into consideration available land area and other physical constraints, combined strategies such as urban forestry + living roofs and urban forestry + lights roofs have the greatest city-wide modeled temperature impacts (0.7^{o}F and 0.6 ^{o}F respectively). Of the single strategy scenarios, light surfaces had the greatest temperature impact (0.4 ^{o}F).

    - Light surfaces, light roofs, and curbside planting are more cost-effective than other strategies.

- The choice of a strategy should consider the characteristics and priorities of the neighborhood, including benefit/cost factors and the available area for implementation of each strategy.

Section 4: Knowledge Dissemination and Information Exchange

This section discusses the dissemination of knowledge and information exchange from specific EMEP program activities, including, where known, quantification of the extent of the activity.

4.1 Overview of Communications Activities

EMEP places a premium on communicating research results to the target audiences. EMEP employs a variety of communication strategies and approaches as highlighted below. In 2002, EMEP program staff developed a Communications Strategy, with the assistance of outside contractors. This Communications Strategy was adjusted as needed and established the framework for the bulk of EMEP communications activities [see Appendix F]. In 2005, EMEP surveyed two dozen representative user groups to refine its Communication Strategies. The results of this recent survey will be used to develop the EMEP Communications Strategy for the next phase of the EMEP program.

Electronic communications have become more and more important in recent years. Table 5 below lists the number of hits on EMEP Web pages, by month; Table 6 shows the top 20 items downloaded from the EMEP site since March 2005, when EMEP first had its own presence on the NYSERDA Web site. A revised and improved EMEP Web site was launched in October 2005.

Table 5: EMEP Web Site Hits by Month and Year

Month	Hits	2005 Total	Month	Hits	2006 Total
March 05	546		January 06	12,546	
April 05	468		February 06	13,642	
May 05	1,147		March 06	18,856	
June 05	965		April 06	28,422	
July 05	2,308		May 06	29,141	
August 05	2,211		June 06	20,068	
September 05	3,610		July 06	18,897	
* October 05	6,703		**2006**		**141,572**
November 05	6,893				
December 05	9,761				
2005		**34,612**			

* The revised EMEP Web site was launched in October 2005.

From November 2005 through July 2006, the EMEP Web site has been one of the top three NYSERDA Web pages (as determined by number of hits on each page). From March 2006 through July 2006, two of the top five NYSERDA Web pages have been EMEP pages.

Table 6: Top 20 Downloads from March 2005 through June 2006

Item	# of Downloads
Fine and Ultrafine Particulate Emission Profiles: Critical Review of Methodologies (Project #6230)	8181
Acid Rain primer	5785
Multipollutant Policies for the Electricity Sector and Environmental Quality in the Empire State: Final Report (Project #7610)	4066
Fine and Ultrafine Particulate Emission Profiles: Test Results for a Cogeneration Plant with Supplementary Firing, Oxidation Catalyst, and SCR at Site Golf (Project #6230)	3704
Fine and Ultrafine Particulate Emission Profiles: Conceptual Model of Sources of Variability in Combustion Turbine PM10 Emissions Data (Project #6230)	3695
Fine and Ultrafine Particulate Emission Profiles: Impact of Operating Parameters on Fine Particulate Emissions from Natural-Gas-Fired Combined Cycle and Cogeneration Power Plants (Project #6230)	2523
Fine and Ultrafine Particulate Emission Profiles: Pilot-Scale Dilution Sampler Design and Validation Tests (Laboratory Study) (Project #6230)	2306
2005 EMEP conference agenda	1982
Fine and Ultrafine Particulate Emission Profiles: Test Results for a Gas-Fired Process Heater (Site Alpha) (Project #6230)	1730
Atmospheric Transport and Fate of Mercury in New York State: Final Report (Project #6488)	1674
Topical Rept: Test Results for a Gas-Fired Process Heater with Selective Catalytic NOx Reduction (Site Charlie) (Project #6230)	1295
EMEP program plan	1201
Fine and Ultrafine Particulate Emission Profiles: Fine particulate test protocol (Project #6230)	1086
Fine and Ultrafine Particulate Emission Profiles: Test Results for a Dual-Fuel-Fired Commercial Boiler (Site Delta) (Project #6230)	1077
2003 conference pres: Afonso (emission control technologies)	939
2003 conference proceedings	894
Innovative Instrument for the Measurement of Ambient Particulate Matter: Final Report (Project #6183)	781
Effects of Atmospheric Deposition of Sulfur, Nitrogen, and Mercury on Adirondack Ecosystems: Final Report (Project #6086)	712
EMEP fact sheet	629
Fine and Ultrafine Particulate Emission Profiles: Final Report (Project #6230)	598

- Since its inclusion on the EMEP Web site in October 2005, the Acid Rain Primer has been one of the top three EMEP downloads every month.

- Of the 49,000 total downloads from EMEP sites from March 2005 through June 2006, 55% were related to contract 6230, which looked at the development of methods for measuring and characterizing fine and ultrafine particle emissions from different sources.

Table 7 lists the communications activities supported by EMEP; for more detailed information on any of the listed activities, please see the EMEP Web page (http://www.nyserda.org/programs/Environment/EMEP/index.asp).

Table 7: EMEP Science & Policy Communication Activities: 1998-2006

Product	Total Number	Date	Focus	Attendees	Target Audience
Conferences, Workshops, Seminars					
EMEP Conferences: Linking Science and Policy	**4**	Dec 7–8, 1999	Linking Science and Policy	184	Scientists, policy makers/ analysts, public interest groups, industry
		Sept 24–25, 2001	Future Directions for a Multipollutant and Multimedia Environmental Protection Strategy (21 posters)	214	
		Oct 7–8, 2003	Science and Policy Issues Related to Nitrogen in the Environment / Increasing the Effectiveness of Science-Policy Communication (46 posters)	234	
		Oct 25–26, 2005	Science and Policy Issues Related to Mercury in the Environment and to Climate Change (48 posters)	267	
Conferences Co-Funded by EMEP	**3**	May 2–3, 2001	Acid Rain: Are the Problems Solved? Washington, D.C.	100	U.S. legislators
		Mar 31–Apr 4, 2003	American Association for Aerosol Research (AAAR) meeting—Particulate Matter: Atmospheric Sciences, Exposure, and the 4th Colloquium on PM and Human Health	550	Scientists, EPA
		Feb 7–11, 2005	AAAR Supersites Program and Related Studies International Specialty Conference	400	Scientists, EPA
Workshops Co-Funded by EMEP/ Briefings Organized by EMEP	**6**	Apr 29–30, 2002	North American Research Strategy for Tropospheric Ozone (NARSTO) Executive Assembly meeting & workshop: Status Report on the PM Assessment and Reviews of the EPA Supersite Program	35	Researchers and agencies involved in the PM Supersite Program
		May 28–30, 2003	Workshop on the Source Apportionment of Particulate Matter Health Effects: Intercomparison of Results and Implications, Arden Conference Center, Harriman, NY (7616)	30	Scientists, policy makers/ analysts
		2000, 2001, 2003, 2004	Environmental Stakeholders meetings	20	Public interest groups, policy analysts
Training Sessions	**2**	Summer 2003	Workshop on Source Apportionment & Health Effects and Review & Training Session on Positive Matrix Factorization and UNMIX Receptor Modeling Package	25	NYS DEC scientists & analysts
		May 24, 2006	Source Apportionment: Positive Matrix Factorization Training Session	11	NYS DEC scientists & analysts

Table 7: EMEP Science & Policy Communication Activities: 1998-2006 (continued)

Product	Total Number	Date	Focus	Attendees	Audience
Program/ Science Advisory Meetings	**14**	1999–2004	Discussion of various EMEP projects, conferences, and future plans *(Summarized in Section 3)*	15-20	EMEP Program Advisory Group and Science Advisors
EMEP Research Plan Development Meetings	**2**	July 2001	Development of a plan to fill critical gaps and identify research priorities	35	Scientists, policy analysts, regulators
Project Review Meetings	**~90**	July 1998–July 2006	Meetings with principal investigators to discuss project progress & findings, including site visits	N/A	NYSERDA, research team
Publications					
Summary Communications	**4**	2003	Nitrogen Pollution: From the Sources to the Sea		Scientists, policy makers/ analysts
		Oct 2003	Developments in Continuous Fine Particle Mass Monitoring: Sample Equilibration and Differential Particle Sampling		
		Dec 2003	Transboundary Pollution: Ozone and Fine Particulate Matter in the Northeast		
		Oct 2005	Reducing Emissions from the Electricity Sector: The Costs and Benefits Nationwide and in the Empire State		
EMEP Newsletter	**3**	Summer 2003: EMEP research priorities, nitrogen pollution Spring 2004: NY acid rain controls, water quality projects, air pollution monitoring projects Spring 2006: Adirondack soil chemistry, new emissions sampling method			Policy makers/ analysts, public interest groups, industry, scientists
EMEP Final Project Reports	**16**	**Atmospheric Deposition of S, N, and Hg, and Ecosystem Response**			
		June 2002	Contributions of Global and Regional Sources to Mercury Deposition in NYS		Scientists, policy makers/ analysts, public interest groups, industry stakeholders
		Apr 2003	Status and Effects of Nitrogen Pollution in Northeastern US		
		Sept 2004	Effects of Atmospheric Deposition of Sulfur, Nitrogen, and Mercury on Adirondack Ecosystems		
		Feb 2005	Monitoring the Deposition and Effects of Air Pollution in the Hudson Valley, NY		
		July 2005	An Assessment of Recovery and Key Processes Affecting the Response of Surface Waters to Reduced Levels of Acid Precipitation in the Adirondack and Catskill Mountains		
		July 2005	Atmospheric Transport and Fate of Mercury and its Impact on New York State		
		Oct 2005	Acid Rain and the Adirondacks: A Research Summary		

Table 7: EMEP Science & Policy Communication Activities: 1998-2006 (continued)				
		Air Quality and Related Health Research: Particulate Matter, Ozone and Co-Pollutants		
		Oct 1999	Least Cost Control Strategies to Reduce Ozone in the Northeast	Scientists, policy makers/ analysts, public interest groups, industry stakeholders
		Oct 2002	A Survey of Monitoring Instruments for Measurement of Airborne Pollutants	
		Jan 2003	Assessing the Effects of Transboundary Pollution on New York's Air Quality	
		Oct 2003	Develop and Field Test Rupprecht and Patashnick Series-6400 Controlled Sampling Continuous Particulate Monitor	
		Oct 2003	Innovative Instrument for an Ambient Air Particulate Mass Measurement Standard	
		Nov 2003	Analysis of Ozone and Fine Particulate Matter in the Northeastern United States	
		Oct 2004	Development of Fine Particulate Emission Factors for Oil- and Gas-Fired Combustion Systems	
		June 2005	PM2.5 Technology Assessment and Characterization Study in New York	
		Research Crosscutting the Topics of Air Quality, Health, and Ecosystem Response		
		May 2005	Reducing Emissions from the Electricity Sector: The Costs and Benefits Nationwide and in the Empire State	Scientists, policy makers/ analysts, public interest groups, stakeholders
Primers	**3**	Acid Rain: Learning from the Past and Looking to the Future		Students, general public, policy makers
		Air Pollution in New York State: Ozone and Particulate Matter		
		Mercury Deposition (forthcoming)		
Peer-Reviewed Publications on EMEP Research *				
Peer-Reviewed Publications	**158**	Encompass journal articles, book chapters, and papers published in peer-reviewed conference proceedings. There have been 123 peer-reviewed publications since EMEP's inception. 35 more are presently in preparation, in review, or in press.		Research scientists, policy analysts
* Principal investigators in the EMEP program have presented findings in hundreds of venues, including technical conferences, community workshops, congressional hearings, and schools, including K–12 programs and university seminars.				

4.2 Relevance, Acceptance, and Use by the Scientific Community

Publication in peer-reviewed journals serves as the primary means of assessing acceptance and use by the scientific community. While simply counting the number of publications in the literature can skew the real value and impact of research, it is one proxy for the acceptance of research by the scientific community.

To date, 123 peer-reviewed publications have arisen from EMEP research, with another 35 currently in the process of being published. Appendix G provides a detailed list of these publications. Articles have been published in a variety of journals. The most frequent journals for publication of EMEP research include:

Atmospheric Environment
Journal of the Air and Waste Management Association
Journal of Geophysical Research
Aerosol Science and Technology
Environmental Science & Technology
Hydrologic Processes
Environmental Pollution
Water Air Soil Pollution
Journal of Applied Meteorology

Analysis of the co-authors of EMEP research papers illustrates the highly collaborative nature of the EMEP research program, with scientists from over a dozen countries participating in these New York-based projects and co-authoring research papers (see Appendix G, Table 3).

A citations analysis was also conducted to assess the subsequent use of the EMEP research by the scientific community. The citations analysis was conducted by Thomson Scientific in 2006. Ninety eight of the EMEP publications were found in their citations database. These papers were sited in peer-reviewed journals 655 times between 1999 and 2005 (Figure 5). The papers were also assessed to determine the degree of impact measured as the average number of citations for a particular journal divided by the actual number of citations for the specific article. Across all EMEP articles, the ratio was 1.3 indicating that the papers were cited more than expected. Papers with the highest impact ratio are shown in Table 8. As can be seen from Table 8, a number of these "high impact" papers resulted from the PM Supersite project and the EMEP project to characterize fine particle and ultrafine particle emissions from combustion sources.

Figure 5: Citations of EMEP Research Papers

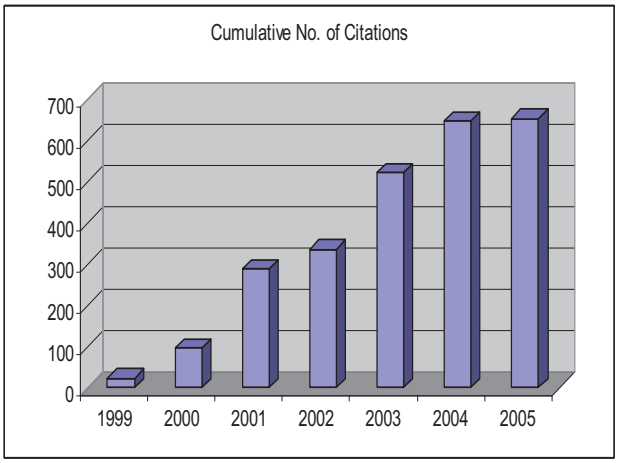


Table 8. Papers with the Highest Impact Ratio (Expected No. of Citations Versus Actual No. of Citations)

No. of Citations	Expected No. of Citations	Impact Ratio	Author	Journal	YR	Title
23	2.8	8.2	Canagaratna, MR	AEROSOL SCI TECH	2004	Chase studies of particulate emissions from in-use New York City vehicles
27	3.6	7.5	Daigle, CC	INHAL TOXICOL	2003	Ultrafine particle deposition in humans during rest and exercise
18	2.8	6.4	Drewnick, F	AEROSOL SCI TECH	2004	Measurement of ambient aerosol composition during the PMTACS-NY 2001 using an aerosol mass spectrometer. Part I: Mass concentrations
2	0.4	5.6	Chang, MCO	J AIR WASTE MANAGE	2004	Measurement of ultrafine particle size distributions from coal-, oil-, and gas-fired stationary combustion sources
5	1.0	4.8	Hogrefe, O	J AIR WASTE MANAGE	2004	Semicontinuous PM2.5 sulfate and nitrate measurements at an urban and a rural location in New York: PMTACS-NY summer 2001 and 2002 campaigns
13	2.8	4.6	Drewnick, F	AEROSOL SCI TECH	2004	Measurement of ambient aerosol composition during the PMTACS-NY 2001 using an aerosol mass spectrometer. Part II: Chemically speciated mass distributions
13	2.9	4.5	Bischoff, JM	WATER AIR SOIL POLL	2001	N storage and cycling in vegetation of a forested wetland: Implications for watershed N processing
10	2.8	3.6	Kim, E	J GEOPHYS RES-ATMOS	2004	Improving source identification of fine particles in a rural northeastern US area utilizing temperature-resolved carbon fractions
18	5.1	3.5	Ren, XR	ATMOS ENVIRON	2003	OH and HO2 chemistry in the urban atmosphere of New York City
12	3.6	3.4	Utell, MJ	INHAL TOXICOL	2002	Cardiovascular effects associated with air pollution: Potential mechanisms and methods of testing

4.3 Relevance, Acceptance, and Use by Policy/Decision Makers and Impacts on New Policies, Regulations, and Resource Management Decisions

This section highlights how EMEP projects have affected energy-related environmental policy to date. The section also highlights areas where EMEP data/studies have been identified as providing critical information to support future policy development and evaluation. Table 9 below highlights some of the EMEP-related briefings that have been given to policymakers.

✓ MERCURY:

- EMEP research has brought to light the vast extent of mercury contamination in fish in waters across New York State. EMEP monitoring data have resulted in one of the largest changes in the fish consumption advisories by the Department of Health in over a decade. *[NYS Department of Health Fish Consumption Advisory, April 2005]*

- EMEP mercury research was used in determining the need for a New York State rule for mercury control from power plants. Relevant EMEP research used by the NYS DEC included: mercury transport and source attribution modeling, wet deposition monitoring data, mercury surveys in fish and loons *[NYS DEC presentation, Stakeholder Meeting for Proposed Rules on Mercury Reduction Program for Coal-Fired Electric Steam Generating Units, July 17, 2006]*

- EMEP mercury data were cited by the Northeast States for Coordinated Air Use Management (NESCAUM) in their comments on the proposed EPA Mercury Rule. *[Comments to Docket Number OAR-2002-0056]*

✓ ACID DEPOSITION:

- Data from the Adirondack Lakes Survey Corporation's (ALSC) Long-Term Monitoring project, of which EMEP is the primary funder, and from the EMEP-funded Adirondack Cooperative Loon Project have been used as the supporting technical rationale for New York's Acid Deposition Reduction Program. *[NYS DEC, public hearing statement, October 14, 2004; and NYS DEC Response to Comments Regarding the Adoption of the Acid Deposition Reduction Program, January 2005]*

- EMEP-sponsored data have also been cited by the U.S. EPA as supporting technical information in evaluating the Clean Air Act Amendments of 1990 *[Response of Surface Water Chemistry to the Clean Air Act Amendments of 1990 - EPA 620/R-03/001, January 2003]* and the Clean Air Interstate Rule

[Benefits of the proposed Interstate Air Quality Rule - EPA 452/-03-001, January 2004]

✓ FINE PARTICLES AND OZONE:

- EMEP data on fine particle emissions from stationary natural gas combustion were used to update the National Emissions Inventory, which is the basis for air quality management plans in New York State and the U.S. *[U.S EPA, NEI Listserv, August 11, 2005, Revised PM emissions in the 2002 NEI for natural gas combustion]*

- Results on the speciation of PM2.5 and role of PM precursors from the Supersites programs, including early results of the NY Supersite, were used in EPA's consideration of the Transportation Conformity Rule Amendments for the New PM2.5 National Ambient Air Quality Standard: PM2.5 Precursors. *[40 CFR Part 93, OAR-2003-0049]*

- EMEP analysis has led to an improved method for treating the uncertainties reported in the Fine Particle Speciation Trends Network (STN). *[U.S. EPA Communications to Receptor Model Workgroup, July 19, 2006]* The STN data will be used in developing fine particle air quality management plans, with New York's State Implementation Plans due in 2008.

- Monitoring research projects such as the EMEP funded NY Supersite will be used to evaluate modeling tools and are expected to significantly increase confidence in the reliability of these air quality planning tools over the next few years. *[personal communication, EPA Supersite Technical Lead]*

- EMEP has supported development of the Fluid Dynamic Measurement System (FDMS), based on Rupprecht & Patashnick's (now Thermo Electron) tapered element oscillating microbalance (TEOM) for semi-continuous measurement of fine particles. USEPA has approved the use of the FDMS by state and local air monitoring agencies as part of the AirNow network for fine PM. In addition, the State of California has recognized the FDMS as a California approved sampler method.

- EMEP-funded ozone and PM research has become central to EPA's science and policy approach with respect to addressing long-range transport, the need for long-term modeling for SIPs, and how models are to be used for making policy. [*EPA/PAG member, personal communication, July 2006*]

- EMEP research was used to update EPA's Guidance on Models and Other Analyses in Attainment Demonstrations for the 8-hour Ozone NAAQS and more recently to was used in EPA's Technical Support Document for the Final Clean Air Interstate Rule, Air Quality Modeling.

- EMEP research advanced the concept of an "airshed" for ozone and PM management - a concept that has now been embraced in a National Academy of Science report which recommends that new regulations consider how air pollution travels from state-to-state. *[National Academy of Sciences, Air Quality Management in the United States, January 2004]*

- Several EMEP research projects are providing the scientific foundation for the development of a PM2.5 State Implementation Plan, which will ultimately affect utilities and other fossil fuel combustion systems in New York.

HEALTH EFFECTS:

✓ SULFUR DIOXIDE:

- The New York State Department of Health recommended that EMEP findings on the effects of short-term SO2 exposure on asthma be considered in EPA's current review of the SO2 national ambient air quality standard *[Docket ID EPA-HQ-ORD-2006-0260]*

Table 9: Highlights of EMEP-Related Briefings to Policymakers			
Date	Presenter(s)	Attendees	Subject
Fine Particle and Ozone Research			
	Dan Luttinger	NYSERDA and NYS Department of Health (DOH) staff	DOH Asthma study
May 30, 2002	Ken Demerjian et al.	NYSERDA and NYSDEC staff	1) NYS supersite program 2) Compare & contrast urban & rural aerosols & chemical compositions 3) Preliminary results of bus-chase studies
October 2002	Glen England	EPA Emission Inventory Group	PM2.5 Emission Factors and Speciation Profiles for Gas-Fired Combustion Sources
January 22-23, 2003	Ken Demerjian	EPA, NYS, researchers, etc.	Briefing at EPA PM Supersites Meeting in Atlanta
May 2003	Phil Hopke	DEC air modeling staff	Training session on source apportionment techniques
May 1, 2003	Ken Demerjian	NYSERDA, NYSDEC, Department of Transportation, DOH, and Environmental Energy Alliance staff	Joint enhanced ozone and PM2.5 technology assessment and characterization study in NY (PMTACS-NY)
July 29, 2003	Ken Demerjian	New York City Metropolitan Transportation Authority	Particle and gaseous emission testing of diesel and compressed natural gas (CNG) buses in NYC
July 31, 2003	NYSERDA EMEP Staff and Ken Demerjian	EPA Region II staff	1) Briefing on EMEP program and key findings 2) PM2.5 technology assessment and characterization study in NY (PMTACS-NY)
January 27-29, 2004	Monica Mazurek	MARAMA-MANE-VU Science meeting	Chemical Composition of Fine Organics
February 11, 2004	George Thurston	NYSERDA and NYSDEC staff	Source Apportionment of PM in NYC
April 5-7, 2004	Monica Mazurek	International State of the Science Workshop on Organic Speciation at DRI	Chemical Composition of Fine Organics
April 12, 2004	Ken Demerjian		1) Carbonaceous PM2.5: Lessons learned from the NY Supersite 2) Carbonaceous PM: The state of the science

Table 9: Highlights of EMEP-Related Briefings to Policymakers (continued)			
Date	Presenter(s)	Attendees	Subject
April 20-23, 2004	Monica Mazurek	United Nations Economic Commission for Europe, Convention on Long-Range Transboundary Air Pollution Cooperative Program for Monitoring & Evaluation of the Long-Range Transmission of Air Pollutants in Europe, U.S. EPA, Environment Canada, international researchers	Workshop on Particulate Matter, Measurement, & Modeling
June 15, 2004	Ken Demerjian and Supersite collaborators	Research team, funders, DEC, DOH, NYSERDA staff	PMTACS-NY winter-intensive review
November 17, 2004	Ken Demerjian	NYSERDA, NYSDEC staff	Joint enhanced ozone and PM2.5 technology assessment and characterization study in NY (PMTACS-NY)
June 16, 2005	Philip Hopke and Tom Holsen	NYSERDA and NYSDEC staff	Semivolatile Project update on sources and mercury briefing
May 23, 2006	Phil Hopke	NYERDA, NYSDEC, and DOH	Briefing on results of PMF modeling of NYS sites
July 2006	Paul Solomon	EPA	Will submit a report on the Supersites program for Congressional Performance Review
Acid Deposition and Mercury Research			
Spring 2001	Charles Driscoll	U.S. Congressional Staff	Workshop on the computer model calculations used in acid deposition studies
May 3, 2001	Charles Driscoll	U.S. House of Representatives Science Committee	Hearing on Acid Rain—The State of the Science and Research Needs for the Future
October 12, 2004	Karen Roy	NYSDEC staff	Legislative public hearings on proposed rules to reduce emissions of NOx and SO2 from fossil-fuel-fired electric generating sources statewide through market-based cap-and-trade programs
September 27, 2005	Karen Roy	Standing Committee on Environmental Conservation Adirondack Water Quality	Public hearing on the status of acid deposition effects in the Adirondacks
Crosscutting Research			
June 13, 2005	NYSERDA EMEP staff	Department of Public Service staff	Energy-related environmental issues
October 27, 2005	USGS PIs	NYSERDA and NYSDEC staff	Nitrogen Isotope briefing
February 16, 2006	NYSERDA staff	NYS Attorney General's Office	Briefing on EMEP program

Section 5: Other Potential Elements of Program Impact Evaluation

5.1 Commercialization Progress: Not Applicable to the Current EMEP Evaluation

Of the 46 projects in the current EMEP portfolio, two projects seek to develop technology and commercialize a product. [See Appendix D Fact Sheet on air quality project 5060, "Developments in Continuous Fine Particle Mass Monitoring."] These products are now being sold commercially and have been approved for use by the USEPA and the California Air Resources Board. NYSDEC has deployed several of these instruments into its monitoring network.

These EMEP commercialization efforts were evaluated in 2004 (Appendix H). Results of the evaluation were reported in the May 2005 New York Energy $mart^{SM} Program Evaluation and Status Report. The peer reviewers concluded that the projects are providing substantial benefits.

Since existing EMEP commercialization efforts were previously evaluated by an independent panel, Commercialization Progress will not be further assessed in this 2006 evaluation.

5.2 Quantification of Energy, Economic, and Environmental Benefits: Not Applicable to the Current EMEP Evaluation

In general, NYSERDA seeks to quantify the energy, economic, and environmental benefits associated with its public-benefit programs, ideally in terms of kWh of energy saved, economic benefit to New Yorkers ($), and tons of pollutants reduced.

Given the nature of the EMEP research programs, a *quantitative* attribution of energy, economic, and environmental benefits resulting from EMEP was not feasible for this 2006 review.

Some desired outcomes which could *potentially* be quantified include:

- Increased NYS capability to address critical environmental issues and increased funding sources available
  - Change in NYS's capability to address critical environmental issues
  - Change in level and stability of funding being made available for environmental research in NY and description of the focus

- Realized Economic Benefits:
  - Status of commercialization of relevant items and quantification of associated environmental and health benefits that have been realized for NY businesses and citizens {previously reviewed in 2005}

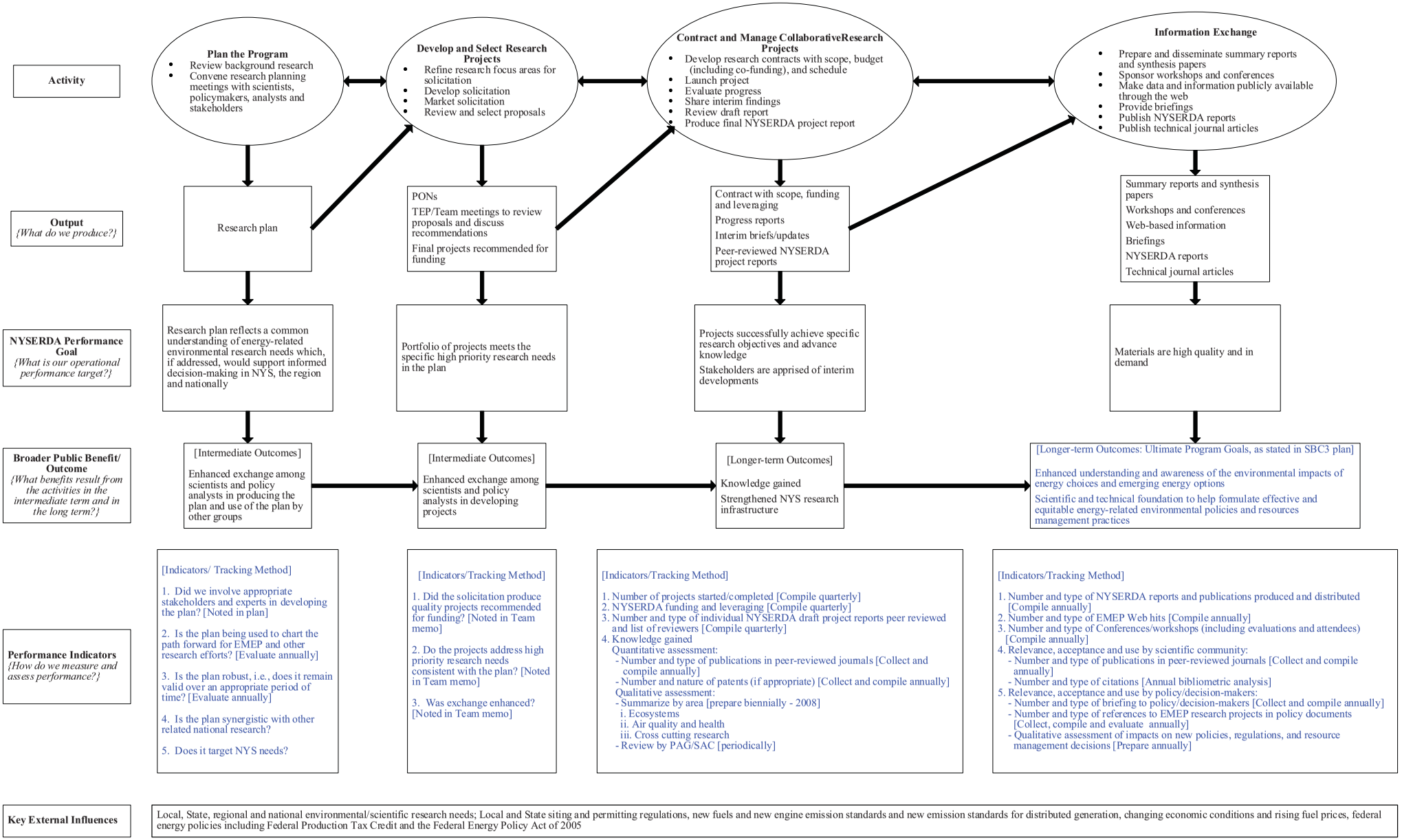
- Potential Environmental and Health Benefits
  - Quantification of associated environmental and health benefits that may be achieved in the future as a result of projects supported through NYSERDA's program.
  - The primary vehicle for EMEP to achieve real-world environmental improvements is through its impact on development of environmental policies, regulations, and guidance. As described in Section 4.3, EMEP data and research have already had an impact on State and National environmental policies, regulations, and guidance.

For the majority of these parameters, quantification of benefits attributable to EMEP would require considerable resources. NYSERDA, with its Evaluation Contractors, will explore potential ways to quantify such EMEP-related benefits where possible. NYSERDA welcomes the input of the peer review panel in this matter.

APPENDIX A

EMEP Program Logic Diagram and Evaluation Framework

Appendix A: EMEP Program Logic Diagram and Evaluation Framework



APPENDIX B

EMEP Program Plan

ENVIRONMENTAL RESEARCH AND MONITORING NEEDS IN NEW YORK STATE

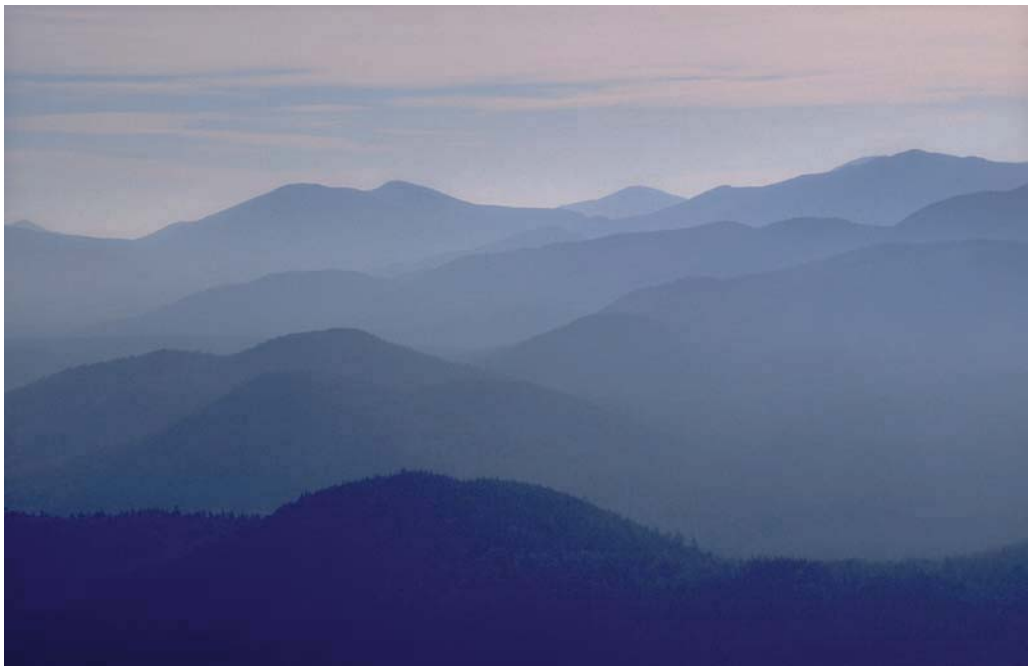


Photo by Barry Lobdell, © Copyright Barry Lobdell, All Rights Reserved

High Peaks Morning

A Multi-Year Research Plan for the
New York State Energy Research and Development Authority's
Environmental Monitoring, Evaluation, and Protection Program

April 1, 2002

NYSERDA

Questions or comments about this research plan or the New York Energy $mart[SM] Environmental Monitoring, Evaluation and Protection (EMEP) Program should be directed to:
Mark Watson, 518-862-1090, ext. 3314, mw1@nyserda.org.

ACKNOWLEDGMENTS

NYSERDA would like to acknowledge the invaluable input and review provided by the members of the Environmental Research Plan Working Groups, and the Environmental Monitoring, Evaluation and Protection Program (EMEP) Science Advisors and Program Advisory Group.

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Air Quality and Related Health Research: Particulates, Ozone, and Co-Pollutants

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Daniel Jacob, Harvard University
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Mark Utell, University of Rochester
James Vickery, U.S. Environmental Protection Agency
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Atmospheric Deposition of Sulfur, Nitrogen, and Mercury, and Ecosystem Response

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INTRODUCTION

BACKGROUND

In 2001 NYSERDA initiated a comprehensive planning effort to provide direction for environmental research in New York State over the next five years, with a focus on pollution associated with the generation of electricity. Potential users of the plan include the New York State Energy Research and Development Authority (NYSERDA), other New York State/regional/national research funding organizations, the scientific community, public benefit organizations and policy makers. The goal and philosophy of this effort is to identify critical research which:

- Is policy-relevant
- Is inter-disciplinary/multi-media
- Will be useable for New York State - not just NYSERDA's **New York Energy $mart**SM Environmental Monitoring, Evaluation and Protection Program (EMEP), and
- Takes advantage of related national research plans and programs to address regional/State needs.

Implementation of the plan's recommendations will help maximize the use of limited resources to serve the needs of New York State and others. Within the plan, NYSERDA has identified and prioritized key research areas which are suitable to be addressed through the EMEP program, as well as in collaboration with other funding organizations.

EMEP OVERVIEW

EMEP is funded through the system benefits charge (SBC) under the New York Energy $martSM Program. The primary mission of EMEP is to support research to address environmental issues related to the generation of electricity. Since its inception in 1998, the EMEP program has provided objective and policy-relevant research to:

- Improve the scientific understanding of electricity-related pollutants in the environment;
- Assess the environmental impact of electricity generation relative to other sources of pollution;
- Help develop approaches to mitigate impacts of electricity generation and improve environmental quality.

EMEP has also supported development of advanced environmental instrumentation.

The EMEP program currently supports research in four critical regional environmental issues related to electricity generation: ozone, fine particles, acid deposition, and mercury (see Appendix A). Approximately $15 million is available through 2006. Program Opportunity Notices (PONs) are issued periodically to seek proposals which address targeted research areas. Projects are reviewed and selected through this competitive process. The program is guided by a steering committee comprised of representatives from the New York State Departments of Environmental Conservation (DEC), Health (DOH), and Public Service (DPS); the U.S. Environmental Protection Agency (U.S. EPA); the New York Academy of Sciences; a university; a utility association; and three environmental/public interest groups. Also, a science advisory committee provides program support and periodic review in critical disciplines.

Under EMEP, NYSERDA sponsors conferences and workshops for policy-makers and scientists to share information. They cover a wide range of topics, from asthma in New York City to mercury in remote regions of the Adirondacks. NYSERDA also plans to commission papers to "translate" scientific results into a form useful for policy-makers. As research reports become available, NYSERDA and its research partners will post information on-line (see www.nyserda.org). Program Opportunity Notices and information about ongoing projects may also be found on the website.

RESEARCH PLANNING PROCESS

NYSERDA convened working groups of science and policy experts to help identify critical gaps and research needs in New York State. Research needs were organized into the following focus areas, representing the major issues related to pollution associated with the generation of electricity:

Atmospheric Deposition of Sulfur (S), Nitrogen (N), and Mercury (Hg), and Ecosystem Response *(Section A)*

Air Quality and Related Health Research: Particulates (PM), Ozone and Co-Pollutants *(Section B)*

Crosscutting Topics *(Section C)*

Policy objectives were identified to guide the research scoping process so that the research would be most useful and applicable to environmental management challenges facing New York State. The overarching policy objectives of the planning process were to identify gaps in the research/information needed to:

Develop and evaluate the effectiveness of pollution control strategies for acid deposition, mercury, ozone and co-pollutants, and particulate matter including providing the scientific basis for a PM2.5 State Implementation Plan (SIP);

Quantify local sources versus regional transport of fine particles, ozone, ozone precursors, mercury, and acid deposition precursors to develop more equitable pollution control strategies;

Assess the relationships between fine particles, ozone, and co-pollutants with health effects to support development of control strategies to effectively mitigate health impacts;

Identify alternative environmental protection and mitigation strategies to reduce the impacts of acidification and exposure to mercury in New York; and

Develop emerging multi-media/multi-pollutant environmental protection strategies.

The potential **scientific scope** was broad and included: biogeochemical cycling and ecosystems impacts of S, N, Hg species; factors limiting or promoting recovery of acidification; relative environmental impacts of atmospheric deposition compared to other sources; economic damage assessments and economic impacts of potential strategies; characterization of atmospheric aerosols, co-pollutants and aerosol precursors; fate and transport of primary and secondary particulate matter, ozone, ozone precursors and co-pollutants with respect to sources and receptors; and relationship of atmospheric concentrations, compositions, and size to human health and other environmental concerns.

Potential priority research areas were identified and presented at the EMEP conference in Albany, NY to over 200 participants for additional input. The draft plan was distributed to the EMEP Program Advisory Group for final review.

Next Steps - Implementing the Research Plan

Solicitations under EMEP are scheduled to be issued starting in early 2002, targeting the research areas prioritized through this planning effort. EMEP solicitations will generally follow the implementation schedule in the plan, with high priority and high urgency projects solicited in 2002 and other initiatives solicited in 2003 and beyond, if funding resources are available (see Table 1). It should noted that the research needs for New York State identified in this plan far exceed the funding currently available under EMEP. As such, in order to complete the work identified in this plan, cofunding of research projects will be required and coordination, collaboration, and leveraging with other state and federal agencies will be necessary.

Science and Policy Integration

Although sound scientific research may increase the knowledge base of energy-environmental systems, the true test of success is the utilization of findings by policy makers to improve both environmental quality and human health. To achieve this goal, research findings need to be synthesized and translated into understandable formats, forums must be provided for scientists and policy makers to discuss issues, and funding organizations must seek opportunities for collaboration, as noted above.

There is an increasing awareness of the need for research funding organizations to support these synthesis and communication activities in addition to traditional scientific pursuits. For example, the National Council for Science and the Environment has issued a report entitled, “Improving the Scientific Basis for Environmental Decisionmaking.” This report contains the recommendations of more than 450 decisionmakers and scientists who participated in a recent National Conference on Science, Policy and the Environment. Key recommendations include:

Sound environmental decisionmaking is dependent on an effective interface between

scientists and policymakers based on reliable and timely "translation" of information and views between the two communities;

There is a crucial need for periodic knowledge assessments that can provide scientists and policymakers with reliable and timely "state of the science" reports on the environment as a whole as well as on particular topics;

Interdisciplinary and multidisciplinary approaches are essential for successful environmental decision-making;

Coordinating the missions and efforts of organization involved in environmental decisionmaking is necessary to decrease the likelihood of voids or duplications in necessary programs.

The EMEP program is attempting to support these challenging goals and approaches to producing useful and policy relevant environmental research in New York State. While the plan presented here will serve as the scientific basis for future EMEP initiatives, and possibly other initiatives in New York, EMEP is developing an aggressive communication and outreach policy to further support the goals of science-policy integration and to ensure that the results of the research program are *used*.

WORK-IN-PROGRESS

This plan should be viewed as a work in progress. As research findings become available and policies are implemented, it will be necessary to continually re-visit and revise this plan to ensure that it effectively addresses the current and future environmental issues of concern.

SUMMARY AND HIGHLIGHTS OF PRIORITY RESEARCH AREAS

Critical research and monitoring needs identified in the planning process are summarized in Table 1. A priority ranging from 1 to 3 was assigned for each research activity, with 1 being most important. In addition, an attempt was made to denote the urgency for the research and approximately how long the research endeavor would take to produce results. A ballpark estimate of cost was also identified. These attributes help define an implementation schedule for the research initiatives.

Many of the science and policy stakeholders strongly recommended that EMEP's first priority should be to support an **assessment of the adequacy of the existing air quality monitoring networks and research field sites** to identify monitoring redundancies and gaps from the perspective of geographic distribution of sites and parameters measured. This high priority item will be pursued in early 2002, as its results will drive other research/monitoring initiatives.

While routine environmental monitoring needs are significant for a multitude of reasons, the general consensus of the participants in the planning process was that the most appropriate EMEP role in the area of monitoring is in:

Assessing adequacy of existing networks and field stations;
Supporting long-term study sites; and
Developing advanced analytical methods and instrumentation.

In the air quality arena, the foremost priority identified was the need for research that will provide the scientific foundation to develop a State Implementation Plan (SIP) for complying with the PM2.5 ambient air quality standard. This SIP will need to be developed in the 2005-2008 timeframe. Work related to this policy objective includes:

Increased effort on PM2.5 **source characterization** and **source-receptor modeling** so that sources of PM2.5 (both emitters of primary particulates and precursors to secondary particulates) can begin to be identified and control strategies can be developed;

Increased research related to **ammonia and organic contribution to ambient particulate aerosols** (which contribute a significant portion of PM2.5 mass in New York);

Increased **integration of PM health research and field studies** (especially building on the wealth of data that are being collected under the New York PM Supersite program); and

An **Integrated Assessment of PM2.5** to bring the PM field studies, survey/monitoring work, and health studies together and to synthesize the information into a form that will be most useful to policy makers. This would build on the PM Supersite program and start in the 2003-2004 timeframe, when more PM data will be available.

The issue of **co-pollutant interactions** was identified as a critical research gap and a priority at the national level. The specific role and contribution of a New York State research effort in this area is dependent on many other related research developments, and it was determined that such research should be pursued in the 2003 timeframe after some model development work takes place on the national level.

Significant research/information gaps that were identified in the areas of acidification and mercury include the following:

In order to better assess the impact of atmospheric loadings on the State's ecosystems, develop methodologies to improve the accuracy of **dry deposition** measurements, since dry deposition often constitutes 50% or more of total deposition of S or N to an ecosystem;

Increased effort on baseflow and **episodic stream chemistry in sensitive watersheds** Statewide to assess the extent and severity of effects, and establish a baseline from which to assess future recovery;

A better **characterization of current soil conditions** to assess effects on sensitive soils, and in doing so, develop a soil database that supports other terrestrial/aquatic effects studies;

To assist in mercury source reduction initiatives,

identify multiple sources and relative contributions of mercury, and determine mercury ecosystem fluxes, transformation and transport;

Continue **synthesis studies** to integrate existing data and information on the inputs, outputs and effects of sulfur, nitrogen and mercury deposition in New York State.

One important cross-cutting energy-related issue that was identified was the need to better understand the **environmental implications of distributed generation**. As a result of deregulation and the current energy situation, a variety of distributed generation equipment is being installed in New York State. The New York State Department of Environmental Conservation has recently initiated a rule-making on emissions from such sources. Timely research/analysis on this issue could be extremely useful in the development of effective policies and regulations that balance both energy and environmental objectives.

In addition, the need for more pro-active initiatives targeting **environmental improvements** were also suggested, including research on **mitigation** of acidified lakes, and the role of **biofuels** in improving air quality.

A description and rationale for each priority research need is presented in the following sections, along with a summary of the New York State relevance and relation to other research in the region and nation.

TABLE 1. DEVELOPING AN ENVIRONMENTAL RESEARCH AND MONITORING STRATEGY FOR NEW YORK
Outline of *Potential* Priority Research Areas

A. Atmospheric Deposition of Sulfur, Nitrogen, and Mercury, and Ecosystem Response

Activity	Importance for NYS	Timing		EMEP Priority and Role
		Urgency	Duration (to results)	
1.0 Baseline Monitoring/Characterization/Surveys				
1.1. Characterize current conditions with respect to baseflow and episodic stream chemistry in sensitive watersheds Statewide to assess the extent and severity of effects, and to establish a baseline from which to assess future recovery.	1	1	3-5 yr	Build on current work in Catskills.
1.2. Characterize current soil conditions to assess effects and recovery potential of sensitive soils, and develop a soil database that supports other terrestrial and aquatic effects studies. Use historic soil data, where possible, to evaluate long-term changes in soil chemistry.	1	1	2-3 yr	Coordinate with ongoing federal and State activities.
1.3 Develop a strategic monitoring and assessment program on long term trends of mercury deposition and effects, Statewide, to understand the health and environmental consequences of mercury deposition.	1	1	TBD	Build on assessment in C1.
1.4. Monitor biota to evaluate recovery of aquatic food webs from plankton to piscivorous birds.	1	1-2	5+ yr	Coordinate with Adirondack Effects Assessment Program.
1.5. Assess the extent of effects of deposition on forest health in geologically sensitive areas of New York State.	1	2	3-5 yr	Leverage resources with USFS work nationally and locally.
1.6. Develop methodologies to improve accuracy of dry deposition measurements.	1	1	TBD	TBD
2.0 Process-level Studies/Fate and Transport/Ecosystem Cycling/Modeling/Effects				
2.1. Conduct assessments of the effects of acid deposition and Hg on biota and food webs; examine the effects of food web structure on elemental transfers to document biological effects of acid deposition.	1-2	1-2	2 - 4 yrs	Current EMEP project may begin Hg zoo-plankton analysis.
2.2 Identify multiple sources (including sources outside of NYS) and relative contributions of mercury; determine mercury ecosystem fluxes, transformation and transport, to assist in source reduction initiatives.	2	2	TBD	Wait on AER and SUNY results for source and transport
2.3. Examine interaction of biogeochemical cycles of nutrients (N, S, C, P, Ca) to identify potentially important but indirect effects of acid deposition.	2	2	2 - 4 yrs	TBD
3.0 Synthesis/Integration Studies				
3.1. Investigate landscapes as integrated ecological units by (1) describing linkages among their physical components; (2) examining approaches to extrapolating from small watershed or plot scales to larger units; (3) determining whether the small number of well-studied sites in some parts of New York are representative of larger areas.	1	1-2	2 -3 yrs	Good opportunity to expand on intensive site research in NYS
3.2. Synthesis and assessment of current information and study site data regarding key issues related to the effects from acid rain and mercury.	1-2	1-2	2 - 3 yrs	Hubbard Brook has ongoing N project, may be early for Hg
3.3. Comprehensive, state-of-science synthesis of acid rain and mercury impacts in New York State.	3	2-3	2 - 4 yrs	Will there be enough Hg data for synthesis?

Activity	Importance for NYS	Timing		EMEP Priority and Role
		Urgency	Duration (to results)	
4.0 Other (Mitigation, Policy/Economic Assessments, Technology Transfer)				
4.1. Conduct modeling to determine critical and target loads.	1-2	1-2	3 yrs	Build on NE/Canada and DEC project
4.2 Assess the effectiveness of cross-sector pollution control strategies in reducing ecological impacts and enhancing recovery.	1-2	1-2	2-3 yrs	TBD
4.3. Assess the economic value of natural resource improvements (aquatic and terrestrial) associated with air pollution control.	2	1-2	2-3 yrs	Coordinate with Resources for the Future project
4.4. Demonstrate techniques for accelerated recovery.	1-2	1-2	3-5 yrs	TBD

B. Air Quality and Related Health Research: Particulate Matter, Ozone and Co-Pollutants

Activity	Importance for NYS	Timing		EMEP Priority and Role
		Urgency	Duration (to results)	
1.0 Ambient Monitoring and Evaluation				
1.1. Develop and integrate improved measurement technologies, including technologies for higher time-resolution composition measurements into network design (2-3 key locations).	2	2 (driven by C.1 outcome)	2-3 yrs	TBD
1.2. Develop course particle (PM10-PM2.5) monitoring data and source-receptor relations for to help New York State comply with likely course particle standard.	2-3	2 (need measurement protocol)	3 yrs to useful data; duration of monitoring TBD	TBD
1.3. Analyze long-term archived PM filter samples to establish long-term trends, baselines, support source apportionment and transport assessments.	3	2	1-2 yr	TBD
2.0 Fate and Transport				
2.1. Develop, apply and interpret PM/Ozone models and data analysis methods to support policy formulation for PM and ozone management.	1	1 (model evaluation priority)	2-3 yrs for model application/ evaluation using existing data; 3-5 yrs+ for dev. of adv. modeling systems	Build on Supersites and other PM field studies.
2.2. Improve understanding of the role of primary & secondary organics in PM in New York State.	1	1 (method development priority)	3-5 yrs for lab/mechanism studies; 3-5 yrs for methods dev.; 1-2 yrs for selected source characterization; 3-5 yrs for field measurements	Build on Supersite and other PM field studies.

Activity	Importance for NYS	Timing		EMEP Priority and Role
		Urgency	Duration (to results)	
2.3. Improve understanding of transport phenomena, specifically aloft and at night.	1	2	1-3 yrs using existing data; 1-2 yr for field study (cloud convection, PBL dynamics, and nocturnal flow)	Would require national cofunding given fundamental nature of research.
2.4. Explore co-pollutant interaction and multi-pollutant effects related to pollution control.	2	2 (driven by dev. under B2.1)	2-3 yrs for existing data analysis, model appl. & dev. of optimized control scenarios; 3-5 yrs for lab/field studies; 5yrs + for augmented field measurements for tracking effectiveness	Build on current national efforts to develop integrated modeling framework.
2.5. Explore feasibility of alternative air quality management strategies on different time scales (e.g., forecasting and real-time control).	2-3	2	2 yrs to demo forecast model using existing data; 2-3yrs to dev. real-time emission projections capability; 3-5 yrs to bring models into use	TBD
3.0 Health Effects				
3.1a. Support the integration and analysis of relevant PM Supersite/network data with exposure/health effects studies.	1	1-2 (dep. on data avail.)	2-3 yrs per study	Build on Supersites and other PM field studies.
3.1b. Support the integration of source attribution methods of PM into exposure/health effects studies (methods development, technology transfer) [relates to 2.1].	1	1-2	TBD	TBD
3.2. Explore feasibility of a targeted cohort study to examine exposure and health effects to “line exposure” from mobile sources.	1	1-2	2-3 yrs	TBD
3.3. Better understand the patterns of, and factors influencing, dose and human exposures to pollutants of ambient origin.	1-2	1-2	TBD	Coordinate with ongoing studies
3.4. Support critical research to identify causal components in PM.	2	2	3-5 yrs	Significant national investment ongoing.
3.5. Develop long-term data for black carbon as surrogate for diesel exposures/Develop exposure data for diesel PM urban environments.	3	2	2 yrs for exploratory studies; +3 yrs for more def. analysis	TBD
4.0 Source Emissions, Technology and Policy Analysis				
4.1. Support method development and characterization of sources of primary and secondary PM emissions impacting NYS.	1	1	2-3 yrs	Build on current EMEP project.
4.2. Integrated assessment of PM in NYS to provide scientific foundation for SIP development.	1	2 (data avail.)	TBD	Build on Supersite/ regional field studies.

Activity	Importance for NYS	Timing		EMEP Priority and Role
		Urgency	Duration (to results)	
4.3. Develop standard test method for particle size distribution for mobile sector emissions: test stand and in-use	2	1	TBD	Significant DEC test program.

C. Research Needs Crosscutting the Topics of Air Quality, Health and Ecosystem Response

Activity	Importance for NYS	Timing		EMEP Priority and Role
		Urgency	Duration (to results)	
1. Assess adequacy of existing monitoring networks as they relate to (i) source attribution, (ii) determining transport, (iii) evaluating health and environmental effects, and (iv) verifying the impacts of changes to pollution controls strategies on air quality.*	1	1	1 yr	Would require regional/national coordination to maximize value.
2. Evaluate Environmental Effects and Strategies for Mitigation of Electricity Generation	1	1	TBD	Primary EMEP priority
3. Evaluate the environmental and energy implications of the distributed generation of electricity in New York State.	1	1	1 yr	TBD
4. Maintain and initiate, where necessary, measurements of fine particulates/precursors, wet and dry deposition of sulfur and nitrogen, and base cations at specific long-term study sites, building on assessment in C1 above.*	1	2 (driven by C1 outcome)	TBD	Would build on existing networks and require regional/ national coordination to maximize value.
5. Identify multiple sources and relative contributions of fixed nitrogen, including ammonia, to NYS ecosystems; examine watershed retention of nitrogen, to assist in source reduction initiatives; improve understanding of the sources of ammonia and role in aerosol formation in NYS - including inventory development and exploration of mitigation options.	1	1	TBD	Build on work underway at Hubbard Brook, Supersite, and MARAMA.
6. Develop evaluation protocols to verify the impacts of pollution control strategies.	2	2	TBD	TBD
7. Assess the feasibility and cost effectiveness of multi-pollutant control strategies for existing generation infrastructure in NYS.	2	1-2	2-3 yrs	Should build on national evaluations and focus on NYS.
8. Evaluate potential effects of emissions trading (e.g. Hg, PM precursors, etc.) on local/regional impacts.	3	2	2-3 yrs	TBD
9. Evaluate the environmental impacts of biodiesel in NYS	2	2	<1yr	EMEP focus on stationary

*EMEP focus would be on evaluating networks, developing advanced measurement methods, and supporting intensive study sites.

Importance: 1 = critical/extremely important; 2 = important; 3 = moderately important

Timing/Urgency: 1 = immediate need; 2 = intermediate term need; 3 = deferred need

A. Atmospheric Deposition of Sulfur, Nitrogen, and Mercury, and Ecosystem Response

SECTION A1.0 - BASELINE MONITORING/CHARACTERIZATION/SURVEYS

Topic A1.1 Characterize current conditions with respect to baseflow and episodic stream chemistry in sensitive watersheds Statewide to assess the extent and severity of effects, and establish a baseline from which to assess future recovery.

Description and Rationale: Episodic acidification in streams has been generally accepted as having an effect on aquatic biota that is similar to chronic acidification. The majority of the acid export from watershed to stream in any given year occurs during high-flows, so traditional methods of periodic stream sampling at base flow do not adequately measure the extent of acidification in New York watersheds. Accurate characterization of stream chemical condition within New York State therefore requires a comprehensive monitoring and survey strategy that captures trends in both base flow and storm flow chemistry. This type of sampling program in New York has been limited, and therefore the extent of stream-water acidification in New York remains uncertain, but could be large. A recent assessment of the Neversink River in the Catskill region found that only 16% of the stream reaches were acidified at baseflow, whereas at high flow 82% of the stream reaches are acidic. This action item would promote projects to develop a network of stations for assessing the current status of base-flow and episodic acidification in New York State.

New York State Relevance: New York State receives among the highest rates of acidic deposition in the United States, and also contains many watersheds with soils that lack sufficient acid neutralizing capacity to protect stream streams from acidification. The Adirondack and Catskill Mountains of New York have been focal points for acid deposition research in the United States because of the extensive evidence of damage by acidification in those areas.

Relation to Other Research in the Region and Nation: The proposed network should parallel integrated monitoring efforts underway in the Catskill Mountains. The Collaborative Environmental Monitoring and Research Initiative (CEMRI) is being piloted in the Delaware River Basin as a potential national integrated monitoring strategy. In addition, the Adirondack Lakes Survey Corporation (ALSC) is currently conducting some limited episodic acidification studies.

Topic A1.2 Characterize current soil conditions to assess effects on sensitive soils, and in doing so, develop a soil database that supports other terrestrial and aquatic effects studies. Use historic soil data, where possible, to evaluate long-term changes in soil chemistry.

Description and Rationale: Monitoring and assessment of acidic deposition effects in New York State has focused on the chemistry of lakes, and to a lesser extent, streams, which, although related to soil chemistry, are often not an accurate reflection of the soil chemistry within a watershed. Characterization of soil chemistry in New York has generally been done only in selected, intensive study watersheds or plots, or in the U.S. EPA Direct Delayed Response Program (DDRP), which included the entire Northeast, but at a sampling density that was insufficient to characterize soils within the sensitive areas of New York. Because an assessment of soil chemistry in the acid-sensitive regions of New York has not been undertaken, the extent of acid rain effects on terrestrial ecosystems remains uncertain, as does the response of soils to declining levels of deposition over the past 3 decades.

New York State Relevance: New York receives higher levels of acidic deposition than any other state in the Northeast, and is likely to have been most effected (Pennsylvania being a close second). These effects include changes in soils (such as calcium depletion), which are an integral component of the

landscape that plays a major role in controlling surface-water quality and forest nutrition and health. The lack of a comprehensive assessment of soil effects greatly limits our understanding of the overall environmental effects of, and recovery from acid rain in New York.

Relation to Other Research in the Region and Nation: A comprehensive assessment of soils effects in New York would provide important information for national acid rain policy makers by combining with the soil assessment work that is currently being conducted by the U.S. Forest Service in Pennsylvania and New Hampshire. This work might prompt similar work in other states where acid sensitive regions exist. Significant opportunity exists for combining resources to conduct a comprehensive soil assessment in New York through ongoing federal and state activities. Other federal projects are also under way at locations in the Catskill region to investigate relationships between soil chemistry and sugar maple health. Coordination of data collection in these studies could fulfill a significant fraction of the effort needed for a comprehensive statewide assessment of forest soils.

Topic A1.3 Develop a strategic monitoring and assessment program on long term trends of mercury deposition and effects, statewide, to understand the health and environmental consequences of mercury deposition.

Description and Rationale: There are several proposals at the national level to establish mercury emission controls in the utility sector. A long-term monitoring program, including baseline evaluation, is essential to assess the consequences of emission controls. Currently the only program in place to evaluate effects of mercury emission controls is the Mercury Deposition Network (MDN). A program is necessary to monitor long-term trends in mercury in the environment. This program would involve the integrated measurement of atmospheric mercury deposition, mercury in soil, mercury in surface waters and mercury in fish and other biota. Additional survey data would be helpful for identifying waters which should have fish consumption advisories, and may pose a threat to wildlife. This mercury monitoring program could be linked to the development and application of mercury cycling models and should be coordinated with the assessment of monitoring networks and needs in Topic C1a above.

New York State Relevance: Many lakes in New York have advisories due to high levels of mercury in fish tissue. This problem is particularly widespread in the Adirondack and Catskill regions. As in the case of acid deposition, New York is likely to be a receptor area for mercury from Midwestern coal-fired power plants. At the same time, coal-fired power plants in New York State are sources for the state and downwind regions. Mercury also clearly is transported into New York State from Canada (Olmez *et al.*, Environ. Sci. Technol. 1998, 32, 3048-3054) and thus, policy makers in New York State must be able to determine the relative contributions of in-state, out-of-state sources, and global sources to the observed mercury species concentrations. Information on mercury levels from specific waters in the State will directly assist local residents, resource consumers and the NYSDEC in making wise decisions on the use of the resource.

Relation to Other Research in the Region and the Nation: The national program for research on the transport, fate and effects of mercury in the environment is supported by the U.S. Environmental Protection Agency STAR program. Through this program several major research initiatives on mercury are underway. The U.S. EPA also funds relevant research on mercury through the REMAP program. Weekly precipitation samples are currently being monitored for mercury concentrations at the MDN site at Huntington Forest in the Adirondacks. A second site is scheduled to be added in the Catskills. Mercury data in New York State are being collected at Sunday Lake, Potsdam, Stockton, and a few other sites in the Adirondacks, with EMEP support. The USEPA and other states have used New York fish contaminant monitoring data for numerous reports and studies (NESCAUM Mercury Study, USEPA Mercury Report to Congress)

Topic A1.4 Monitor biota to evaluate recovery of aquatic food webs from plankton to piscivorous birds.

Description and Rationale: The examination of recovery in aquatic systems from damage caused by atmospheric deposition has focused almost exclusively on water chemistry. As more aggressive emission controls are implemented, the assessment of aquatic biota will be essential in order to determine whether ecosystem recovery has been achieved. This effort would examine different levels of biota that live in, and depend on, aquatic systems impacted by acid deposition to document short-term and long-term changes in ecosystem structure and function as deposition is reduced and recovery progresses.

New York State Relevance: New York State has suffered a tremendous amount of ecosystem damage from acidic deposition. Although chemical recovery of aquatic ecosystems is important, it is only part of the recovery process. Changes in the structure and function of aquatic biota will signal the return of healthy ecosystems.

Relation to Other Research in the Region and Nation: Currently, the Adirondack Effects Assessment Program (AEAP), implemented in 1994, is examining recovery in the biota of aquatic ecosystems impacted by acid deposition. It is focused on the southwest quadrant of the Adirondack Park, and is scheduled to continue monitoring through 2006. The Adirondack Lakes Survey Corporation (ALSC) has also recently conducted surveys to document changes in fish populations in the North Branch Moose River watershed, and is comparing this data to earlier surveys. The effort outlined here should build on the efforts achieved by the AEAP during the period 1994-2006, the ALSC and others.

Topic A1.5 Assess the effects of deposition on forest health in geologically sensitive areas of New York State.

Description and Rationale: Acid rain effects research has demonstrated that (1) acid fog damages foliage, (2) depletion of Ca and Mg (essential tree nutrients) from the soil, has been documented within New York State, (3) biochemical indicators of stress in foliage of red spruce trees are found in soils with low amounts of available Ca, (4) trends in Ca concentrations in wood tissue of red spruce trees are consistent with theorized changes in soil chemistry over the past 100 years, and (5) nitrogen, normally a growth limiting nutrient for forests, is accumulating to levels at which nitrification is stimulated, a condition which leads to surface water acidification and negative effects on tree growth. This information strongly suggests that acid rain is affecting tree growth in New York. The degree to which this is occurring is uncertain, but could be significant because much of the New York Forest grows in the geologically sensitive areas of the Adirondacks, Catskills and Allegheny plateau.

New York State Relevance: Effects on tree growth are important in New York for its substantial forest products industry and the protection of water quality for both recreational uses and drinking water supplies.

Relation to Other Research in the Region and Nation: Other states in the Northeast and Mid-Atlantic have reported dieback of species such as sugar maple and red spruce that is likely to be related to additional stress caused by acidic deposition. Assessment work in New York would support and be supported by effects studies on trees that are underway in northern New England, and Pennsylvania. There is significant potential for leveraging resources through collaboration with several U.S. Forest Service Research Projects that are active in the southwest Catskills and Allegheny Plateau, as well as the national survey's that the U.S. Forest Service is conducting that include New York.

Topic A1.6 Develop methodologies to improve accuracy of dry deposition measurements.

Description and Rationale: Oxides of nitrogen (N) and sulfur (S) are emitted to the atmosphere and are deposited downwind of their sources via wet (rain and snow), dry (gases and particles) and in some locations cloud or fog deposition. Dry deposition often constitutes 50% or more of total deposition of S or

N to an ecosystem. The technologies currently available to measure dry deposition are inadequate resulting in measurements with large uncertainties. Better methodologies and protocols are needed in the near term. Also, due to an insufficient number of dry deposition monitoring stations in New York State, additional sites should be installed, using accepted protocols.

New York State Relevance: The density of dry deposition monitoring stations in New York is inadequate, and not all are operated by the same organization. There are no current efforts to increase the density of dry deposition monitoring networks in New York. In addition, the inability to estimate total deposition to complex terrain severely constrains the ability to accurately assess atmospheric loading to ecosystems. The success of efforts to expand dry deposition in New York State and provide reliable data are dependent on the better measurement techniques and protocols.

Relation to Research in other Regions and Nation: (See relation statement in Topic C1)

SECTION A2.0 - PROCESS-LEVEL STUDIES/FATE AND TRANSPORT/ECOSYSTEM CYCLING/ MODELING/EFFECTS

Topic A2.1 Conduct assessments of the effects of acid deposition and mercury on biota and food webs; examine the effects of food web structure on element transfer to document biological effects of acid deposition.

Description and Rationale: Much of the current research effort and monitoring underway in New York and throughout the US emphasizes the effects of acid precipitation and mercury deposition on water chemistry and the biogeochemical cycling of elements and nutrients. Little of this work involves studies of biota such as fungi, phytoplankton, and zooplankton. A clearer indication of the impacts of atmospheric deposition in New York may be obtained by examining the cascading effects of acid and mercury deposition on biota as they are linked through the food web. This research will need to be placed within the context of the role of biota in the biogeochemical cycling of elements that regulate acidification processes, mercury transport, and the resulting deleterious impacts on ecosystem health and water quality. A project goal should be to provide a greater understanding of the biological resources at risk as a result of atmospheric deposition of acids and mercury to provide a stronger basis for effective management strategies. There is also a need to integrate existing data on biota with what is known about acidification processes, and other documented effects of acid deposition.

New York State Relevance: The number of biological resources at risk from current levels of atmospheric deposition of acids and mercury will provide a stronger basis for potential future emissions reductions. Resource managers need to know if reductions in atmospheric sulfur deposition will lead to reductions in mercury methylation and reduced mercury levels in fish and other aquatic organisms.

Relation to Research in other Regions and Nation: This research should build on existing work in New York State, and include significant leveraging of funds. Similar research is needed and is likely to proceed in other regions with sensitive ecosystems such as mountainous areas of the southeast, mid-Atlantic states, and Colorado.

TOPIC A2.2 Identify multiple sources and relative contributions of mercury; determine mercury ecosystem fluxes, transformation and transport, to assist in source reduction initiatives. Use data collection and modeling to predict environmental responses under different deposition scenarios.

Description and Rationale: Mercury is emitted to the atmosphere from fossil fuel combustion and other anthropogenic (e.g., incineration, chlor-alkali facilities) and natural processes. Subsequent atmospheric deposition of mercury contributes to the supply of mercury to surface waters and sediments. It is evident

that considerable mercury has accumulated in soil as a result of atmospheric deposition, although the ultimate fate of this mercury is unclear. Under reducing conditions sulfate reducing bacteria convert inorganic mercury to methyl mercury, which bioconcentrates within the aquatic food chain. Methyl mercury is a powerful neurotoxin and human exposure largely occurs through the consumption of fish. There are important linkages between acidic deposition and mercury. For example, in regions experiencing surface water acidification, concentrations of mercury in fish increase with decreases in lake pH. A better understanding is needed of the transformation of atmospheric sources of mercury into biologically active methyl-mercury, and the role of sulfur from acid deposition in the methylation process. Models could be useful in assessing the fate and effects of atmospheric mercury deposition on natural resources and predicting the response of ecosystems to mercury emission controls.

New York State Relevance: As part of the Clean Air Act Amendments of 1990, New York State has reduced emissions of mercury from municipal and medical waste combustion and other sources. However, fish consumption advisories have been issued by the New York State Department of Health for 30 bodies of water throughout the state. Additional testing of fish may reveal an even larger number of water bodies for which fish consumption should be restricted. The proposed effort would provide information which could lead to development of more effective mercury control strategies.

Relation to Research in other Regions and Nation: Human health concerns associated with atmospheric deposition of mercury are ubiquitous throughout the United States. Research on mercury performed in New York will complement studies currently underway throughout the U.S.

Topic A2.3 Examine interaction of biogeochemical cycles of nutrients (N, S, C, P, Ca) to identify potentially important but indirect effects of acid deposition.

Description and Rationale: Recent research has revealed many second order effects from acidic atmospheric deposition including depletion of soil base cations and consequent deleterious effects on sugar maple. Many of these potential second order effects of acid deposition have yet to be thoroughly investigated, but are important to gain a more complete understanding of the effects of acidic deposition. Studies that examine the linkages between the cycles of multiple nutrients have the potential to more thoroughly evaluate the manner in which acid deposition alters nutrient cycling processes in sensitive ecosystems. Additionally, the recovery of aquatic ecosystems from reduced levels of atmospheric sulfate deposition over the past two decades has been slower than originally predicted, and the interaction of multiple element cycles must be considered to accurately predict future recovery.

New York State Relevance: Ecosystems in New York receive among the highest rates of acidic atmospheric deposition in North America. Additionally, New York contains large areas in the Adirondacks and Catskills that are especially sensitive to acidic deposition. Therefore, New York is one of the most likely locations to experience alteration of nutrient cycles caused by acidic deposition, especially as atmospheric nitrogen inputs become more dominant. Water resource managers in New York State need information on whether current and planned emissions reductions will be adequate to allow previously acidified aquatic and forested ecosystems to recover.

Relation to Research in other Regions and Nation: Other areas with high rates of acidic atmospheric deposition combined with sensitive ecosystems include the Allegheny Highlands of Pennsylvania, the Great Smoky Mountains of Tennessee and North Carolina, and the Blue Ridge of Virginia. Past and current research underway in these regions examining the relation of acid deposition to multiple nutrient cycles will complement work supported under this topic in New York.

SECTION A3.0 - SYNTHESIS/INTEGRATION STUDIES

Topic A3.1 Investigate landscapes as integrated ecological units by: (1) describing linkages among their physical components; (2) examining approaches to extrapolating from small watershed or plot scales to larger units; and (3) determining whether the small number of well-studied sites in some parts of New York are representative of larger areas (physiographic unit, state, or region).

Description and Rationale: Individual studies of air pollution deposition effects are often conducted on the plot or small watershed scale for reasons of convenience (established boundaries for mass-balance accounting) or for the establishment of identifiable geographic entities (single lake, stand of trees, etc.). However, individual elements or sites often have sharply different characteristics, including the potential to act as sources vs. sinks for particular materials. Several approaches have proven useful to "assemble" knowledge of these relatively small units in a way that improves understanding of larger units.

Characterizing a large area with a small number of intensively-studied sites is a common issue and is generally approached through a combination of process studies, surveys, and monitoring. It is important to know whether the sites used to generate some model or relationship span the range in independent variables for the state/region. For both these reasons, being able to place these "intensive" sites in a broader context becomes valuable.

New York State Relevance: Funding agencies have expended resources and researchers have committed time to individual air pollution effects studies in New York and their ultimate value is greatly increased if they can be placed in a broader context. Because of time and money constraints, obtaining the desired coverage of detailed study sites may never be achieved, and developing approaches for extrapolating (or knowing when not to extrapolate) will provide great benefits.

Relation to Other Research in the Region and Nation: Issues of scaling, linkage and representativeness are important nationwide and globally. Efforts along these lines in New York State can benefit from work elsewhere and also contribute fundamentally to solution of these problems.

Topic A3.2 Synthesis and assessment of current information and study site data regarding key issues related to the effects from acid rain and mercury.

Description and Rationale: There are several topic areas that are considered key to understanding the air pollution effects in New York that may be associated with sulfur, nitrogen, and mercury deposition. These topics have been and are the subject of intensive research efforts and/or play significant roles in process-based model formulations. Knowledge in these areas is evolving rapidly. The major topic areas of interest include:

- Base cation depletion from forest soils as a consequence of acidic deposition and land use,
- Chemical and/or biological recovery of surface waters in response to decreased sulfur deposition,
- Sources and sinks of mercury,
- Retention of atmospherically-deposited nitrogen in forested and mixed-land use watersheds,
- Interactions between natural sources of acidity (including organic acids associated with wetlands) and atmospheric deposition in acidified watershed systems.

Research is needed to synthesize the results of recent and on-going site-specific studies within New York. The resulting documents will help in the interpretation of the results of individual studies and will be useful to guide additional research.

New York State Relevance: New York is the site of numerous studies, many of which have been long-term and focused on developing a better understanding of the above-indicated topic areas. Model input data, for multiple biogeochemical air pollution effects models, are available for many watersheds that receive significant deposition of sulfur, nitrogen, and mercury. Thus, New York is an appropriate state in which to continue such studies and for which synthesis efforts will be timely and useful.

Relation of Other Research in the Region and Nation: Research on these topics is being carried out in many areas, including the Appalachian Mountain region, northern New England, and throughout northern Europe. A major synthesis and modeling effort is currently underway, as part of the Southern Appalachian Mountains Initiative (SAMI). Commonalities and differences elsewhere will provide a valuable basis for assessment within New York.

Topic A3.3 Comprehensive, state-of-the-science synthesis of acid rain and mercury impacts in New York State.

Description and Rationale: There is a need to undertake efforts to synthesize and integrate existing data and information on the inputs, outputs and effects of sulfur, nitrogen and mercury deposition in New York State. While primary research is critical to advancing scientific understanding of biogeochemical cycles, synthesis activities are needed to summarize this understanding in a way that is clear and accessible to the research community and policymakers. Three state-of-the-science products are needed, two targeted to the research community and one targeted to policy makers and the public:

- State-of-science synthesis on nitrogen and sulfur deposition and effects (chemical and biological) in the Adirondack and Catskill Mountains,
- State-of-science synthesis on mercury deposition, cycling, and effects throughout New York, and
- Outreach summary (interpretive report geared to a nontechnical audience) regarding policy-relevant aspects of mercury fluxes, transformations, and health implications.

Products should emphasize what is known, what is not known, spatial patterns, temporal (long-term, annual, seasonal, episodic) trends, on-going monitoring efforts, monitoring needs, research needs, and major knowledge gaps.

New York State Relevance: As a state that receives high deposition of these pollutants, New York State has an interest in furthering the scientific understanding of these issues. Moreover, the New York legislature, administration, and congressional delegation are very active in advancing pollution control policies to benefit New York State. Such activities serve to elucidate the nature and extent of the problem, guide research activities, educate policymakers and the public, and provide a tool to evaluate the effectiveness of potential policy options. In some cases, synthesis activities are combined with outreach work to translate and disseminate the findings.

Relation to Other Research in the Region and Nation: Synthesis projects specific to New York State would relate to ongoing and completed projects undertaken by EPA, USGS, NYSDEC, NAPAP, Adirondack Park Agency, Hubbard Brook Research Foundation, Institute of Ecosystem Studies and others in recent years. EMEP is currently supporting two synthesis projects - one focusing on nitrogen pollution in the Northeast, the other focusing on acid rain in New York. The proposed effort would build on these studies.

SECTION A4.0 - OTHER (MITIGATION, POLICY/ECONOMIC ASSESSMENTS, TECHNOLOGY TRANSFER)

Topic A4.1 Conduct modeling to determine critical and target loads.

Description and Rationale: In the U.S., pollution regulations have been geared toward controls on emissions. However, the ecologically important measurement to achieve recovery is the amount of deposition a landscape or water body receives. In Europe, the critical loads approach has been used to determine what loading rates are critical to sustaining a healthy ecosystem. Advances have been made in understanding the relevance of this approach to the U.S. and more has been learned about the application of critical loads to forest ecosystems. This analysis would apply state of the art deposition modeling to determine critical loads for N, S and mercury from an ecosystem perspective and then use input and information from policy experts and/or economists to recommend a target load for those elements. The target load is that load which regulators will aim to achieve given the ecological, policy and economic factors.

New York State Relevance: This work could provide information to help with the development of a total maximum daily load (TMDL) program in New York State for critical waterbodies.

Relation to Other Research in the Region and Nation: The New England Governors and Eastern Canadian Premiers have initiated a forest mapping project in the Northeast and Eastern Canada to determine critical loads for forests in this region. New York State Department of Environmental Conservation (NYSDEC) is currently supporting a pilot TMDL study for an acidified lake in the Adirondacks.

Topic A4.2 Assess the effectiveness of cross-sector pollution control strategies in reducing ecological impacts and enhancing recovery.

Description and Rationale: A wide range of pollution control options are under consideration at the state and federal level, yet there does not exist an assessment of the relative value of each in reducing ecological impacts. This assessment would consider the merits of controls on various sources (generating plants versus mobile sources), the potential ecological impacts of trading of S, N and mercury, and the effect of short and long-term implementation plans on recovery of terrestrial and aquatic ecosystems in New York State. This project would also investigate the effects of various pollution control options on ecological structure and function. Other co-benefits, (e.g. effect on visibility/haze) should also be addressed, if possible. A multidisciplinary team will likely be needed to conduct this work.

New York State Relevance: New York State ecosystems have been adversely affected by mercury and acidic deposition. Information about the relationships between pollution control strategies and ecosystem effects could assist in an expedited resource recovery, resulting in healthier and more diverse biological communities.

Relation to Other Research in the Region and Nation: Information from this effort would be useful for policy makers and resource managers in other northeastern states, Canada and other countries.

Topic A4.3 Assess the economic value of natural resource improvements (aquatic and terrestrial) associated with air pollution.

Description and Rationale: Considerable effort has been made to understand and document the ecological impact of atmospheric deposition on aquatic and terrestrial ecosystems as well as on physical infrastructure and human health. However, little emphasis has been placed on understanding and quantifying the economic effect of these impacts. This project would examine the natural resource

economics to describe and quantify the cost of long-term pollution with respect to aquatic, terrestrial, health and materials resources. This information will be critical to understanding the societal impact of atmospheric deposition.

New York State Relevance: A more complete picture of the value of reduced pollution in New York State would be helpful to policy makers and researchers as mitigation options are being considered.

Relation to Other Research in the Region and Nation: Researchers at Resources for the Future are working to quantify in monetary terms the change in total economic value (the sum of use and non-use value) that would result from a change in the attributes of the Adirondack Park that might be affected by increased or diminished air pollution deposition.

Topic A4.4 Demonstrate techniques for accelerated recovery.

Description and Rationale: As pollution controls are implemented and acidic deposition reduced, it is an opportune time to consider options for accelerating the recovery of aquatic and terrestrial organisms, and forest ecosystems in New York State. This project would experiment and demonstrate various options for accelerating recovery, such as calcium additions, re-introductions, and forest/watershed management strategies. This could include addressing other related water quality issues such as nitrogen leaching. Alternative strategies for improving water quality would be evaluated. Lessons should be shared with other resource managers to encourage proactive improvement of environmental conditions as deposition reductions are achieved.

New York State Relevance: Aquatic resources in New York State have been adversely affected by acidic deposition and calcium concentrations in watersheds have decreased due to long-term acidification impacts. If the rate of recovery can be increased, then the resource would be restored sooner, resulting in healthier and more diverse biological communities. The 30 to 40 ponds already in the NYSDEC liming program provide additional waters for recreational fishing which would not otherwise be available. The liming program is intended to be a management tool and not an alternative to emission reductions.

Relation to Other Research in the Region and Nation: Research findings from efforts to accelerate recovery of aquatic ecosystems would be useful for resource managers in other northeastern states, Canada and other countries. Other regions have also been impacted by acidic deposition and would benefit from information on restoring these ecosystems as quickly as possible.

B. Air Quality and Related Health Research: Particulate Matter, Ozone, and Co-Pollutants

SECTION B1.0 - AMBIENT MONITORING AND EVALUATION

Topic B1.1 Develop and integrate improved measurement technologies, including technologies for higher time-resolution composition measurements, into network design.

Description and Rationale: Highly time resolved data representative of the area in which people are exposed are needed to examine the relationship between constituents in airborne particulate matter and health effects. The National Ambient Air Quality Standard for fine particulate matter ($PM_{2.5}$) arose primarily because of observed statistical relationships between measured $PM_{2.5}$ concentrations and reported mortality and morbidity. Recent toxicology experiments in which animals are exposed to concentrated ambient $PM_{2.5}$ have shown different level of effects, suggesting that specific constituents in the particles are the cause of the observed effects. To assess these relationships, it is necessary to collect data over a

sufficiently long interval that there are an adequate number of reported health effects. In prior studies, this minimum time is of the order of three years.

One of the significant problems with regulating PM is the integrating time for which the standard is set. The bulk of the existing data is for 24 hour intervals. Only recently has the technology been available for continuous mass monitoring of airborne particles and some specific constituents (SO_2, NO_x, OC/EC/TC). There have also been some initial studies indicating that exposure to short duration and high concentrations are related to health effects (Dolphin *et al.*, 1998; Morgan *et al.*, 1998; Simpson *et al.*, 1997). Thus, we need both composition data on a highly time resolved basis.

New sampling and analysis techniques permit the estimation of elemental compositions on time scales of as little as 15 minute intervals. Real-time monitoring of ultrafine particle (diameters less than 0.1 μm) number concentration (NC) is also needed to assess health effects. Wichmann *et al.* (2000) found significant associations of elevated cardiovascular and respiratory disease mortality with various fine (and ultrafine) particle concentration indices evaluated in Erfurt, Germany. In this study, significant associations were found between mortality and ultrafine particle number concentration (NC), ultrafine particle mass concentration (MC), fine particle mass concentration, or SO_2 concentration. The correlation between MC0.01- 2.5 and NC0.01- 0.1 is only moderate, suggesting it may be possible to partially separate effects of ultrafine and fine particles.

New York State Relevance: Augmenting monitoring programs associated with exposure and other health-related research may be useful in indicating possible causal linkages as described in Topics B3.3 and B3.4. This coupled with source/receptor modeling may provide information to base source-specific emission control regulations by NYSDEC as part of SIPs.

Relation to Other Research in the Region and Nation: There are measurements using such techniques as part of the various supersite efforts that are taking place in New York City, Pittsburgh, Baltimore, St. Louis, Houston, Fresno, and Los Angeles. These measurements are also on-going in the Southeastern Aerosol Research Characterization (SEARCH) Program (Atlanta, Birmingham, Gulfport, and Pensacola and paired rural sites), and by the Harvard School of Public Health (HSPH) in Cambridge, and Philadelphia. With the exception of SEARCH and HSPH, the measurements are being conducted over a relatively short time interval (1 to 1.5 years). Although the New York City Supersite activity is planned to continue, there has not yet been a single fixed site that will be maintained over an extended time period.

Topic B1.2 Develop coarse particle (PM10-PM2.5) monitoring data and source-receptor relations for to help New York State comply with likely coarse particle standard.

Description and Rationale: The US EPA will be changing its NAAQS for coarse particles in 2003 and will likely promulgate a PM(10-2.5) standard to replace the current PM10 standard. At this time there is relatively sparse data available on the concentration and composition of coarse particles (that deposit in the thorax) in New York State and nationwide. In advance of the development of new sampling technology for a new coarse particle fraction (PM10-PM2.5), current generation dichotomous samplers could be deployed at one location in New York State to provide information on the concentrations and compositions of PM(10-2.5) particles in ambient air in New York State. Co-locating these samplers at sites with concurrent measurement of concentration of and composition of PM2.5 and PM10 that are linked to health effect studies would increase what can be learned.

New York State Relevance: Provide needed information to assess impact of potential new regulations on State Implementation Plans. Since New York State is a leading manufacturer of air monitoring equipment, efforts to develop improved sampling methods for PM(10-2.5) could provide significant economic benefits though the commercialization of new sampler developments.

Relation to Other Research in the Region and Nation: Currently, this activity is not being undertaken in the region nor nationally. The EPA plans for compliance monitoring for their new coarse particle NAAQS will be to site two samplers (PM10 and PM2.5) side-by-side and estimate the coarse particle concentration

by difference. This, however, will not provide samples of coarse particles for chemical or biological characterization. There are no continuous monitors currently available for PM(10-2.5) measurement. If a new coarse particle standard is proposed, research funds may be provided by EPA to support ambient monitoring activities.

Topic B1.3 Analyze long-term archived PM filter samples to establish long-term trends, baselines, support source apportionment and transport assessments.

Description and Rationale: Archived filter samples from past monitoring programs may provide a means to establish long-term trends, baselines and to support source apportionment and transport assessments. It is important to know if actions taken to improve air quality actually result in the expected changes in atmospheric concentrations. Given the natural variability of the atmosphere, it is generally necessary to collect data over a long time in order to ascertain trends.

New York State Relevance: Re-analysis of archived samples can provide long term trend information on number of parameters such as metals which can be used for source apportionment as well.

Relation to Other Research in the Region and Nation: (See relation statement in Topic C1)

SECTION B2.0 - FATE AND TRANSPORT

Topic B2.1 Develop, apply and interpret PM/Ozone models and data analysis methods to support scientifically sound policy formulation for PM and Ozone Management.

Description and Rationale: Recent extensive research measurements underway as part of NYSERDA and cooperative federal and state-sponsored programs (i.e. PMTACS-NY Supersite and other regional Supersites (in Baltimore and Pittsburgh) and the network of Speciation Sites in the northeastern U.S.) will provide a rich data base for the evaluation and further development of photochemical air quality simulation models (PAQSM) anticipated for use in formulating air quality management plans for PM and ozone. Current PAQSM have undergone testing and evaluation with regard to ozone prediction, but require method development to discern the anthropogenic signal in ambient pollutant data to better quantify the impact of emission controls on air quality. In addition, little if any performance testing has been considered for PM. The present generation PAQSM have rudimentary aerosol process modules that treat PM mass and provide limited chemical speciation and particle sizing information. Performance evaluation of the PM components of these models using the enhanced data sets cited above will help identify the most significant sources of error in PM air quality predictions and should provide insights as to the most productive model enhancements needed to minimize these errors. Models are also needed to correlate the urban or regional air quality (measured at monitoring sites or predicted by the PAQSM model) to contaminant concentrations in micro-environments such as urban street level and around buildings. This will facilitate more accurate exposure and health risk assessment, and provide outdoor air quality data that will also be useful for studying the interactions between outdoor and indoor environments. The data also provides an opportunity to test, develop and independently evaluate source apportionment techniques and to provide corroborative analyses in conjunction with PAQSM as to the source contributions to ambient PM. Also of interest is application of these models to evaluate the environmental implications of promising energy-related technologies, such as truck-stop electrification and use of biofuels. Lastly, development and application of models that integrate economic analyses/control costs with air quality are needed.

New York State Relevance: The development of accurate quantitative relationships that couple pollutant emissions, air quality and control costs are essential to sound air quality management practice and effective environmental decision-making. Understanding of the transformation, fate and transport of the primary and secondary pollutant emissions in the atmosphere is essential in the development of both emission-based (e.g. PAQSM) and observation-based (e.g. source-receptor models) air quality models.

New York State must have state-of-the-science tools available to assess the impact of its emissions contributions and those emissions from adjacent regions on its air quality.

Relation to Other Research in the Region and Nation: The U.S. EPA Supersite program will bring together eastern Supersite researchers (New York, Pittsburgh, Baltimore) as well as model developers and data analyst to address a series of science policy questions that are hypothesis driven. Results from these studies will provide insights into the state of our knowledge of the chemical and physical characterization of PM air quality and the developments needed to provide credible PM air quality management tools.

Topic B2.2 Improve understanding of the role of primary and secondary organics in PM in New York State.

Description and Rationale: Recent chemical speciation measurements of PM in New York City indicate that approximately 45% of the total PM mass is carbon based and measurements show little seasonal variation. Unlike sulfate and nitrate, whose composition and precursor sources are generally well known, the composition and sources of carbon based PM, are not well understood. Effective tools for the development of mitigation strategies for PM must have sound quantitative relationships for the sources and formation processes for the carbon component. To develop the necessary understanding, the following research and development is needed: a) perform laboratory studies using representative precursor (biogenic and anthropogenic) compounds to elucidate formation mechanisms for secondary organic aerosols in controlled environments; b) develop analytical methods for laboratory and field measurements of semi-volatile and non-volatile organic aerosols; c) characterize semi-volatile and non-volatile organic compounds in selected high priority sources (i.e. largest potential emitters); and d) perform field measurements of semi-volatile and non-volatile organic compounds in rural and urban environments.

New York State Relevance: Given that approximately half of the PM2.5 mass observed in New York City is carbon-based, attribution of the primary and precursor sources for this carbon is essential to the development of effective emission controls.

Relation to Other Research in the Region and Nation: (See relation statement in Topic B2.1)

Topic B2.3 Improve understanding of transport phenomena, specifically aloft and at night.

Description and Rationale: The impact of pollutant emissions on air quality is closely tied to transport and dispersion in the atmosphere. Although significant advances have been made in meteorological meso-scale modeling of atmospheric flows, vertical mixing, in terms of planetary boundary layer growth and cloud convection, and nocturnal jets and nighttime sheer flows are not adequately understood in current generation coupled meteorological-photochemical air quality simulation models (PAQSM). Improved understanding of the overnight transport and downward mixing of pollutants trapped aloft in the previous day's residual layer have significant implications on urban and regional air quality (O_3, PM and acid deposition) and the contributions of out-of state sources to in-state air quality.

New York State Relevance: The development of accurate quantitative relationships that couple pollutant emissions and air quality are essential to sound air quality management practice and effective environmental decision-making. The accurate depiction of transport phenomena is critical to the development of credible air quality modeling systems for use in air quality impact assessments of the contribution of primary and secondary pollutant emissions within New York State and from surrounding regions. New York State must have state-of-the-science tools that reflect these developments to assure the credibility of its environmental decisions.

Relation to Other Research in the Region and Nation: Recent extensive research measurements underway as part of NYSERDA and cooperative federal and state sponsored programs (i.e. PMTACS-NY Supersite as well as other regional Supersites (in Baltimore and Pittsburgh) and the NE-OPS (Philadelphia study, especially the summer 2001aircraft data) will provide data bases for the evaluation of the selected

transport phenomenon and enhancements to minimize errors in current PAQSM predictions of concentrations associated with pollutant transport and dispersion. Recently, transport phenomena have gained broad community interest with studies on intercontinental transport of dust and pollutants over space scales >1000 kilometers. This has stimulated interest at NSF, NOAA, DOE and NASA, which may spill over to EPA.

Topic B2.4 Explore co-pollutant interaction and multi-pollutant effects related to pollution control.

Description and Rationale: Significant scientific and technical issues surrounding the mitigation of the warm season PM2.5 /co-pollutant complex and its interdependence with O_3 air quality and acid deposition through coupled photochemical pathways, common precursors, and similar dependencies upon meteorology must be addressed if effective control strategies are to be implemented. In addition, the interdependence of cold season PM2.5 and acid bearing species through common heterogeneous formation pathways and precursor emissions must also be addressed. Field measurements of primary and secondary pollutants at strategically located field stations across the State in conjunction with data analyses and the application of integrated modeling systems should be applied to demonstrate the effectiveness of instituted emissions controls for PM2.5, ozone and acid deposition and to quantify out-of-the-state contributions. These studies could be followed by the development of emission control scenarios designed to optimize mitigation responses for PM2.5, ozone and acid deposition simultaneously.

New York State Relevance: Ozone, PM2.5 and acid deposition represent significant air quality issues in New York State that will require demanding mitigation strategies to achieve federally mandated standards. The development of accurate quantitative tools that couple pollutant emissions across multiple air quality end points will be essential to the implementation of effective emission control strategies within the air quality management framework for PM2.5, ozone and acid deposition.

Relation to Other Research in the Region and Nation: It is likely that similar research will be undertaken in other states across the nation, but New York's unique geographical location in the cross roads of regional pollutant transport suggests that it should take a leadership role in this area. The U.S. EPA and NOAA are currently investing in development of an integrated multi-pollutant modeling framework.

Topic B2.5 Explore feasibility of alternative air quality management strategies on different time scales (e.g., forecasting and real-time control).

Description and Rationale: The current U.S. EPA air quality management approach applies air quality simulation models to develop control strategies to meet worst-case scenarios that may occur once in three year or even once in ten years. The approach, which establishes across the board emission control limits based on these rare events, is neither practical nor cost effective. Alternate approaches could be explored. One example would be to explore the feasibility of developing an interactive strategic emission control system within an air quality forecast modeling framework to mitigate ozone exceedances in anticipation of forecasted episodic events. The cost benefit of such an approach, if viable, would be substantial. In addition, it would provide a more accurate means for the valuation of emission credits for trading. The current emission trading system does not take into consideration that the value of an emission credit (i.e. the cost of a ton of emission reduced) is very much a function of when and where that reduction occurs.

New York State Relevance: (See relevance in Topic B2.3)

Relation to Other Research in the Region and Nation: The U.S. EPA and NOAA have recently indicated an interest in Air Quality Forecast Modeling Systems.

SECTION 3.0 - HEALTH EFFECTS

Topic B3.1a Support the integration and analysis of relevant PM Supersite data with exposure/health effects studies.

Description and Rationale: The Supersite in New York, as well as other regional Supersites (in Baltimore and Pittsburgh) and the network of Speciation Sites in the northeastern U.S. will provide, for the first time, a substantial body of data on the chemical composition and particle size distributions of ambient air particulate matter. These data, when combined with human health status data on appropriate population groups in time-series analyses will make it possible to examine the hypothesis that certain specific PM components are more closely associated with adverse health outcomes than others, possibly providing a basis for more targeted and efficient National Ambient Air Quality Standards (NAAQS) and/or emission standards and State Implementation Plans (SIPS). This effort could also include development of databases of key potential health-related PM components (including aldehydes, acid aerosols, and ultrafines) which could be integrated into health studies.

New York State Relevance: New York State, as well as adjacent regions in the northeast and industrial midwest, were found to have substantially higher relative risks for daily mortality and hospital admissions than other parts of the U.S. in the 90-city NMAPS study. This could have been due to several factors, such as a more acidic ambient aerosol or a greater proportion of fine particles (PM2.5) within the PM10 in this region. The validity of these and other hypotheses can be tested with the kinds of analyses being proposed here. Such results could lead to more effective targeted air quality management strategies.

Relation to Other Research in the Region and Nation: It is likely that similar research will be undertaken in other states across the nation, and any commonalties and/or differences in findings elsewhere will provide a valuable basis for hypothesis testing and validation.

Topic B3.1b Support the integration of source attribution methods of PM into health/exposure studies (methods development, technology transfer).

Description and Rationale: Atmospheric PM is a complex mixture of chemical compounds resulting from the mixed composition of the major anthropogenic sources, their chemical and physical transformations in and near discharge pipes and stacks, and their further transformations within the atmosphere. Other important PM sources include dusts from construction, demolition, agricultural operations, and resuspension of previously deposited particles by vehicles and natural weather phenomena. It has been hypothesized, based on prior time-series based epidemiological studies, that the relatively freshly generated PM mixture from combustion sources is more toxic than PM from other sources. Because of the physical and chemical complexity of ambient air PM, it may not be possible to separate out the contributions to health effects of individual PM components. It may, however, be more feasible in the future to integrate source apportionment techniques into health studies to identify a limited number of source categories and their contributions to the health effects, since each is expected to have an identifiable "signature" based on differences in its contents of trace elements and compounds. Prior to application of source apportionment methods, some initial work is needed to harmonize techniques and data collection formats, with the goal of facilitating common and combined analysis of the role of different source types in eliciting health effects.

New York State Relevance: (See relevance statement in Topic B3.1a)

Relation to Other Research in the Region and Nation: (See relation statement in Topic B3.1a)

Topic B3.2 Explore feasibility of a targeted cohort study to examine exposure and health effects to "line exposure" from mobile sources.

Description and Rationale: Recent research has implicated close proximity to major multi-lane express highways as a risk factor for cardiopulmonary disease morbidity. Pollutants with steep concentration gradients attributable to truck and auto traffic include nitric oxide, carbon monoxide, the number concentration of particles (ultrafines), and re-suspended road dust (coarse particles). An observational study of a population cohort of residents living in close proximity to express roadways and one or more matched reference populations living in the same general neighborhood but at greater distances from express roads, coupled with representative measurements of pollutant concentrations and time activity patterns for the cohort could provide a needed test of the hypothesis that freshly-generated primary pollutant emissions from motor vehicles are important risk factors for cardiopulmonary disease and/or its exacerbation. Given the resources required for this type of project, a phased approach with a feasibility study followed by implementation is recommended. Significant leveraging of funds will be required.

New York State Relevance: New York State may be an ideal model location to undertake a multi-center (in this case, multi-New York-cities) study to assess the association between daily rates of symptoms, pulmonary function, cardiac function, and/or absence from school or work and particle number concentration (in comparison with PM2.5 mass). PM2.5 monitoring is supported by the State and a number of monitoring programs (with fines and ultrafines) are funded by EPA, NYSERDA and via other mechanisms. It would be feasible to design the studies such that respiratory and cardiovascular response attributed to ultrafine (or fine PM) could be compared in the highly populated urban area of NYC with the less densely populated Upstate cities with populations in close proximity to line sources (including populations of Rochester, Buffalo, Syracuse, Albany, etc.).

Relation to Other Research in the Region and Nation: Research currently supported by EPA is examining the geographic variability of gaseous and PM concentrations in the South Bronx.

Topic B3.3 Better understand the patterns of, and factors influencing, dose and human exposures to pollutants of ambient origin.

Description and Rationale: To date, air quality monitoring research supported by NYSERDA has focused largely on measurements of outdoor concentrations at fixed sites. However, the link between ambient concentrations and human health effects is mediated by a variety factors which modify individual human exposures to particles of ambient origin, including local concentrations, indoor/outdoor activity patterns, penetration efficiencies from outdoors to indoors, indoor decay rates, and other factors. Recent studies have demonstrated high correlations over time between indoor and outdoor PM2.5 concentrations, and have illuminated some of the factors influencing these relationships. However, little is known about the dose and human exposures to particle sub-classes defined on the basis of size and/or composition. Thus, to better understand the links between ambient concentrations and human health effects for particle sub-classes, New York State studies are needed on patterns of, and factors influencing, dose and human exposures to particles of ambient origin.

New York State Relevance: New York State is home to one of the largest and most diverse populations in the Nation. Findings regarding human particle exposures specific to New York State populations are urgently needed to better understand the true impacts of emissions control programs in the State. In addition, findings from New York State will have relevance to federal air quality control efforts.

Relation to Other Research in the Region and Nation: Funding for human exposure research has to date originated largely from U.S. EPA. However, large PM-related funding programs at EPA, such as the PM Centers, have focused mainly on epidemiology and clinical studies (like NYSERDA), leaving important exposure-related questions under-studied.

Topic B3.4 Support critical research to identify causal components in PM .

Description and Rationale: All past and current National Ambient Air Quality Standards (NAAQS) for airborne particulate matter (PM) (TSP, PM10, PM2.5) have been based on gravimetric concentration measurements in a predetermined aerodynamic particle size range. Until recently, little attention has been paid to the particle number or surface area (e.g., ultrafines) as potential contributors to toxicity. However, there is strong suggestive, but not conclusive, evidence that some components of the complex PM mixture in ambient air contribute disproportionately to the overall health effects. Identification of the more causal components of PM would provide a basis for more efficient and effective NAAQS and for the implementation of source controls.

Despite the strong association between particulate matter and health effects that may be found in the epidemiological studies, epidemiology is rarely able to establish causality. Toxicologic studies are needed to define the underlying mechanisms. Furthermore, the significance of results will be greatly enhanced if results obtained in controlled clinical studies can contribute plausible explanations of underlying biological mechanisms for ambient particulate-matter-associated health effects as occurred with ozone.

New York State Relevance: (See relevance statement for Topic B3.1a)

Relation to Other Research in the Region and Nation: (See relation statement on Topic B3.1a)

Topic B3.5 Develop long-term data for black carbon as a surrogate for diesel engine exhaust exposures/Develop exposure data for diesel PM urban environments.

Description and Rationale: Diesel engine exhaust is generally the major source of elemental (black) carbon (EC) in community air, as well as a significant source of organic carbon (OC), and there is suggestive evidence that diesel exhaust particles are a contributory factor for the prevalence and exacerbation of pediatric asthma in urban settings. The opacity of air sampling filters as measured by British (or Black) Smoke (BS) and Coefficient of Haze (CoH) has provided an approximation of black carbon in ambient air in historic air quality networks, but reliable and consistent calibration data are scarce or sometimes nonexistent. Both retrospective and prospective studies of the role of black carbon in ambient air in relation to asthma impacts and other cardiopulmonary diseases could yield useful new insights if it is possible to reliably relate filter opacity to black carbon concentrations and indices of cardiopulmonary diseases.

New York State Relevance: Urban centers in New York State and the adjacent region have historically been exposed to relatively high concentrations of black carbon, and until recent years, there was a long record of data collected in terms of CoH readings. This could create unique opportunities to further the understanding of the relationship between black carbon and health effects. Furthermore, continuous measurements of EC and OC using current state-of-the-art instrumentation are underway in various locations in New York State.

Relationship to Other Research in the Region and Nation: In addition to current EC/OC measurement programs in New York State, comparable measurements are being made in other urban regions throughout the U.S. This provides an opportunity to determine the extent and variation of EC and OC, and the other environmental factors that can influence the readings provided by the continuous monitors.

SECTION B4.0 - SOURCE EMISSIONS, TECHNOLOGY AND POLICY

This section addresses five subject areas where additional effort is needed to provide valuable policy-relevant information to the State of New York in assessing control strategies and energy production options to minimize air pollution impacts. These areas suffer from lack of national attention, and additional

effort will not only provide valuable technical input to the State's energy/environmental policy, but also provide regional and national leadership in a critical gap area.

Topic B4.1 Support method development and characterization of sources of primary and secondary PM emissions impacting New York State.

Description and Rationale: In July 1997 the EPA proposed new NAAQS for fine particles (PM2.5) and for fine plus coarse particles (PM10). These standards were developed, in part, based on the NMAPS, which related adverse health effects to particle size and mass concentrations (see relevance statement in Topic B3.1). Airborne particles arise from direct emissions for a great variety of natural and anthropogenic sources, and indirectly through the formation of particles secondarily from gaseous compounds (such ozone, sulfur dioxide, oxides of nitrogen, ammonia, and volatile organic compounds) via chemical and physical processes in the atmosphere.

Methods are needed to determine the size distribution, the chemical composition and the mass-emission rates of primary particles and the reactive gases that lead to secondary particle formation through atmospheric chemical reactions. These methods and the source characterizations are needed to support atmospheric modeling of primary and secondary particulate matter through transport and transformation, to determine the sources of biologically important characteristics of airborne particles once identified by health researchers (see description and rationale in 3.3), and to support development of emissions control strategies. Traditional source testing methods do not provide information on size distribution and chemical composition for these purposes. The approach thought to address source characterization is one that attempts to simulate the physical phenomena of cooling and dilution that occurs in a plume using a dilution sampling schemes.

New York State Relevance: The development of standard methods for characterizing the contribution of stationary and mobile combustion sources, disbursed area-wide sources and industrial processes with respect to PM2.5 will be helpful in gathering source strength information that can be used in designing emission control strategies for the State to meet the 1997 NAAQS.

Relation to Other Research in the Region and Nation: Currently, NYSERDA is co-sponsoring a methods development/source characterization program for fine and ultrafine particles from stationary combustion sources fired by oil and gas with the Gas Technology Institute (GTI), the California Energy Commission (CEC), the U.S. Department of Energy's National Petroleum Technology Office (DOE NPTO), the American Petroleum Institute (API), and with cooperation from the U.S. Environmental Protection Agency (EPA). These technologies and methodologies will provide information to assess the source contributions of combustion sources with respect to ambient fine (smaller than 2.5 microns) and ultrafine (smaller than 0.1 microns) particulate matter. This three-year program began in January 2001and will characterize up to ten sources with a test of a large-scale boiler in New York City during 2002. Additional source types including wood combustion and coal-fired power plants should be added to the test program.

Topic B4.2 Synthesize available information on PM in New York State and produce an integrated assessment to provide scientific foundation for SIP development (include Supersite data, other field sites, health/exposure studies)

Description and Rationale: There are several major PM research and monitoring initiatives going on in New York State and the region. These include the Supersite program, several EMEP field studies in the New York City metropolitan area and upstate New York, emission source characterization efforts, PM health research and exposure studies, as well as regulatory monitoring initiatives. The proposed Integrated Assessment would synthesize available data and put it in a form that will be most useful to policy makers. All too often, environmental research dollars are expended on costly field campaigns and data collection efforts, with too little resources devoted to data analysis and synthesis. The proposed

effort would attempt to avoid this problem in the PM area and would provide timely and geographically relevant information to policy makers in New York. The Assessment would:

Evaluate and synthesize data coming from all NYS PM sites,
Evaluate regional PM issues, drawing on northeast PM Supersites program,
Apply receptor modeling/chemical transport modeling to assess source-receptor relations, where needed,
Begin to lay out framework for assessing economics of control options,
Focus on policy implications.

New York State Relevance: In the 2005-2008 timeframe, New York State will need to develop a State Implementation Plan (SIP) to comply with ambient PM2.5 air quality standards. Preliminary data indicate that several areas in New York State will be out of compliance with the annual standard. The proposed assessment could provide useful information for the development of the SIP.

Relation to Other Research in the Region and Nation: NARSTO has recently completed a PM assessment focusing on the tri-national areas of Canada, the U.S., and Mexico. The effort would build on the efforts on the Northeast Supersites program, focusing on data analysis and synthesis. The effort would need to be timed properly to maximize value of ongoing studies, i.e., possibly starting in 2004.

Topic B4.3 Develop standard test method for particle size distribution for mobile sector emissions: test stand and in-use.

Description and Rationale: Comparative assessments of stationary and mobile emission sources currently lack standardized test methods such that "source strength" terms for fine-PM emissions from various combustion types could be provided to the atmospheric chemistry and health communities. Contributions from internal combustion engines to atmospheric fine-PM levels are presently based on PM mass emissions whereas size-specific PM contributions from all categories of combustion sources will be necessary to guide policy decisions in the face of PM2.5 non-attainment. While PM mass data for real-world vehicles is itself sparse, the inference of fine-PM contribution from total mass is at best tenuous.

The objective to be realized is to demonstrate mini-diluter sampling concepts that would condition a real-time slipstream exhaust sample to standard conditions for subsequent particle number, size, and chemistry characterization. The dilution and sample handling conditions would be sufficiently defined to yield a test method that could give matched results in different laboratories applied to diverse stationary or mobile combustion fuel and technology types. Transient combustion events are known to be major contributors of fine-PM in the mobile sources case. Dilution methods and attendant instrumentation for particle mass and number characterization must accurately account for transients on the time scales typical of engines, control systems, and vehicle dynamics.

A source-strength metric for PM number, size, and chemistry that includes transient events must include not only the slip-stream characterization of exhaust mentioned above, but also the variable exhaust flow rate from the combustion source. The data reduction steps necessary to combine exhaust mass flow rate and the particle number/size/chemistry information form a critical step in the objective to yield a true "source strength" integrated metric that can distinguish among the various sizes of sources impacting the atmospheric chemistry or heath professional. Further reactions and atmospheric processes will change the direct emissions, but it will be useful and necessary to develop standard test methods that can be applied across a wide range our sources that affect atmospheric fine-PM in order to sort out best policy options to reduce the combined impacts form many sources.

New York State Relevance: New York State will certainly face the need for reductions in PM2.5 in order to bring ambient levels under the NAAQS. Exactly what options are available are at present only speculative, and are based on insufficient data. These options can point in vastly different directions and impact dramatically different sectors. It may be that diesel engines both on and off-road will need to have

strict controls placed on them such as California is presently implementing. However, old cars that burn excess lubricating oil may be found to be a significant part of the PM2.5 problem, as has been documented in Denver. Far better data than what presently exists will be needed to insure that policies are scientifically well-grounded as New York enters the PM2.5 control era. The fact that we lack a standardized method of characterizing even different sources within a single category [i.e. diesels vs. oil-burning gasoline] indicates the uncertain policy choices that soon will face New York.

Relation to Other Research in the Region and Nation: Development of standard methods for evaluating both stationary and mobile sources for especially PM2.5, but also for toxic and ozone precursors, will have value to several other New York research efforts. The health research initiatives would greatly benefit by access to sector-specific source estimates of ozone, PM2.5, and toxic emissions, which are now lacking. The Super Sites atmospheric characterization efforts, and ozone atmospheric modeling research presently underway in New York, present an even more direct link. The advent of standard test methods can open the door to providing input data to atmospheric chemistry sector that has not been available.

Considerable work to document how direct diesel emissions are transformed in the immediate plume of a moving vehicle is becoming available, and the results of these studies will provide the foundation for setting the fixed conditions that will be used in defining standard dynamometer test methods as proposed here. European researchers and policy makers have recognized this need and are proceeding to set test methods according to their base of information and instruments. EPA has thus far not entered the world of testing emissions for particle number and size with a view toward a standard test method. As total mass of PM emissions from advanced technology diesel engines becomes virtually a non-detectable level using conventional mass testing methods, the possibility and value of documenting a more refined metric that hinges on particle numbers and sizes may emerge as a companion to mass. This is certainly true for the health and atmospheric process communities, less so from a pure regulatory view. The long-term opportunities for collaborative leveraging of research resources are multi-faceted in this case.

C. Research Needs Crosscutting the Topics of Air Quality, Health and Ecological Response

Topic C1 **Assess adequacy of existing monitoring networks as they relate to (i) source attribution, (ii)determining transport, (iii) evaluating health/environmental effects, and (iv) verifying the impacts of changes to pollution controls strategies on air quality (accountability).**

Description and Rationale: A review of current air quality monitoring networks and related research activities in New York State is needed to identify monitoring redundancy and gaps from the perspective of geographic distribution of sites and parameters measured. A related assessment of the state of instrumentation/monitoring technology and development needs would help identify future technology investment priorities.

There are multiple needs for the monitoring of air and environmental quality including estimation of human exposure, identification and apportionment of pollutant sources including understanding of transport and fate of the atmospheric constituents, provision of a data base to develop and test models, and measurement of the changes in concentrations resulting from active intervention (regulatory or related actions). These various needs often require different approaches to the design of the monitoring network, the selection of species to be measured, and the instruments to be deployed. Given limited resources for monitoring and increasingly challenging air quality objectives, it is essential that an efficient and effective, interconnected monitoring program be developed for New York State in order to provide the required variety of policy-relevant information.

New York State Relevance: New York State spends considerable resources on the monitoring of air and environmental quality. [Several key networks and research sites are shown in Figure 1] Despite a number of air quality improvements over the years, acid deposition, ozone, and ambient particulate matter still remain a paramount concern in New York. Tackling these pollution problems in the future will require *better* information on transport, better understanding of source-receptor relations and total deposition, and better monitoring of environmental/health endpoints to assess effectiveness of intervention strategies.

Relation to Other Research in the Region and Nation: The U.S. EPA is launching an evaluation of air quality monitoring networks nationwide. The effort proposed here could build on the national analysis as a regional pilot focusing on the augmentation of regulatory networks with long-term study sites.

NYSDEC maintains several networks for the monitoring criteria air pollutants (SO_2, CO, NOx, O_3 and PM2.5), acid deposition network, the federal reference method (FRM) network for PM2.5 mass, speciated PM2.5 network, an air toxics network, as well as sites in New York State associated with the Interagency Monitoring of Protected Visual Environments (IMPROVE) and the Photochemical Aerosol Monitoring Station (PAMS). These networks are supplemented by a number of programs supported by NYSERDA and other entities. NYSDEC, as part of the EPA speciation network, is establishing sites at Downtown Rochester, Pinnacle State Park, Whiteface Mountain, and several NYC sites (e.g., Bronx Botanical Gardens, Queens College, and IS52). Other speciation network sites exist in Burlington, VT, Additional sites in Buffalo and Manhattan will be established in the future. There are IMPROVE sites at Pinnacle, Lye Brook and Proctor Maple, VT, Chicopee, MA and Cornwall, CT. Currently, NYSERDA is supporting supplementary monitoring at Whiteface Mountain and Pinnacle, in Tuxedo and at Hunter College in Manhattan, and in Potsdam and Stockton. NYSDOH supports the station at Mayville, Chautauqua County.

The National Atmospheric Deposition Program (NADP), Clean Air Status and Trends Network (CASTNet), Atmospheric Integrated Air Monitoring Network (AIRMon) and Mountain Acid Deposition Program (MADPro) networks exist to estimate wet, dry and cloud deposition, respectively. In addition, there is at least one independent monitoring station that estimates wet and dry deposition (Institute of Ecosystem Studies' Environmental Monitoring Program, Millbrook, NY). One-half dozen dry deposition monitoring sites exist in New York State. There are no current efforts to increase the density of dry deposition monitoring networks in New York, and the cloud deposition monitoring network may be facing elimination. The Adirondack Lakes Survey Corporation, in collaboration with DEC, NYSERDA, and U.S. EPA is supporting a 52 lake water quality monitoring program to evaluate the effects of acid deposition in the Adirondacks.

Topic C2. Evaluate Environmental Effects and Strategies for Mitigation of Electricity Generation

Description and Rationale: The siting of electricity generation is often a contentious process, with much discussion, analysis and concern about the local and regional impact on land-use, habitat, air quality, public health, and impact on aquatic systems associated with water used for power production or cooling. Research is needed to address ways to assess, monitor, and reduce these adverse impacts including the evaluation of new and emerging cooling technologies and their impacts. The development of tools that can facilitate the siting process are also needed.

New York State Relevance: As a result of increased demand for electricity and the restructuring of the electric industry, New York State is in the midst of siting numerous power plants, primarily within the Hudson Valley, New York City and Long Island. Although these power plants are extremely clean compared to the current stock of power plants, siting is often hindered and delayed by questions about the impact on aquatic resources, land-use, habitat, air quality and public health in New York. In addition to meet future power demands in downstate load pockets, distributed generation, combined heat and power sources, and emergency generators will play a greater role in meeting base and peak power demand.

Research and monitoring activities in the region and nationally are not adequate to assess local effects associated with this development.

Relation to Other Research in the Region and Nation: This work should be coordinated with the assessment of distributed generation "Topic C3." The selection of any new monitoring sites would be informed by the assessment of monitoring networks and needs under Topic C1. Technology development initiatives should be coordinated with related public-benefit efforts in other states and nationally.

Topic C3. Evaluate the environmental implications of the distributed generation of electricity in New York State.

Description and Rationale: New York utilities and government organizations, as well as utilities in New England, are currently trying to sign up owners of large existing backup generators (typically diesel) to produce electricity for situations when "capacity deficiency" occurs. Many of these engines were permitted to run only in case of emergency. These sources are high NOx emitters and a source of primary fine particles and air toxics. They are also expected to come on line (or produce power off line to relieve load on the grid under contract agreements with the serving utility) when air pollution levels are very high (summer ozone episodes). The environmental implications of the emerging use of distributed generation technology, in particular the use of large diesel engines, needs to be better understood. A variety of alternative policies and pollution control strategies should be evaluated including after treatment technology, fuel switching (e.g., biodiesel), and combined heat and power applications.

New York State Relevance: Increased use of fossil fueled distributed generation is anticipated in New York State and elsewhere in the region given the changes in the energy industry, the demand for power, and regional transmission constraints. In addition, backup generators (or emergency generators) may play an increased role in the supply of energy in critical areas in New York State in times of high demand.

Relation to Other Research in the Region and Nation: California is evaluating alternative control options for these high-emitting engines. An EPA/regional study is underway to do case studies of retrofitted engines to evaluate achievable reductions in NOx and toxics emissions (including particulates).

Topic C4. Maintain and initiate, where necessary, measurements of fine particulates and precursors, wet and dry deposition of Sulfur and Nitrogen, and base cations at specific *long-term study sites*, building on assessments described in C1 above.

Description and Rationale: Although data from long-term monitoring programs are critical to answering research, management and policy questions, funding for monitoring programs is hard to find, and once found, difficult to maintain. This effort, as well as the identification of potential funding organizations, will be based on the findings of Topic C1.

New York State Relevance: (See relevance statement in Topic C1.)

Relation to Other Research in the Region and Nation: (See relation statement in Topic C1.)

Topic C5. Identify multiple sources and relative contributions of fixed nitrogen, including ammonia, to New York State ecosystems; examine watershed retention of nitrogen to assist in source reduction initiatives; improve understanding of the sources of ammonia and its role in aerosol formation in New York State - including inventory development and exploration of mitigation options.

Description and Rationale: The fixed nitrogen that contributes to atmospheric deposition originates from at least three major emission sources: (1) stationary sources, (2) vehicles, and (3) agronomic systems.

There may also be substantial inputs of nitrogen through biological fixation in some ecosystems. In devising strategies for source reductions of nitrogen emissions, data are needed on the relative contributions of atmospheric nitrogen inputs to ecosystems from these various sources. Additionally, nitrogen arriving from the atmosphere from different sources and in different forms (e.g., nitrate, ammonium, organic N, NOx) may have different ecosystem retention capacities. Current published studies show widely varying proportions of ecosystem retention of nitrogen from the atmosphere.

Ammonia appears to be a critical component in the formation of PM in the Northeast after organic carbon. Currently, there is little information on the sources and levels of ammonia emissions impacting New York State. An initial assessment of what is known about area and point sources, including the agricultural sector, that also explores measures to control emissions and thereby reduce secondary PM formation will be helpful in control of ambient PM levels.

New York State Relevance: New York State has required electricity generators to reduce NOx emissions to reduce acidic deposition and summer ozone levels. Sites located in New York that are part of the NADP indicate that about one-third of atmospheric nitrogen deposition is ammonium, which primarily originates from agricultural activities. The relative contributions of stationary vs. mobile sources of nitrogen in atmospheric deposition across the State are unknown. Data are needed to define source apportionment for atmospheric nitrogen deposition in New York to maximize effectiveness of nitrogen-related control programs.

Relation to Research in other Regions and Nation: Mid-Atlantic Regional Air Management Association (MARAMA) is currently developing an ammonia inventory. Hubbard Brook Research Foundation, with NYSERDA support, is currently conducting a synthesis study on the status and effects of nitrogen pollution in the northeastern U.S. In addition, the New York Supersite program is evaluating the ammonium portion of PM and is investigating whether ammonium is the limiting reactant in PM formation in the region.

Topic C6. Develop evaluation protocols to verify the impacts of pollution control strategies.

Description and Rationale: Billions of dollars have been spent on reducing emissions in an attempt to improve air quality and environmental health in the nation. This effort would attempt to develop better evaluation protocols to draw scientifically defensible associations between changes in pollution control and emissions, ambient air concentrations, and health/environmental endpoints (i.e., verification/ accountability). The effort may include the use of statistical approaches, analytical methodologies, models, and the synthesis of monitoring data and research findings to strengthen the cause and effect relationship.

New York State Relevance: Because New York State is impacted more adversely by the pollutants of concern than many other areas of the country, the state would benefit from better information on the relationships between pollution control strategies and health/environmental response. For example, many strategies have been employed in New York State in an attempt to reduce ozone levels, however uncertainties exist regarding the effect of the measures. The intent of this research topic is to ultimately generate more effective decision-making and policy development, and more focused and efficient research efforts.

Relation to Other Research in the Region and Nation: This activity has been identified as a priority by the U.S. EPA and NARSTO, and limited research is underway.

Topic C7. Assess the feasibility and cost effectiveness of multipollutant control strategies for existing generation infrastructure in New York State.

Description and Rationale: New York produces about half of its electricity through the use of fossil fuels (natural gas, 25%; coal, 16%; petroleum, 10%). With the continued need for improvement of the quality of

the environment, it is very important to investigate the feasibility and cost effectiveness of various control technologies (including multi pollutant control technologies) and strategies (including fuel switching) to further reduce emissions of NOx, SO2, particulate matter, mercury, other toxic pollutants, and potentially CO2. The analysis should be done for both the near-term (3 to 5 years) and long-term (10 years and beyond), along with sensitivity studies, since there is a wide range in level of feasible controls for the four pollutants. Additionally, the effort should evaluate outstanding issues and barriers for technology (as well as fuels and processes) penetration and use. The emphasis of this effort should be on power plants that contribute to pollution in New York and should take into account size, age, type of boilers, fuels, sulfur content, existing federal and state requirements for NOx and SO2, etc., including market-based cap and trade approaches.

New York State Relevance: One of the stated objectives of the EMEP program is to "help develop approaches to mitigate impacts of electricity generation and improve environmental quality." A key input to meet this objective is information on the technical feasibility and cost effectiveness of pollution controls for power plants contributing to pollution in the State. The emphasis of this effort should be on power plants that contribute to pollution in New York and should take into account size, age, type of boilers, fuels, sulfur content, existing federal and state requirements for NOx and SO2, etc., including regional and national market-based cap and trade approaches.

Relation to Other Research in the Region and Nation: There are currently a number of alternatives, serious proposals and bills under discussion in the U.S. Senate and the House dealing with substantial reductions in emissions from electricity sector. Many of these bills involve multi-pollutant strategies to control various emissions from the electricity generation sector, especially from coal-fired boilers. These coal-fired boilers are a significant fraction of emissions from this sector (in the U.S. and in the New York state) of SO2 (almost 100%), NOx (more than 90 %), mercury (almost 100%), and CO2 (estimated to be above 70 to 80 percent).

The technology and strategy evaluation at the national and regional level is, by necessity, general in nature since the population of such units is quite large. Such a national evaluation is just starting, but it will not meet the specific needs of the New York State. The emphasis of this effort therefore should be specific to the power plants in New York by taking into account size, age, type of boilers, fuels, sulfur content, existing federal and state requirements for NOx and SO2, etc., including regional and national market-based cap and trade approaches.

Topic C8. Evaluate the potential effects of emissions trading (e.g. mercury, fine particulate precursors, etc.) at local and regional level.

Description and Rationale: Several northeast states have raised questions about potential adverse local impacts of pollution control programs that incorporate national/regional emissions trading. Additional research is needed to understand the local risks in the context of regional/national trading programs. SO2 and NOx should be considered - both are precursors to PM2.5; NOx is also a major precursor to ozone; both PM2.5 and ozone have federal ambient air quality standards to protect public health. Additionally, mercury emissions from coal-fired boilers are becoming the focus of rapidly emerging national, regional, and state policies. There are serious questions being raised about the feasibility of trading-based mechanisms for mercury mitigation since they may not provide protection against adverse local impacts if not designed with care. This project should evaluate the local emissions impacts in the context of existing national and regional strategies to control SO2 and NOx. It should also evaluate the feasibility of and constraints on any market-based approaches to control mercury emissions in New York State.

Market-based approaches, when designed properly (for example, establishing an adequately stringent cap in the "cap and trade" program, and defining limits on trading to mitigate local impacts) have the potential to result in significant cost savings as well in significant emission reductions. It is important that any strategies to reduce SO2, NOx, and mercury emissions from power plants take advantage of market mechanisms to reduce cost and at the same time provide protection against local adverse health impacts.

New York State Relevance: The evaluation of mercury and primary and secondary PM trading is necessary to support development of appropriate State Implementation Plans.

Relation to Other Research in the Region and Nation: A recent university study has evaluated additional health risks from local emissions in the context of regional strategies in Massachusetts. A regional group is evaluating the scientific knowledge of mercury speciation in the power plant flue gases and how that may affect the design of a market-based approach for mercury emission reductions that are cost effective and also protective of ecological and public health. Several environmental economists have evaluated the local impacts of the Title IV trading program.

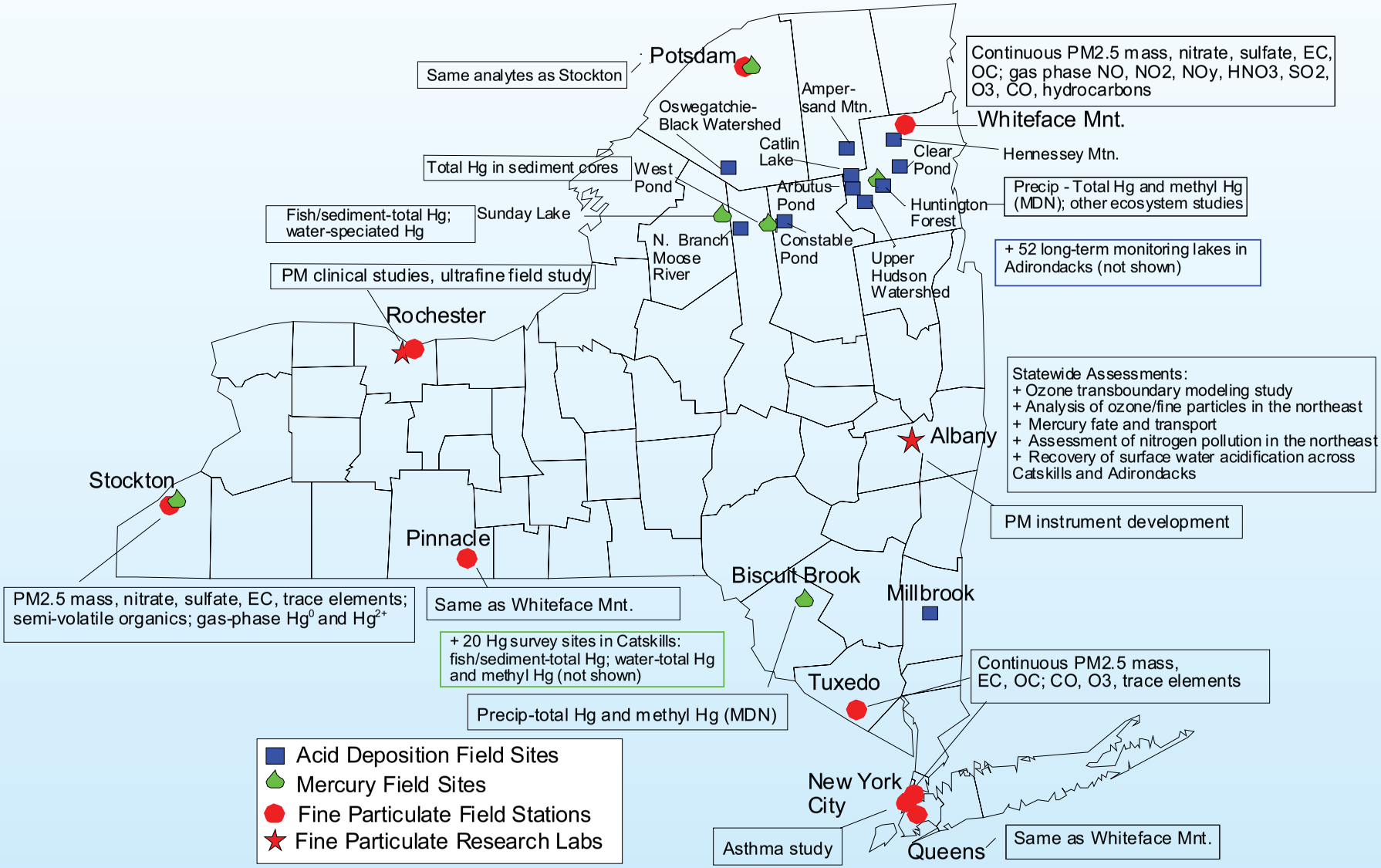
Topic C9. Evaluate the environmental impacts of biodiesel in New York State

Description and Rationale: This initiative will include an assessment of the environmental impact of biodiesel, focusing on the potential for biodiesel to improve air quality in New York State. In addition, to being a "home-grown" renewable fuel, an attractive attribute of biodiesel has been the *potential* environmental benefit compared to conventional diesel fuel, including reduced primary particulates and reduced NOx emissions.

New York State Relevance: Unlike most other energy resources, New York State has the potential to be a supplier of biodiesel and other biofuels. Use of biodiesel in New York State in stationary (e.g., distributed generation, home heating) and mobile sector applications could possibly provide a more cost-effective means of improving air quality than alternative pollution controls; however we currently lack necessary field data to fully evaluate the potential impacts in New York.

Relation to Other Research in the Region and Nation: The U.S. EPA and DOE are supporting some emissions tests for a variety of biofuels. This initiative should be coordinated with Topic C.3 (Distributed Generation).

NYSERDA
Environmental Monitoring, Evaluation, & Protection Program
Field Stations and Research Sites



Appendix 2: NYSERDA - New York Energy $mart sm Environmental Monitoring, Evaluation, and Protection Program Project Portfolio					
Contract #	Title	Principal Investigator and Research Organizations	Site	Total Project Cost	NYSERDA Cost
Fine Particle and Ozone Research Projects					
4913	*Clinical Studies of Exposure to Ultrafine Particles	Dr. Mark Utell, Univ. of Rochester Medical Center	Rochester (clinical)	$817,141	$480,851
6084	Source Apportionment of Fine Particles in New York City	Dr. George Thurston, NYU Medical Center	New York City, Tuxedo	$801,432	$489,358
6083	Impact of In-and Out-of-State Power Plants on Semivolatile Pollutants in New York	Dr. Philip Hopke, Clarkson University	Stockton, Brockport (NYS northwest border)	$769,196	$563,121
4914	*Analysis of Ozone and Fine Particles in the Northeast	Dr. S.T. Rao, SUNY-Albany	Statewide (modeling)	$537,652	$537,652
6085	Assessing the Effects of Transboundary Pollution on New York's Air Quality	Dr. S.T. Rao, NYS Dept. of Environmental Conservation	Canadian-NYS border, statewide (modeling)	$660,569	$387,919
4918	*Enhanced Measurements of Oxidants, Fine Particles and their Precursors	Dr. Kenneth Demerjian, SUNY-Albany	Whiteface Mountain, Pinnacle State Park, NYC/Queens	$8,176,143**	$2,737,689
5060	Development and Demonstration of Continuous Ambient Particulate Monitor (R&P 6400 series)	Dr. Harvey Patashnick, Rupprecht & Patashnick Co., Inc.	Albany (lab work), field site (TBD)	$122,078	$49,880
6183	Development and Demonstration of Innovative Instrument for Ambient Particulate Matter Mass Measurement Standard	Dr. Harvey Patashnick, Rupprecht & Patashnick Co., Inc.	Albany (lab work), field site (TBD)	$1,328,580	$450,000
6484	Fine Particle Constituents and Acute Asthma in Urban Areas	Dr. Daniel Luttinger, Health Research Inc./NYSDOH	New York City	$293,511	$184,966
6820	Monitoring Particle Size Distribution in Rochester	Dr. Philip Hopke, Clarkson University	Rochester, NY	$246,555	$165,783
6230***	Fine/Ultrafine Particulate Emissions Profiles	Mr. James McCarthy, Gas Technology Institute; Dr. Glen England, GE-EER	New York State (TBD), California, others	$2,020,000	$165,000
				$15,772,857	***$6,212,219***

Appendix 2: NYSERDA - New York Energy $mart sm
Environmental Monitoring, Evaluation, and Protection Program Project Portfolio

Contract #	Title	Principal Investigator and Research Organizations	Site	Total Project Cost	NYSERDA Cost
Acid Deposition and Mercury Research Projects					
4915	*Long-Term Monitoring Program for Evaluating Changes in Water Quality in Adirondack Lakes	Karen Roy, Adirondack Lakes Survey Corporation (ALSC)	52 Lakes in Adirondacks	$9,112,942	$3,845,443
4917	*Evaluation of the Recovery from Acidification of Surface Waters in the Adirondacks	Dr. Myron Mitchell, SUNY College of Environmental Science and Forestry - Syracuse	Arbutus Pond, Huntington Wildlife Forest, & Statewide modeling	$989,538	$802,861
4916/6818	*Mercury in Adirondack/Catskills Wetlands, Lakes and Terrestrial Systems	Dr. Ronald Munson, Tetra Tech, Dr. Charles Driscoll, Syracuse University, Dr. Mike McHale, U.S. Geological Survey	Sunday Lake (Adirondacks) & various sites in the Catskills	$904,830	$741,960
6086	Effects of Atmospheric Deposition of S, N, Hg on Adirondack Ecosystems	Dr. Dudley Raynal, SUNY College of Environmental Science and Forestry	Huntington Forest; Oswegatchie-Black Watershed; Constable, West, Clear Ponds; Upper Hudson Watershed, Moose R.	$413,400	$282,613
6485	Critical Gaps in Research on Mercury in New York State	Dr. Christian Seigneur, Atmospheric & Environmental Research, Inc.	Statewide (modeling)	$107,098	$96,805
6486/6490	An Integrated Assessment of the Recovery of Surface Waters from Reduced Levels of Acid Deposition in the Catskills and Adirondacks	Dr. Douglas Burns, US Geological Survey, Dr. Gary Lovett, Institute of Ecosystem Studies	Adirondacks and Catskills (modeling and assessments)	$277,199	$245,519
6487	Status and Effects of Nitrogen Pollution in North Eastern United States	Kathy Fallon Lambert, Hubbard Brook Research Foundation	Statewide	$399,320	$169,320
6488	Atmospheric Transport and Fate of Mercury in New York State	Dr. Chris Walcek, Research Foundation of SUNY	Statewide (modeling)	$139,271	$103,000
6819	Monitoring Deposition and Effects of Air Pollution in the Hudson Valley	Dr. Gary Lovett, Institute of Ecosystems Studies	Millbrook, NY	$133,333	$100,000
				$12,476,931	***$6,387,521***
	Total Funds Committed			**$28,249,788**	**$12,599,740**

*Projects identified in the New York Public Service Commission 1998 System Benefits Charge Order
**Includes $3.449 million of EPA support for PM2.5 supersite.
***Non-SBC Statutory funds

APPENDIX D

Project Fact Sheets

PROJECT UPDATE

January 2006

New York State Energy Research and Development Authority

Environmental Monitoring, Evaluation, and Protection Program

ULTRAFINE PARTICLES AND CARDIAC RESPONSES: EVALUATION IN A CARDIAC REHABILITATION CENTER

Principal Researcher

MARK J. UTELL

WILLIAM BECKETT

University of Rochester Medical Center

Project Location

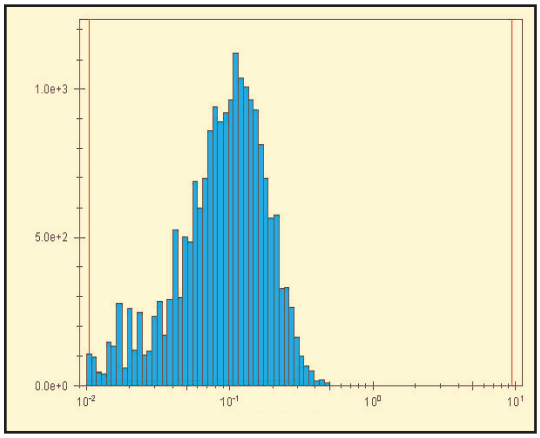
PROJECT FOCUS

As the U.S. Environmental Protection Agency (EPA) and New York State are proceeding with the implementation of mass-based National Ambient Air Quality Standards (NAAQS) for particular matter (PM), clarification of the effects of exposure to ultrafine particles (UFPs) is a high-priority research need. Focusing on a group of sensitive, high-risk patients, this study will assess how exposure to ambient levels of UFPs affects the indicators of cardiovascular function, both at rest and during exercise.

CONTEXT

Epidemiological studies have demonstrated that ambient PM pollution increases cardiac morbidity and mortality. However, the role that different PM components (e.g., organics, metals, and UFPs) play in cardiovascular health effects is still unclear. Several hypotheses have been proposed, and various components and characteristics of PM have been targeted for exploration. Recent research has pointed to UFPs as potentially playing an important role in these deleterious effects.

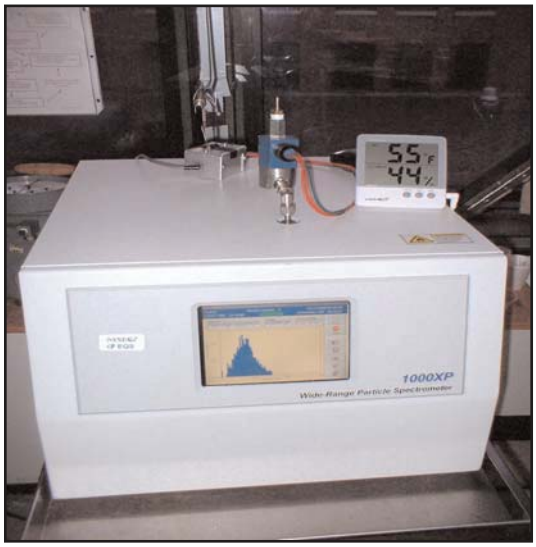
UFPs are extremely small particles, less than 0.1 micron in diameter, that are primarily generated from combustion processes, including stationary fossil-fueled electric-power generation, industrial processes, boilers, and car and truck engines. For the same PM mass, these particles have much higher number concentrations and surface area than larger particles, as well as very high deposition rates in the human respiratory tract. Clinical studies have shown changes in cardiac parameters for healthy subjects when UFPs were inhaled in high numbers in a laboratory setting. The current research builds on two previous studies of UFPs, which



Credit: Mark Utell

Typical particle size distribution

- Characterized the UFP temporal variation year-round at Rochester NY, finding a morning peak for UFPs, believed to be associated with rush-hour traffic, and an afternoon peak believed to be associated with a nearby coal-fired power plant.
- Studied the effects of controlled exposures to UFP at concentrations ranging from 10-50 $\mu g/m^3$, finding alterations in cardiovascular function in healthy, exercising volunteers in the laboratory.



Credit: Mark Utell

Air monitoring equipment

Contact Information

For more information on this project see:

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

or contact Ellen Burkhard at: egb@nyserda.org

Keywords

- Biomarkers
- Cardiovascular health effects
- Fine particles (FPs)
- National Ambient Air Quality Standards (NAAQS)
- Ultrafine particles (UFPs)

PROJECT UPDATE

January 2006

Credit: Mark Utell

Indoor sampling site

Project Status

- Initiated October 2005
- Project ongoing

New York Energy Smart SM

PUB

George E. Pataki, Governor

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

Not yet available.

The project team hypothesizes that in vulnerable subjects elevated levels of ambient UFPs and fine particles (FPs) are associated with

- Slower and compromised rehabilitation;
- Changes in autonomic nervous system function;
- Changes in myocardial substrate and myocardial vulnerability; and
- Changes in indicators of enhanced cardiovascular risk.

Credit: Mark Utell

PROJECT UPDATE

New York State Energy Research and Development Authority

Environmental Monitoring, Evaluation, and Protection Program

Physical and Chemical Characterization of Laboratory-generated Secondary Semi-Volatile Organic Particles

Principal Researcher

KENNETH L. DEMERJIAN

Atmospheric Sciences Research Center, University at Albany, SUNY

Albany, NY

Project Location

Credit: Kenneth Demerjian

A view of the ASRC Aerosol Laboratory.

Contact Information

For more information on this project see:

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

or contact Ellen Burkhard at: egb@nyserda.org

Keywords

- Aerosol
- PMTACS-NY Supersite
- Primary $PM_{2.5}$
- Secondary $PM_{2.5}$
- Semi-volatile organic compound

PROJECT FOCUS

This project aims to improve our current understanding of the physical and chemical characteristics of secondary organic particulate matter (PM) through laboratory studies of organic aerosols and the application of findings to available data. The main components of the research are

- Generation of primary and secondary organic aerosols in SUNY-Albany's Atmospheric Science Research Center (ASRC) Aerosol Generation and Calibration Facility;
- Characterization of generated aerosols and investigation of their photochemical aging; and
- Application of findings to the New York City Supersite's database of ambient aerosol measurements, allowing improved estimates of the contribution of anthropogenic and biogenic secondary organic PM to ambient air in New York State.

CONTEXT

Airborne PM is a broad class of materials that are emitted from a variety of natural processes and human activities and are transported in the air as solid particles or liquid droplets. Some of these particles are emitted directly into the atmosphere from primary sources, e.g., motor-vehicle exhaust, home fireplaces and heating appliances, manufacturing plants, commercial and domestic food preparation, tar application, forest fires, wind erosion, and natural and cultivated vegetation. Other "secondary" particles are formed in the atmosphere through photochemical reaction and oxidation processes involving ozone and other gas-phase oxidants.

In July 1997, motivated by concerns about the adverse health effects of particulate pollution, the U.S. Environmental Protection Agency proposed a new National Ambient Air Quality Standard (NAAQS) for particulate matter of less than 2.5 microns in diameter ($PM_{2.5}$), including daily maximum (65 micrograms per cubic meter [$\mu g/m^3$] and annual maximum ($15 \mu g/m^3$) average concentrations. Approximately 65 million people in the United States live in areas with annual average $PM_{2.5}$ levels in excess of $15\ \mu g/m^3$.

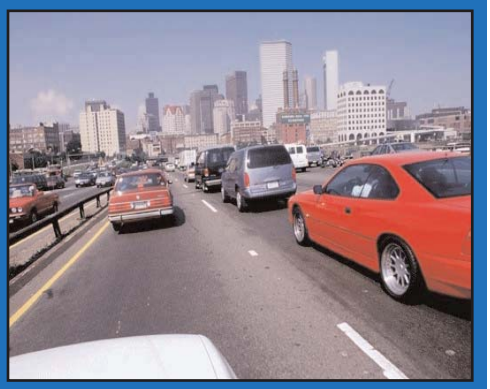
Credit: http://airnow.gov/

Particles contribute to haze

Recent $PM_{2.5}$ measurements through the $PM_{2.5}$ Technology Assessment and Characterization Study-New York (PMTACS-NY) Supersite program have shown that 45%–50% of PM mass can be attributed to carbon-bearing aerosols. However, standard filter-based aerosol measurements, which provide no compound-specific data, offer extremely limited information for distinguishing primary and secondary contributions to carbon PM or for identifying the principal sources that contribute to observed levels of pollutants.

PROJECT UPDATE

December 2005



Credit: http://www.epa.gov

Project Status

- Initiated January 2005
- Project ongoing

New York Energy Smart℠ PUB

George E. Pataki, Governor

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

This project has just gotten underway. The project team has conducted an evaluation of the optimal combination of aerosol sizing instrumentation with well established operational protocols.

PROJECT UPDATE

New York State Energy Research and Development Authority

Environmental Monitoring, Evaluation, and Protection Program

Assessment of Carbonaceous Fine Particles ($PM_{2.5}$) for New York and the Region

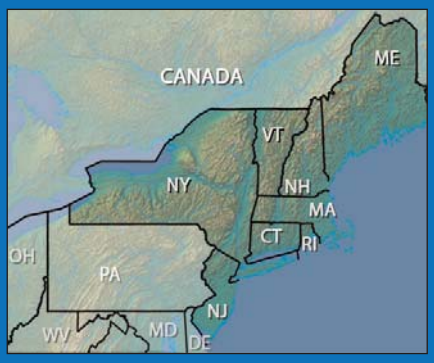
Principal Researchers

PHILIP JOHNSON

JOHN GRAHAM

Northeast States for Coordinated Air Use Management
Boston, Massachusetts

Project Location



Contact Information

For more information on this project see:

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

or contact Ellen Burkhard at: egb@nyserda.org

Keywords

- Carbonaceous $PM_{2.5}$
- Control Strategies
- Emissions Sources
- Fine Particulate Matter ($PM_{2.5}$)
- Health Effects

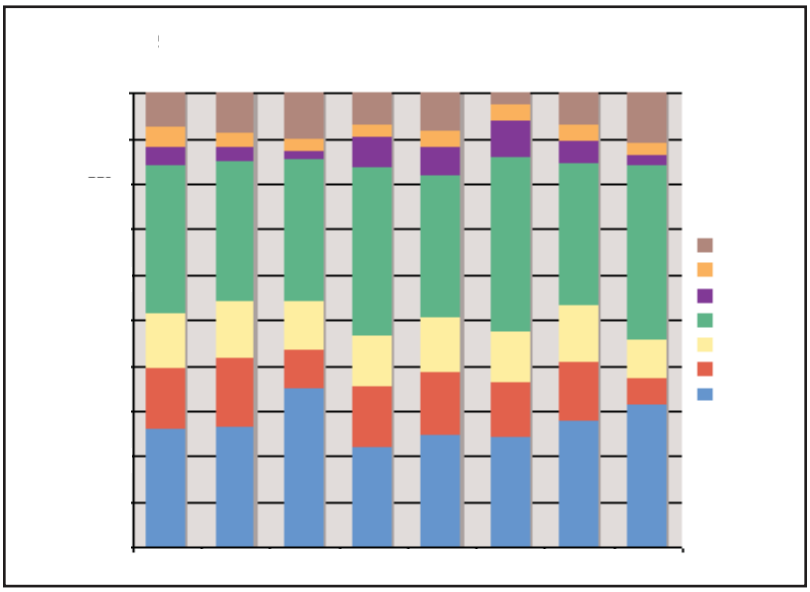
PROJECT FOCUS

This project aims to produce a policy-relevant, comprehensive assessment of carbonaceous fine particulate matter ($PM_{2.5}$) in New York and the region. In order to integrate scientific knowledge and policy efforts, available and emerging information in three key areas will be synthesized:

- Atmospheric emissions sources and chemistry
- Health effects
- Control strategies

CONTEXT

Airborne PM is a broad class of materials, transported as solid particles or liquid droplets (aerosols). These particles are emitted from a variety of natural processes and human activities, including fossil-fuel combustion, forest fires, wind erosion, agricultural practices, industrial manufacturing, and construction. They can be emitted directly into the atmosphere (primary particles) or formed in the atmosphere (secondary particles) from precursor gases such as sulfur dioxide, nitrogen oxides, ammonia, and volatile organic compounds.



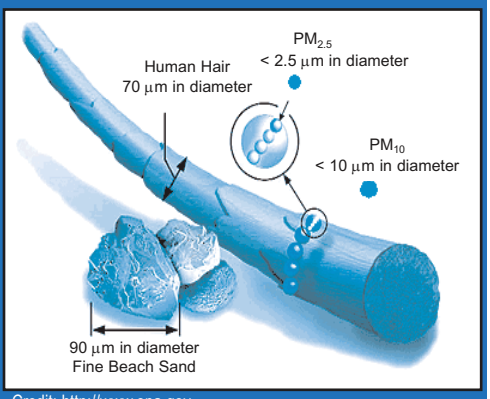
New York State $PM_{2.5}$ Speciation Trends Network (STN) Results
The graphic shows the relative contribution of major mass component species (Sulfate, Nitrate, Ammonium, Organic Carbon, Elemental Carbon, and Soil) to total $PM_{2.5}$ levels at eight New York State DEC fine particle speciation monitors over the period of April 2000-August 2004.

In July 1997, motivated by concerns about adverse health effects associated with $PM_{2.5}$, the U.S. Environmental Protection Agency proposed new National Ambient Air Quality Standards (NAAQS). The current health-based standards consist of a 24-hr average (65 $\mu g/m^3$) and an annual mean (15 $\mu g/ m^3$). Although these standards use $PM_{2.5}$ mass concentrations to gauge air quality, some particles that contribute to PM mass may be more toxic than others. Thus, focusing on all particles that contribute to PM mass may lead to less efficient and effective control strategies than focusing specifically on the particles that are more implicated in adverse health effects.

Carbonaceous $PM_{2.5}$, a significant component of $PM_{2.5}$ pollution in many areas in the Northeast, may play a critical role in observed adverse health effects associated with particulate matter exposure. At an urban location such as New York City, pollutant levels are influenced by many factors, including local and distant point sources, land use patterns, and mobile sources. The carbonaceous component of New York City aerosol levels may reach as high as 50% of total $PM_{2.5}$ mass (see Figure above).

PROJECT UPDATE

December 2005



Credit: http://www.epa.gov

Particle Size of PM $_{10}$ and PM $_{2.5}$

Project Status

- Initiated November 2004
- Project ongoing

New York Energy Smart℠

PUB

George E. Pataki, Governor

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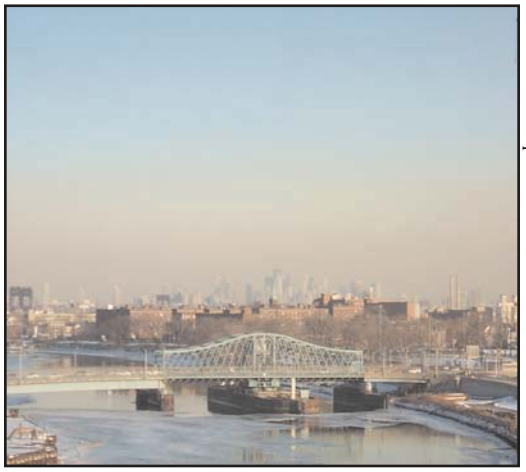


Credit: http://www.hazecam.net/

"Bad" air quality over New York City, as seen from Newark, NJ, 2005.

Credit: http://www.hazecam.net/

"Good" air quality over New York City, as seen from Newark, NJ, 2005.

PROJECT UPDATE

New York State Energy Research and Development Authority

Environmental Monitoring, Evaluation, and Protection Program

Formation and Transformation of Particles in Motor Engine Exhaust

Principal Researcher

FANGQUN YU

Atmospheric Sciences Research Center, University at Albany

http://genesis.sannet.gov/infospc/templates/cd1/issue_traffic.jsp

Contact Information

For more information on this project see:

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

or contact Ellen Burkhard at: egb@nyserda.org

Keywords

- Aerosols
- Engine-generated emissions
- Nucleation-mode particles
- Volatile nanoparticles
- Ultrafine particles (UFPs)
- Fuel sulfur content

PROJECT FOCUS

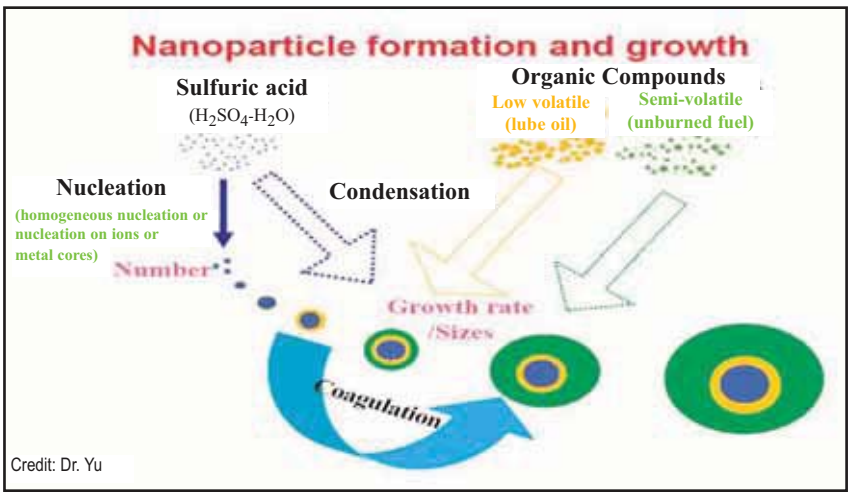
This study aims to improve our understanding of particulate emissions from motor-vehicle engines. The research focuses specifically on clarifying the processes whereby nucleation-mode particles – produced in the conversion of gases to particulate matter – are formed in an engine's exhaust. The contribution of organic compounds to the growth of engine-generated particles is also being explored.

CONTEXT

Airborne particulate matter (PM) is a broad class of materials, transported in the air as solid particles or liquid droplets (aerosols). These particles are emitted from a variety of natural processes and human activities, including fossil-fuel combustion, forest fires, wind erosion, agricultural practices, industrial manufacturing, and construction. While some particles are directly emitted into the atmosphere (primary particles), others are formed in the atmosphere from precursor gases such as sulfur dioxide, nitrogen oxides, ammonia, and volatile organic compounds (secondary particles). In July 1997, motivated by concerns about adverse health effects, the U.S. Environmental Protection Agency proposed a new National Ambient Air Quality Standard (NAAQS) for particulate matter of less than 2.5 microns in diameter ($PM_{2.5}$), including daily maximum (65 micrograms per cubic meter [$\mu g/m^3$]) and annual average ($15 \mu g/m^3$) concentrations.

In order to choose the most effective $PM_{2.5}$ control strategies, the relative contributions to $PM_{2.5}$ from different sources need to be determined. Motor-vehicle engines are known to contribute substantially to particulate pollution, especially in urban regions or near heavily traveled roads. Their exhaust emissions are composed of gas molecules and particles. In addition to primary soot particles of the exhaust, secondary "nucleation-mode" particles may also be involved in the formation of $PM_{2.5}$. As exhaust cools down and mixes with ambient air, precursor gas molecules can nucleate to form new particles or condensate on existing particles. Nucleation increases the number concentration (the number of particles per volume air) of particles in the exhaust, while condensation increases the size of the particles. Particles also coagulate with each other, which reduces the particle number concentration while increasing the size of particles, while total mass remains unchanged.

Nucleation-mode particles are generally less than 50 nanometers (nm) or 0.05 microns in diameter. While these particles contribute little to the total PM mass, on which standards are based, their number concentrations can be very high. As a result of a number of factors – high number concentrations and surface area, and a high propensity to penetrate the epithelium – these particles may be directly responsible for the adverse health effects of PM. Moreover, nucleation-mode particles may also pick up and accumulate precursor gases in the atmosphere, which would increase their size, and may thus contribute directly to ambient $PM_{2.5}$ mass. We do not currently have an adequate physical understanding of the mechanisms by which these particles form during combustion in motor-vehicle exhaust, although several theories exist. A clear understanding of the nanoparticle formation mechanisms is critical to designing effective control strategies.



Credit: Dr. Yu

PROJECT UPDATE

August 2005

Credit: Dr. Yu

The experimental set-up for the measurements of ions in the exhaust of a Honda gasoline generator.

Project Status

- Initiated 2003
- Project ongoing

New York Energy Smart℠

PUB

George E. Pataki, Governor

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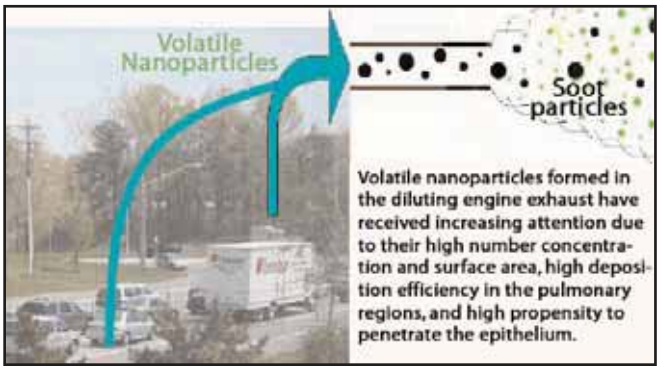


PRELIMINARY FINDINGS

Formation Mechanism of Volatile UFPs

- Concentrations of chemiions in diesel and gasoline engines were measured to be in the range of 10^6-10^8 per cm^3. Simulations taking into account the contribution of these ions to nanoparticle formation can explain some important properties of nanoparticles observed in the engine exhaust. Ion concentrations at the tailpipe exit depend on engine operation conditions, residence time inside the tailpipe, and soot particle concentrations.
- For vehicles running on fuel with typical current sulfur content (~400 ppm), the BHN of sulfuric acid and water may significantly contribute to the formation of nanoparticles in vehicular exhaust when the ambient temperature is low and the relative humidity is high. The same vehicle may emit quite different amounts of volatile nanoparticles when driven in different locations and/or under different weather conditions. The BHN rate is very sensitive to fuel sulfur content: simulations indicate that sulfuric acid-water BHN is negligible under all realistic ambient conditions if the fuel sulfur content is reduced to less than 100 ppm.
- It is likely that both homogeneous nucleation and nucleation on ions contribute to new particle formation for New York State vehicles, which have a typical fuel sulfur content of 300-500 ppm. Under certain conditions, such as cold weather and high relative humidity, homogeneous nucleation controls the number of nanoparticles formed. In other conditions, such as warm weather and low relative humidity or with low fuel sulfur content, nucleation on ions is the dominant process. Nevertheless, it is clear that when fuel sulfur is reduced to below 50 ppm, homogeneous nucleation is negligible in all atmospheric conditions.

Contribution of Organic Species to Particle Growth

Organic species of low volatility, such as those associated with unburned fuel and lubrication oil, appear to dominate the growth rate and therefore the mass of the nucleation-mode particles.

PROJECT UPDATE

New York State Energy Research and Development Authority

Environmental Monitoring, Evaluation, and Protection Program

CHEMICAL COMPOSITION OF FINE ORGANIC PARTICLES FROM URBAN AND REGIONAL BACKGROUND LOCATIONS IN NEW YORK STATE

Principal Researcher

MONICA MAZUREK

Department of Civil and Environmental Engineering,

Rutgers, State University of New Jersey

Project Locations

Project Cofunder

Northeast States for Coordinated Air Use Management

Contact Information

For more information on this project see:

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

or contact Ellen Burkhard at: egb@nyserda.org

Keywords

- Elemental carbon
- Molecular markers
- Organic carbon
- Organic particulate matter
- Primary emission sources
- Secondary emission sources

PROJECT FOCUS

The project is part of an ongoing research effort aimed at improving our understanding of the role of primary and secondary carbon particulate matter (PM) in New York State (NYS) air. While the broader research will identify molecular markers for different source types and determine the amount of organic PM from primary and secondary sources, this project will help improve understanding of the atmospheric abundances and sources of fine carbon PM in various urban and regional locations in the state, providing information that is essential for developing appropriate strategies to control pollutant concentrations in ambient air.

CONTEXT

In July 1997, motivated by concerns about the adverse health effects of particulate pollution, the U.S. Environmental Protection Agency proposed a new National Ambient Air Quality Standard (NAAQS) for particulate matter of less than 2.5 microns in diameter ($PM_{2.5}$), including daily maximum (65 micrograms per cubic meter [$\mu g/m^3$]) and annual maximum (15 $\mu g/m^3$) average concentrations. Approximately 65 million people in the United States live in areas with annual average $PM_{2.5}$ levels in excess of 15 $\mu g/m^3$. Recent epidemiological and toxicological studies suggest that the health effects of particulate matter (PM) can vary by source category.

Airborne PM is a broad class of materials that are emitted from a variety of natural processes and human activities and are transported in the air as solid particles or liquid droplets. Some of these particles are emitted directly into the atmosphere from primary sources, e.g., motor-vehicle exhaust, home fireplaces and heating appliances, manufacturing plants, commercial and domestic food preparation, tar application, forest fires, wind erosion, and natural and cultivated vegetation. Secondary particles are formed in the atmosphere through photochemical reaction and oxidation processes involving ozone and other gas-phase oxidants. Each of the various emission source types has characteristic chemical and/or physical patterns and signatures. Organic molecular markers are individual compounds or groups of related compounds (homologous compounds such as n-alkanes, n-alkanoic acids, hopanes and steranes) that at a molecular level comprise the chemical profile or "fingerprint" for specific emission source types. Individual molecular markers and groups of marker compounds are linked quantitatively to major emission sources of urban fine particles and also to known chemical emission profiles.

Credit: www.photospin.com

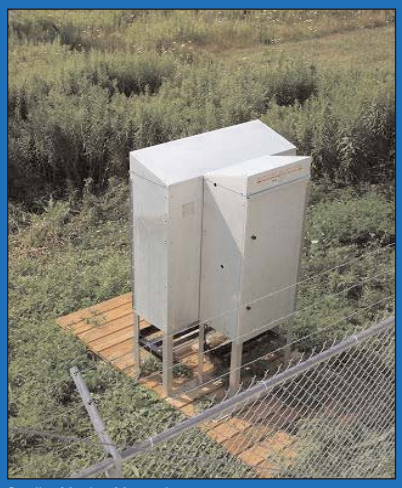
Suites of common cooking oils, lard, and fats (e.g. from fast food frying operations) will be investigated in the laboratory

Credit: Monica Mazurek

Intermediate School 52, Bronx, NY, air quality monitoring site is operated by the NYSDEC

PROJECT UPDATE

January 2006



Credit: Monica Mazurek

Rutgers Tisch 2- and 4-Channel co-located samplers collect fine particle samples. Pinnacle is upwind of the NY metropolitan area and represents regional background.

Project Status

- Initiated October 2003
- Project Ongoing

New York Energy Smart℠

PUB

George E. Pataki, Governor

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.

PRELIMINARY FINDINGS

Fine-particle ambient samples collected as part of the SOAP project have yielded important new results concerning the importance of vehicular emissions and food cooking operations (commercial fast-food restaurants, home cooking) for urban receptor sites in the metropolitan NYC area.

PROJECT UPDATE

New York State Energy Research and Development Authority

Environmental Monitoring, Evaluation, and Protection Program

NYSERDA

Fine Particle Constituents and Acute Asthma in Urban Areas

Principal Researcher

DANIEL LUTTINGER

Toxicological Assessment Section,
New York State Department of Health

Project Location

Contact Information

For more information on this project see:
www.nyserda.org/programs/environment/emep

or contact Ellen Burkhard at:
egb@nyserda.org

Keywords

- Acute asthma
- Elemental carbon
- Emergency room visits
- National Ambient Air Quality Standards (NAAQS)
- $PM_{2.5}$, PM_{10}

PROJECT FOCUS

This project aims to improve understanding of the relationship between exposure to ambient air concentrations of a variety of pollutants and effects on respiratory health. Specifically, the research team is evaluating temporal associations between an array of air contaminants and acute asthma exacerbation, as measured by emergency room (ER) visits for asthma by residents in two communities in New York City (NYC): the South Bronx and Manhattan. In addition, ambient levels of various air pollutants in these two NYC communities are being compared. The air contaminants measured include gaseous compounds (ozone, sulfur dioxide, nitrogen oxides, aldehydes, nitrous acid, nitric acid, hydrochloric acid, and ammonia) and particulate components (metals, elemental and organic carbon, sulfate, hydrogen ion, pollen, mold spores, and particle mass and number).

The project objectives are to:

- Evaluate whether ambient levels of these pollutants differ in the two NYC neighborhoods, which have different rates of hospital admissions for asthma and different socio-economic characteristics;
- Compute the overall rates of asthma ER visits of residents of the two communities that are attributable to air contamination, and test whether the magnitude of the health effect from air pollution differs in the two communities; and
- Investigate which air pollutant or combination of pollutants is most associated with acute asthma exacerbation in each community.

CONTEXT

In 1997 the U.S. Environmental Protection Agency (EPA) set a new National Ambient Air Quality Standard (NAAQS) for fine airborne particles smaller than 2.5 microns in diameter, called $PM_{2.5}$. Currently, the New York State Department of Environmental Conservation (NYSDEC) is conducting a three-year monitoring program to identify areas in New York State that may or may not meet the mass-based $PM_{2.5}$ NAAQS. Reducing NYS ambient $PM_{2.5}$ concentrations to levels that are compliant with the NAAQS will likely require new emissions regulations.

Fine particles ($PM_{2.5}$), which may be both generated locally and transported over regional scales, have a variety of constituents, including carbon, metals, nitrates, sulfates, and semi-volatile organics. Combustion processes play a major role in the production of these particles, which can be emitted directly into the atmosphere (primary particles) or formed in the atmosphere from precursor gases (secondary particles). Important sources are stationary fossil-fuel; electric-power generation; industrial processes; industrial boilers; incinerators; and car and truck engines. While epidemiological studies have shown a correlation between increased concentrations of $PM_{2.5}$ very little is known about the relationship between ambient concentrations of the various components of $PM_{2.5}$ and human health.

PROJECT UPDATE

August 2005

Using statistical tools, this study analyzes the relationship between air contamination and ER visits for asthma and other respiratory conditions in two NYC communities.

Project Status

- Initiated 2001
- Project ongoing

New York Energy Smart℠ PUB

George E. Pataki, Governor

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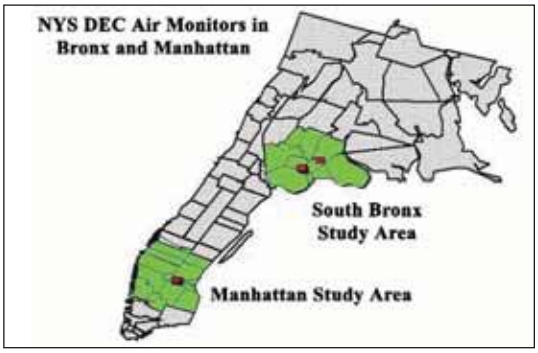

RECENT FINDINGS

For most air contaminants, concentrations in Manhattan tended to be slightly higher than those in the Bronx, with the exceptions of ozone and pollen. In general, pollutant levels at the two sites were highly correlated.

- For both sites, PM_{10} and $PM_{2.5}$ levels varied throughout the day and peaked, along with elemental carbon, between approximately 7 and 9 AM. Low levels were observed in the middle of the night and in the mid-afternoon, and the highest levels were observed in the morning.
- Elemental carbon (soot) hourly averages varied throughout the day for both sites; the highest levels were observed in the morning.
- Organic carbon hourly averages (between peak concentrations and lowest concentrations) varied only in Manhattan; the highest levels were seen in the evening.

Analysis of air trajectories showed similar results for the two sites. In 1999, ~15% of sulfur dioxide, 45% of sulfate, and 30% of $PM_{2.5}$ mass were transported from the Midwest. The rest of the air contaminant mass can be attributed to sources within approximately 100 miles. In addition, there were seasonal variations in the composition of the $PM_{2.5}$ mass; the sulfate component (17–31%) was highest from June to September.

PROJECT IMPLICATIONS

The data and findings of this project will help fill a critical need to further clarify the complex relationship between different contaminants in ambient air and potential health effects. Distinguishing between $PM_{2.5}$ components in relation to reported health effects is desirable for the development of effective control strategies for reducing health risks. Speciation of $PM_{2.5}$ within the ambient air mixture is also useful in distinguishing source types and their relative contributions, and for the identification of potential source control opportunities.

Additionally, the data will offer greater insight into the health impacts of local sources of air contamination. The results of this study are likely to prove relevant to other large cities. Information about daily, weekly, and seasonal variations may also aid policy makers in formulating appropriate health advisories and creating successful preventive measures, as well as devising and implementing effective controls.

PROJECT UPDATE

New York State Energy Research and Development Authority

Environmental Monitoring, Evaluation, and Protection Program

Fine and Ultrafine Particulate Emissions Profiles

Principal Researcher

GLENN ENGLAND

GE Energy and Environmental Research Corporation

Project Location

Statewide

Credit: England

The Dilution Tunnel Sampler enables the use of a broad range of sampling media and analytical techniques to determine full PM component profiles.

Contact Information

For more information on this project see:

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

or contact Barry Liebowitz at: bnl@nyserda.org

Keywords

- Chemical speciation
- Dilution tunnel sampling
- Emission factors
- Emission inventories
- Fine particles
- Source apportionment

PROJECT FOCUS

Generally, to foster the development of a new method to measure and characterize fine and ultrafine particulate matter emissions from natural gas and oil combustion systems.
Primary objectives were to:

- Design a compact dilution sampler/method, for the measurement of fine, and ultrafine particles (FPs and UFPs, respectively) emitted from combustion sources; and
- Conduct field tests using this method to collect data from stationary sources and to compare it to traditional source sampling methods.

CONTEXT

Airborne PM comprises a broad class of materials, transported in the air as solid particles or liquid droplets (aerosols). These particles are emitted from a variety of natural processes and human activities, including fossil-fuel combustion, forest fires, wind erosion, agricultural practices, industrial manufacturing, and construction. In July 1997, motivated by concerns about the adverse health effects of PM, the U.S. Environmental Protection Agency proposed a new National Ambient Air Quality Standard (NAAQS) for particulate matter of less than 2.5 microns in diameter ($PM_{2.5}$), including maximum daily concentrations of 65 $\mu g/m^3$ and maximum annual average concentrations of 15 $\mu g/m^3$. UFPs are an important component of $PM_{2.5}$. Extremely small particles of less than 0.1 µm in diameter, UFPs are primarily generated from combustion processes, including stationary fossil-fuel electric power generation, industrial processes, boilers, and car and truck engines.

Traditional hot-filter/impinger sampling methods for measuring PM have a number of limitations. One important problem is the variety of different conventions for sampling, analysis, and reporting, which may make data from different measuring efforts incompatible. With regard to the chemical processes involved in these methods, the condensable components of PM pose certain difficulties because of the liquid-phase conversion of gases to solids and insufficient measurement precision. Low PM concentrations can also pose a challenge for traditional sampling methods.

METHODOLOGY

Development of Dilution Tunnel Sampling Method

Using a dilution tunnel sampler (DTS; see figure) the sampled gas is cooled to near ambient temperatures by dilution with filtered ambient air, resulting in conditions similar to those in the actual plume, where exhaust gases leaving the stack mix with the atmosphere. The DTS method produces fewer artifacts than traditional impinger-based methods, thus reducing bias in the results. The DTS allows a broad range of sampling media and analytical techniques to be used for full chemical and physical characterization of PM components as used in ambient air quality testing. This aspect of the project involved:

- Conducting tests to determine the effects that sampler design and operating parameters may have on the PM mass and particle size distribution;
- Designing a “next-generation” dilution sampler that is more portable and compact without sacrificing data integrity; and
- Developing a standard method for the use of dilution sampling for $PM_{2.5}$ mass measurement and characterization.

Field Tests

Field tests were conducted primarily on gas-fired combustion sources. Additional tests were conducted on a commercial dual-fuel heater and diesel engine generator. For most tests, $PM_{2.5}$ mass and precursor emission factors and $PM_{2.5}$ chemical speciation profiles for 40+ elements, major ions, and volatile and semivolatile organic compounds (VOCs and SVOCs, respectively) were determined.

Credit: England
Compact Dilution Sampler (top). Method 5 vs. Dilution Sampler (below).

Project Status

- Initiated 2000
- Completed 2004

New York Energy Smart℠
PUB

George E. Pataki, Governor

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These tests also compared the performance of the DTS method with existing methods used as a reference in the regulatory arena. They also allowed further refinement of the DTS method. A database of test results from this and other selected projects will be developed as the basis for an industry-specific tool for estimating emissions from industry sources.

PROJECT FINDINGS

Traditional Hot-Filter/Impinger Sampling Methods

- $PM_{2.5}$ emissions from gas-fired sources are extremely low, generally below the capability of traditional methods to measure with confidence.
- Liquid-phase conversion of dissolved sulfur dioxide to sulfate in impingers, which is subsequently counted as PM mass in the analysis procedure, remains a significant source of bias and variability in PM emissions measurements from gas-fired and, in some cases, other fuel sources.
- The condensable portion of primary $PM_{2.5}$ may be overestimated due to the significant presence of sulfate artifacts.

Dilution Tunnel Sampling

Dilution methods offer the potential for clarification of $PM_{2.5}$ emission factors and broad chemical and physical characterization.

- The method was successfully applied to seven field campaigns on gas- and oil-fired sources, and comprehensive inorganic and organic chemical speciation profiles were developed.
- The current size of the sampler limits applications to units with adequate platforms. For widespread use, design and operating parameters for different applications and a consensus standard method need to be developed.

General Remarks

- Different test methods provide very different results. Data accumulated using traditional methods should not be mixed with speciation profiles from dilution sampling methods.
- For source apportionment and source-receptor modeling, dilution tunnel results are most accurate.

PROJECT IMPLICATIONS

Currently, PM air-quality regulations focus on the FP fraction of total PM. A proper understanding of emission inventories and source contributions is therefore necessary to ensure that initiatives addressing impacts from FP are based on sound data. In particular, adequate characterization of source emission profiles is a key factor in developing equitable regulations that properly address public health concerns.

While traditionally, PM mass has been measured by testing emissions from industry smoke stacks, little attention has been paid to determining its chemical composition or to quantifying its UFP or aerosol-precursor components. Existing emissions inventories are inadequate for developing air-quality management plans as they may overestimate or underestimate the contribution of some energy-related sources to airborne PM based on the method used. Moreover, the FP and UFP emissions data currently available are very limited. Additional efforts are needed to develop realistic source emission profiles and mass emission rates. This information would serve as a basis for scientifically sound emission inventories and for successful strategies to reduce emissions from source types of special concern.

This project addressed these needs by generating both the methodology and emissions data necessary for the development of accurate emission inventories. On the basis of this study and other data, the EPA has announced it will revise the PM emissions from natural gas combustion in the final version of the 2002 National Emissions Inventory. The revision will decrease the emission factors for PM_{10} and $PM_{2.5}$ by about 95%. The reason for this adjustment is that EPA believes that the current AP-42 factors for condensable emissions are too high.

PROJECT UPDATE

August 2005

New York State Energy Research and Development Authority

Environmental Monitoring, Evaluation, and Protection Program

Effects of Transboundary Pollution on New York's Air Quality

Principal Researcher

S. TRIVIKRAMA RAO

NYS Department of Environmental Conservation

Study Region

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For more information on this project see:

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Keywords

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

PROJECT FOCUS

Combining data analysis and air-quality modeling techniques, this project examined spatial and temporal trends in ozone and its precursors in the region, and the impact of Ontario emission controls on transboundary pollution in New York State (NYS). Researchers also assessed the most advanced meteorological and photochemical modeling systems used to design emission control strategies for meeting the national standards. They considered the uncertainties associated with model predictions of ozone concentrations and developed methods for the use of models in evaluating control strategies with an increased degree of confidence.

This project and a related NYSERDA-funded study "Modeling and Analysis of Ozone and Fine Particulate Matter in the Northeastern United States" aimed to assist policymakers and state regulatory agencies in designing optimal control measures for reducing ambient ozone and fine particulate pollution. 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 undertaken is an important advance in 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 ozone (O_3) and fine particulate matter ($PM_{2.5}$; diameter < 2.5 microns), pollutants that have major adverse consequences for human and ecosystem health and productivity. When the new ozone standards come into effect in 2004, they will likely be exceeded in several locations throughout NYS. The attainment of ambient ozone levels that are compliant with the NAAQS may require new emissions regulations. Therefore, improvements in the identification of the sources of NYS ozone concentrations and the modeling of the transport of O_3 and its precursors would considerably benefit policymakers in formulating a control regime and New York's attainment of consistent compliance with the new standards.

Ground-level ozone is produced through a series of chemical reactions involving its precursors, nitrogen oxides (NO_x) and volatile organic compounds (VOCs). These chemicals are generally released into the lower atmosphere as a consequence of combustion processes. Major sources include fossil-fuel electric power generation, industrial processes, industrial boilers, incinerators, and motor vehicles. While ozone and its precursors may be produced locally, they are also transported regionally. The long-range transport of ozone and its precursors from sources in the Midwest and Canada is an important factor in addressing air-quality problems in NYS.

METHODOLOGY

Data Analysis

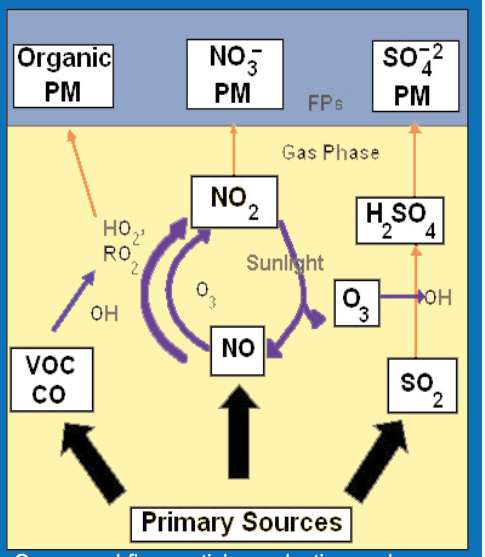
This project expanded the database used by the NYS DEC to assess the impacts of ozone transport in the region covering Ontario, Canada and NYS. Pertinent meteorological, source-emission, and air-quality data reflecting conditions in Ontario, Canada and the eastern United States were assembled in collaboration with the Ontario Ministry of the Environment. These expanded databases were subsequently analyzed in order to determine spatial and temporal trends in ozone and its precursors over the region and to examine the impact of Ontario emission controls on transboundary pollution in NYS. A Memorandum of Understanding between the NYS DEC and the Ontario Ministry of the Environment, developed as part of this project, facilitated the exchange of scientific information between NYS and Ontario.

Modeling

- Three regional air-quality models developed in the US and Canada, MODEL3/CMAQ (U.S. EPA), UAM-V (SAI), and CHRONOS (Canada) were compared in terms of their ability to predict ozone air quality. For evaluation, simulation results from these models were compared to actual observations from 1995.
- Methods were developed for using modeling results in a regulatory setting with an increased degree of confidence.
- The effects on ozone concentrations in Ontario and NYS were simulated for two scenarios in which (1) Ontario and (2) NYS anthropogenic emissions were eliminated.

PROJECT UPDATE

August 2005



Ozone and fine particle production cycle.

Project Status

- Initiated 1999
- Completed 2003

New York EnergySmart℠ PUB

George E. Pataki, Governor

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PROJECT FINDINGS

Data Analysis

- Concentrations of ozone precursors have been decreasing throughout Ontario and the New York City (NYC) metropolitan area (1983–1998). These decreases are consistent with the emissions control programs implemented in both areas. Ozone itself has been decreasing in the NYC metropolitan area, but increasing throughout Ontario.
- Higher than average ozone concentrations in the Northeast are associated with winds from the Ohio River Valley and the industrial Midwest.

Modeling

Model sensitivity analysis reveals that even with the same inputs, O_3 concentrations predicted by different modeling systems can vary by as much as 20–30%. Thus, the uncertainty in predicting the daily peak ozone concentration is on the order of 20% for the models studied.

Current-generation modeling systems perform best at predicting ozone fluctuations on timescales longer than one day. The reliability of model results in the regulatory context would benefit considerably from:

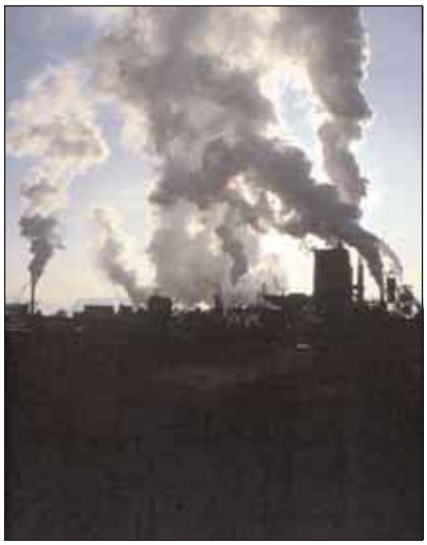
- Simulation periods longer than 2–3 episodic-type modeling days;
- Model outputs that are averaged over all simulation days, to build confidence in results; and
- Interpreting the modeling results in a probabilistic manner, in assessing the effectiveness of emission control strategies in meeting and maintaining the relevant air quality standards.

The probabilistic framework proposed in these studies, which aimed at integrating the spatial and temporal provided by observations with model predictions, was applied to ozone concentrations for demonstration purposes. It should be expanded to address multipollutant problems based on an ensemble of multiple models.

Results of Simulations Eliminating Ontario and NYS Emissions

- No Ontario emissions: Ontario peak O_3 concentrations decreased 15% or more. NYS peak O_3 concentrations decreased 6% or more throughout most of NYS.
- No NYS emissions: NYS peak O_3 concentrations decreased 3–15%. Even in southern Ontario, the ozone decreased ~6%.

Since the above percentage reductions reflect seasonal averages, they are not representative of the ozone changes on any particular day. These simulations reaffirm the results of the analysis of observational data: the O_3 and $PM_{2.5}$ problem crosses state and international boundaries. Therefore, out-of-state versus in-state contributions of reactive pollutants like O_3 and $PM_{2.5}$ cannot be distinguished from just a few monitoring sites, as the pollutant concentrations are interdependent among several states within the 600 km airshed.



Credit: US EPA

Industrial stack emissions.

PROJECT UPDATE

New York State Energy Research and Development Authority

Environmental Monitoring, Evaluation, and Protection Program

NYSERDA

Source Apportionment of Fine Particles in New York City

Principal Researcher

GEORGE D. THURSTON

School of Medicine,
New York University

Project Location

Project Status

- Initiated 1999
- Project ongoing

Contact Information

For more information on this project see:
www.nyserda.org/programs/environment/emep

or contact Ellen Burkhard at:
egb@nyserda.org

Keywords

- Aerosol
- Elemental carbon
- Particulate matter ($PM_{2.5}$)
- Source apportionment
- State Implementation Plans

PROJECT FOCUS

This project monitored 2001 levels of fine particulate matter ($PM_{2.5}$) at two locations: Hunter College in Manhattan, New York City (NYC) and New York University's satellite campus in Sterling Forest, near Tuxedo, Orange County (SF). Beginning in January 2001, researchers collected daily $PM_{2.5}$ data from the two sites in order to measure $PM_{2.5}$ mass concentrations, to distinguish the relative contributions of local and regional sources to $PM_{2.5}$ pollution in NYC, and to determine the categories of responsible sources. Information from the SF site, which is located in a rural setting approximately 35 miles to the north and west of NYC, was used as reference data to indicate regional air quality, representing $PM_{2.5}$ mass concentrations transported from upwind sources.

CONTEXT

In 1997, the U.S. Environmental Protection Agency (EPA) set a new mass-based National Ambient Air Quality Standard (NAAQS) for airborne particles smaller than 2.5 microns in diameter, called $PM_{2.5}$, including a daily maximum (65 $\mu g/m^3$) and an annual daily average (15 $\mu g/m^3$). When these standards come into effect, they will likely be exceeded in New York State (NYS). Currently, the New York State Department of Environmental Conservation (NYS DEC) is conducting a three-year monitoring program to identify areas in New York State that may not meet the mass-based $PM_{2.5}$ NAAQS.

Airborne particulate matter (PM) is a broad class of materials of different composition and sizes that are transported in the air as solid particles or liquid droplets. PM is emitted from a variety of natural processes and human activities, including fossil fuel combustion, forest fires, wind erosion, agricultural practices, industrial processes, and construction. Particles may be emitted directly into the atmosphere (primary particles) or formed in the atmosphere from precursor gases (e.g., sulfur dioxide, nitrogen oxides, ammonia, and volatile organic compounds).

Epidemiological studies have found correlations between elevated ambient concentrations of $PM_{2.5}$ and increased morbidity and mortality. $PM_{2.5}$ constituents include carbon, metals, nitrates, sulfates, and semivolatile organics. As is the case with ozone and its precursors, $PM_{2.5}$ may be transported over regional scales. The selection and application of the most appropriate control regimes and policies require identification of the important sources and types of $PM_{2.5}$ that adversely affect human health.

METHODOLOGY

Instruments monitored $PM_{2.5}$ mass, elemental and organic carbon, ozone, and carbon monoxide in real time. Filter sampling was deployed for the analysis of metals. Both continuous $PM_{2.5}$ sampling and integrated 24-hour filter $PM_{2.5}$ sampling were conducted simultaneously at each site.

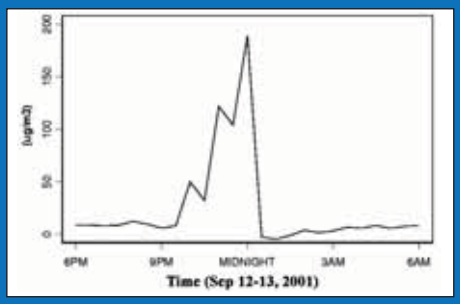
Researchers compared the daily mean $PM_{2.5}$ mass and carbon concentrations at the two sites. Plotting the NYC data against the SF data allowed an estimation of the relative amounts of $PM_{2.5}$ pollution caused by upwind sources and by local NYC sources. In addition, the difference between the two sites was compared to the NYC carbon concentrations for each day in order to test the assumption that it resulted from local NYC sources, as well as to test the hypothesis that elemental carbon can serve as a marker for the contribution of local sources.

PROJECT UPDATE

August 2005

A researcher checks the elemental and organic carbon sampler system at the Sterling Forest site in Tuxedo, New York

The World Trade Center Plume Clearly Registered at the Hunter College Site



New York Energy Smart℠
Public Service Commission — NYSERDA
George E. Pataki, Governor

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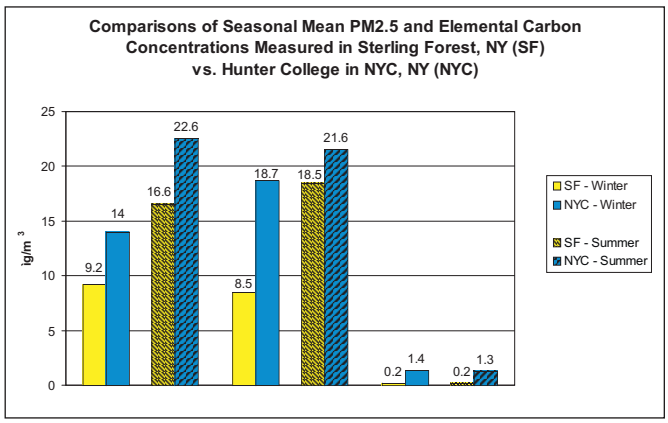
$PM_{2.5}$ sources are identified using different statistical approaches and modeling. Concentrations of various species (e.g., elements and ions) at the ambient sampling sites are analyzed in order to identify the major particle sources, to determine their appropriate source profiles, and to obtain their respective contributions to the total mass. Identification of the trajectory of the air masses, which can be determined from an analysis of meteorological information, allows for the assessment of regional influences.

RECENT FINDINGS

Preliminary data from 2001 indicate:

1. $PM_{2.5}$ concentrations were higher in summer than in winter (see graph).
2. $PM_{2.5}$ concentrations at the two sites are highly correlated: Regionally transported air pollution affects both sites similarly, while the NYC site is also affected by local transportation sources.
3. Since the elemental carbon concentrations in NYC are much higher than in SF, most of the elemental carbon in NYC is assumed to be more local in origin. The difference between the NYC and the SF $PM_{2.5}$ is proportional to the elemental carbon concentrations in NYC. This indicates that differences between the two sites result from local NYC pollution, and that the NYC elemental carbon level is a reasonable marker of the local air pollution.
4. Source apportionment work identified numerous sources, both local and non-local. Transported aerosols are estimated to be the major contributors to NYC $PM_{2.5}$ pollution. Sources identified in order of importance include the World Trade Center fires plume (see sidebar); soil; transported aerosols; dust, including that from the World Trade Center's collapse; traffic; and residual oil combustion.
5. A. *Summer*: Most (roughly 3/4) of the NYC $PM_{2.5}$ mass is accounted for by the upwind $PM_{2.5}$ mass (measured at SF), and only about 1/4 or less is local in origin.

   B. *Winter*: Most (roughly 2/3) of the NYC $PM_{2.5}$ mass is accounted for by the upwind $PM_{2.5}$ mass (measured at SF). Thus, data suggest that a majority of NYC $PM_{2.5}$ mass is transported into the City in this season, and that only ~1/3 is local.



Winter: January 1-March 31, 2001; Summer: June 1-August 31, 2001

PROJECT IMPLICATIONS

The development of state implementation plans (SIPs) to attain national ambient air quality standards will require the identification of the sources of ambient $PM_{2.5}$ pollution. These $PM_{2.5}$ mass analyses indicate that the mean NYC $PM_{2.5}$ levels through August 2001 averaged above the federal annual standard. Preliminary results from this study suggest that the majority of this pollution was transported into NYC from outside sources. A higher proportion of the total NYC $PM_{2.5}$ mass was transported into NYC from upwind sources in the summer than in the winter. The research team's future plans include further analysis of NYC samples for $PM_{2.5}$ mass, organic and chemical carbon, and trace elements. The project will continue to evaluate the relative roles of transported and local sources at the NYC site through the application of source apportionment methods and wind trajectory information to the NYC and SF $PM_{2.5}$ data.

PROJECT UPDATE

August 2005

New York State Energy Research and Development Authority

Environmental Monitoring, Evaluation, and Protection Program

NYSERDA

Impact of Power Plants on Semivolatile Pollutants and Fine Particles in New York State

Principal Researchers

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Clarkson University

THOMAS M. HOLSEN
Department of Civil and Environmental Engineering,
Clarkson University

MICHAEL S. MILLIGAN
Department of Chemistry,
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Project Location

Contact Information

For more information on this project see:
www.nyserda.org/programs/environment/emep

or contact Ellen Burkhard at:
egb@nyserda.org

Keywords

- Fine particles
- Polycyclic aromatic hydrocarbons (PAHs)
- Reactive gaseous mercury (RGM)
- Semivolatile organic compounds (SVOCs)
- Speciation

PROJECT FOCUS

This sampling and analysis program aims to measure the concentrations of different components of airborne particulate matter over several years and to develop a database of these measurements. In addition to fine particulate mass and chemical speciation, components being measured include black carbon, sulfates and nitrates, speciated polycyclic aromatic hydrocarbons (PAHs), reactive gaseous mercury (RGM), and total vapor-phase mercury (metallic mercury [Hg°] + RGM). The collected data will allow:

- Identification of seasonal concentration values and patterns of source contributions;
- Application of models to locate sources or source areas of pollutants within and outside New York State (e.g., Canada);
- Determination of the relative importance of electricity generation as a source of ambient atmospheric pollution in New York State; and
- Establishment of a baseline against which the impact of future emissions controls may be assessed.

While there has been considerable research on the contribution of New York sources to SO_2 and particulate sulfate concentrations measured in the State, this project represents the only effort to date to determine the amount of elemental mercury, RGM, and PAH compounds for which New York electric utilities could be partially responsible. Completion of the project is anticipated in February 2006.

CONTEXT

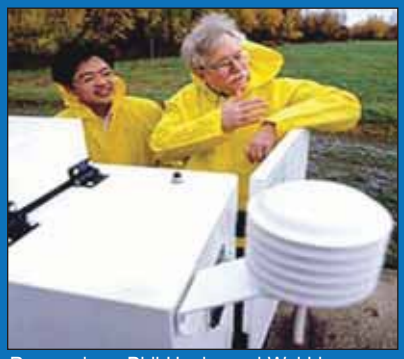
Epidemiological studies have shown a correlation between increased concentrations of fine particles and increased morbidity and mortality. These pollutants can directly and indirectly affect public health, both by inhalation and by potential uptake into the food chain, and contribute to stress on ecosystems through interaction with vegetation, deposition into lakes and streams, and accumulation in the soil.

In 1997 the U.S. Environmental Protection Agency (US EPA) set new ambient air quality standards for particulate matter of less than 2.5 microns ($PM_{2.5}$) in diameter. There are several multi-pollutant bills pending in Congress, as well as the Clear Skies Initiative, that would reduce sulfur dioxide, nitrogen oxide, and mercury emissions from the electricity generation sector. Such changes will likely affect the operations and operating costs of power plants and other combustion sources of $PM_{2.5}$.

It is important to acquire a set of baseline data for these pollutants in New York State, so that the effectiveness of future regulatory actions can be assessed. In addition, as is the case with ozone and its precursors, fine particles are transported regionally. Prevailing southwesterly winds can carry material emitted in the Midwest into the air shed of New York State. As this project aims to locate out-of-state sources of New York fine particles and mercury air pollution, the findings may be useful in future efforts to hold these sources accountable.

PROJECT UPDATE

August 2005



Researchers Phil Hopke and Wei Liu examining particle sampler.

Project Status

- Initiated 1999
- Project ongoing

New York Energy Smart℠

PUB

George E. Pataki, Governor

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, and 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.

RECENT FINDINGS

- The greatest contributors to $PM_{2.5}$ mass in Stockton and Potsdam are sulfate, nitrate, ammonium, and black carbon, as expected from previous results.
- The probable source area for much of the sulfur measured at Stockton is the Midwest, including the Ohio River Valley and the southern border of the Great Lakes area.
- Likely sources of vapor-phase mercury at Potsdam include areas both in Canada (western Quebec and eastern Ontario) and in the eastern United States. At Stockton, US sources predominate.
- No clear relationship was found between ozone and RGM concentrations, although previous work has found significant correlation.
- Concentrations of $PM_{2.5}$ mass are higher during summer months.
- Nitrate levels increase and sulfate concentration levels decrease in the winter.
- There is no positive correlation found between RGM and total vapor phase mercury, possibly owing to different sources of emission or different removal mechanisms.

Clarkson University researchers taking air samples.

PROJECT UPDATE

New York State Energy Research and Development Authority

Environmental Monitoring, Evaluation, and Protection Program

NYSERDA

Developments in Continuous Fine Particle Mass Monitoring

Principal Researcher

JEFFREY AMBS

Thermo Electron Corporation

Credit: Rupprecht and Patashnick

After the events of 11 September 2001, R&P TEOM monitors were used to monitor air quality at the World Trade Center site, gauging the effects of the events and the clean-up of the area on ambient air. The enclosures house standard TEOM monitors which are set up to measure $PM_{2.5}$.

Contact Information

For more information on this project see:

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

or contact Barry Liebowitz at: bnl@nyserda.org

Keywords

- Federal Reference Method (FRM)
- Particulate mass monitoring
- $PM_{2.5}$
- Semivolatile organics
- TEOM method

PROJECT FOCUS

This project developed two products designed to improve the semi-continuous monitoring of fine particulate matter ($PM_{2.5}$) mass in ambient air. Both are based on an existing method for measuring particulate mass: Thermo's (formerly Rupprecht & Patashnick) standard Series 1400a Tapered Element Oscillating Microbalance (TEOM®) monitor. The goals of this study were:

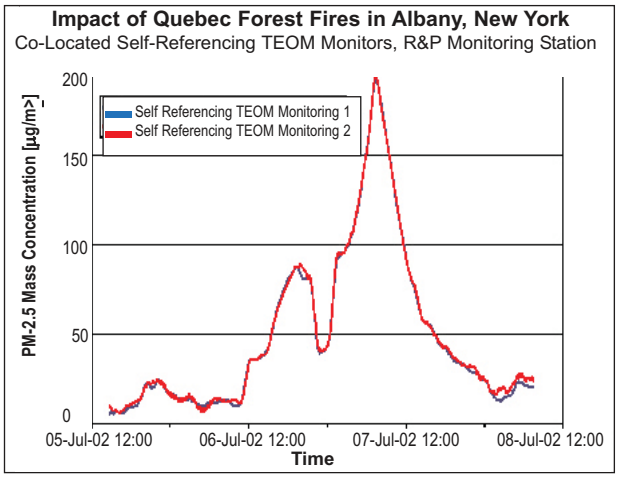
- To increase the consistency of measurements made using the TEOM to those made using the Federal Reference Method (FRM), which provides a 24-hour filter-based mass measurement. Studies have shown that when there is a significant semivolatile organic component, the TEOM monitor can underreport the particulate mass compared to the FRM. To address this problem, the "sample equilibration system" (SES) was designed, which allows the TEOM to operate at a reduced temperature of 30°C. At this lower temperature, the system retains more of the semivolatile components.
- To develop a monitoring system that better represents the mass of fine particles in ambient air than measurements made using FRM techniques. The Differential TEOM concept was developed to account for effects taking place on the filter (e.g., gas adsorption, desorption, or chemical reactions), thus providing greater certainty about particulate mass in ambient air.

CONTEXT

Combustion processes play a major role in the production of fine particulate matter ≤2.5 microns in diameter ($PM_{2.5}$). Important sources are fossil-fuel electricity-power generation, industrial processes, industrial boilers, incinerators, and car and truck engines. Constituents of the $PM_{2.5}$ "soup" include carbon, metals, nitrates, sulfates, and semivolatile organics. These particles can be emitted directly into the atmosphere (primary particles) or formed in the atmosphere from precursor gases (secondary particles).

In July 1997, the National Ambient Air Quality Standards (NAAQS) were revised to include annual and 24-hour standards for $PM_{2.5}$ mass in ambient air. Bringing New York ambient $PM_{2.5}$ mass to levels that are compliant with the NAAQS will likely require new emissions regulations. The NAAQS are based on $PM_{2.5}$ measurements made with an FRM sampler. In this procedure, a filter at a defined temperature and humidity is weighed. Then, a sample is collected on the filter for 24 hours at ambient temperature and humidity. The filter is then reweighed under the original laboratory conditions. The difference in weight is used to derive the 24-hour average ambient $PM_{2.5}$ mass concentration. This method has several drawbacks, however, and ultimately provides an indication of the average $PM_{2.5}$ mass, rather than a precise representation of air as it is breathed under ambient conditions. The standard TEOM monitor is a significant advance in measuring ambient PM mass, allowing ambient PM mass concentrations to be monitored in near real time for extended periods, without the burden and costs of operator intervention.

Credit: Image provided by Orbital Imaging Corporation



Credit: Rupprecht and Patashnick

During July 2002, numerous forest fires were raging in Quebec Province, Canada. Weather patterns caused the smoke generated by the fires to blanket eastern New York and New England. Pollution monitors such as the R&P TEOM mass monitor are able to track the effects of such events in real time.

PROJECT UPDATE

August 2005

Credit: Rupprecht and Patashnick

A R&P 1400 TEOM monitor, set up for PM_{10} sampling, installed on a busy street in Hong Kong to monitor PM levels.

Project Status

- Initiated 1999
- Completed 2003

New York Energy Smart℠ PUB

George E. Pataki, Governor

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PROJECT FINDINGS

SES-TEOM Tests: SES-TEOM 24-hour average mass concentrations were more closely correlated with the FRM results than with the standard TEOM monitor results.

- *Humidity*: Under low humidity, the SES-TEOM monitor and the standard TEOM monitor measurements were consistent. With changes in the humidity level in the sample chamber, the standard TEOM monitor showed an effect, while the SES-TEOM monitor was unaffected.
- *Temperature*: During warm weather, TEOM sample temperatures were much closer to ambient temperatures (the collection temperature of the FRM). In these conditions, SES-TEOM and standard TEOM results were both closely correlated with the FRM. In cold weather, the difference in sample temperatures was greater for the standard TEOM, and SES-TEOM results were better correlated with the FRM than those of the standard TEOM.

Differential TEOM Tests: Tests have proven that the Differential TEOM monitor resolves issues related to adsorption and evaporation in the collected sample.

- *Nonvolatile aerosols*: Under conditions with very little semivolatile material in the atmosphere, the different methods reported similar results, as expected. For example, when sampling a nonvolatile aerosol (sodium chloride), the Differential TEOM monitor and the SES-TEOM monitor collected similar amounts and reported similar mass concentrations.
- *Semivolatile aerosols*: With ammonium nitrate aerosol, the SES-TEOM monitor reported lower mass concentrations of ammonium nitrate than did the Differential TEOM, as expected. With the ESP turned off, the Differential TEOM reported a mass concentration similar to that of the SES-TEOM. However, with the ESP on, the Differential TEOM showed that ammonium nitrate was evaporating from the filter. The mass concentration measured during the "ESP-on" periods indicated the evaporation rate of the ammonium nitrate. The data were corrected accordingly, yielding a final overall mass concentration that was significantly greater than that reported by the SES-TEOM.

Filter Dynamics Measurement System (FDMS). As a follow up to the Differential TEOM project, a simpler filter-based system of the monitor, the Filter Dynamics Measurement System (FDMS) was developed. The Series 8500 FDMS is designed for agencies that need a monitor as part of a routine monitoring network. The FDMS provides results similar to the ESP-equipped Differential TEOM, but with the same ease of use as the standard TEOM monitor. Since its release, the FDMS has been widely accepted by the industry and received approval from the Air Resources Board of California for both PM_{10} and $PM_{2.5}$ sampling.

PROJECT UPDATE

New York State Energy Research and Development Authority

Environmental Monitoring, Evaluation, and Protection Program

NYSERDA

Enhanced Measurements of Oxidants, Fine Particles and Precursors

Principal Researcher

KENNETH L. DEMERJIAN

Atmospheric Sciences Research Center, State University of New York at Albany

Project Location

Contact Information

For more information on this project see:
www.asrc.cestm.albany.edu/pmtacsny/index.html
and
www.nyserda.org/programs/environment/emep.asp

or contact Barry Liebowitz at:
bnl@nyserda.org

Keywords

- Compressed Natural Gas (CNG)
- Continuous Regenerating Technology (CRT)
- Diurnal patterns
- $PM_{2.5}$/co-Pollutant complex
- Speciation
- U.S. EPA PMTACS-NY Supersite

PROJECT FOCUS

This NYSERDA project, begun in 1999, subsequently leveraged New York State funds with US EPA funds in 2000 to establish a "$PM_{2.5}$ Supersite" program in NYS. The NYS program is one of eight nationally, providing measurement data on the chemical and physical properties of fine particles smaller than 2.5 microns in diameter ($PM_{2.5}$) and associated precursors. These data will support the development of process science, observation-based analysis tools in atmospheric chemistry and source-receptor modeling, and health-related exposure assessments.

The objectives of the Joint Enhanced Ozone-$PM_{2.5}$ Technology Assessment and Characterization Study in New York (PMTACS-NY) are to:

- Measure the temporal and spatial distribution of $PM_{2.5}$ and its copollutants at five monitoring sites. These measurements will provide data needed to characterize the chemical composition of $PM_{2.5}$ within New York City and the regional background of upstate New York, which is affected by transported pollutants.
- Monitor the effectiveness of new emission-control technologies introduced for mobile sources in New York City, such as Compressed Natural Gas (CNG) buses, Continuously Regenerating Technology (CRT), and hybrid electric buses and their impact on ambient air quality.
- Test and evaluate new measurement technologies and provide technology transfer of robust technologies for use in the monitoring network. This will include mobile and fixed-site measurements of CO, NO_2, NO, SO_2, H_2CO, CH_4, HONO, CN, and aerosol chemical composition.

CONTEXT

In July 1997, the US Environmental Protection Agency (US EPA) set forth a new National Ambient Air Quality Standard (NAAQS) for ozone and particulate matter (PM). Airborne PM is a broad class of materials of different composition and sizes that are transported in the air as solid particles or liquid droplets (aerosols). Particles can be emitted directly into the atmosphere (primary particles) or formed in the atmosphere from precursor gases (secondary particles). Combustion processes are an important source of both ozone and $PM_{2.5}$ pollution. In addition, the production of ozone and $PM_{2.5}$ in the atmosphere is linked in complex ways. Both are associated with adverse health effects.

METHODOLOGY

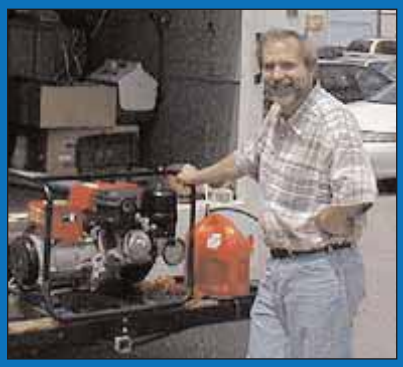
This project conducts high-resolution measurements of oxidants, $PM_{2.5}$, and their precursors at three urban New York City (NYC) sites and two representative regional sites: Whiteface Mountain (WFM) in Wilmington, Essex County, and Pinnacle State Park (PSP) in Addison, Steuben County. In addition to collecting standard measurements of criteria pollutants and the mandated $PM_{2.5}$ mass and chemical speciation measurements, the research team also operates advanced instruments for improved chemical and temporal specification of the air quality. Factors affecting ozone and $PM_{2.5}$ on both regional and local scales are being analyzed.

The project's real-time "vehicle-chase" studies use a mobile platform equipped with instruments in order to characterize on-road emissions of Metropolitan Transit Authority (MTA) buses (standard diesel, CRT-equipped, CNG, and diesel hybrid technologies) and diesel trucks operating in New York City (see photograph). Analysis of the measurements includes correlating the exhaust emissions with speed, fuel grade, and ambient temperature.

New measurement technologies are tested at the Aerosol Generation and Calibration Facility, developed as part of the Supersite program at the Atmospheric Sciences Research Center, as well as at rural and urban monitoring sites. Field and laboratory tests have provided NYSDEC with advanced knowledge on performance and operational issues associated with these technologies.

PROJECT UPDATE

November 2003



A researcher prepares for a vehicle chase using the Aerodyne Mobile Laboratory, which collects exhaust emission samples from moving buses and trucks.

Project Status

- Initiated 1999
- Project ongoing

New York Energy Smart SM
PUB I

George E. Pataki, Governor

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, and 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.

RECENT FINDINGS

URBAN vs. RURAL $PM_{2.5}$: A study conducted at Queens College (NYC) and WFM (summers 2001 and 2002, respectively) characterized chemical and physical properties of the $PM_{2.5}$/co-pollutant complex and local photochemical production processes of $PM_{2.5}$ sulfate, nitrate, and organic carbon. The findings indicate that diurnal patterns in ambient air concentrations are:

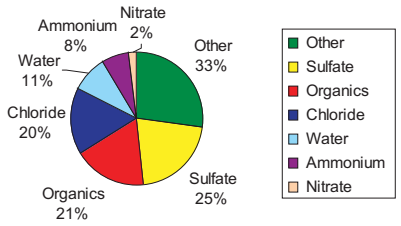
- Mainly determined by primary source emissions in urban environments, where secondary production processes play a much less significant role.
- More noticeable with proximity to the source and owing to prevailing winds.
- Significantly less well defined in rural environments, where, to the extent that they are observed, they may be identified with local secondary production processes.

Findings also suggest that primary and secondary pollutant levels can vary significantly within 24-hour periods. Concentrations of long-lived species are predominantly affected by transport/meteorological conditions; concentrations of short-lived species are affected by emissions and chemical transformations.

ORGANIC PM (NYC): Studies using the Aerosol Mass Spectrometer (AMS) measurement technology indicate that a significant fraction of the observed organic PM mass comes from mobile sources. Observed organic particles with a diameter of ~70 nm are associated with condensed lube oil formed in the combustion exhaust not only of diesel sources, but also of poorly maintained, oil-burning, spark-ignition gasoline engines.

SULFATES (NYC): The observed levels and diurnal patterns of SO_2 concentrations in NYC suggest that fossil-fuel combustion from mobile and stationary sources contributes significantly to NYC sulfate levels. The local production of summertime sulfate from the reaction of SO_2 and OH can represent a significant fraction of the total observed sulfate concentration during high photochemical PM production periods.

VEHICLE EMISSIONS ON THE ROAD (NYC): Direct measurement of in-use vehicle emissions has provided an extensive database characterizing gaseous and PM emissions from a variety of standard diesel-powered trucks and buses as well as from CNG-fueled and retrofitted diesel-fueled CRT buses (DF-CRT). Real-world measurements show significantly more variation in emissions than observed in laboratory testing. These measurements indicate that both CNG and DF-CRT significantly reduce vehicle PM emissions in comparison with standard diesel buses (60–70% reduction). However, DF-CRT bus NO_2 emissions were 30% of total NO_x, compared to less than 5% of total NO_x in standard diesel buses. In another series of measurements, exhaust plumes of CNG buses showed ~5–10 times more formaldehyde than observed in standard diesel bus and truck plumes.



PROJECT IMPLICATIONS

Project findings suggest that the implementation of the federally mandated low-sulfur rules, which address on-road mobile sources, and the proposed inclusion of off-road mobile sources (e.g., construction, marine and farm equipment), would have significant benefits for PM mitigation. The NYS Acid Deposition Reduction Initiative, which could result in the decreased use of high-sulfur residual fuel in utilities in NYC and the region, may prove an additional effective measure. Results also indicate that tracking and reducing sulfur levels in distillate fuel burned for stationary applications, which is not currently being addressed by the proposed federal rules, could have significant benefits.

On-road tests show encouraging reductions in the PM emissions of CNG-fueled and retrofitted diesel-CRT vehicles. The higher formaldehyde emissions suggest that either combustion modification or possibly the addition of oxidative catalysis will likely be required if CNG-fueled vehicles are to become a significant portion of the mobile fleet.

The accumulated data and findings of this joint project will provide the scientific basis for the assessment of ambient ozone and $PM_{2.5}$ standards in NYS. They also allow us to determine the impact of recent and future emissions reductions in terms of emission-control effectiveness and air-quality response. Understanding the relative importance of local and regional sources will enable better evaluation of the effectiveness of different mitigation strategies for achieving air-quality standards.

PROJECT UPDATE

August 2005

New York State Energy Research and Development Authority

Environmental Monitoring, Evaluation, and Protection Program

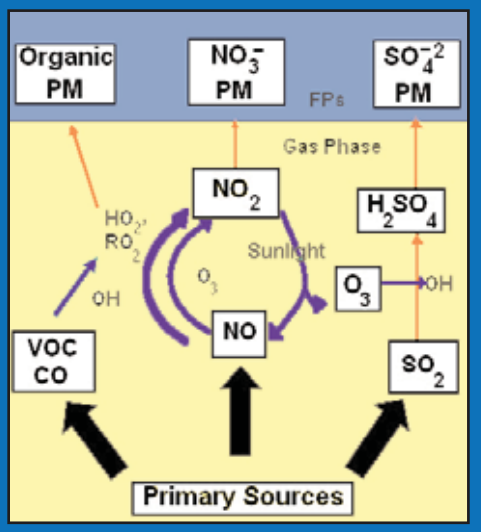
NYSERDA

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.

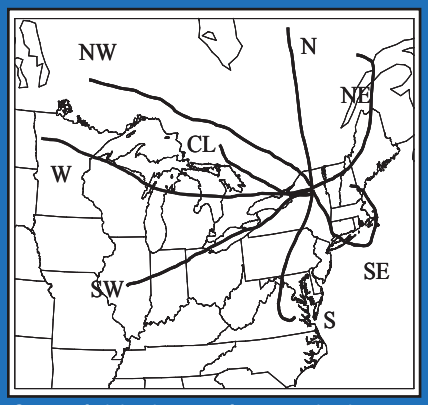
METHODOLOGY

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℠
Public Service Commission — NYSERDA
George E. Pataki, Governor

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PROJECT FINDINGS

Spatial and Temporal Features of Data

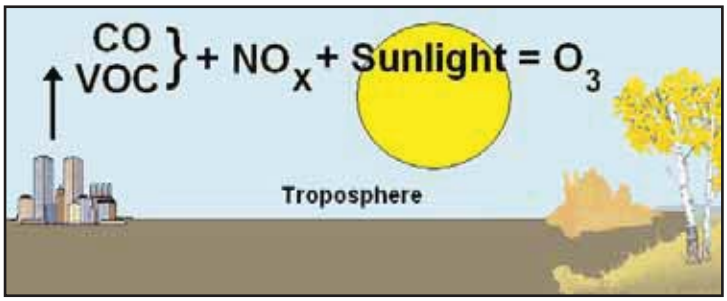
- Changes in data reporting practices can cause erroneous trend estimates to be derived from observational databases.
- Spatial and temporal features in pollutant data are sensitive to differences in the sampling procedures between the monitoring networks.
- Trace-element pollution is a regional-scale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

PROJECT UPDATE

August 2005

New York State Energy Research
and Development Authority

Environmental Monitoring, Evaluation,
and Protection Program

Clinical Studies of Exposure to Ultrafine Particles

Principal Researcher

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Project Location

Contact Information

For more information on this project see:
www.nyserda.org/programs/environment/emep

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Keywords

- Airway inflammation
- Cardiac repolarization
- Leukocyte
- National Ambient Air Quality Standard (NAAQS)
- Ultrafine particle (UFP)

PROJECT FOCUS

Ambient ultrafine particles (UFPs) are important with regard to respiratory health for several reasons. They are biologically more reactive than larger particles and elicit effects at low mass concentrations. At the same ambient mass concentration, UFPs have a much higher concentration in terms of the number of particles and surface area than fine particles (see table). They also show a high deposition efficiency in the pulmonary region, since the probability of deposition by diffusion increases as particle size decreases. UFPs exhibit a higher propensity to rapidly reach the systemic circulation; they may therefore be linked to the cardiovascular effects attributed to the fine particle fraction.

The project initiated clinical studies of exposure to UFPs in healthy human subjects. The research team's hypothesis was that the increases in morbidity and mortality that are associated with ambient air pollution are related to the exacerbation of airway inflammation in susceptible individuals. In addition, they proposed that UFP exposure through ambient air alters pulmonary and vascular function, activation of circulating white blood cells (leukocytes), and the recovery of the heart from a beat (cardiac repolarization).

CONTEXT

In 1997, the U.S. Environmental Protection Agency (EPA) set a new mass-based National Ambient Air Quality Standard (NAAQS) for airborne particles smaller than 2.5 microns in diameter, called $PM_{2.5}$. Currently, the New York State Department of Environmental Conservation (NYS DEC) is conducting a three-year monitoring program to identify areas in New York State that may not meet the mass-based $PM_{2.5}$ NAAQS.

Airborne particulate matter (PM) is a broad class of materials of varying composition and sizes that are transported in the air as solid particles or liquid droplets. Airborne particles are emitted from a variety of natural processes and human activities, including fossil-fuel combustion, forest fires, wind erosion, agricultural practices, industrial manufacturing, and construction processes. The particles can be emitted directly into the atmosphere (primary particles) or formed in the atmosphere from precursor gases (e.g., sulfur dioxide, nitrogen oxides, ammonia, and volatile organic compounds). Ultrafine particles (UFPs) are extremely small particles, less than 0.1 micron in diameter. These particles are primarily generated from combustion processes, including stationary fossil-fueled electric-power generation, industrial processes, boilers, and car and truck engines.

While a variety of studies have shown a correlation between elevated concentrations of ambient particulate matter and adverse health effects, the exact mechanisms and chemical components responsible for the biological activity are not fully understood. Consequently, as EPA and the states proceed with the early phases of implementation of the mass-based PM NAAQS, numerous parallel research projects are underway to clarify which components in the PM mixture are responsible for the adverse health effects. Several hypotheses have been proposed, and various components and characteristics of PM have been targeted for exploration, including the UFP component of PM. This project explores the hypothesis that UFPs are a key culprit responsible for adverse health effects associated with fine particles. The results could have a significant impact on national regulatory control strategies and future ambient air quality standards.

Numbers and Surface Area of Particles Unit Density of Different Sizes at a Mass Concentration of 10μg/m³

Particle Diameter μm	Particle Number 1/cm³	Particle Surface Area μm²/cm³
0.02	2,400,000	3016
0.1	19,100	600
0.5	153	120
1.0	19	60
2.5	1.2	24

The ultrafine particle exposure system incorporated a bicycle to examine the effects of UFP exposure during exercise.

Project Status

- Initiated 1999
- Project ongoing

New York Energy Smart SM
PUB

George E. Pataki, Governor

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RECENT FINDINGS

The studies show that UFP inhalation by healthy subjects has a number of cardiovascular, rather than pulmonary, effects to which women may be more susceptible. These may be persistent or delayed, lasting for at least 21 hours after exposure. The project found:

- A statistically significant decrease in blood oxygen saturation in females after exposure to 25 $\mu g/m^3$ UFPs.
- No significant physiological changes in response to breathing 10 $\mu g/m^3$ UFPs at rest. Also, no evidence for airway inflammation or irritant effects or an early immune system response at 10 µg/m3 or 25 $\mu g/m^3$ with intermittent exercise.
- Signs of alterations in cardiac repolarization (QT interval). The change observed during exercise was more pronounced with UFP exposure than with pure air, and remained in effect for several hours after UFP exposure, but not after pure air exposure. While the changes are small, they could affect heart function in people with severe cardiac disease.
- A high pulmonary deposition rate that increased with exercise. As expected, the smallest particles had the highest deposition rate. No gender difference was found in terms of deposition.
- A number of effects on circulating leukocytes, such as a reduction in the percentage of blood monocytes in females that was greatest 21 hours after exposure.
- Effects consistent with changes in blood vessel walls and how leukocytes move through the blood vessels.

PROJECT IMPLICATIONS

While the particles generated for these studies from elemental carbon are relatively inert compared to UFPs in ambient air, this research suggests that exposure to even these relatively benign particles at very low mass concentrations during exercise has subclinical effects on blood flow to the lungs, circulating leukocytes, and cardiac repolarization in healthy subjects (particularly females). If these findings are confirmed, they will provide convincing support for current hypotheses about the health threats posed by UFPs. The project team is presently conducting a new study that aims both to confirm previous findings and to assess the effects of 50 $\mu g/m^3$ UFP exposures with intermittent exercise.

The adverse health effects of UFPs raise the question of whether mass-based NAAQS are adequately protective of human health. While current $PM_{2.5}$ standards address mass concentrations of particulate matter in ambient air, a small mass concentration of particulate matter can mean very high number concentrations of UFPs. The results of further assessments of the cardiovascular and pulmonary effects of UFPs may necessitate reconsideration of the regulatory regime for $PM_{2.5}$.

PROJECT UPDATE

December 2004

New York State Energy Research
and Development Authority

Environmental Monitoring, Evaluation,
and Protection Program

Chemical Composition of Fine Organic Particles from Urban and Regional Background Locations in New York State

PROJECT FOCUS

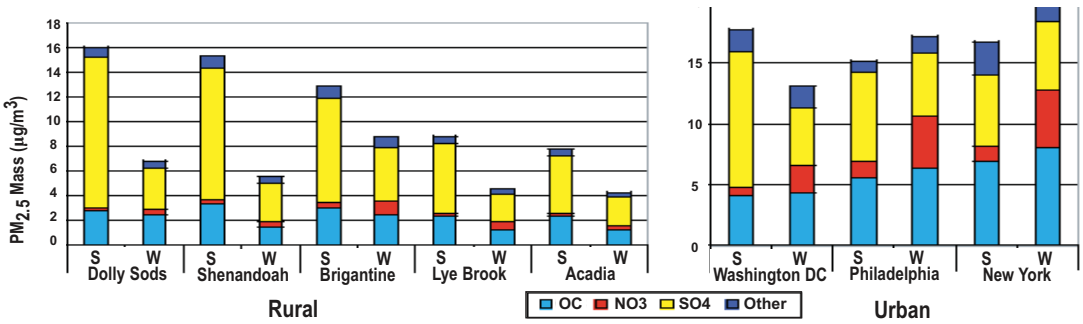
The primary objective of this research is to improve the current understanding of organic compounds associated with fine particles in New York State. This work builds upon a current air monitoring and source apportionment project supported by the Northeast States for Coordinated Air Use Management (NESCAUM) that measures fine particulate matter ($PM_{2.5}$) in the New York City area. Additional chemical measurements of the molecular markers and acidic organic compounds in $PM_{2.5}$ aim to improve estimates of fine carbon particle source contributions in the New York City (NYC) metropolitan airshed over an annual cycle.

CONTEXT

In July 1997, motivated by concerns about the adverse health effects of particulate pollution, the U.S. Environmental Protection Agency proposed a new National Ambient Air Quality Standard (NAAQS) for particulate matter of less than 2.5 microns in diameter ($PM_{2.5}$), including daily maximum (65 micrograms per cubic meter [$\mu g/m^3$]) and annual maximum (15 $\mu g/m^3$) average concentrations. There are about 65 million people in the United States who live in areas with annual average $PM_{2.5}$ levels in excess of 15 $\mu g/m^3$. Recent epidemiological and toxicological studies suggest that particulate matter (PM) health effects can vary by source category.

Airborne PM is a broad class of materials that are transported in the air as solid particles or liquid droplets. These particles are emitted from a variety of natural processes and human activities. The particles can be emitted directly into the atmosphere from primary sources such as motor-vehicle exhaust, home fireplaces and heating appliances, manufacturing plants, commercial and domestic food preparation, tar application, forest fires, wind erosion, and natural and cultivated vegetation. Secondary particles are formed in the atmosphere through photochemical reaction and oxidation processes involving ozone and other gas-phase oxidants. Each of the various emission source types has characteristic chemical and/or physical patterns and signatures. Organic molecular markers are individual compounds or groups of related compounds (homologous compounds such as n-alkanes, n-alkanoic acids, hopanes and steranes), which at a molecular level comprise the chemical profile or "fingerprint" for specific emission source types. An individual molecular marker or groups of marker compounds is linked quantitatively to major emission sources of urban fine particles also with known chemical emission profiles. The molecular-level technology used in the current study matches chemical fingerprints of the PM samples collected to emission sources.

The presence of functional groups containing oxygen or nitrogen atoms on some molecular markers (e.g., carboxylic acids) can increase their solubility in aqueous media (e.g., in atmospheric water vapor, fog, and rain) causing "regional haze." These groups can also impart an acidic or basic character to fine particles, govern their fate and transport in the atmosphere, and influence their uptake by biological systems, including their absorption within the human respiratory tract. Thus, in addition to linking PM composition to emission sources, the presence of polar marker compounds provide additional information on physical and chemical processes influencing the fate and transport of atmospheric carbonaceous particles.



Credit: U.S. EPA IMPROVE, CASTNet and AIRS air quality monitoring programs, NARSTO Assessment, 2003.

PROJECT UPDATE

December 2004

Credit: M. Mazurek
Installation of a clean quartz fiber filter for fine particle collection using a Tisch 2-channel collector.

Project Status

- Initiated 2003
- Project ongoing

New York Energy Smart SM
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George E. Pataki, Governor

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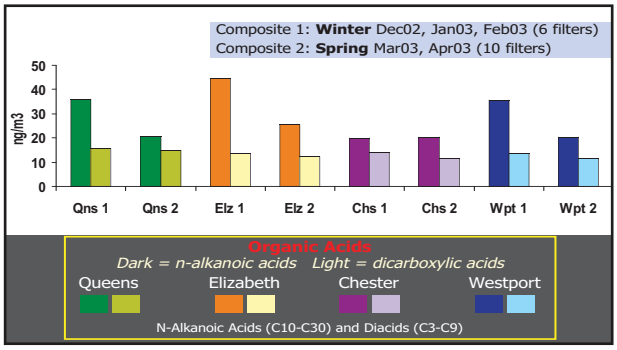
PRELIMINARY FINDINGS

The adjacent figure presents preliminary seasonal and spatial findings from analyses of samples collected at the four NYC area sites. The ambient mass concentrations of n-alkanoic acids (biogenic sources; dark bar) and diacids (photochemical conversions, combustion; light bar) for most sites show higher ambient mass levels in the early winter compared to the spring. This finding is consistent with the general trends seen for OC mass concentrations in $PM_{2.5}$ measured in urban northeastern airsheds, where winter ambient mass concentrations can exceed summer OC concentrations.



For the winter and early spring, urban emission marker (such as hopane, which is characteristic for motor vehicle exhaust) concentrations were greatest for the urban sites (Elizabeth, NJ and Queens, NYC), followed by Westport, CT (suburban) and lowest or not detected at Chester, NJ - the rural sampling location. Biogenic markers (originating from natural sources, such as microbiota, vegetation, and seed oil or plant waxes) were present at all sites where seasonal composites were compared. Ambient mass concentrations at the Elizabeth, Queens, and Chester sites were roughly the same for biogenic markers. Molecular indicators for secondary photochemical compounds measured at all locations were at roughly the same levels for daily composites.

Higher plants contribute organic acids from the waxy coatings of leaves; the level maximizes in the late summer and fall when leaf aging occurs, then falls off during the winter. Commercial and residential cooking operations, especially frying, consume seed oils, which may become airborne and form fine particles. This fine carbon particle emission source in the metropolitan NYC area is currently unregulated and its strength is unknown.

Further work in progress will determine the updated chemical profile of vehicular exhaust markers emitted from the current vehicle fleet in the NYC area. Mass ratios of these markers to OC and EC masses will allow an estimate of the contribution of vehicular traffic OC mass to the fine particle concentrations.

Note: Although this work was reviewed by EPA and approved for publication, it may not necessarily reflect official Agency policy.

PROJECT IMPLICATIONS

This project is expected to identify monthly and seasonal concentrations of organic $PM_{2.5}$, offering more detailed chemical information that will be useful for air quality and related health-effects research on the components in PM. Updated chemical profiles for today's vehicle fleets will assist in establishing a baseline with which future vehicle emission systems can be compared in terms of their impacts on air quality, as well as for choosing the best regulatory or technological controls.

In addition, the project's detailed molecular marker work on secondary acidic compounds in the $PM_{2.5}$ organic acid mass will contribute to the development of methods and the characterization of sources of primary and secondary PM emissions affecting NYS. These improved methods, needed to identify important sources both in the state and in the region, should prove invaluable in the process of developing a State Implementation Plan (SIP) for attaining federal standards.

PROJECT UPDATE

December 2005

New York State Energy Research and Development Authority

Environmental Monitoring, Evaluation, and Protection Program

ASSESSMENT OF NITROGEN AND ACIDIC DEPOSITION IMPACTS TO TERRESTRIAL AND AQUATIC ECOSYSTEMS OF TUG HILL

Principal Researchers

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MICHELLE PEACH
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Project Location

Tug Hill Region

Contact Information

For more information on this project see:

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

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Keywords

- Acidic deposition
- Foliar chemistry
- Forest canopy
- Soil chemistry
- Surface water quality

PROJECT FOCUS

This project will assess the extent to which aquatic and terrestrial ecosystems in the Tug Hill region of New York are affected by excess nitrogen (N) and acidic deposition. The two-year study will provide much-needed baseline data for a region of New York State (NYS) that is susceptible to the effects of acidic deposition but where little is known about the extent and magnitude of these effects. The present study includes:

- Synoptic surveys of surface water quality at 40 sites across the Tug Hill region;
- Testing of soil chemistry, forest vegetation composition, and plant tissue chemistry at locations adjacent to the surface water samples; and
- Synthesis of data for site-level assessments of the effects of acidification on soils, including base cation nutrient depletion and potential for N saturation.

CONTEXT

Fossil-fuel combustion sources are major emitters of sulfur dioxide (SO_2) and nitrogen oxides (NO_x). These pollutants undergo complex reactions in the atmosphere to form nitric and sulfuric acids, which, through atmospheric deposition in forests and bodies of water, affect ecosystems in complex ways and contribute to the acidification of soils, lakes, and streams. Over the past 20 years, federal policies such as the Clean Air Act Amendments of 1990 (CAAAs) have resulted in decreased atmospheric emissions and deposition of sulfur in NYS. In the same period, atmospheric emissions of nitrogen, which were not capped by the CAAAs, have not changed significantly.

Tug Hill, the third largest intact, forested region in New York, is subject to especially high levels of nitrogen and acidic deposition for the eastern United States. Given the significance of the region for plant and wildlife habitats, forest products, fisheries, and drinking water, it is critical to understand the extent to which the region's aquatic and terrestrial ecosystems are affected by excess nitrogen and acidic deposition. In comparison with other regions of New York, such as the Adirondacks, Catskills, and the Allegheny Plateau, Tug Hill has the highest long-term (1980-2002) average annual deposition rates for ammonium (NH^{4+}), nitrate (NO^{3-}), total inorganic N, sulfate (SO_4^{2-}), and hydrogen (i.e., H^+, affecting pH). For example, Tug Hill is subject to inputs of N and H^+ that are, respectively, 1.9 and 1.5 times greater than in the central Adirondacks. In addition, because the Tug Hill forests are similar to those of the Adirondacks and northern New England, and much of the region has strongly acidic soils, it is likely that Tug Hill is affected by N saturation and acidification. Despite these considerations, there has been no regional assessment of the effects of atmospheric deposition on Tug Hill's forests and streams.

Credit: Greg McGee

Greg McGee and Laura Hartley (field assistant) mapping out a study site.

Credit: Greg McGee
Pat Crast canoeing on Tug Hill.

Project Status

- Initiated January 2005
- Project ongoing

New York Energy Smart℠
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George E. Pataki, Governor

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PROJECT IMPLICATIONS

The Tug Hill region contains approximately 6,400 km of streams that contain world-class fisheries and serve as the source of drinking water for several municipalities. The region's forests support an $80 million wood products and paper manufacturing industry that is comprised of 70 wood-using businesses on or near Tug Hill. This economically important region of New York has not been subject to adequate monitoring efforts, despite its susceptibility to the impacts of acidic deposition. This project's analysis of current conditions in the region will seek to fill this information gap, significantly expanding our knowledge of the effects of atmospheric deposition on aquatic ecosystems and forests in the Northeast. The data accumulated will benefit the development of sound policies for the management and protection of New York's forest resources.

PROJECT UPDATE

December 2005

New York State Energy Research and Development Authority

Environmental Monitoring, Evaluation, and Protection Program

ASSESMENT OF FOREST HEALTH AND STREAM AND SOIL CHEMISTRY IN THE CATSKILL MOUNTAINS, NEW YORK

Principal Researchers

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U.S. Geological Survey

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U.S. Forest Service

Project Location

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Keywords

- Acidic deposition
- Forest health
- Geographic Information Systems (GIS)
- Soil calcium
- Surface water chemistry

PROJECT FOCUS

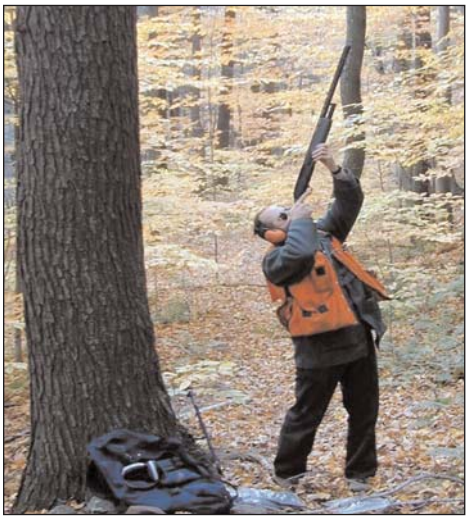
This project, a joint effort of the U.S. Geological Survey (USGS) and U.S. Forest Service (USFS), will combine field and remote-sensing data in order to produce the most detailed maps available of forest, soil, and surface-water conditions in the Catskill Mountain region of New York State (NYS). The database of geographical information compiled will highlight the forest stands and watersheds in the region that are sensitive to changes in atmospheric deposition and land use.

CONTEXT

Fossil-fuel combustion sources are major emitters of sulfur dioxide (SO_2) and nitrogen oxides (NO_X). Undergoing complex reactions in the atmosphere to form nitric and sulfuric acids, these pollutants affect ecosystems in complex ways and, through atmospheric deposition in forests and bodies of water, contribute to the acidification of soils, lakes, and streams. A major adverse effect of acid rain on forest health and productivity is a reduction in the available supply of calcium (Ca) and other base cations (positively charged ions) in soil that are needed for forest growth. The Catskill Mountain region of NYS has among the highest rates of sulfur and nitrogen deposition in the state and the lowest values for soil calcium availability. Significantly, the forested watersheds of this region provide the New York City water supply.

Credit: Rich Hallett

Forest health and stream water quality depend on the integrity of biogeochemical cycles within forest ecosystems. It has been clearly established that both atmospheric deposition and forest management can alter the biogeochemistry of forest ecosystems, inducing significant changes in forest production, species composition, and stream water quality. Over the past 20 years, federal policies such as the Clean Air Act Amendments of 1990 (CAAAs) have resulted in decreased atmospheric emissions and deposition of sulfur in NYS. In the same period, atmospheric emissions of nitrogen, which were not capped by the CAAAs, have not changed significantly.


Credit: Rich Hallett
Sampling foliage with a shotgun

Monitoring the biogeochemical status of forest and stream ecosystems is a key component of assessing environmental quality in the northeastern United States. Spatially continuous monitoring of ecosystems requires remote-sensing technology. Forest canopies are the only portion of the system accessible to optical remote sensing instruments and thus offer the most likely target surface for monitoring forest health in this spatial mode. The usefulness of remote sensing of canopy chemistry depends on tight relationships between canopy chemistry and the critical processes of forest production and element losses in drainage water.

PROJECT UPDATE

December 2005

Credit: http://earthobservatory.nasa.gov
Forest canopy

Project Status

- Initiated July 2004
- Project ongoing

New York Energy Smart SM
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George E. Pataki, Governor

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PROJECT FINDINGS

Thirty plots have been sampled within the study area (for which hyperspectral remote sensing imagery was collected in 2001) in order to provide forest health, foliar chemistry, and soil chemistry data for calibration and validation.

The project team is also currently developing algorithms to map tree health by species using hyperspectral remote sensing imagery. Once developed, these techniques will be able to pinpoint areas of early decline before the symptoms are visible to ground crews.

Forest health, canopy chemistry, stream chemistry, species, and soil chemistry data layers will subsequently be compiled, providing the basis for an integrated GIS-based model that can be used to aid critical management decisions and help determine the extent and magnitude of terrestrial and aquatic responses to acidic deposition.

PROJECT IMPLICATIONS

PROJECT UPDATE

August 2005

New York State Energy Research and Development Authority

Environmental Monitoring, Evaluation, and Protection Program

NYSERDA

Mercury Deposition Monitoring Network: Adirondacks and Catskills

Principal Researchers

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Syracuse University

MICHAEL MCHALE
U.S. Geological Survey

Project Location

Adirondack and Catskill regions outlined

Contact Information

For more information on this project see:
www.nyserda.org/programs/environment/emep

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Keywords

- Dry deposition
- Mercury (Hg)
- Mercury Deposition Network (MDN)
- Speciated mercury data
- Wet deposition

PROJECT FOCUS

This project supports the only two mercury deposition monitoring stations in New York State (NYS). The project currently funds speciated mercury (Hg) wet deposition collection at Huntington Wildlife Forest (owned and operated by the State University of New York College of Environmental Science and Forestry, in cooperation with Syracuse University) in the Adirondack Mountains, and at Biscuit Brook in the Catskill Mountains (operated by the U.S. Geological Survey and the Frost Valley YMCA). Both of the sites are part of the National Atmospheric Deposition Program (NADP) Mercury Deposition Network (MDN). Participation in this network allows comparisons to be made between atmospheric mercury deposition in the Adirondacks and the Catskills, as well between NYS deposition and national rates, thereby broadening the understanding of mercury deposition across the state. This project also provides background mercury deposition data necessary for detailed mercury cycling studies that are being conducted in the Adirondacks and Catskills.

CONTEXT

In the past century, anthropogenic emissions of mercury have caused a concomitant increase in the atmospheric deposition of this toxic chemical. In areas remote from point sources, such as the Adirondack region, atmospheric deposition is the main contributor to elevated mercury concentrations. Analyses of lake sediment show that the current rate of mercury deposition in the Northeast is 2 to 5 times greater than historical levels (before ~60 years ago). The major anthropogenic sources of emissions are the combustion of mercury-containing fuels or materials, such as coal, in the production of electricity and in industrial processes. Mercury emissions from coal-fired power plants, which are currently unregulated under federal law, constitute ~30% of U. S. anthropogenic emissions.

In the northeastern United States, mercury deposition has resulted in higher levels of mercury in freshwater ecosystems. As it accumulates in organisms exposed to it (bioaccumulation), mercury also poses a danger to organisms higher up in the food chain (biomagnification). An issue of particular concern for human health is the accumulation of mercury in fish muscle tissue, which is eaten by human beings. When mercury concentrations reach high enough levels, it can impair neurological development in fetuses and young children, and damage the central nervous system of adults. In New York, fish consumption advisories currently cover over 70 lakes, rivers, and reservoirs because of high mercury levels.

Huntington monitor

Mike McHale setting up the mercury monitor at the Biscuit Brook project site.
Photograph by: Mark Watson

Project Status

- Initiated 2002
- Project ongoing

New York Energy Smart℠
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George E. Pataki, Governor

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METHODOLOGY

To assess wet deposition inputs of mercury in New York State, the two NADP/MDN stations will continue monitoring activities through 2006. Syracuse University operates Huntington Forest (HF) station in the Adirondacks, and the U.S. Geological Survey, in cooperation with Frost Valley YMCA personnel, operates Biscuit Brook station (BB) in the Catskills.

In addition to monitoring deposition, the project team will:

- Provide annual summaries of the mercury concentration and deposition data for the HF and BB sites.
- Compare the wet deposition of mercury at HF, BB, and other regional sites in the network.
- Develop preliminary total mercury deposition maps for the Adirondack region, using information on wet deposition at HF, and throughfall and litter deposition (i.e., dry deposition) of mercury obtained from Sunday Lake, HF, and other areas of the Adirondacks.

RECENT FINDINGS

HUNTINGTON FOREST

The annual volume-weighted concentration of total mercury for the site is 7.3 ± 5.0 ng/L, with values ranging from 1.3 to 29.2 ng/L. The annual wet deposition of mercury is 9.4 $\mu g/m^2$ per year. These values are similar to values reported in the network for other sites in eastern Northern America.

BISCUIT BROOK

The Biscuit Brook monitoring station began operation March, 2004. Samples are being collected weekly in accordance with MDN protocols by Frost Valley YMCA personnel. Volume-weighted concentrations of total mercury for the site have ranged from 3.0 to 28.7 ng/L.

PROJECT IMPLICATIONS

The choice of a regulatory regime for mercury and the evaluation of future controls requires a reliable data record of atmospheric deposition rates, on the basis of which the effects of emission reductions may be predicted and ultimately evaluated. The data gathered at the two stations supported through this project are essential for the interpretation of spatial and seasonal trends in mercury deposition in New York State and provide the reference information for detecting future changes in wet deposition rates. The work performed at the stations also benefits other studies of mercury in the region, such as the NYS Department of Environmental Conservation's extensive survey of mercury concentrations in fish in NYS waters. As part of the MDN, these sites will contribute to a national data-base of weekly concentrations of total mercury in precipitation and seasonal and annual fluxes of total mercury in wet deposition.

PROJECT UPDATE

August 2005

New York State Energy Research and Development Authority

Environmental Monitoring, Evaluation, and Protection Program

Assessment of Chemistry and Benthic Communities in Streams of the Oswegatchie-Black River Basins of the Adirondack Region

Principal Researchers

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Project Location

Adirondack Mountain Region outlined.

Contact Information

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Keywords

- Acidic deposition
- Benthic communities
- Macroinvertebrates
- Periphytic diatoms
- Stream chemistry
- Stream reaches

PROJECT FOCUS

The U.S. Geological Survey (USGS), in collaboration with several other organizations, is conducting a survey of streams in the Black River and Oswegatchie River watersheds of the western Adirondack region of New York State (NYS) to assess the impacts of acidic deposition. These watersheds are representative of the region likely to be most affected by acidic deposition in New York and possibly in the United States.

The project team is using a new approach for quantifying the length of stream reaches that are affected by chronic and episodic acidification. The research involves:

- Sampling stream water at approximately 200 semi-randomly chosen locations for analysis of water chemistry;
- Sampling soils of fifteen watersheds to infer calcium status of soils (from information on stream chemistry under different flow conditions);
- Resampling sites that have been previously assessed (1980-1985) and sites currently being sampled in other projects, in order to allow historical and other comparisons; and
- Collecting macroinvertebrates and periphytic diatoms at locations that represent a range of chemical and physical conditions, in order to analyze trends in species composition in relation to acidification factors.

CONTEXT

Fossil-fuel combustion sources are major emitters of sulfur dioxide (SO_2) and nitrogen oxides (NO_x), which through complex reactions in the atmosphere form nitric and sulfuric acids. The deposition of these compounds contributes to the acidification of soils and waters. New York's Adirondack Mountains, located downwind of midwestern coal-burning power plants, are one of the regions most sensitive to acidification in North America, partly owing to their geological and soil characteristics. However, neither the proportion of affected streams nor the spatial extent of soil acidification has been determined.

Two important measurements for categorizing acidification are pH and acid-neutralizing capacity (ANC), measured in microequivalents per liter (µeq/L). Bodies of water exhibit a wide range of pH and ANC values under natural conditions that can be lowered by acidic deposition. Naturally acidic surface waters, however, do not contain measurable amounts of inorganic monomeric Aluminum (Al), which make this measure a definitive indicator of acidic deposition effects. In general, ANC values less than 50, pH values less than 5.5, and inorganic monomeric Al concentrations greater than 2.0 micromoles per liter are considered detrimental to aquatic ecosystems.

Credit: Greg Lawrence, USGS
Bear Brook, near Raquette Lake.

In addition to water chemistry parameters, biota found in benthic communities (the groups of organisms living in or on the sediment in a body of water) are important indicators of river water quality. Since each species has a certain tolerance for water chemistry and other environmental factors, species composition can be used as an index of general water quality. Benthic communities in Adirondack streams contain a wide variety of periphytic diatoms, single-celled microalgae that grow on all moist or submerged surfaces (e.g., rocks, sediment, or plants). Freshwater macroinvertebrates, larger-than-microscopic invertebrates including aquatic insects, worms, clams, snails, and crustaceans, are widely used in biomonitoring programs for assessing water quality because of their abundance and their sensitivity to environmental impacts.

PROJECT UPDATE

August 2005

Credit: Greg Lawrence, USGS

Examples of macroinvertebrates collected for the study.

Project Status

- Initiated 2003
- Project ongoing

New York Energy Smart℠

PUB

George E. Pataki, Governor

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.

METHODOLOGY

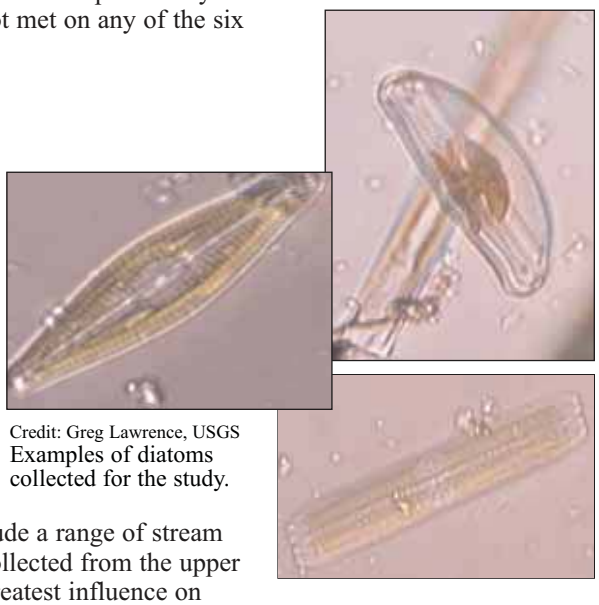
This survey involves a new approach for quantifying the length of stream reaches affected by chronic and episodic stream chemistry. Previous research suggests that the acidity of stream water in upland regions increases or remains the same in the upstream direction. This tendency is being used to estimate the total length of acidic stream reaches in the study region and in the following components of the project's sampling efforts:

Water Chemistry

- Collection of stream water for chemical analysis from approximately 200 streams. Sampling will take place during high and low flows in the early spring, late summer, and late fall of August 2003 through April 2005. The sites were randomly selected from a population of all accessible stream sampling locations that are not greatly influenced by upstream lakes and ponds.
- Collection of stream water for chemical analysis from 13 sites sampled in 1980–1985. Chemical concentrations determined on different dates shall be compared for each site to determine seasonal variations that can be used to infer acidification status. With this approach, the sites will be considered chronically acidic if ANC is less than 10 µeq/L, pH is less than 5.5, and inorganic monomeric aluminum (Al) concentrations are greater than 2.0 µmol/L on all six sampling dates. Sites will be considered episodically acidic if these criteria are met on 1–5 sampling dates, and nonacidic if not met on any of the six sampling dates.

Benthic Communities

- Collection of periphytic diatoms at the same 200 stream sampling locations to determine species composition.
- Collection of macroinvertebrates in 40 selected streams that vary chemically. Some of these streams were similarly sampled in 1980 -1985. Species occurrence, richness, and relative abundance will be measured.



Credit: Greg Lawrence, USGS

Examples of diatoms collected for the study.

Soil Chemistry

- Collection of soil samples for chemical analysis in 15 watersheds. The watersheds will be selected to include a range of stream acidification levels. Samples will be collected from the upper part of the soil profile, which has the greatest influence on stream chemistry during high flows. Streams that are chronically acidic, as well as those that become acidic during high flows will be expected to have low amounts of calcium in the soil. Calcium is an important nutrient for tree growth and aquatic ecosystems, as well as being the primary component for neutralizing acidic deposition.

PROJECT STATUS

All sampling has been conducted and chemical analyses are complete. Data analysis is underway.

PROJECT IMPLICATIONS

While the acidity of deposition has declined in New York over the past 20 years, insufficient data exist for determining whether the acidity of streams has decreased in response to these developments. More adequate baseline data will also be needed for identifying and evaluating future trends in the acidity of soils and streams. In the absence of sufficient information, policy efforts at restoring and protecting these natural resources will have to be made with a considerable degree of uncertainty.

This project addresses these needs by better characterizing the current status of streams and soils in the western Adirondack region, an area that is highly sensitive to acidic deposition. The project's innovative method for quantifying stream reaches will be evaluated for possible use in assessing acidic deposition impacts in other regions of the Adirondack Mountains and New York State.

PROJECT UPDATE

August 2005

New York State Energy Research and Development Authority

Environmental Monitoring, Evaluation, and Protection Program

Strategic Monitoring of Mercury in New York State Fish

Principal Researcher

HOWARD SIMONIN
New York State Department of Environmental Conservation

Project Location

Adirondack and Catskill regions outlined.

Contact Information

For more information on this project see:
www.nyserda.org/programs/environment/emep

or contact Mark Watson at:
mw1@nyserda.org

Keywords

- Atmospheric deposition
- Bioaccumulation
- Biomagnification
- Fish consumption advisories
- Mercury

PROJECT FOCUS

The New York State Department of Environmental Conservation (NYS DEC), supported by NYSERDA, is currently conducting a comprehensive monitoring program to determine mercury (Hg) concentrations in New York State fish. As part of this four-year project, which began in June 2003, data is being collected that is critically needed for establishing baselines and for assessing progress under proposed mercury emission control policies. Specifically, the project team is:

- Sampling fish mercury concentrations in selected NYS waters that have never been surveyed;
- Monitoring fish from lakes for which historical mercury data is available, to determine any possible trends;
- Providing data to improve our understanding of mercury bioaccumulation in lakes;
- Evaluating the possible use of a simple model to predict mercury levels in fish, based on lake pH and other variables; and
- Summarizing the statewide database of mercury concentrations in freshwater fish.

Dustin Edwards and Erik Latremore setting a gill net to collect fish for the mercury monitoring project.
Photograph by: Howard Simonin

CONTEXT

In the past century, anthropogenic emissions of mercury have caused an increase in the atmospheric deposition of this toxic chemical. In the northeastern United States, this has resulted in higher levels of mercury in freshwater ecosystems. Major sources of mercury emissions are electricity production and industrial processes that involve the combustion of mercury-containing fuels or materials, such as coal. Inventories indicate that ~150 tons of mercury are emitted from U.S. anthropogenic sources each year. As a result of emission controls, a moderate reduction has been recorded recently in atmospheric mercury deposition and acidic deposition in the Northeast. It is important to determine whether mercury concentrations in fish are following these trends.

As it accumulates in aquatic organisms such as fish (bioaccumulation), mercury also poses a danger to organisms higher up in the food chain (biomagnification). An issue of particular concern for human health is the accumulation of mercury in fish muscle tissue, which is eaten by human beings. Large predatory fish are known to bioaccumulate high concentrations of mercury, and the highest concentrations are found in older fish. In human beings, when mercury concentrations accumulate to high enough levels, the chemical can impair neurological development in fetuses and young children, and damage the central nervous system of adults. In response to these pronounced dangers, the U.S. Food and Drug Administration has decreed that fish with higher concentrations than one microgram of mercury per gram (i.e., 1 ppm) of wet weight are hazardous and are banned from interstate commerce. Additionally, 45 states have issued fish consumption advisories. In New York, fish consumption advisories for over 70 lakes are currently in place owing to high mercury levels. However, only ~200 of New York's ~4,000 lakes have been sampled for mercury concentrations.

PROJECT UPDATE

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Yellow perch (top) and *walleye* (bottom), as pisciverous fish, are useful in the study of mercury bioaccumulation.

Credit:
Http://interactive.usask.ca/ski/fisheries/fish/index.html

Project Status

- Initiated 2003
- Project ongoing

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METHODOLOGY

In this and a companion project conducted by the Adirondack Lakes Survey Corporation (ALSC), a total of 126 lakes are being sampled over three years. For these sites (see map), the concentrations of mercury in fish as well as water-chemistry variables and other watershed attributes are being analyzed. Sampling is conducted in cooperation with regional DEC fisheries staff and with the assistance of the ALSC. In addition to including a number of previously unsampled lakes, this project is also surveying lakes from an existing NYS DEC fisheries database, which contains information on mercury and other data for fish from 166 lakes, ponds, and reservoirs. Overall, waters in three categories are being surveyed:

- Lakes that have been previously surveyed; new data will supplement the existing database and allow evaluation of changes in mercury concentrations.
- Lakes that have not been surveyed for mercury, but have data available for related criteria.
- Lakes and ponds in the Adirondacks, Catskills, and Hudson River valley that have never been surveyed, but based on water chemistry are believed to have high mercury levels in the larger predatory fish (perch, bass, and/or walleye).

In its study of bioaccumulation, the project will focus on largemouth and smallmouth bass, walleye and yellow perch, since these piscivorous fish have been shown to accumulate high mercury concentrations and are therefore useful indicators of potential problems.

Erik Latremore setting a gill net to collect fish for the mercury monitoring project
Photograph by: Jeff Loukmas

Erik Latremore and Dustin Edwards removing fish from a gill net.
Photograph by: Jeff Loukmas

RECENT FINDINGS

Currently, fish and water samples have been collected from 117 lakes across New York State. More than 1700 fish samples and over 100 water samples have been analyzed. The data set has been provided to the NYS Department of Health, which has recently added waterbodies to their fish consumption advisories based on this data.

PROJECT IMPLICATIONS

Coal-fired power plants, which are responsible for ~30 % of U.S. industrial emissions, are the largest unregulated source of mercury emissions. In the absence of regulations and/or better control technologies, mercury emissions from coal-fired power plants are expected to increase as the demand for energy production and coal combustion increase. Policymakers at the state and federal levels are currently considering regulations of mercury emissions from the utility sector and other control mechanisms. Information is therefore critically needed for evaluating the impacts of recent and potential reductions in mercury deposition on aquatic resources.

This project's analyses should greatly improve our understanding of mercury concentrations in NYS waters. Ultimately the project will provide information about fish mercury concentrations in over 100 lakes for which no data are currently available. The results will constitute a major addition to the available mercury database, which currently includes information on fish for only ~5% of NYS lakes. With this baseline data, potential trends in mercury concentrations in fish can be evaluated and determinations made as to whether there have been any significant changes in mercury concentrations in the recent 10–15 years. This information will benefit the choice of mercury controls and the assessment of their effectiveness in the future. Determining the status of mercury in particular lakes will assist resource managers and the NYS Department of Health in deciding whether additional fish consumption advisories are needed.

PROJECT UPDATE

August 2005

New York State Energy Research and Development Authority

Environmental Monitoring, Evaluation, and Protection Program

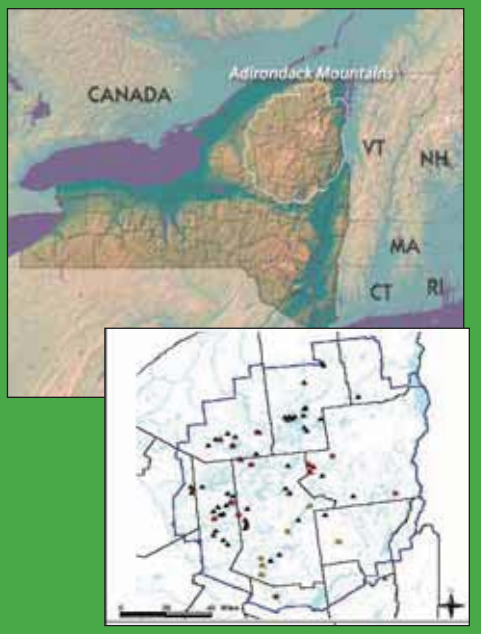
Long-Term Monitoring and Assessment of Mercury Using the Common Loon, Prey Fish, Water, and Sediment

Principal Researcher

NINA SCHOCH
Wildlife Conservation Society - Adirondack Cooperative Loon Program (ACLP)

DAVID EVERS
Biodiversity Research Institute

Project Location



Contact Information

For more information on this project see:
www.adkscience.org/loons/
and
www.nyserda.org/programs/environment/emep
or contact Mark Watson at:
mwl@nyserda.org

Keywords

- Bioaccumulation
- Biomagnification
- Common loon (*Gavia immer*)
- Methylmercury (MeHg)
- Wildlife criterion value (U.S. EPA)

PROJECT FOCUS

This collaborative project aims to assess mercury (Hg) exposure and risk in aquatic ecosystems in the Adirondack Park of New York State (NYS) by using the common loon (Gavia immer) as an indicator species. Involved in this effort are the Wildlife Conservation Society, BioDiversity Research Institute, and the NYS Department of Environmental Conservation, partners of the Adirondack Cooperative Loon Program. The objectives of the study are threefold:

- Developing a mercury "exposure profile" by evaluating abiotic (sediment; water column) and biotic (prey fish; crayfish; zooplankton; loon blood, feathers, and eggs) Hg levels in the aquatic environment.
- Developing a mercury "hazard profile," using the loon as indicator species, by determining the reproductive success and survival of loons and evaluating these parameters in relation to the blood mercury levels of the birds.
- Assessing mercury risk in Adirondack aquatic ecosystems by developing a "wildlife criterion value," using a U.S. Environmental Protection Agency formula that provides a water column mercury value that is protective of wildlife at the population level.

ACLP volunteers monitor loons on an Adirondack lake
Photograph by: Nina Schoch

CONTEXT

Mercury cycles in the environment as a result of both natural and human activities. The major sources of anthropogenic emissions are the combustion of mercury-containing fuels or materials, such as coal, in the production of electricity and industrial processes. Analyses of lake sediment cores show that the current rate of mercury deposition in the Northeast is 2–5 times greater than historical levels (before ~60 years ago), an increase that is attributed to deposition resulting from these emissions. Studies comparing mercury concentrations in fish with rates of atmospheric deposition have found that anthropogenic sources account for a major contribution to aquatic system mercury levels. As it accumulates in the organisms exposed to it (bioaccumulation), mercury poses a danger to organisms higher up in the food chain (biomagnification), even at low exposures. In aquatic ecosystems, methylmercury (MeHg), the toxic form of elemental mercury, accumulates in fish muscle tissue, posing a threat to fish-eating species, including humans.

In aquatic ecosystems across the Northeast, MeHg is currently at levels that pose a risk to human and ecological health. The level of risk varies considerably according to MeHg availability, which is affected by lake hydrology, biogeochemistry, habitat, topography, and proximity to airborne sources. The loon, which breeds on bodies of water throughout New York's Adirondack Park, is a fish-eating predator at the top of the food chain that may be detrimentally affected by mercury and other toxins that bioaccumulate and biomagnify through the environment. Risk assessments have shown that the loon is a suitable indicator of the toxicity of aquatic mercury.

METHODOLOGY

This four-year project expands on loon mercury exposure and reproductive success data collected previously in the Adirondack Park (1998–2000) by the U.S. Fish and Wildlife Service and BioDiversity Research Institute. Abiotic and biotic samples are being collected on ~40–50 lakes inhabited by loons within the Adirondack Park over a four-year period (2003–2006). During the 2003-2004 field season, loons were captured and sampled on 44 lakes.

PROJECT UPDATE

August 2005

Banding loons is a common way of monitoring their behavior
Photograph by: J. Ozard, NYS DEC

Project Status

- Initiated 2003
- Project ongoing

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2003-2004 Sampling

Category	Lakes Sampled
Fish	42
Water	44
Zooplankton	43
Crayfish	26
Sediment	32
Loon blood and feathers	44
Nonviable loon eggs	18

Data from these lakes will be coordinated with other water-quality research to enable analysis of water chemistry in relation to the sampled mercury levels. Long-term monitoring of mercury contamination and reproductive success of Adirondack loons will be evaluated through analysis of mercury in the abiotic and biotic samples that were collected from loon territories. This information will serve as an indicator of the broader risk mercury poses to environmental quality in northern NYS.

Specifically, the research will involve chemical analysis of loon blood samples to determine short-term mercury accumulation and of loon feathers to indicate long-term mercury accumulation in the birds. Using available data, the project team will develop a mercury exposure profile and assess the risk that mercury deposition poses to Adirondack ecosystems through the development of a wildlife criterion value. Common loon blood and egg mercury levels will be used as the primary indicators for assessing ecological health risks. A population model will be developed to determine if the Adirondack loon population is being negatively impacted by mercury contamination of the aquatic ecosystem.

RECENT FINDINGS

Previous results have indicated that 17% of the loons sampled in the Adirondacks were estimated to be at risk for harmful effects from mercury contamination. Additional results from sampling in 2003-2004, and future sampling in 2005-2006 will augment the database that is being developed.

NYS DEC biologist releasing an immature banded loon on an Adirondack lake
Photograph by: Nina Schoch

PROJECT IMPLICATIONS

This project's determination of levels of abiotic and biotic mercury exposure will contribute to the assessment of the risks posed by mercury pollution to human and ecological health in NYS and the Northeast. Results will be coordinated with related projects, with the aim of improving assessment of the impacts of mercury exposure on loons. Findings should prove useful in broader evaluations of the impact of mercury toxicity and the extent of mercury distribution in northeastern aquatic ecosystems in relation to deposition. The evaluation of mercury levels in prey fish will also aid in identifying Adirondack lakes that should be evaluated for fish consumption advisories to prevent human exposure to mercury.

Currently, although pollution prevention programs exist to remove mercury from the environment and products, mercury emissions from coal-burning power plants are not regulated. A federal rule to reduce mercury emissions is scheduled to be phased in over the next two decades. The findings of this and related projects on mercury should benefit the evaluation of the geographically specific effects of deposition on ecosystems and its risks for human health, as well as the selection of an optimal regulatory regime for mercury.

PROJECT UPDATE

August 2005

New York State Energy Research and Development Authority

Environmental Monitoring, Evaluation, and Protection Program

NYSERDA

The Potential Recovery of Water Chemistry and Stream Biota due to Reduced Acid Deposition at a Sensitive Watershed in the Catskill Mountains

Principal Researchers

DOUGLAS A. BURNS
U.S. Geological Survey

ROBERT W. BODE
New York State Department of Environmental Conservation

KAREN R. MURRAY
U.S. Geological Survey

Project Location

Catskill region outlined

Contact Information

For more information on this project see:

www.nyserda.org/programs/environment/emep

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Keywords

- Acid deposition
- Acid neutralizing capacity (ANC)
- Indicator species
- Macroinvertebrates
- Periphyton

PROJECT FOCUS

This project returned in 2003 to a set of sites in the Neversink River, located in the Catskill Mountains, that were sampled in 1987 to examine changes in stream chemistry and biota in relation to recorded declines in the acidity of precipitation. The study's objective is to determine whether spatial patterns in species composition of aquatic macroinvertebrates, fish, and periphyton (algae) have changed as a function of surface water chemistry. Additionally, two stream reaches in zones of sharp pH transitions were sampled in order to clarify the relationship between biota and pH, acid neutralizing capacity (ANC), and aluminum concentrations in light of improvements in precipitation acidity.

CONTEXT

Fossil-fuel combustion sources are major emitters of sulfur dioxide (SO_2) and nitrogen oxides (NO_x), precursors of the nitric and sulfuric acids that, through deposition, contribute to the acidification of lakes and streams. Several chemical criteria indicate conditions that pose a danger to aquatic biota. Biota are at risk from surface water acidification when surface water pH is less than 6.0, ANC is less than 50 µeq/L, or concentrations of toxic inorganic aluminum are greater than 2 µmol/L. These criteria are "biologically relevant indicators," the first level of data necessary for understanding and restoring aquatic ecosystem structure and function.

The Catskill Mountains of southeastern New York State (NYS) not only receive levels of acidic deposition that are among the highest in the U.S., but also are particularly susceptible to acidification owing to their geological and soil characteristics. As a result, the region contains numerous streams with low ANC. The Neversink River is the most acid-sensitive watershed in the Catskills region, and among the most sensitive in NYS. Numerous tributaries of this river and upper reaches of its East and West Branches have base-flow pH < 5.2 and ANC < 0 µeq/L. These acidic conditions and related high aluminum concentrations have affected fish populations in the watershed.

East Branch of the Neversink River – Kelly's Ledge

METHODOLOGY

At sixteen sites, sampled on 16–18 September 2003, a stream reach of about 50 meters in length was defined. Four types of data were collected:

- Surface water chemistry;
- Fish (species diversity, weight, and length);
- Aquatic macroinvertebrates; and
- Periphyton, gathered from all available habitats.

While most of these sites were the same as those sampled in the 1987 study, two additional reaches were added in a region of sharp pH change in the West Branch Neversink River, and two tributary reaches sampled in 1987 were dropped. Flow conditions similar to those during the 1987 sampling were chosen in order to minimize the effects of stream flow on chemistry and biota.

Robert Bode and Margaret Novak of the NYS DEC collecting a kick sample of stream macroinvertebrates on the East Branch Neversink River.
Photograph by: Karen Murray

Mayfly larvae are particularly sensitive to stream acidity.

Project Status

- Initiated 2003
- Project ongoing

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Public Service Commission — NYSERDA
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Stream chemistry, macroinvertebrate, and fish data from 1987 and 2003 will be compared using statistical tests. The periphyton data collected in 1987 were generally qualitative, and do not allow a direct statistical comparison with the more quantitative 2003 data. The entire 1987 dataset will also be compared to the 2003 dataset. In addition to these statistical tests, qualitative comparisons will be made using graphical techniques.

Through this analysis, the project team will attempt to determine the extent to which changes in stream chemistry and biota from 1987 to 2003 are related to reduced acidic deposition, while taking into account other factors that may affect stream chemistry and biota, such as climate, flow conditions, fishing, predation, and disease. The known environmental tolerances and requirements of different species of the biota will be used to help define trends and differentiate causes.

Karen Murray and Douglas Burns of the U.S. Geological Survey electroshocking a reach of the West Branch Neversink River to assess fish species diversity in September 2003.
Photograph by: Robert Bode

RECENT FINDINGS

Data collected by the NYS Department of Environmental Conservation and U.S. Geological Survey in 1987 indicated that stream pH and ANC values are strongly related to the number of mayfly species in the Neversink River watershed. These data suggest that mayfly species diversity may be a good indicator of recovery following pH and ANC increases resulting from reduced levels of acidic deposition.

Preliminary analysis of the 2003 data and comparisons with the 1987 data indicate a similar general pattern of downstream change in mayfly and fish species as pH increases in the Neversink River. There are, however, some differences between the two years. In the process of comparing data from the two years and attributing any changes to reduced acidic deposition, the fact that 2003 was a very wet year has proven to be a challenge. Summer streamflow in 2003 in the Neversink River was the highest of any summer in the past 30 years. Current efforts are aimed at determining whether the primary cause of the subtle differences in stream chemistry and biota is, in fact, changes in acidic deposition, or simply the result of the very wet summer and the physical and chemical changes in stream habitat that accompany frequent high flows.

PROJECT IMPLICATIONS

In the past two decades, mandated reductions in SO_2 emissions, such as those of the 1990 Clean Air Act Amendments, have resulted in a decrease in the acidity of precipitation, in particular in levels of sulfuric acid, in New York State. While the widespread recovery of streams in the Catskills is as yet unconfirmed, recent data do suggest that recovery may be under way in waters with ANC values in the range of 30–70 μeq/L. These potential early improvements in stream chemistry may eventually result in the recovery of acid-intolerant biota in affected streams.

Better knowledge of the relationship between emissions reductions and the rate of environmental recovery is critical for the process of choosing the optimal cost-effective control measures and for evaluating the effects of current regulations. This project's comparison of 1987 and 2003 data from the Neversink River will contribute to our understanding of how reductions in the acidity of deposition affect water chemistry and biota. Additionally, the data accumulated by the project will provide a basis for comparison against which future changes in the acidity of precipitation and in the acid-base status of surface waters in the Neversink basin may be evaluated.

East Branch of the Neversink River, above New Road Hill bridge.

PROJECT UPDATE

August 2005

New York State Energy Research and Development Authority

Environmental Monitoring, Evaluation, and Protection Program

Assessment of Extent to Which Intensively Studied Lakes Are Representative of the Adirondack Mountain Region

PROJECT FOCUS

Launched in 2003, this project is a collaborative effort that extrapolates research, monitoring, and modeling results from a few intensively studied lakes in the Adirondack region of New York to the larger regional Adirondack population of acid-sensitive lakes. The major objectives are to:

- Develop methods for increasing knowledge of chemical and biological recovery of acid-sensitive lakes and their watersheds;
- Develop a statistically representative database for Adirondack soils; and
- Classify watersheds according to their responsiveness to ongoing and future changes in sulfur (S) and/or nitrogen (N) deposition.

CONTEXT

Fossil-fuel combustion sources are major emitters of sulfur dioxide (SO_2) and nitrogen oxides (NO_x), which, through complex reactions in the atmosphere, form nitric and sulfuric acids. The deposition of these compounds contributes to the acidification of lakes and streams. In addressing this problem, several chemical criteria are used to identify the degree to which surface water is acidified and poses a danger to aquatic biota. Specifically, many species of aquatic biota are at increased risk when the pH of water is less than 5.5, acid-neutralizing capacity (ANC) is less than 50 microequivalents per liter (µeq/L), and/or concentrations of toxic inorganic aluminum (Al) are greater than 2 micromoles (µmol/L).

The Adirondack Mountains of New York State are among U.S. regions that are very sensitive to acidic deposition. Ecosystem damage from air pollution, including surface-water acidification and deleterious effects on aquatic and terrestrial biota, has been substantial. Many surface waters have shown decreases in pH and ANC, and increases in inorganic aluminum concentrations with adverse impacts on fish, zooplankton, and other aquatic biota. Furthermore, studies in other parts of the country have shown a pattern of lower streamwater ANC in watersheds having lower soil base saturation (BS). Models suggest that soil base saturation will decline in the future unless deposition is reduced.

While the acidity of precipitation in New York was greatest in the 1970s, in recent years sulfur deposition has been declining. This decline is attributed to the enactment of the Clean Air Act of 1970 and its subsequent amendments of 1990 (CAAAs). For the past few decades, long-term monitoring programs have been gathering chemical and biological data at selected lakes in the region, some of which show evidence of limited recovery from acidification. However, at present there is no mechanism available for extrapolating the results of these studies to the larger regional population of Adirondack lakes. This gap seriously limits the ultimate utility of these important but limited data.

Credit: Tim Sullivan et al.

Forest cover of the Adirondack mountains.

METHODOLOGY

Data Compilation: The project team has acquired chemical and biological long-term monitoring data for all seventy watersheds included in this effort. Intensively studied sites are part of Rensselaer Polytechnic Institute's Adirondack Effects Assessment Program (AEAP) and the Adirondack Lakes Survey Corporation's Long-Term Monitoring Program (ALTM). A subsample of Adirondack lake watersheds was selected from the U.S. Environmental Protection Agency's (US EPA) Environmental Monitoring and Assessment program (EMAP) for regional characterization. Watershed data are being compiled on atmospheric deposition, vegetation, soil types, and land use and disturbance history.

Principal Researcher

TIM SULLIVAN
E & S Environmental Chemistry, Inc.

Project Location

Adirondack mountain region outlined.

Contact Information

For more information on this project see:

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

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Keywords

- Acid deposition
- Acid neutralizing capacity
- MAGIC Model
- PnET-BGC Model
- Soil survey
- Watershed classification

PROJECT UPDATE

August 2005

Credit: Tim Sullivan et al.
Research team conducting a soil survey.

Project Status

- Initiated 2003
- Project ongoing

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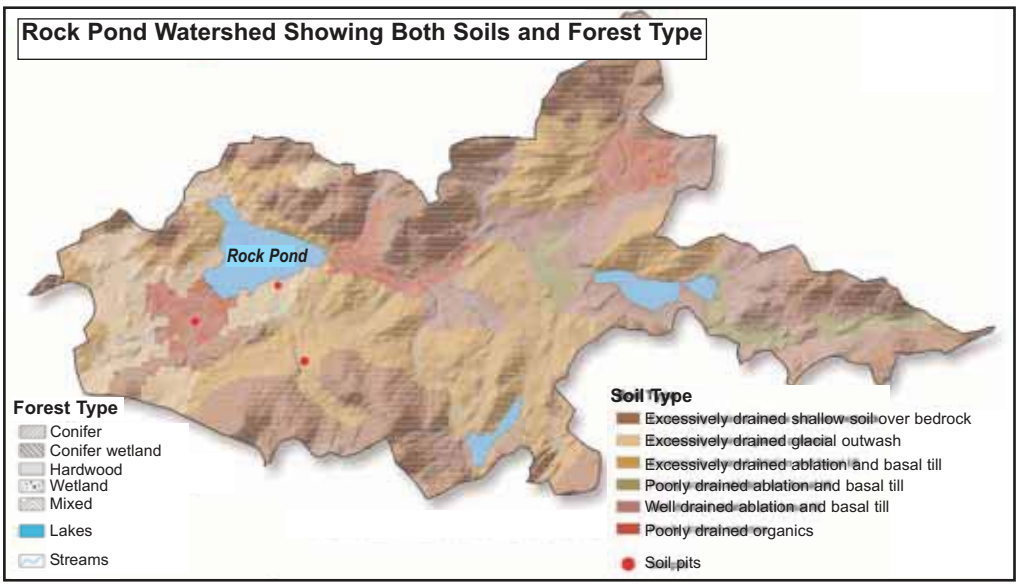
Soils Database: A statistically representative soils database has been developed through a survey of soil chemistry at over 200 locations within 70 long-term monitoring and EMAP watersheds. This new soils database will provide a current, regionally-representative database, which will serve as a benchmark against which future soils conditions can be compared. Results have been sorted by lakewater ANC, soil type, and forest cover type.

Modeling: Two models, the Model of Acidification in Groundwater in Catchments (MAGIC) and PnET-BGC Model, are being applied to the 70 study watersheds in order to simulate past and future responses of lakewater chemistry to changing levels of sulfur and nitrogen deposition. Subsequently, the project team will:

- Classify watersheds according to responsiveness to future decreases in S and N deposition;
- Develop model-based and clustering approaches to extrapolate results from the intensively studied sites to the regional population, based on the statistical framework of EMAP; and
- Compare and contrast output from the two models MAGIC and PnET-BGC.



PRELIMINARY FINDINGS

Soil survey results indicate that B-horizon soils having low base saturation (BS < 15%) are widely distributed throughout the Adirondack region. However, low BS values tend to be more strongly associated with sites forested with conifers than with hardwood trees. In general, the mineral soils of the intensively studied sites more often tend to be very low in BS than soils of the statistically representative EMAP watersheds. The intensively studied group of watersheds also includes a higher frequency of watersheds that were mainly forested (greater than 75% green timber) shortly after the turn of the 20th century.

Watershed modeling with MAGIC and PnET-BGC is ongoing. The models will be used to project how each study lake will respond to further future reductions in acidic deposition.

PROJECT IMPLICATIONS

PROJECT UPDATE

August 2005

New York State Energy Research and Development Authority

Environmental Monitoring, Evaluation, and Protection Program

Deposition and Effects of Air Pollution in the Hudson Valley

Principal Researchers

GARY M. LOVETT
Institute of Ecosystem Studies (IES)

Project Location

Millbrook

Contact Information

For more information on this project see:

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

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Keywords

- Acidic deposition
- Forest nitrogen cycle
- Litterfall
- Nitrogen mineralization
- Nutrient cycling

PROJECT FOCUS

NYSERDA funding for this project supports the continuation of the long-term forest ecosystem research program at the Institute of Ecosystem Studies (IES) in southeastern New York State (NYS). The aim of the program is to measure the effects over time of the atmospheric deposition of energy-related pollutants on forest ecosystems in the Hudson Valley region. Specifically, the work involves the following activities:

- Measuring the wet and dry atmospheric deposition of sulfur (S), nitrogen (N), and other nutrients and pollutants to the research site;
- Determining the effects of these pollutants on the forest ecosystem; and
- Determining the interactions between air pollution and other forest stresses, in particular "exotic" forest pests.

Forest Ecosystem Monitoring at IES

Vegetation	Biogeochemistry	Animals
✦ Production	✦ Atmospheric Deposition	✦ Gypsy Moth
✦ Species Composition	✦ Throughfall	✦ Hemlock Woolly Adelgid
✦ Mortality	✦ Soil Solution	✦ Small Mammals
✦ Regeneration	✦ Litterfall	✦ Deer Browse
✦ Seed Production	✦ Foliar N Concentration	✦ Black-legged Ticks
✦ Crown Condition	✦ Soil C and N	✦ Lyme Disease Infection Rates
	✦ N Mineralization/Nitrification	

CONTEXT

Fossil-fuel combustion sources are major emitters of sulfur dioxide (SO_2) and nitrogen oxides (NO_x). These pollutants undergo complex reactions in the atmosphere to form nitric and sulfuric acids, which, through atmospheric deposition in forests and bodies of water, affect ecosystems in complex ways and contribute to the acidification of soils, lakes, and streams. Over the past 20 years, federal policies such as the Clean Air Act Amendments of 1990 (CAAAs) have resulted in decreased atmospheric emissions and deposition of sulfur in NYS. In the same period, atmospheric emissions of nitrogen, which were not capped by the CAAAs, have not changed significantly.

In 1983, a long-term environmental monitoring program was initiated at the IES in Millbrook, NY. This site hosts one of the few monitoring stations located in the lower Hudson Valley, a region that may be undergoing environmental change as a result of development of electricity generating facilities. Over the past two decades, the program has generated a valuable record of precipitation chemistry, air quality, meteorology, wet and dry deposition, forest growth, forest nutrient cycling, and stream chemistry.

METHODOLOGY

Beginning in 1992, two plots in the Cannoo Hills, a mixed oak forest that comprises 150 ha of the 800+ ha (2,000+ acre) IES property, have been regularly sampled to examine:

- Soil solution from below the rooting zone,
- Foliar and litter (fallen leaves) chemistry,
- Soil nitrogen mineralization and nitrification, and
- Throughfall, i.e., rain that falls through and is collected under the tree canopy (1993–1999 only).

Wet and dry deposition and climate variables have been measured since 1988. In 1996 an experiment to evaluate the response of the forest N cycle to the increasing availability of N was initiated in six pairs of plots distributed throughout the ridgetop forest at IES. Each pair of plots consists of (1) a control plot that is unfertilized and (2) a plot to which N fertilizer (ammonium nitrate [NH_4NO_3]) is added in four equal applications per year, for an annual rate currently totaling 50 kg N per hectare. In the N fertilization plots, the measurement scheme is the same as detailed above, but throughfall is not collected and the number of samples is reduced because of the smaller plot size. The experiment is designed to allow assessment of the long-term effects of chronic nitrogen deposition on the ecosystem.

Credit: Gary Lovett, IES

Collecting leaf litter at a long term monitoring plot and sampling foliage.

PROJECT UPDATE

August 2005

Credit: USDA Forest Service
Gypsy moth defoliation.

Credit: USDA Forest Service
Fifth instar gypsy moth larva.

Project Status

- Initiated 2002
- Completed 2005

New York Energy Smart℠
PUB

George E. Pataki, Governor

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

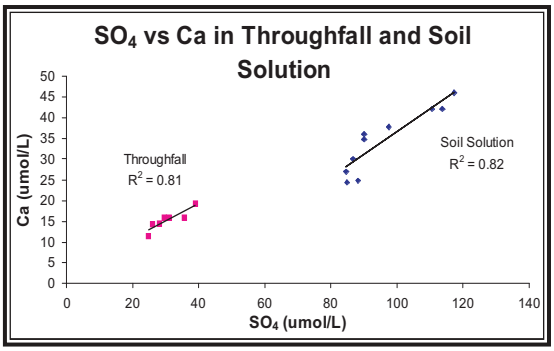
Atmospheric Deposition: This area has shown a decline in total (wet and dry) atmospheric deposition of both N and S since 1988.

- Total S deposition has declined substantially (1988–2000), as a result of reductions of regional SO_2 emissions. However, S emissions from power plants in the Hudson Valley area have decreased much less than emissions from power plants in the Northeast as a whole. Statistical correlations indicate that deposition trends at the site were more influenced by regional than by local emissions.
- Atmospheric deposition of N has also declined in this area since 1988, although it increased again in 2000.

S and N Trends and Cycling: Reduced deposition (1988–2000) has led to declines in the amounts of N and S in throughfall and of S in soil solution.

Sulfur: Sulfate concentrations in throughfall and soil solution indicate a lower flux of S through the ecosystem.

- Soil solution S concentrations are much higher than throughfall concentrations and indicate a substantial internal source of S in these forests, most likely from the weathering of the shale and slate bedrock in the area.
- Sulfate and calcium are highly correlated in throughfall and soil solution.
- The decline in atmospheric deposition of S has decreased the leaching of calcium from the canopy and soil, despite the fact that mineral weathering adds a substantial amount of S to this ecosystem.



Credit: Gary Lovett, IES
Sulfate and calcium are highly correlated in throughfall and soil solution. Changes in SO_4^{2-} flux produce corresponding changes in base cation flux.

Nitrogen: No decrease in inorganic N concentration in soil solution has been observed.

- Under current Nitrogen deposition conditions, there is minimal loss of N in drainage waters, suggesting almost complete retention of nitrogen. Nitrogen is strongly retained both in the forest canopy and in the soil, through complex plant, microbial, and abiotic processes.
- Overall, the N retention capacity for many forests in the Hudson Valley would be expected to be quite high, because of the area's history of widespread burning and harvesting in the 19th century and the dominance of oaks, which tend to have low rates of N cycling and loss.

Forest Dynamics and Exotic Pests: These forests are affected by multiple biotic stresses, primarily owing to the introduction of exotic pests. The two most problematic, the gypsy moth and the hemlock woolly adelgid, have substantial effects on N cycling and retention. Gypsy moth defoliation can radically alter the forest N cycle. While this perturbation usually causes little N loss from the forest in drainage waters, under certain conditions, such as N saturation, N losses can be significant.

N Cycling Experiment: Fertilized plots show signs of N enrichment. Foliar and litterfall N have increased significantly, as has NO_3 leaching. The surprisingly high NO_3 leaching indicates that N saturation may occur at this site much earlier than expected based on other studies, suggesting that the ecosystem is susceptible to N saturation. This accelerated trend toward N saturation may result from qualities of the site, which is an oak forest on thin soils in a ridgetop location. However, the site is representative of a major ecosystem type in southern NYS and is typical of sites attacked by the gypsy moth. This susceptibility to both N saturation and gypsy moth defoliation indicates that the interaction of these stresses should be further studied.

PROJECT IMPLICATIONS

This project has produced a valuable data set and tracked trends in the key indicators of forest ecosystem responses to atmospheric deposition. By tracing the effects of recent deposition changes on the forest ecosystem studied, the information will prove useful in evaluating the effectiveness of current legislation in reducing deposition to the Hudson Valley region. The long-term data accumulated will be beneficial in evaluating trends in response to the impacts of future legislation.

Results indicate that regional S emissions rates are more influential in determining local deposition than those of local sources, highlighting the importance of regional efforts to mitigate emissions. Recent reductions in regional S emissions have caused a decline in S deposition at this site, and that has reduced the loss of calcium, a critical plant nutrient, from the soils. With regard to nitrogen, it is important to note that while these oak forests do not leach N under ambient conditions, they appear to reach N saturation very quickly under conditions of elevated N input. Thus, increased N emissions could have a pronounced effect on the ecosystems studied. Currently, there are no caps in place on NO_X emissions from electrical utilities. Under present circumstances, N emissions and deposition are likely to increase in the future as the demand for electricity increases.

PROJECT UPDATE

August 2005

New York State Energy Research
and Development Authority

Environmental Monitoring, Evaluation,
and Protection Program

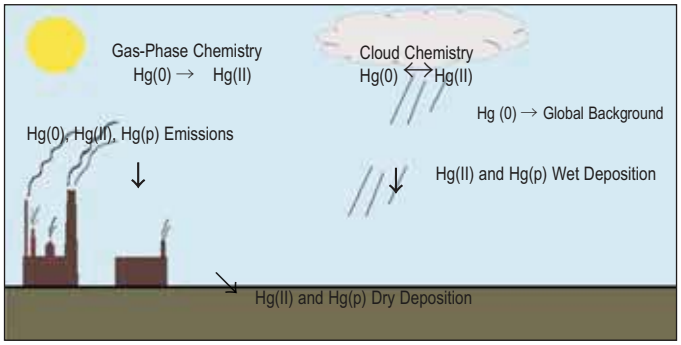
Atmospheric Transport and Fate of Mercury in New York State

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.

Principal Researcher

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Study Region

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For more information on this project see:

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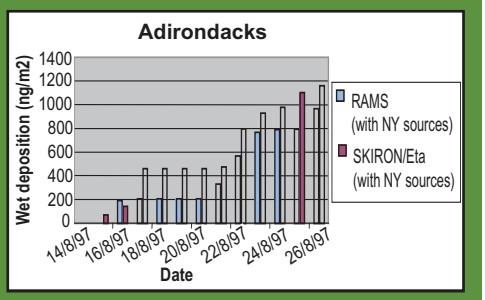
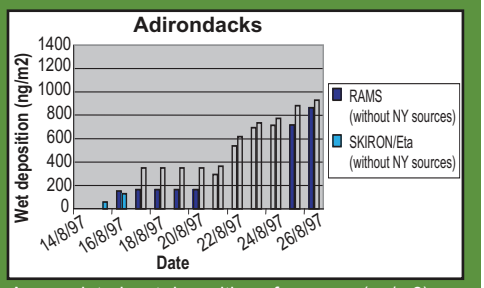
Keywords

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

PROJECT UPDATE

August 2005





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

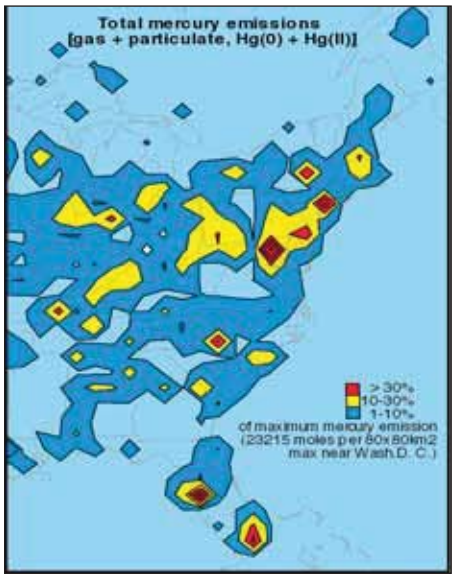
New York Energy Smart℠ PUB

George E. Pataki, Governor

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.

PROJECT UPDATE

August 2005

New York State Energy Research and Development Authority

Environmental Monitoring, Evaluation, and Protection Program

NYSERDA

Status and Effects of Nitrogen Pollution in the Northeastern United States

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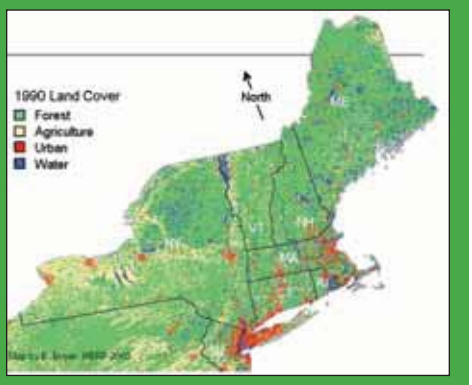
Project Location



Credit: Beth Boyer

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Keywords

- Estuary
- Eutrophication
- Nitrogen cascade
- Nitrogen loading
- Reactive Nitrogen

PROJECT FOCUS

Improved understanding of the complex ways in which ecosystems respond to elevated levels of nitrogen is essential for developing successful policies to mitigate nitrogen pollution. The goal of this project was to provide an integrated assessment of nitrogen pollution across New York State (NYS) and New England that will contribute to the formulation of effective mitigation strategies. The investigation identified the relative contributions of sources and the full spectrum of effects, ranging from the acidification of headwater streams to the eutrophication of coastal estuaries. The data were reviewed and synthesized within the context of current and proposed public policies in order to compare the effectiveness s of these different options in the long term, with regard to ecosystem and human health. Specifically, the project considered the

- Value of seasonal versus year-round NO_x controls in reducing pollutant effects (e.g., acidification and eutrophication);
- Response of sensitive ecosystems, such as the Adirondacks and Catskills, to proposed power-plant emission reductions;
- Effectiveness of different emission reduction scenarios targeting utilities, transportation, and non-point sources (e.g., fertilizer application and wastewater treatment plants) in controlling the input of nitrogen to surface waters and estuaries.

CONTEXT

Over the past century, environmental concentrations of reactive nitrogen, the form of nitrogen used by all living organisms, have greatly increased as a result of human activity. The primary anthropogenic sources are the manufacture and application of fertilizer, the combustion of fossil fuels, and the production of human and animal waste. Thus, energy generation and both the production and consumption of food generate reactive nitrogen as a byproduct. A certain amount of nitrogen is needed for all living organisms, and supports higher crop yields and greater energy production; but when this amount exceeds what can be assimilated, reactive nitrogen released into the environment degrades air, land, and water resources. In fact, a single nitrogen atom can set off a chain of adverse environmental effects known as the “nitrogen cascade” (see chart). With these effects, nitrogen pollution, which is currently increasing in the northeastern United States, contributes to a wide array of environmental problems.

METHODOLOGY

Using long-term research from the Hubbard Brook Experimental Forest (HBEF) and other sites across the Northeast, data on the effects of nitrogen pollution were synthesized and ecosystem responses to reductions were assessed. Eight large watersheds in the Northeast were also analyzed in order to determine the sources of reactive nitrogen that cause nitrogen pollution.

To evaluate the effects that current and future policies may have on airborne nitrogen pollution in the Northeast, the project team used a mathematical model that incorporates climate data, atmospheric emissions and deposition, and known forest processes to predict resulting soil and stream conditions. Researchers applied the model to two well-studied watersheds: the HBEF in New Hampshire and the Biscuit Brook watershed (BBW) in New York. Different policy scenarios were used to evaluate the effects of emission reductions from transportation, utilities, and agriculture on different indicators of chemical stress that are associated with nitrogen pollution over time.

Several scenarios for reducing the input of reactive nitrogen to northeastern estuaries were evaluated with a model for assessing watershed nitrogen reduction scenarios. Two estuaries with different land-use characteristics were used as case studies: Long Island Sound in Connecticut and New York, and Casco Bay in Maine. Researchers defined the nitrogen reduction scenarios by targeting different contributing sources in each scenario.

PROJECT UPDATE

August 2005

THE CASCADE EFFECT OF NITROGEN POLLUTION

Air Quality
- Elevated ground-level ozone
- Increased concentrations of particles in air
- Reduced visibility
- Increased acid rain and nitrogen deposition

Forests
- Increased acidity of forest soils
- Nitrogen saturation of forest ecosystems
- Ozone damage to forests

Water Quality
- Elevated acidification of lakes and streams
- Groundwater contamination
- Over-enrichment of coastal ecosystems

Other
- Increased production of greenhouse gases contributing to global climate change
- Adverse human health effects from particulate matter and ground-level ozone

Project Status

- Initiated 2001
- Completed 2003

New York Energy Smart℠
Public Service Commission — NYSERDA
George E. Pataki, Governor

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RECENT FINDINGS

Major contributors to nitrogen pollution in the northeastern United States are nitrogen in food imported into the region (released as sewage), emissions into the air through combustion processes, and nitrogen fertilizer use.

The Hubbard Brook Stream during high flow.

WATERSHED NITROGEN SOURCES: In the eight studied coastal watersheds in the Northeast, nitrogen pollution was traced to a variety of sources, including (in order of priority) food imports, nitrogen fertilizer, and atmospheric deposition. Nitrogen entering estuaries downstream of the analyzed watersheds is dominated by wastewater effluent (36–81%) and atmospheric deposition (14–35%). The analysis shows that the rate at which reactive nitrogen is added to the watersheds varies widely. Nitrogen sources also vary significantly in forested headwaters compared to densely populated coastal zones.

WATERSHED NITROGEN REDUCTION SCENARIOS (Long Island Sound and Casco Bay): The model shows that improved wastewater treatment results in the largest reduction in the reactive nitrogen input to Long Island Sound (~55%) and Casco Bay (40%). Differences in land use and population size also have a substantial impact on the relative effectiveness of the reduction scenarios. Of all scenarios considered, an integrated management plan that includes nitrogen controls on both air and water sources achieves the maximum reductions, reducing reactive nitrogen loading to Long Island Sound by 60% and Casco Bay by ~45%.

ATMOSPHERIC EMISSION REDUCTION SCENARIOS (HBEF and BBW): Controls on NO_x emissions from transportation and power generation produce the largest reductions in airborne nitrogen pollution to the two watersheds analyzed in the study. The model shows that emissions reductions called for in the 1990 Clean Air Act Amendments (CAAA) will not reduce nitrogen deposition below a target level of 8 kg per hectare per year at either site, and they will be insufficient to mitigate elevated nitrogen runoff or acid rain effects. Additional reductions in emissions (~30%) would reduce nitrogen runoff to less harmful levels. When additional nitrogen emission reductions and a simultaneous 75% cut in SO_2 emissions from electric utilities beyond the 1990 CAAAs are considered, it is predicted that by 2050 HBEF would experience marked improvement in soil conditions and water quality and BBW would achieve nearly full chemical recovery.

PROJECT IMPLICATIONS

Reactive nitrogen originates from numerous sources and has a complex relationship with other pollutants. It therefore requires integrated management strategies and policies addressing multiple rather than individual sources. It is important to note that there is currently no water quality standard that limits the total loading of reactive nitrogen to surface waters and no air quality standard for ammonia. Moreover, since the CAAA did not cap total NO_x emissions from electrical utilities, it is possible that emissions will actually increase in the future as energy generation increases.

This project's assessment of nitrogen pollution in the region shows that the current CAAA has not had a substantial effect on airborne nitrogen emissions. Together with efforts to reduce SO_2, CO_2, and other pollutants, nitrogen in the Northeast can be further decreased through a number of strategies: reducing power-plant nitrogen emissions, improving wastewater treatment to remove nitrogen from effluent, reducing the use and increasing the efficiency of nitrogen fertilizers, and creating and restoring natural nitrogen sinks in wetlands and floodplains. A number of innovative nutrient management projects currently being implemented on farms throughout the region provide hopeful examples.

Wastewater treatment is an effective means of reducing nitrogen loading. Wards Island wastewater treatment system

Modeling results offer insight into the relationship between different emissions reduction scenarios and ecosystem recovery. Appraisal of the rate of recovery of different Northeast ecosystems under a variety of policy scenarios indicates that:

- Controls on vehicle and electric utility NO_x emissions produce the largest reductions in airborne nitrogen pollution.
- Nitrogen removal from wastewater at a basin-wide scale is the single most effective means of reducing nitrogen loading to estuaries in the Northeast.

PROJECT UPDATE

August 2005

New York State Energy Research and Development Authority

Environmental Monitoring, Evaluation, and Protection Program

An Assessment of Recovery and Key Processes Affecting the Response of Surface Waters to Reduced Levels of Acid Precipitation in the Adirondack and Catskill Mountains

Principal Researchers

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Project Location

Adirondack and Catskill Mountain regions outlined.

Contact Information

For more information on this project see:

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

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Keywords

- Acidification
- Nitrogen cycling
- PnET-BGC Model
- Sugar maple
- Surface water chemistry

PROJECT FOCUS

While previous studies have documented local effects of acidic deposition in New York, thus far there has been no comprehensive effort to synthesize data and compare results across broader geographical regions in the state. This project provides the first in-depth assessment of the extent to which recovery from acidification is occurring in the Catskills and Adirondacks, two regions of New York State that are especially sensitive to the effects of acidic deposition. The goals of this study were to:

- Assess trends in key indicators of acidification in precipitation and surface-water chemistry at several intensively monitored sites in the Adirondack and Catskill regions;
- Examine the role of tree species in nitrogen cycling; and
- Model the effects on regional water chemistry of several possible future acid deposition scenarios.

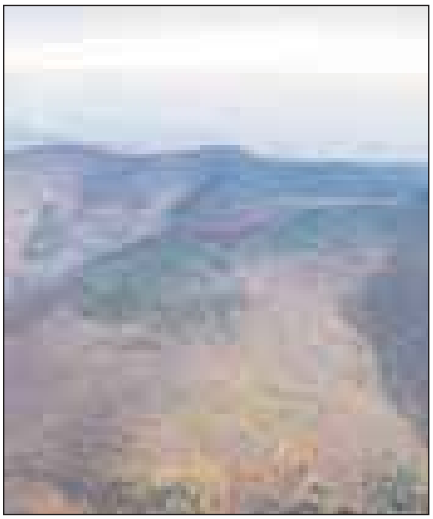
CONTEXT

Fossil-fuel combustion sources are major emitters of sulfur dioxide (SO_2) and nitrogen oxides (NO_x), which, through complex reactions in the atmosphere, form nitric and sulfuric acids. As a result, sulfate (SO_4^{2-}) and nitrate (NO_3^-) are deposited on land and in water, contributing to the acidification of lakes and streams.

Credit: USGS
Biscuit Brook, looking upstream.

In both the Adirondack and Catskill regions of New York, surface-water acidification has had deleterious effects on aquatic and terrestrial biota; a decline in habitat has resulted in a decline in acid-sensitive species. To address this problem, several chemical criteria were used to identify the degree to which surface water is acidified and poses a danger to aquatic biota. Biota are at risk when water pH is less than 5.5, acid-neutralizing capacity (ANC) is less than 50 microequivalents per liter (μeq/L), and/or concentrations of toxic inorganic aluminum (Al) are greater than 2 micromoles per liter (μmol/L).

METHODOLOGY



Credit: USGS
The Winisook watershed in the Catskill Mountains where recovery from acidification is being studied.

Trends in precipitation chemistry were evaluated for 1984-2001 using data from six sites that are part of the National Acid Deposition Program (NADP) and are located close to the Adirondack and Catskill regions. Dry deposition, the other main component of acidic deposition, was not evaluated in this study. Trends in surface water chemistry were analyzed for five Catskill streams and 12 Adirondack lakes using data from 1992-2001, the minimum length of record that includes all study sites. In addition, soil chemistry and vegetation data were compiled from stands of differing tree species composition in the Catskills and Adirondacks to determine how the dynamics of tree species modify the effects of nitric acid from precipitation and the nitrogen cycle in forested ecosystems. Finally, the PnET-BGC model was used to simulate the important processes that affect the acid-base chemistry of four Adirondack lakes and one Catskill stream. The model was also used to predict surface water chemistry under three different future acid deposition scenarios.

PROJECT UPDATE

August 2005

Credit: USGS
The Arbutus watershed in the Adirondacks is an intensive research site at which nitrogen cycling and retention will be estimated.

Project Status

- Initiated 2001
- Completed 2005

New York Energy Smart℠
Public Service Commission — NYSERDA
George E. Pataki, Governor

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

Trends in Precipitation Chemistry

Precipitation pH has increased an average of about 0.02 units in the Adirondacks and Catskills from 1984 to 2001; three-fourths of this increase has resulted from decreases in SO_4^{2-} concentrations and about one-fourth from decreases in NO_3^- concentrations. These changes are paralleled by, and are assumed to result from, similar decreases in sulfur (S) and nitrogen oxide (NO_x) emissions largely from power plants in the predominant source region of acidic precipitation to the State.

Trends in Surface Water Chemistry

During 1992 to 2001, sulfate (SO_4^{2-}) concentrations decreased significantly at every surface water site by an average of 3.3 μeq L^{-1} yr^{-1} in Adirondack lakes and 2.5 eq L^{-1} yr^{-1} in Catskill streams. These decreases in SO_4^{2-} concentrations in surface waters were highly synchronous among surface waters and in surface water–precipitation comparisons, which demonstrates the tight link between atmospheric deposition and the sulfur cycle in these watersheds. Nitrate (NO_3^-) showed significant decreasing trends at most surface-water sites, however, the decreases were generally three- to ten-fold less than those of SO_4^{2-}. The trends in NO_3^- were generally not synchronous across the two regions or within the Adirondacks, a result of the numerous factors other than atmospheric N deposition including sugar maple that affect the N cycle and surface water NO_3^- concentrations. Other factors that affect the N cycle include land-use history, long-term climate variability, and short-term climate disturbances such as soil freezing, wind storms, ice storms, and floods, insects and pathogens, and aquatic processes.

Overall, H^+ concentrations decreased significantly at about 60% of surface water sites. ANC increased significantly at about 50% of surface-water sites, and these increases averaged 14 μeq L^{-1} in 7 of the 12 Adirondack lakes with significant trends, and 5 μeq L^{-1} in 1 of the 5 Catskill streams with significant trends during 1992-2001. Inorganic monomeric aluminum, a metal that is toxic to many acid-sensitive species, also decreased at most surface-water sites during 1992-2001. The trends in base cation concentrations (C_B), ANC, and H^+ were not generally synchronous in surface waters within and among these regions, nor in precipitation–surface water comparisons. Thus, the myriad complexities that affect the cycles of N and C_B partially mask the otherwise strong relation between precipitation and surface-water SO_4^{2-} concentrations, an indication that trends in acid-base chemistry (ANC and H^+) respond in part to factors such as climate variation that are independent of the acidity of precipitation.

The Role of Sugar Maple in the Nitrogen Cycle

In sugar maple stands, rates of nitrification and nitrate leaching are higher than in those of other common hardwood and softwood species. A number of factors may account for this phenomenon, including the rate at which leaf litter decomposes in the soil and soil chemistry in the stands. Although sugar maple is the most dominant species in northern hardwood forests of New York, conditions such as beech bark disease, climate change, soil calcium depletion, and pest infestations may affect the future abundance of sugar maple and consequently nitrogen cycling and ANC trends in these regions. Thus, future trends in nitrate concentrations in surface waters may depend on changes in tree species composition, which are determined by multiple environmental factors.

Model Simulations

The PnET-BGC model results indicate that the 1990 Clean Air Act Amendments (CAAA) will result in little additional change in surface water ANC in these two regions, but that a future scenario in which sulfur dioxide (SO_2) emissions were reduced by 50% and NO_x emissions by 30% would increase surface-water ANC by an average of 24 μeq L^{-1} from 2001 to 2050 in the 5 water bodies that were modeled. These changes were sufficient to increase ANC to > 0 μeq L^{-1}, a critical value for many surface-water biota, in the most acidic of the surface waters that were modeled.

PROJECT IMPLICATIONS

With implementation of the Clean Air Act Amendments of 1990, it was expected that increases in precipitation pH would result in increases in pH and ANC in sensitive surface waters and decreases in sulfate (SO_4^{2-}), nitrate (NO_3^-), and aluminum (Al) concentrations. This would allow the recovery of species diversity in biota affected by surface-water acidification during the 20th century. Adequate data on surface-water chemistry are now available to evaluate whether these intentions are being realized. However, the accuracy of future trend analyses for flow-sensitive criteria such as NO_3^- concentrations and ANC would be strengthened by the availability of more streamflow data at the outlets of Adirondack lakes.

The results of this study indicate that surface waters are slowly recovering due to reduced levels of acid precipitation, but that additional recovery may require reductions in SO_2 and NO_x emissions greater than are mandated under the 1990 CAAA. Although reduced SO_4^{2-} concentrations in precipitation are the major cause of increased ANC and pH and decreased Al concentrations in sensitive surface waters in New York, future changes in climate and ecosystem disturbance that may affect the cycling rates of N, DOC, and C_B should be closely monitored over multi-year periods because these constituents also affect pH and ANC, and have the potential to negate recovery due to decreased SO_4^{2-} concentrations in precipitation and surface waters. A quantitative understanding of the factors other than acid precipitation that may affect surface-water pH and ANC is necessary to separate the effects of clean air laws and atmospheric deposition from natural variability and disturbance.

PROJECT UPDATE

August 2005

New York State Energy Research and Development Authority

Environmental Monitoring, Evaluation, and Protection Program

NYSERDA

Contributions of Global and Regional Sources to Mercury Deposition in New York State

Principal Researcher

CHRISTIAN SEIGNEUR
Atmospheric & Environmental Research, Inc.

Project Location

Adirondack and Catskill regions outlined

Contact Information

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Keywords

- Dry deposition
- Gaseous divalent mercury (Hg [II])
- Gaseous elemental mercury (Hg [0])
- Long-range transport
- Particulate divalent mercury (Hg [p])
- Wet deposition

PROJECT FOCUS

The development of effective emission control strategies requires a rigorous assessment of the relative importance of local, regional, continental, and global sources of Hg deposition. However, since significant uncertainties remain in our understanding of the fate and transport of Hg in the environment, the attribution of Hg deposition to various sources must be qualified by any associated uncertainties. This project responded to these needs by:

Atmospheric Fate and Transport of Mercury Species

- Assessing the contributions of local, regional, and global mercury sources to mercury deposition in New York State (NYS), and
- Identifying critical gaps in the data required to further refine these estimates.

CONTEXT

Mercury, a naturally occurring inorganic element, 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, in particular, coal-burning electrical utilities, municipal waste combustors, commercial and industrial boilers, medical waste incinerators, chlor-alkali plants, hazardous waste combustors, lamp breakage activities, mining, and cement manufacture. Recent inventories indicate that ~150 tons of mercury are emitted from U.S. anthropogenic sources each year. The mercury transported through the air is deposited in water and on land, where humans and wildlife may be exposed to it as methylmercury. Since it accumulates in exposed aquatic organisms such as fish (bioaccumulation), mercury also poses a danger to organisms higher up in the food chain that consume a large amount of fish (biomagnification). When its concentrations reach high enough levels, mercury can act as a neurotoxin, impairing neurological development in fetuses and young children, and damaging the central nervous system of adults. Owing to the possible dangers posed by mercury contamination, 45 states have issued fish consumption advisories.

Mercury is present in the atmosphere in different forms with various lifetimes: as gaseous elemental mercury (Hg[0]), gaseous divalent mercury (Hg[II]), and particulate divalent mercury (Hg[p]). Hg(0) remains in the atmosphere for a few weeks, whereas Hg(II) and Hg(p) tend to be removed much more rapidly, with lifetimes on the order of a day and a week, respectively. The potential effects of atmospheric Hg emissions may range from the local impacts of species with shorter lifetimes, caused by the wet/dry deposition of Hg(II) and the wet deposition of Hg(p), to the regional and global impacts of species with longer lifetimes, caused by the long-range transport of Hg(0) and, under dry conditions, Hg(p). Conversion between the forms of mercury occurs in the atmosphere, particularly in the presence of clouds. The potential range of impacts of atmospheric mercury emissions thus depends on the Hg species involved, meteorological processes (e.g., wind and precipitation), and chemical transformations.

METHODOLOGY

A model was used to simulate the transport, transformation, and deposition of mercury. Three scenarios were considered: (1) a nominal or baseline scenario, (2) a scenario conducive to local deposition, and (3) a scenario conducive to long-range transport. The source areas considered were NYS; the continental United States (U.S.) not including NYS; Canada; Mexico; Europe; Asia; South America; Africa; Oceania; and natural sources. Scenarios 2 and 3 were designed to provide plausible Hg concentrations and deposition rates

compared to observations, thereby reflecting the sensitivity of the model to some changes in inputs. The wet and dry deposition rates of mercury were analyzed at three locations in NYS identified as potentially sensitive areas: the Adirondack Mountains, the Finger Lakes District, and the Catskill Mountains.

Further analysis assessed the major sources of uncertainty in model predictions of Hg deposition in NYS watersheds and bioaccumulation in the aquatic food chain. As part of this effort, existing databases were reviewed for atmospheric Hg concentrations and deposition, Hg concentrations in fish, and lake-watershed data.

RECENT FINDINGS

In all scenarios, U.S. emissions (non-NYS) were the largest source of total Hg deposition at all three sites in NYS. Overall, results from scenarios 2 and 3 (local deposition and long-range transport) vary only slightly from those of the baseline scenario.

BASELINE SCENARIO: U.S. emissions were the largest source of total Hg deposition at all three sites. Dry deposition: Dominated at all sites by NYS and U.S. emissions. Wet deposition: Much greater contribution from sources outside North America.

LOCAL DEPOSITION SCENARIO: An increase in contributions from U.S. and NYS sources to total deposition compared to baseline scenario. U.S. sources contributed the most, while NYS, Asian, and natural emissions constituted most of the remaining portion. Dry deposition: The impact of NYS and U.S. sources increased, while the impact of natural sources decreased. Wet deposition: The impact of NYS, U.S., and Canadian emissions generally increased, while that of the other emission sources decreased.

LONG-RANGE TRANSPORT SCENARIO: U.S. emissions were the largest source of total deposition at the NYS sites. Canadian and NYS contributions to total deposition decreased compared to baseline scenario, while the impact of sources outside North America increased. Dry deposition: Again dominated by NYS and U.S. emissions, though NYS impact decreased. Wet deposition: Continued to be more affected by sources outside North America.

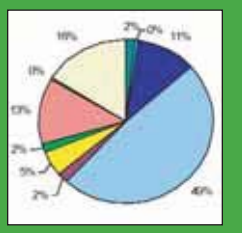
UNCERTAINTIES AND DATA GAPS: Model performance was evaluated by comparing results to actual measurements of ambient Hg species concentrations and wet deposition rates. The comparison suggested that the model captures most of the processes that govern the atmospheric fate and transport of Hg. However, the results of source attribution must be seen as preliminary, as uncertainties remain in our understanding of the atmospheric fate and transport of mercury. Major sources of uncertainty include emissions (including Hg species), the dry deposition of Hg(II), and, for lake mercury cycling models, the sediment burial rate. Knowledge of atmospheric Hg chemistry is still incomplete; laboratory experiments are needed to identify and characterize the most important reactions. Finally, there is a great need for Hg measurements with which to evaluate the models, including ambient atmospheric concentrations of Hg(0), Hg(II), and Hg(p), and wet and dry deposition rates of mercury.

PROJECT IMPLICATIONS

An important concern in the case of mercury is how controls operating in one particular geographical area - e.g., in a specific state, region, or in the country as a whole - would affect mercury deposition in another area, such as NYS. To this end, it is vital to identify the major contributing sources of mercury deposition in a given area and to determine what regulatory regimes would operate most effectively in reducing mercury deposition on the regional, national, and international levels. Despite remaining uncertainties, this analysis represented the state of the science three years ago with regard to our understanding of the fate and transport of mercury. As such, it provided a useful indication of the relative contributions of local, regional, and global sources to Hg deposition in NYS. Recent developments in our understanding of the atmospheric fate and transport suggest that the results obtained in this study provide an upper limit to the contribution of local sources to mercury deposition in NYS. This information will be essential in evaluating the different policy proposals currently under discussion and in gauging the effectiveness of regulations implemented in the future. Policy options under discussion at the state and federal levels include mercury emissions trading, standards and caps, and greater enforcement of existing regulations. Currently, coal-fired power plants in the U.S., which are responsible for ~40% of U.S. industrial emissions, are the largest unregulated source of mercury emissions. In the absence of regulations and/or better control technologies, mercury emissions from coal-fired power plants are expected to increase as the demand for energy production and coal combustion increase.

Regional & Global Contributions to Total Hg Deposition at Three NYS Sites
(Baseline Senario)

Adirondacks



Catskills

Finger Lakes

Key

Project Status

- Initiated 2001
- Completed 2002

New York Energy Smart℠
PUB

George E. Pataki, Governor

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PROJECT UPDATE

August 2005

New York State Energy Research and Development Authority

Environmental Monitoring, Evaluation, and Protection Program

Effects of Atmospheric Deposition of Sulfur, Nitrogen, and Mercury on Adirondack Ecosystems

Principal Researchers

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Project Location

Adirondack region outlined.

Contact Information

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Keywords

- Fish species richness
- Nitrogen fixation
- Riparian vegetation
- Speckled alder (Alnus rugosa)
- Wetlands

PROJECT FOCUS

This project was designed to clarify the causes and long-term effects of acidic deposition in the Adirondacks and investigate the factors that have slowed the recovery of Adirondack Lakes from acidification. It also addressed mercury (Hg) pollution by assessing historical and current rates of Hg deposition and fish species richness in lakes and streams in the region.

The evaluation of ecosystem response to future reductions in atmospheric deposition involves a number of factors that need to be better understood. Especially important are the biogeochemical links between vegetation and surface water chemistry. The composition of wetland vegetation affects nitrogen (N) concentrations in soil and surface waters and contributes to the diverse responses of Adirondack ecosystems. The project specifically aimed to further the analysis of temporal and spatial patterns in the chemistry of major solutes in Adirondack waters, including the role of dissolved organic nitrogen (DON), and to estimate the abundance of speckled alder (Alnus rugosa) and its N contribution to wetlands. In addition, time-series analyses, mass-balance estimates, and modeling were undertaken using available data.

CONTEXT

The Adirondack region of New York State, located directly downwind of major coal-burning sources in the Midwest, receives elevated levels of atmospheric sulfur (S), nitrogen, and mercury, which has resulted in the acidification of waters and increased uptake of Hg in fish. As a result, this region has been a focal point for numerous research efforts designed to identify the processes involved in these effects, and contribute information needed for analyzing impacts of current and potential regulations on environmental recovery.

Ongoing measurements show that the wet deposition of sulfate (SO_4^{2-}) to the Adirondacks has decreased over the past two decades, as expected from reductions in sulfur dioxide (SO_2) emissions mandated by the Clean Air Act (CAA) and its 1990 Amendments (CAAAs). In contrast, there has been little change in the wet deposition of nitrate (NO_{3-}) or ammonium (NH_{4+}) over the monitoring period, consistent with the limited changes in NO_x and NH_3 emissions from polluting sources. To date, researchers have found that despite reduced sulfate deposition, surface waters in the Adirondacks have shown limited recovery from acidification. Additional reductions in emissions and deposition, as well as a timeframe of several decades, may be necessary for the recovery of the more sensitive of these waters. However, the emission reduction levels that would be needed and resulting impacts on recovery are as yet unknown.

METHODOLOGY

Time series of precipitation and lake chemistry were analyzed and mass balance estimates (lake input and output) were made, using data obtained from the Adirondack Lakes Survey Corporation and other sources. The project also addressed the:

- Role of DON in Adirondack watersheds, including the relationships between DON and other solutes, especially dissolved organic carbon (DOC).
- Distribution and abundance of speckled alder, its retention of atmospheric N ("nitrogen fixation"), and its N contribution to Adirondack wetlands. Using data gathered at a number of sites, the range of N fixation, its resulting input of nitrogen to alder wetlands, and alder-related N inputs at the regional watershed scale were estimated.
- Current and historical rates of Hg deposition in Adirondack lakes. Sediment cores were collected from eight lakes and analyzed to determine Hg concentrations over time. Current levels were analyzed through a new monitoring station established at Huntington Forest.
- Recovery of fish species in response to changes in atmospheric deposition, assessed in the North Branch of the Moose River (NBMR). Comprehensive surveys were conducted on 16 lakes and 11 streams within the NBMR watershed in 2000 and compared with the results of earlier studies.

Modeling (PnET-BGC) of several representative sites in the Adirondacks and Catskills simulated the response of surface waters to deposition. The model also evaluated the response of five forest ecosystems to changes in atmospheric deposition and land disturbances and predicted the ecosystem responses to three emission control scenarios.

PROJECT UPDATE

August 2005

Credit: Mark Watson

Dr. Raynal inspects the nitrogen-fixing root nodules of speckled alder.

Project Status

- Initiated 2000
- Completed 2004

New York Energy Smart℠ PUB

George E. Pataki, Governor

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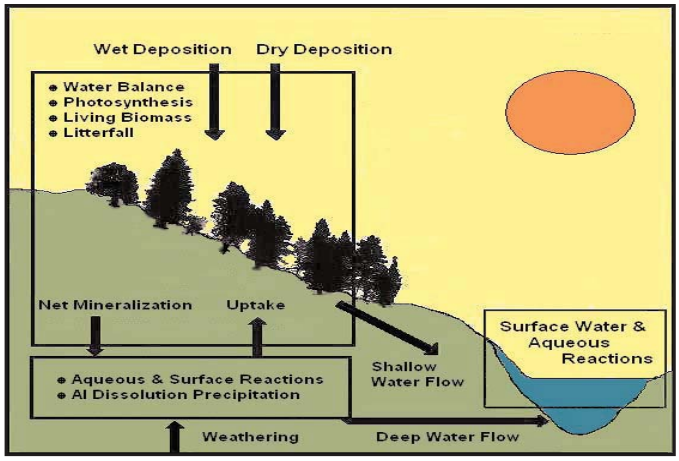


The PnET-BGC model simulates the response of surface waters to deposition, evaluates the response of ecosystems to changes in deposition, and predicts ecosystem responses to emission control scenarios.

PROJECT FINDINGS

Acidification. Acidic deposition over 150 years has resulted in the acidification of soil and water in the Adirondack region. Some chemical recovery has taken place in the last 30 years, as a result of mandated emission reductions. However, projections suggest that under current deposition patterns, lakes either will continue to acidify or will recover at a very modest rate. Model predictions suggest that additional reductions in SO_2 and NO_x emissions will boost the recovery rate, but also that the period of chemical recovery will be decades.

Mass balance estimates. Spatial patterns in N deposition and landscape features (e.g., presence of wetlands and water flow paths) all play a role in N retention and drainage loss.

DON. Mean annual concentrations and fluxes of DON were strongly related to the concentrations and fluxes of DOC. DON and DOC concentrations and fluxes were higher at lake watersheds with larger wetland areas.

Speckled Alder. Speckled alder fixes substantial quantities of N along the lake inlets. Wetlands with abundant alder had 6 times higher nitrate accumulation than reference wetlands without alder. Surface waters in alder-dominated wetlands contained approximately 3 times more nitrate than non-alder counterparts. In specific alder-dominated wetlands, nitrogen addition from alder exceeds atmospheric deposition by as much as 3 times.

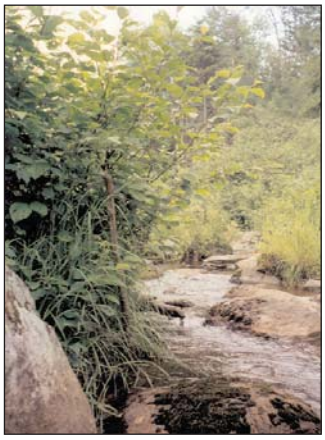
Hg Deposition. Analyses showed marked increases in sediment Hg deposition, beginning in the 19th Century. Sediment Hg deposition generally peaked during the period 1973–1995, with rates that were on average 5.8 times greater than pre–Industrial Revolution values. In the last 20 years, the region experienced a decrease in Hg deposition of approximately 33%.

Fish Species Richness. Comparisons with earlier studies show that declines in species richness have stabilized and the trend may be reversing. Future surveys could ascertain whether there is a pattern of biological recovery following decreases in acidic deposition and improvements in water chemistry.

Modeling. Atmospheric deposition was the dominant source of acidity (>90%), while mineral weathering was the major source of improved acid neutralizing capacity for all the sites. Simulations indicated that these ecosystems would show little recovery after 2010 under the 1990 Clean Air Act Amendments.

PROJECT IMPLICATIONS

While there have been improvements in the water chemistry of many Adirondack lakes, the rate of improvement remains relatively low. Declines in sulfate deposition, coupled with steady nitrate deposition and concentrations, suggest that NO_x emissions have come to play a more important role in determining precipitation acidity and its effects. Project findings highlight the importance of several factors that affect aquatic N concentrations, such as the biogeochemical attributes of the watershed and landscape, including the presence of alder-dominated wetlands. The effectiveness of measures to reduce N emissions and deposition will depend on these factors. The project confirms the need for additional controls, beyond the current provisions of CAA, on emissions and deposition to improve the rate of recovery of Adirondack ecosystems. Currently, no caps are placed on NO_x emissions, which could increase considerably as population size and the demand for transportation and electricity grow. With regard to mercury, understanding long-term and recent changes in deposition is particularly critical in interpreting future changes in deposition in relation to long-term Hg patterns in the region.



Credit: Mark Watson

Deer Lake Inlet, Huntington Forest Speckled alder in the foreground.

PROJECT UPDATE

August 2005

New York State Energy Research and Development Authority

Environmental Monitoring, Evaluation, and Protection Program

Evaluation of the Recovery from Acidification of Adirondack Ecosystems

Principal Researcher

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Project Location

Adirondack region outlined

Contact Information

For more information on this project see:
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Keywords

- Acid neutralizing capacity (ANC)
- Dissolved organic nitrogen (DON)
- Nitrate (NO_3)
- Sulfate (SO_4^{2-})
- Watershed

PROJECT FOCUS

This "synthesis" project focused on the integration and analysis of long-term data related to surface water chemistry and atmospheric deposition at the Arbutus Lake watershed (AW) in Huntington Forest (HF), located in the center of the Adirondack region. Its primary objective was to evaluate the relationship between changes in the amount of nitrogen (N) and sulfur (S) exported from AW (i.e., drainage losses) and changes in climate and atmospheric deposition. A further goal of the study was to investigate causes of the substantial differences in soil and surface water chemistry in subcatchments of AW, especially with respect to nitrate and calcium.

SUNY ESF students prepare to conduct field work at the Arbutus Lake inlet

Investigations at AW have played a critical role in national and international efforts to evaluate the impact of air pollutants on ecosystem health. Over the past two decades, HF has been the site of a large number of studies on forest ecosystems. It is the only site in the Adirondacks that has the history, instrumentation, and background necessary for comprehensive analyses of atmospheric, chemical, hydrological, and biotic components.

CONTEXT

Combustion processes are major contributors to atmospheric sulfur dioxide (SO_2) and nitrogen oxide (NO_x) pollution. These compounds are chemical precursors of other forms of sulfur and nitrogen, such as sulfate (SO_4^{2-}) and nitrate (NO_3^-) ions, which may ultimately be deposited in bodies of water as strong acids, contributing to their acidification. The Adirondack region of New York State, located directly downwind of major coal-burning sources in the Midwest, is subject to elevated levels of S and N deposition and may be the region most sensitive to acidification in North America, partly owing to its geological and soil characteristics. As a result, the region has been the focus of numerous research efforts designed to identify the processes involved in acidification and its effects on surface waters, and to evaluate the effectiveness of emissions controls.

Recent research has shown marked decreases in sulfate concentrations in Adirondack lakes, following decreases in atmospheric emissions and deposition of S in the region over the last 20 years. While atmospheric N deposition has not changed over the same period, nitrate concentrations have also decreased in many of the same lakes. The possible causes of this decrease, which indicates a retention of N in the lake watershed, are not evident. In the waters of the region, these marked decreases in sulfate and nitrate concentrations have resulted in increases in pH. Nevertheless, the recovery of surface waters from acidification has been limited. At current rates of decrease in acidic deposition, however, the timeframe of chemical recovery at these lakes will still be several decades.

METHODOLOGY

This project included interpretation and analyses of data on wet and dry deposition, weather, water chemistry and discharge at the AW inlet and outlet, and biogeochemical attributes of lake subcatchments. Wet and dry deposition data on N and S were compiled by evaluating previously collected data. The project continued baseline monitoring at the inlet and outlet of Arbutus Lake. Throughfall (dry litter), soil water, groundwater, and stream parameters were measured weekly during the snow-free season (May–August) and monthly during the winter season (September–April) for two subcatchments. Temporal trends in air chemistry, dry deposition, wet deposition, and surface water chemistry were evaluated.

In total, the range of biogeochemical information available at HF/AW includes the influences of atmospheric inputs, vegetation effects, soil water, ground water, and wetlands on the chemistry of surface waters, including both spatial and temporal patterns. Through a synthesis of these data, the biogeochemical response of AW to atmospheric pollutants was analyzed. Using the comprehensive database developed, a model was used to predict patterns in the water chemistry.

PROJECT UPDATE

August 2005

Arbutus Lake

The sugar maple: an important indicator species.

Project Status

- Initiated 1999
- Project ongoing

New York Energy Smart℠ PUB

George E. Pataki, Governor

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RECENT FINDINGS

SULFUR: Sulfate concentrations in lake discharge markedly decreased in the 1990s, reflecting declining patterns in both wet and dry S deposition. Despite decreases in atmospheric deposition and hydrologic losses, sulfate was still the dominant negatively charged ion in drainage water, and therefore a cause of declines in concentrations of positively charged ions. Declining surface water concentrations of base positively charged ions will have a great impact on future trends in surface water recovery from acidification. In addition, watershed S loss was found to greatly exceed the total S input. This discrepancy could be attributed to internal soil processes, e.g., mineral weathering, desorption, and mineralization of organic S. Results indicate that organic S export could represent another important pathway of S loss from the internal S cycling through soil organic pools.

NITROGEN: In contrast to the case of sulfates, no long-term trend in nitrate concentrations in lake discharge was found in the 1990s. However, nitrate concentrations were found to be correlated to interannual changes in air temperature (1983–2001). The strong relationship between air temperature and watershed nitrate loss (January–March) suggests that snowmelt responses to winter temperature fluctuations play a critical role in nitrate loss variability in different years. The contrasting seasonal patterns that were observed might be explained by the high biological demand for nitrate and the microbial production of dissolved organic nitrogen (DON) during warm summer months. The close relationship observed between temperature and nitrate/DON loss suggests that the biotic and hydrological processes affecting N loss may be especially sensitive to changes in climate, as well as to changes in atmospheric N deposition. This response of watershed N to variations in climate and atmospheric deposition may determine the long-term patterns of N loss from the watershed.

The inclusion of both dry deposition and organic N substantially elevates estimates of N retention in AW. This result, along with very low summer NO_3^- concentrations in drainage water, suggests that there is a strong biological retention of both organic and inorganic N in this watershed. In addition, the lowest NO_3^- concentrations have been found in subcatchments with the highest proportion of wetlands, suggesting the importance of wetlands as sites of denitrification.

FOREST SPECIES COMPOSITION: Results show that species composition is a critical factor in forest nutrient dynamics, especially with respect to the processing of N. Thus, factors that change the forest community (e.g., pests; climate change) could have a dramatic impact on how the Adirondacks respond to atmospheric pollutant deposition. The influence of species composition has been shown clearly in a study of subcatchments within the Arbutus Watershed. A subcatchment with a large component of sugar maple and white ash (species that show high rates of nitrogen mineralization and nitrification) exhibited greater losses of nitrate than other subcatchments. While American beech and sugar maple were the predominant species in terms of biomass, red maple was the only species to increase in biomass. However, total aboveground biomass decreased during the period, while annual litter production remained constant.

MODELING RESULTS: Simulations of internal fluxes of major elements at AW compared well to previously published measured values. The measured and simulated S budget for the Arbutus watershed indicated little S retention and considerable temporal variability in N retention. Atmospheric deposition was found to be the largest source of acidity, while the exchange of positively charged ions, mineral weathering, net mineralization, and in-lake processes all contributed to acid neutralizing capacity (ANC).

PROJECT IMPLICATIONS

The results of this project, which clearly indicate the effects of atmospheric deposition of S and N in the Adirondacks, are important in evaluating the effectiveness of the present regulatory regime, including the 1990 Clean Air Act Amendments (CAAAs). Although some recovery is evident, the Adirondack region continues to be at high risk from acidic deposition. Findings show that current regulations are likely inadequate to protect the most sensitive waters in the region from its effects. These results, and continued monitoring at HF/AW, will not only provide critical information for assessments of forest and aquatic resources in the region, but also prove useful in predicting and evaluating the impact of policy options and future legislation on Adirondack air and water quality. Importantly, this study also shows how the effects of changes in atmospheric pollutant concentrations need to be placed in the context of other environmental influences, such as changes in climate and forest biota, in order for us to understand the major factors influencing the environmental health of the Adirondacks.

PROJECT UPDATE

August 2005

New York State Energy Research and Development Authority

Environmental Monitoring, Evaluation, and Protection Program

NYSERDA

Mercury in Adirondack Wetlands, Lakes and Terrestrial Systems

Principal Researcher

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Tetra Tech, Inc.

CHARLES DRISCOLL
Department of Civil and Environmental Engineering, Syracuse University

Project Location

Adirondacks and Catskills outlined.

Contact Information

For more information on this project see:
www.nyserda.org/programs/environment/emep

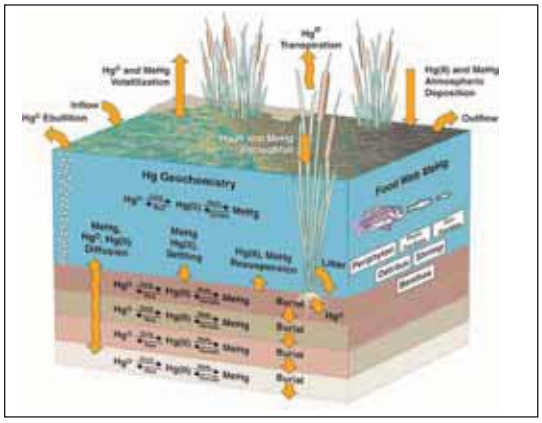
or contact Mark Watson at:
mw1@nyserda.org

Keywords

- Bioaccumulation
- Biomagnification
- Drainage lake
- Mercury cycling
- Methylmercury
- Watershed hydrology

PROJECT FOCUS

Few studies conducted to date have investigated mercury cycling in temperate drainage lake-watershed systems, which constitute 85% of Adirondack lakes. This project is the most comprehensive assessment to date of watershed mercury (Hg) cycling in the Northeast. Beginning with a full chemical and hydrological characterization of a representative lake-watershed system (Sunday Lake) and an analysis of mercury concentrations in fish, the project team has developed an integrated simulation model (MAWLTS) that accounts for terrestrial, wetland, and in-lake processes influencing mercury cycling and accumulation in fish tissue.



The geochemistry of mercury's interaction with the environment

CONTEXT

Mercury, a naturally occurring element, cycles in the environment as a result of both natural and human activities. Major anthropogenic sources of mercury emissions are the combustion of mercury-containing fuels or materials, such as coal, in the production of electricity and in industrial processes. Mercury is deposited in water and on land, where humans and wildlife may be exposed to it. As it accumulates in exposed organisms (bioaccumulation), mercury also poses a danger to organisms higher up in the food chain (biomagnification), even at low exposures. An issue of particular concern for human health is the accumulation of mercury in the form of highly toxic methylmercury (MeHg) in fish muscle tissue, which is then eaten (and accumulated) by human beings. When its concentrations reach high enough levels, MeHg acts as a neurotoxin, impairing neurological development in fetuses and young children and damaging the central nervous system of adults. In response to these pronounced dangers, 45 states have issued fish consumption advisories, and the U.S. Food and Drug Administration has established a federal action level for fish containing 1.0 micrograms of mercury per gram (i.e., 1.0 ppm) of wet weight. Fish with higher mercury concentrations are considered to be hazardous and are banned from interstate commerce.

The Adirondack region of New York State, which is "remote" from point sources of mercury, is considered to be an area of concern by the New York State Department of Environmental Conservation (NYSDEC), owing to elevated mercury levels found in fish. Atmospheric deposition is the major source of mercury to lake-watershed systems in the region. Mercury cycling in drainage lake-watershed systems involves the interactions of a variety of complex processes. Previous research has indicated that, in these systems, terrestrial and wetland processes play a vital role in determining aqueous chemical characteristics and fish tissue mercury concentrations. Several correlations have been found between mercury concentrations in fish and water-quality parameters, such as pH, dissolved organic carbon (DOC), and calcium. Particularly important for the Adirondacks region, which has been subject to acidification, is the relationship observed in surface waters worldwide between high mercury concentrations in fish and low aqueous pH. A relationship has also been found between increasing concentrations of DOC and percentage of wetlands in the drainage basin.

METHODOLOGY

The analysis of mercury in drainage lake-watershed systems included the hydrological and chemical characterization of Sunday Lake, to determine water inputs/outputs and flowpaths and to track mercury movement and transformations. Water samples were analyzed for total mercury, MeHg, major anions and cations, pH, ANC, DOC, dissolved inorganic carbon, and aluminum. mercury concentrations in litterfall and throughfall (dry deposition) and mercury concentrations in zooplankton (indicating mercury concentrations moving up the food chain) were also analyzed. As several mercury transformation rates are dependent on the concentrations of other aqueous constituents, pH, ANC, and various chemicals were measured.

Sunday Lake
Photograph by: Robert Newton

An integrated model (MAWLTS), calibrated based on the Sunday Lake data, was produced to simulate the terrestrial, wetland, and in-lake processes that influence the levels of Hg in fish tissue. The model integrates all available information into a single, coherent framework, which can be used to assess impacts of potential regulatory options on mercury behavior in drainage lake systems.

The project also included the following components:

Dr. Robert Newton of Smith College makes streamflow measurements in the outlet stream from Sunday Lake during high-flow conditions.
Photograph by: Ron Munson, Tetra Tech, Inc.

- Establishment of a mercury deposition monitoring station at Biscuit Brook in the Catskills. This station, part of the National Atmospheric Deposition Network/Mercury Deposition Network (NADP/MDN), will help broaden understanding of mercury deposition across NYS.
- Surveys of water and fish mercury concentrations in the Catskills to assist evaluation of high fish mercury concentrations in reservoirs that supply drinking water to New York City. Three regional surveys of mercury concentrations in water and sediment in the Neversink and adjacent watersheds, as well as a one-time sampling and analysis of fish for tissue mercuryg concentrations at ~20 locations in Catskills reservoirs, were conducted.
- A modeling study to evaluate the relative impacts of changes in acidic deposition versus changes in mercury deposition and fish mercury concentrations.

RECENT FINDINGS

- Calculations during the analysis of Sunday Lake indicated that dry deposition, which is not currently being measured, may be an important mercury input to the watershed.

Dr. Robert Newton of Smith College downloads hydrologic data from the outlet of Sunday Lake.
Photograph by: Ron Munson, Tetra Tech, Inc.

- Preliminary calibration of the model shows that simulated and observed values match well, except for a slight deviation during the summer. The model accurately simulates the dynamic range of total mercury concentrations, but the timing of the summer maximum concentration is slightly off. For MeHg, the simulated concentrations match the general pattern of observations, but the range of observed concentrations is slightly greater than the simulated range.
- Based on the preliminary calibration, a scenario analysis was conducted to determine the response of total and MeHg concentrations to a 50% reduction in atmospheric mercury deposition. The response is a nearly linear decline in fish mercury concentrations over the five-year simulation period.

PROJECT IMPLICATIONS

Models such as MAWLTS, verified through data from environmental monitoring, are a vital tool for policymakers in assessing the processes and timescales of effects on fish mercury concentrations of changes in emission, deposition, water chemistry, and watershed hydrology. Since studies have indicated a relationship between decreased pH levels in lakes and elevated mercury concentrations in fish, a prevailing regulatory question facing federal and state policymakers is how decreased sulfur and nitrogen emissions, which would reduce acidification, would impact fish mercury concentrations, in comparison with direct decreases in mercury emissions. The MAWLTS model will be used to conduct a rigorous scenario/sensitivity analysis to provide answers to such questions.

Further analyses through this project will contribute to the development of regulations for mercury and related pollutants that adequately protect human health and the environment. Mercury-related health advisories issued by the NYS Department of Environmental Conservation for all lakes in the Adirondacks reflect the additional negative economic impact of elevated mercury concentrations in fish, which affects recreational fishing and tourism in the region. The optimal effectiveness of the regulatory regimes developed at the state and federal levels for the Adirondacks will require better knowledge of mercury cycling and accumulation in drainage lake systems.

Project Status

- Initiated 1999
- Project ongoing

New York Energy Smart℠
PUB

George E. Pataki, Governor

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, and 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 UPDATE

February 2006

New York State Energy Research and Development Authority

Environmental Monitoring, Evaluation, and Protection Program

Long-Term Monitoring Program for Evaluating Changes in Water Quality in Adirondack Lakes

Principal Researcher

KAREN M. ROY

Adirondack Lakes Survey Corporation, New York State Department of Environmental Conservation

Project Location

Adirondack region outlined

Contact Information

For more information on this project see:
www.adirondacklakessurvey.org
and
www.nyserda.org/programs/environment/emep

or contact Mark Watson at:
mw1@nyserda.org

Keywords

- Acid deposition
- Acid neutralizing capacity (ANC)
- Episodic acidification
- pH
- Toxic aluminum

PROJECT FOCUS

The primary focus of this Adirondack Lakes Survey Corporation (ALSC) program is to collect and analyze the spatial and temporal data needed for assessing seasonal and long-term patterns in the chemistry of representative Adirondack waters, and to provide data and findings for the research and policy communities. The ongoing assessment identifies changes in water chemistry over time, allowing the evaluation of future emission or deposition changes, thus providing reliable information for decisions relating to pollutant control measures. The main program objectives are to determine long-term trends and to evaluate episodic acidification for its potential impact on aquatic biota.

CONTEXT

Fossil-fuel combustion sources are major emitters of sulfur dioxide (SO_2) and nitrogen oxides (NO_X), chemical precursors of acidic deposition (acid rain). The Adirondack mountain ecosystem of New York State, located downwind of Midwestern coalburning power plants, is one of the regions most sensitive to acidification in North America, partly owing to its geological and soil characteristics. As a result, this region is a focal point for numerous research efforts designed to identify the processes involved in acidification and its effects on aquatic resources, and to evaluate the effectiveness of emissions controls.

In 1982, researchers at Syracuse University and others began monthly sampling of 17 lakes in the western Adirondacks. In 1984, the ALSC was established to determine the extent and magnitude of surface water acidification in the entire Adirondack region. The ALSC found that deposition-related acidification was occurring throughout the region. In 1992, following the enactment of the 1990 Clean Air Act Amendments, which directly addressed the issue of acidic deposition, the ALSC extended a long-term monitoring (LTM) project for evaluating changes in water chemistry in 52 representative waters in the region. In 1998, funding for this program was provided by the **New York Energy $mart**SM Program. A primary goal of the project is to assess the effectiveness of the 1990 legislation, which mandated significant reductions in emissions of SO_2 and NO_X.

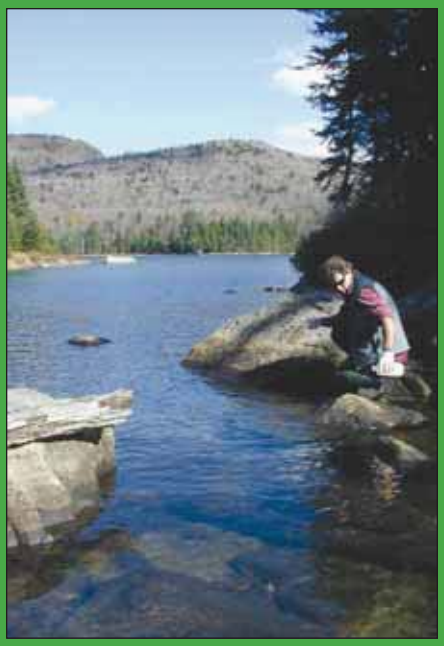
There are several critical chemical criteria that coincide with damage to aquatic biota. Biota are at risk from surface water acidification when surface water pH is less than 6.0, acid neutralizing capacity (ANC) is less than 50 meq/L, or concentrations of toxic inorganic aluminum are greater than 2 mmol/L. These are called biologically relevant indicators and are the first level of data necessary for understanding and restoring aquatic ecosystem structure and function.

METHODOLOGY

Researchers collect and analyze water samples from 52 lakes (monthly) and from three streams (weekly) located in the Adirondack Park. These lakes, chosen from among 1,469 lakes surveyed in the mid-1980's, have been sampled monthly since 1992. Seventeen of these lakes have a continuous monthly data record dating from June 1982. In twelve ALTM lakes, more intensive weekly sampling is conducted during the critical spring snowmelt when acidification conditions are most severe. Lake samples are analyzed for 20 different chemical parameters using the highest quality assurance/quality control measures. Weekly sampling of three southwestern Adirondack streams is an extension of a USEPA seasonal acidification project conducted originally during 1988 to 1990. Among these is Buck Creek, which has been one of the longest study sites for documenting the persistence of acidic episodes in upland regions of the Adirondacks as well as the northeastern United States.

PROJECT UPDATE

February 2006



Researcher collects water samples

Project Status

- Initiated 1999
- Project ongoing

New York Energy Smart℠ PUB

George E. Pataki, Governor

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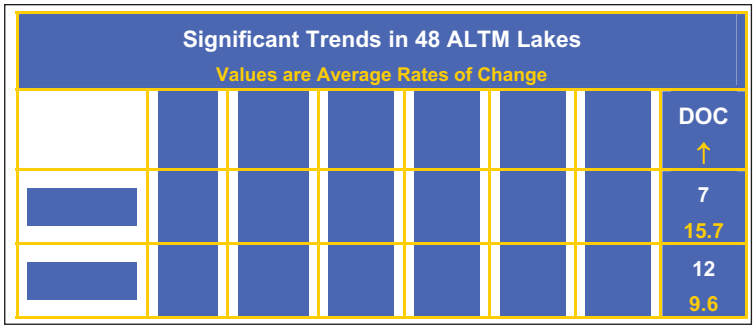
FINDINGS

LAKE TREND RESULTS:

The first trend analysis (1982-1991) conducted on the original 17 ALTM lakes found sulfate decreasing in many lakes, with patterns of increasing nitrate in over half of the waters. No improvements in acid neutralizing capacity (ANC) or pH were observed. The first analysis of the expanded 52-lake survey (1992-2000) showed new indications of change. During this time, rainfall chemistry was improving, with most of the pH increases occurring from 1991 to 1995. The following key trends were observed in ALTM lakes:

RECENT FINDINGS:

More recently in 2005, another time-series analysis was conducted with four years of additional data (1992-2004). These results show that while a greater number of lakes are exhibiting positive trends, the slopes or the rates of those trends have slowed. This further indicates that full chemical recovery for these lakes will be in the order of decades. Critically high levels of toxic aluminum and other chemical indicators continue to occur particularly during spring snowmelt. The patterns and mechanisms for these changes are being further analyzed across lake types.



PROJECT IMPLICATIONS

Findings of this project indicate that when declines in emissions result in declines in acidic deposition, these improvements can translate into changes in water chemistry. Time-series analysis of water chemistry conducted from 1982-2000 data and more recently through 2004 show improvements have occurred in a number of lakes, albeit slightly, as a result of changes in atmospheric deposition. It is important to note, however, that these data do not indicate that lake recovery is complete, only that it is beginning. Acidic deposition still impacts sensitive ecosystems in the Adirondacks. At current rates, it will take decades to alleviate acidification stress to biota in these waters. For example, in many of the studied lakes, inorganic aluminum levels remain above toxic levels for fish, especially during spring snowmelt. ANC and pH values also remain too low for healthy biota in many waters. The results indicate that further reductions in NO_x and SO_2 emissions would contribute to the recovery process of these lakes.

PROJECT UPDATE

December 2005

New York State Energy Research and Development Authority

Environmental Monitoring, Evaluation, and Protection Program

ASSESSING THE SENSITIVITY OF NEW YORK FORESTS TO CATION DEPLETION

Principal Researcher

RUTH YANAI
SUNY College of Environmental Science and Forestry

Project Locations

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

- Acidic deposition
- Base cation
- Liming
- Mineral weathering
- Soil calcium depletion

PROJECT FOCUS

To improve our understanding of the sensitivity of forests across New York State (NYS) to soil calcium (Ca) depletion, this project seeks to:

- Describe the distribution of Ca-bearing minerals in soil (or soil parent material, the material from which soil forms);
- Assess the relative ability of important tree species to access Ca from various sources, including trace minerals; and
- Assess how changes in soil Ca content resulting from nitrogen (N) deposition would affect the storage of carbon (C) in soil.

CONTEXT

Fossil-fuel combustion sources are major emitters of sulfur dioxide (SO_2) and nitrogen oxides (NOx). These pollutants undergo complex reactions in the atmosphere to form nitric and sulfuric acids, which, through atmospheric deposition in forests and bodies of water, affect ecosystems in complex ways and contribute to the acidification of soils, lakes, and streams. Over the past 20 years, federal policies such as the Clean Air Act Amendments of 1990 (CAAAs) have resulted in decreased atmospheric emissions and deposition of sulfur in NYS. In the same period, atmospheric emissions of nitrogen, which were not capped by the CAAAs, have not changed significantly.

Credit: Ruth Yanai
Soil sample collection.

A major adverse effect of acid rain on forest health and productivity is a reduction in soil of the available supply of calcium and other base cations that are needed for forest growth. Scientific predictions of soil Ca depletion related to acid rain, however, have been based on the assumption that only salt-exchangeable Ca is available to plants. The influx of Ca from another possible source, the weathering of Ca-containing materials in soil, has been considered too gradual a process to play an important role in mitigating the acidifying effects of air pollution on soils. Because of these assumptions, the role of easily weathered trace minerals containing calcium, such as apatite and calcite, has been overlooked in assessments of Ca depletion from acid rain. In addition, recent research linking changes in levels of extractable cations to soil C and N content has raised the question of whether changes in soil Ca pools could in turn influence soil C and N storage.

Credit:http://www.hubbardbrook.org/
A helicopter flies low over trees, spreading Ca on the forest

PROJECT UPDATE

December 2005

gears.tucson.ars.ag.gov
Maple leaf litter.

Project Status

- Initiated January 2005
- Project ongoing

New York Energy Smart PUB

George E. Pataki, Governor

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METHODOLOGY

Distribution of Ca-bearing minerals: Based on bedrock geology and the distribution of soil types, 30 sites were selected in New York State for sampling of soils. A sequential extraction procedure is being used to quantify the amount of calcium that is exchangeable, readily weathered (such as apatite), and resistant to weathering (such as silicate minerals).

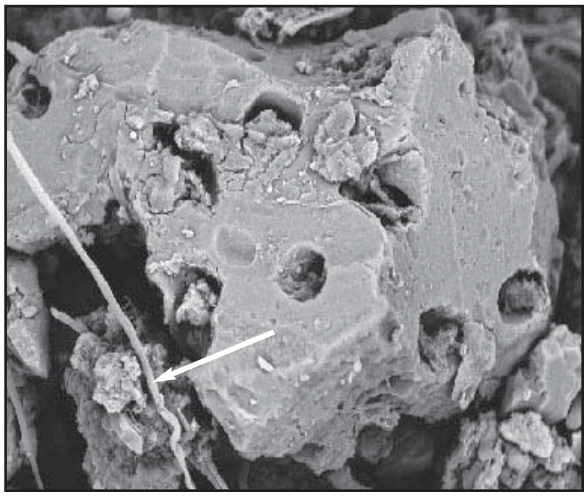
Tree Species: At the same sites, leaf litter is being collected from the dominant species present to determine how similar types of forest fare on soils formed from contrasting materials and how different tree species or forest types vary in accessing different sources of Ca from the same substrate. Strontium isotopes and the ratio of calcium to strontium will be used to determine the relative importance of atmospheric deposition, silicate weathering, and trace minerals as Ca sources for vegetation.

Carbon Storage: Additional samples, collected at sites where Ca was added in liming experiments 14 to 41 years ago, will be analyzed for C and N in order to determine whether patterns observed at the landscape level are likely to predict changes over time with the continued atmospheric deposition of N and leaching of Ca.

PROJECT FINDINGS

Findings thus far indicate that an accurate assessment of the threat of Ca depletion by acid rain and forest harvesting depends on understanding the contribution of apatite weathering to Ca cycling in forest soils. Apatite is important in granitoid parent materials (igneous rock) but not in sedimentary rocks. The soil parent materials derived from clastic sedimentary rocks averaged 80 ppm Ca from apatite, compared to 720 ppm in the parent materials derived from igneous rocks.

Parent material is likely more important than glaciation in determining apatite availability in soils. Sugar maple decline has been observed to occur on unglaciated soils of the Allegheny Plateau, while glaciers tend to rejuvenate reservoirs of fresh minerals available for weathering. Two sites in Pennsylvania were selected to bracket the southern extent of the Wisconsin glaciation. The fact that both sites had very little apatite, with the glaciated site having the least, suggests that the importance of apatite across the landscape should be predictable from bedrock composition and the glacial transport of parent materials, with crystalline bedrock providing more apatite than sedimentary rock.



Roots and fungi, including mycorrhizae, play a role in mineral weathering, and it has been suggested that apatite weathering is at least in part under biotic control (see figure above). The spruce-fir forest site at Hubbard Brook appears to have greater access to apatite as a Ca source than does the hardwood forest.

PROJECT UPDATE

New York State Energy Research and Development Authority

Environmental Monitoring, Evaluation, and Protection Program

Quantifying the Environmental Benefits of Increased Deployment of Combined Heat and Power Technologies in NYS and the Impact of Proposed Emissions Standards for Small Distributed Generation

Principal Researcher

JIM CARTER
Navigant Consulting, Inc

Project Participants

B. Hedman
Energy and Environmental Analysis, Inc.

F. Zalcman
Pace Energy Project

Project Location

Statewide

Credit: Navigant Consulting
A distributed generation - combined heat and power unit.

Contact Information

For more information on this project see:

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

or contact Mark Torpey at:
mrt@nyserda.org

Keywords

- Air emissions
- Combined heat and power (CHP)
- Distributed generation (DG)
- Emission scenarios
- Market penetration
- Multi-Area Production Simulation software (MAPS)

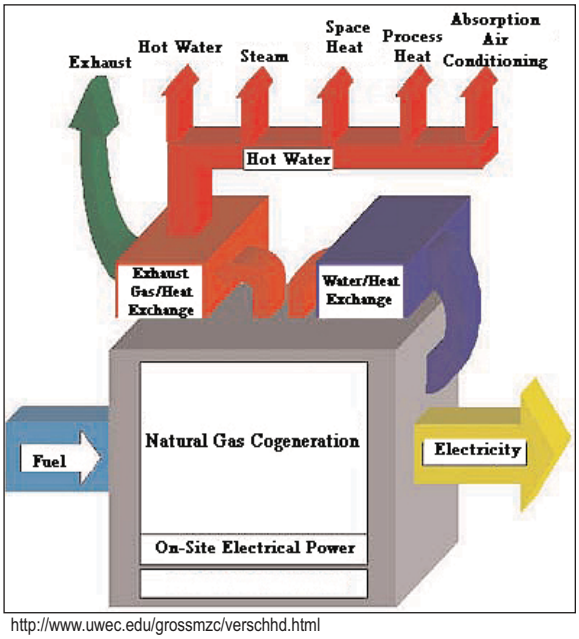
PROJECT FOCUS

The project will analyze how the widespread use of distributed generation (DG) systems operating in combined heat and power (CHP) applications throughout New York State (NYS) would affect emissions of criteria air pollutants and the wholesale electricity market.

The project team will analyze emissions for these pollutants: carbon monoxide (CO), nitrogen oxides (NO_x), sulfur oxides (SO_x), mercury (Hg), particulate matter (PM), volatile organic compounds (VOCs), and carbon dioxide (CO_2). Economic impacts on the electricity market will be gauged by wholesale market electricity prices.

CONTEXT

Distributed generation is defined as the use of various small-scale resources for generating power that are located close to the site where the power will be used. The DG systems are energy efficient and have the potential to improve air quality while lowering the costs of electricity for consumers. DG can also improve the reliability of transmission of power and its system of distribution. Combined heat and power technologies use a single fuel to produce both heat (steam) and electricity. While much of the heat produced with conventional electricity generation is wasted, with CHP systems that heat is recovered. DG/CHP technologies include fuel cells, reciprocating engines, microturbines, gas turbines, back-pressure steam turbines, and hybrid power systems. Lower costs are thus possible if energy-efficient (low operating cost) DG/CHP systems can be collectively utilized to offset the operation of less efficient (high operating cost) central power plants.



http://www.uwec.edu/grossmzc/verschhd.html
The process of excess energy being caught and utilized.

The results of a NYSERDA-funded study reported in 2002 that DG/CHP installations could provide up to 2,400 and 6,000 megawatts of electric power (MWe) within New York State by 2010 and 2020, respectively. New York's peak electric power demand occurs during the summer months and is nearly 35,000 MWe. Because of the structure of New York's wholesale electric power market, if a sufficient number of DG/CHP systems are installed throughout New York State, it may not be necessary to draw on extra capacity from older, less efficient, more costly and polluting centralized power plants, as is currently the practice.

Credit: NYSERDA

http://www.maineenvironment.org/energy/earthjustice.htm
Emissions from industrial stacks.

Project Status

- Initiated 2003
- Project ongoing

New York Energy Smart PUB

George E. Pataki, Governor

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PROJECT IMPLICATIONS

This project's analyses of the implementation of DG/CHP technologies in three potential regulatory scenarios will make an important contribution to our understanding of the environmental and economic costs and benefits of the widespread deployment of these technologies. Certain technologies might not meet the strict emissions standards or might only do so at a significant cost. The effects on CHP system economics arising from these additional costs or the narrowing of technology choices will ultimately affect technology deployment within the various scenarios and thus CHP penetration into the market. Two of these scenarios should shed light on the optimum "phased in" emission rate limit that could result in improved air quality if the widespread use of DG/CHP resources is encouraged. The hypothesis is that if emission standards are too stringent and effectively limit DG/CHP market penetration, air quality could be adversely affected over time as a consequence.

PROJECT UPDATE

New York State Energy Research and Development Authority

Environmental Monitoring, Evaluation, and Protection Program

NYSERDA

Analysis of New Pollution Control Strategy Utilizing Emission Reduction Credits and Small-Scale Combined Heat and Power Units

Principal Researcher

ANDREW GREENE
Navigant Consulting, Inc

Project Participants

Thomas Bourgeois & Daniel Rosenblum
Pace Energy Project

Project Location

Statewide

http://www.rocairport.com/org36.asp?storyID=2158
The combined-heat-and-power (CHP) cogeneration plant for the Rochester International airport.

Contact Information

For more information on this project see:

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

or contact Ellen Burkhard at: egb@nyserda.org

Keywords

- Cap-and-trade programs
- Combined heat and power (CHP)
- Emission reduction credits (ERCs)
- Energy efficiency
- NO_x and SO_2 allowance set-asides

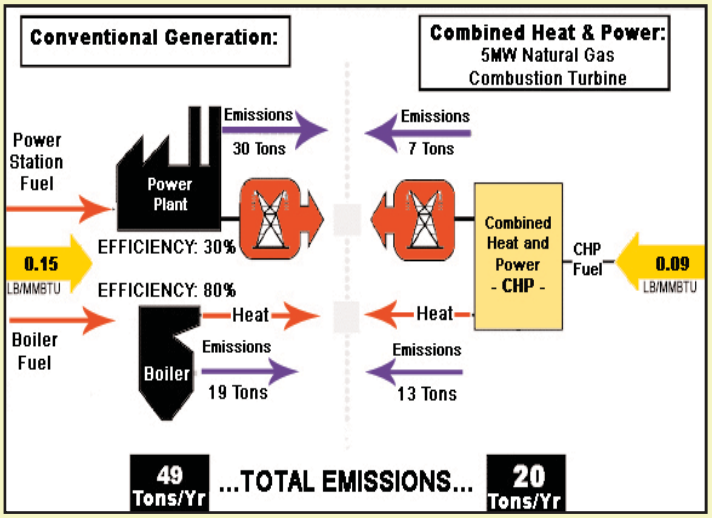
PROJECT FOCUS

This project involves the development of an emission reduction credit (ERC) guidebook that is intended to assist smaller combined-heat-and-power (CHP) systems in applying for and securing ERCs from the New York State (NYS) Department of Environmental Conservation (DEC). ERCs can be granted for reductions in emissions of nonattainment pollutants that result from the deployment of small-scale CHP applications in New York State. In addition, the project team will assess how CHP units could be incorporated into the DEC nitrogen oxides (NO_x) and sulfur dioxide (SO_2) emission allowance set-aside programs now in effect. Information emerging from these findings will be presented in a NO_x and SO_2 Allowance Set-Aside Report. By receiving ERCs and/or set-aside allowances, CHP projects can tap into significant incremental sources of market value. These incentives may help to promote the installation of additional CHP systems, benefiting the environmental and economic health of New York State.

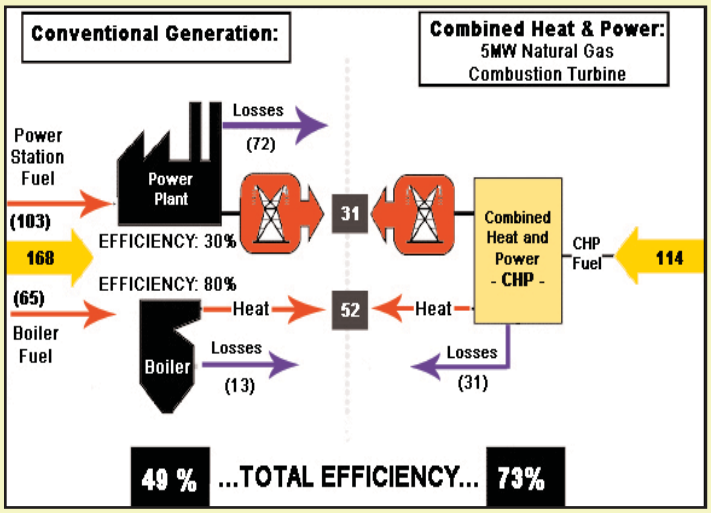
CONTEXT

CHP, which involves the coincident production of heat and electrical/mechanical power from a single process and fuel source, may be a suitable option in industrial, institutional, commercial, municipal, and residential applications. CHP can be cleaner and more efficient and reliable than conventional methods of separately generating heat and power, as heat that is normally wasted in generating central-station electricity is instead used near the CHP system. By taking advantage of this otherwise wasted heat, CHP significantly increases overall energy efficiency. In addition, because CHP is located at the end-user's site, there are virtually no transmission and distribution line losses, which typically diminish the amount of power delivered from central power plants to the consumer by 5%-10%. The installation and operation of CHP units can also partially displace or enable the retirement of existing inefficient, high-emission, on-site customer boilers, producing additional efficiency and air-quality improvements. While there is significant technical potential in New York State for thousands of smaller CHP projects (<15 megawatt (MW)) at commercial and institutional facilities, the economic rationale for such projects has not been compelling to date, and there are few such facilities in existence.

An Illustrative Comparison Between the NO_x Emissions and the Total Efficiency of Separate Heat and Power (Conventional) and Combined Heat and Power Applications



The conventional generation units are assumed to operate on gas or No. 2 fuel oil and are typical of older, existing fossil units.



Fuel input, heat output, electrical output and losses are all shown in the same (unspecified) unit of measure for illustrative purposes.

Credit: Andrew Greene

http://www.energyprojects.co.uk/chp.htm
CHP heat exchanger.

Project Status

- Initiated 2003
- Project ongoing

New York Energy Smart℠
Public Service Commission — NYSERDA
George E. Pataki, Governor

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PROJECT IMPLICATIONS

Although there is currently ~5000 MW of installed CHP capacity at 210 sites in New York State, approximately 78% of this capacity is produced by a few large CHP (15+ MW) units located predominantly at industrial facilities. A recent NYSERDA study found that of the 8500 MW of technical potential for new CHP installations, 74% is for small systems of less than 5 MW that could be located primarily at commercial and institutional facilities. Despite this significant technical potential, the market penetration of small CHP units has been minimal to date. The findings of this project will contribute significantly to the development of market incentives in New York State that facilitate the transition to cleaner and more efficient technologies with environmental and economic benefits.

PROJECT UPDATE

New York State Energy Research and Development Authority

Environmental Monitoring, Evaluation, and Protection Program

NYSERDA

Reducing Emissions from the Electricity Sector: The Costs and Benefits Nationwide and in the Empire State

Principal Researcher

KAREN PALMER
Resources for the Future (RFF)

Project Location

Statewide

http://www.isgs.uiuc.edu/servs/pubs/geobitspub/geobit12/gb12a.htm
Fine particulate matter (PM) emissions from a power plant.

Contact Information

For more information on this project see:

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

or contact Mark Watson at: mw1@nyserda.org

Keywords

- Cap and trade
- Emissions caps
- Clean Air Interstate Rule (CAIR)
- Multi-pollutant policy
- Regional strategy

PROJECT FOCUS

This research project analyzed how new federal rules to reduce emissions of SO_2, NO_X, and mercury from the electricity sector will likely affect air quality, acid deposition and the cost of supplying electricity to New York residents and to electricity consumers across the nation. The research analyzed the Clean Air Interstate Rule (CAIR) coupled with a number of different proposed approaches to reduce mercury emissions from the electricity sector.

CONTEXT

The generation of electricity through the combustion of fossil fuels, in particular coal, is a major contributor to air pollution, emitting more SO_2 than any other source (68% of U.S. total), as well as NO_X (22% of U.S. total), CO_2 (40% of U.S. total), and mercury (40% of U.S. total). Coal-burning power plants are the largest unregulated source of mercury emissions in the country. These pollutants have a range of negative consequences for the environment and human health, including particulate matter, ozone, and mercury pollution; global warming (CO_2); and acidic deposition.

A number of multipollutant policies have recently been considered at the national and regional levels for mitigating the effects of air pollution related to electricity generation. These include CAIR and a companion mercury rule. Together these rules address three pollutants (NO_X, SO_2, and Hg) with a regional cap on NO_X in the eastern United States, a tighter regional cap on SO_2 layered on top of a preexisting national cap and national restrictions on mercury emissions.

Alternative proposals for reducing mercury emissions have also been suggested by the states and there is much disagreement about the wisdom of using a cap and trade approach to reduce mercury emissions. The emission reduction targets and approach to reducing Hg emissions have important implications for the cost and for the location of emissions of NO_X, SO_2, and Hg, as reductions in Hg are often achieved jointly with reductions in other pollutants.

METHODOLOGY

The project used a suite of models, including a model of capacity planning and operation for the U.S. electricity sector, an integrated assessment model of air transport and environmental effects, and a state-of-the-art air chemistry model for the eastern United States. The combined use of these tools, modified for the purposes of this project, allowed for a broad assessment of the costs and benefits

EPA Proposed SO_2 NO_x Rule, including June 10, 2004 Supplement

Summary
EPA proposes implementing a cap and trade program for 28 eastern States[1] and the District of Columbia to reduce emissions of SO_2 and NO_x from electricity generating units. Participation in the regional trading program is optional for the 28 States and the District of Columbia. States that opt-out of the trading program must meet State-level emission caps.

Affected Facilities (both proposals)
- Fossil fuel-fired[2] electricity generating units with a capacity greater than 25 MW, **AND**
- Fossil fuel-fired steam co-generation units with a capacity greater than 25 MW that sell more than 1/3 of their potential electric output.

Regional Annual Allowance Allocation Caps
SO_2: 3.86 million tons by 2010 and 2.70 million tons by 2015.
NO_x: 1.60 million tons by 2010 and 1.33 million tons by 2015.

[1] The 28 States are: Alabama, Arkansas, Delaware, Florida, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, New Jersey, New York, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Texas, Virginia, West Virginia, and Wisconsin.
[2] Fossil-fuel fired units are those that fire: natural gas, petroleum, coal, or any fuel derived from such materials, alone or in combination with any other fuel.

Prepared by David Lankton. More information may be found at www.rff.org/multipollutant/.

Credit: Karen Palmer, RFF

Project Status

- Initiated 2004
- Project complete

New York Energy Smart PUB

George E. Pataki, Governor

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.

of potential national and regional policies. In evaluating the potential environmental benefits of these proposals, researchers specifically analyzed how they would influence emissions from power plants that affect air quality in New York and the nation. The analysis of environmental effects includes air quality parameters, such as concentrations of fine particulate matter (including nitrates and sulfates) and ozone, and acidic deposition. Potential improvements in air quality are translated into economic benefits, in dollars, associated with health improvements among residents. Additional economic studies focus on the costs, for the electricity sector and consumers, of pollution controls that would have to be installed and on the extent to which residents and businesses would pay for them.

EPA Proposed Mercury[2] (Hg) Rule

Summary

The EPA proposes two options for reducing national Hg emissions from coal-fired utility units:

1. Maximum Available Control Technology (MACT), OR
2. National Mercury Cap and Trade Program.

Choice of program will depend on legal interpretation of the Clean Air Act (CAA) and its amendments:

- EPA believes it has the authority, under section 111 of the CAA, to implement a national cap and trade program for mercury.
- However, some interpretations of sections 111 and 112 of the CAA and two (apparently contradictory) amendments passed in Congress may restrict EPA's authority. If this is the case, EPA suggests MACT.

Affected Facilities (both proposals)

- Coal-fired electricity generating units with a capacity greater than 25 MW, **AND**
- Coal-fired steam co-generation units with a capacity greater than 25 MW that supply more than 1/3 of their potential electric output to an electricity generator.

[1] Prepared by David Lankton. This document can be found at www.rff.org/multipollutant/.

[2] The rule also proposes Nickel emission limitations on oil-fired generators, which are not discussed in this summary.

FINDINGS

- Benefits to the nation and to New York State significantly outweigh the costs associated with reductions in SO_2, NO_X and mercury, and all policies show dramatic net benefits.
- The manner in which mercury emissions are regulated will have important implications not only for the cost of the regulation, but also for emission levels for SO_2 and NO_X and where those emissions are located.
- Contrary to EPA's findings, CAIR as originally proposed by itself would not keep summer emissions of NO_X from electricity generators in the SIP region below the current SIP seasonal NO_X cap. In the final CAIR, EPA added a seasonal NO_X cap to address seasonal ozone problems. The CAIR with the seasonal NO_X cap produces higher net benefits.
- The effect of the different policies on the mix of fuels used to supply electricity is fairly modest under scenarios similar to the EPA's final rules.
- A maximum achievable control technology (MACT) approach, compared to a trading approach as the way to achieve tighter mercury targets (beyond EPA's proposal), would preserve the role of coal in electricity generation.
- The evaluation of scenarios with tighter mercury emission controls shows that the net benefits of a maximum achievable control technology (MACT) approach exceed the net benefits of a cap and trade approach.

Through the integrated use of a set of modeling tools, this project combined scientific, economic, and public policy approaches to addressing pollution from the electricity sector. The project's findings are intended to provide New York with information necessary not only for the state's effective participation in the ongoing debate on multipollutant policy options, but also for the development of successful regional and state policies benefiting the environment and human health.

http://djfink.com/grafix/personal/RI-May2003.html
Power Plant in Queens, New York.

PROJECT UPDATE

August 2005

New York State Energy Research and Development Authority

Environmental Monitoring, Evaluation, and Protection Program

NYSERDA

Quantifying Atmospheric Nitrogen Sources with New Stable Isotope Techniques

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Project Location

Statewide

Credit: E.W. Boyer
Fall Creek, in the Finger Lakes region of New York.

Contact Information

For more information on this project see:

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

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Keywords

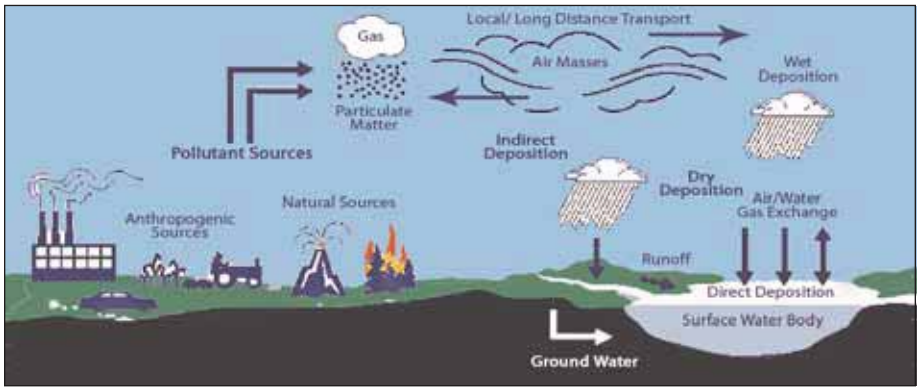
- Acid deposition
- Atmospheric nitrogen
- Isotope
- Nitrates
- Source attribution

PROJECT FOCUS

This new study uses novel chemical tracer techniques to assess the importance of atmospheric nitrogen (N) deposition throughout New York. Isotopes of nitrate are used to fingerprint sources of nitrogen in air, precipitation, and surface water samples in New York State. In particular, new methods are being refined to measure three isotopes in the nitrate (NO_3-) molecule: oxygen-17 ($\Delta^{17}O$), oxygen-18 ($\delta^{18}O$), and nitrogen-15 ($\delta^{15}N$). Investigating the feasibility of using this trio of isotope tracers will quantify: (1) the relative contributions of different sources of atmospheric N to precipitation (e.g., distinguishing between stationary, automotive, and agricultural sources), and (2) the relative contributions of different sources of atmospheric nitrate to several New York watersheds.

CONTEXT

Over the past century, concentrations of reactive nitrogen (available for use by living organisms) in the environment have greatly increased as a result of human activity. The primary anthropogenic sources of reactive N are the manufacture and application of fertilizer, the combustion of fossil fuels, and the production of human and animal waste. The sources of atmospheric N deposition include industrial, automotive, and agricultural emissions. Thus, energy generation and both the production and consumption of food generate reactive N as a byproduct.



Multiple pathways for nitrogen to be present in the environment.

While a certain amount of nitrogen is needed by living organisms and supports higher crop yields and greater energy production, when this amount exceeds what can be assimilated, reactive N released into the environment can degrade air, land, and water resources. In the Northeast, increasing inputs of reactive N have been linked to many environmental concerns, such as forest decline, the acidification of ecosystems, lakes and streams, accumulation of N in groundwater, and eutrophication of waterways.

One method for tracing N sources involves characterizing nitrate isotopes in water samples. Isotopes are atoms of a particular element that have different mass numbers; that is, a different number of neutrons in their nuclei. As emissions from various sources can have different ratios of nitrate isotopes, isotopic composition can provide clues as to the sources of emissions and subsequent reactions.

Recent advances in isotopic techniques provide researchers with powerful tools for quantifying sources of N delivered to landscapes and waterways. New methods for characterizing the $\delta^{18}O$, $\Delta^{17}O$ and $\delta^{15}N$ composition of nitrate requires much smaller sample volumes and less manpower to analyze than previous methods permitted, making it feasible to analyze large numbers of samples.

Photo by E.W. Boyer
Passive dry deposition samplers installed in a confined animal feedlot dairy operation in central New York.

PROJECT UPDATE

New York State Energy Research and Development Authority

Environmental Monitoring, Evaluation, and Protection Program

AMBIENT GASEOUS AMMONIA: EVALUATION OF CONTINUOUS MEASUREMENT METHODS SUITABLE FOR ROUTINE DEPLOYMENT

Principal Researcher

JAMES SCHWAB
SUNY Atmospheric Sciences Research Center

Project Locations

Contact Information

For more information on this project see:

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

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Keywords

- Ammonia
- Ammonia Analyzers
- Fine Particulate Matter ($PM_{2.5}$)
- National Ambient Air Quality Standards (NAAQS)
- EPA NCORE Level 2 site

PROJECT FOCUS

A better understanding of the formation and transformation of particulate matter (PM) in the atmosphere requires advances in methods for measuring ambient gaseous ammonia and for quantifying the types and amounts of ammonia emitted to the atmosphere. This project aims to establish the viability of routine continuous measurements of gaseous ammonia and to begin conducting such measurements at one or more sites. The accumulated data will help clarify the formation and transformation of fine particulate matter ($PM_{2.5}$), and allow researchers to better quantify the types and contributions of ammonia sources while making measurements more reliable and routine.

CONTEXT

Airborne PM is a broad class of materials, transported as solid particles or liquid droplets (aerosols). These particles are emitted from a variety of natural processes and human activities, including fossil-fuel combustion, forest fires, wind erosion, agricultural practices, industrial manufacturing, and construction. They can be emitted directly into the atmosphere (primary particles) or formed in the atmosphere from precursor gases such as sulfur dioxide, nitrogen oxides, ammonia, and volatile organic compounds (secondary particles). In July 1997, motivated by concerns about adverse health effects, the U.S. Environmental Protection Agency proposed a new National Ambient Air Quality Standard (NAAQS) for particulate matter of less than 2.5 microns in diameter ($PM_{2.5}$), including daily maximum (65 $\mu g/m^3$) and annual maximum (15 $\mu g/m^3$) average concentrations.

Credit: www.ecy.wa.gov
Jersey cows

Ammonia (NH_3) is emitted into ambient air from a variety of sources. The major contributor to NH_3 concentrations is thought to be animal agriculture, which accounts for as much as 50%-85% of anthropogenic emissions in the United States. During the decomposition of animal manure, reduced nitrogen compounds are converted to ammonia, which enters the air. Gaseous ammonia can travel long distances and is therefore a global concern, playing an important role in a host of environmental effects such as the eutrophication of surface waters and the acidification of soils. In addition, through complex chemical reactions in the atmosphere, it combines with other compounds to form fine particles ($PM_{2.5}$). In fact, ammonium sulfate and ammonium nitrate combined contribute more than 50% of the $PM_{2.5}$ mass in the eastern United States. Although ammonia contributes a significant proportion of ambient air $PM_{2.5}$, however, emissions from animal agriculture are not at present specifically regulated.

PROJECT UPDATE

December 2005

http://www-gte.larc.nasa.gov/
Aerosol multi-layers

Project Status

- Initiated January 2005
- Project ongoing

New York Energy Smart[SM]
PUB

George E. Pataki, Governor

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 IMPLICATIONS

Reliable measurements of gaseous ammonia are necessary for an improved understanding of the formation and transformation of particulate matter in ambient air, providing greater insight into the sources, ambient levels, and atmospheric chemistry of ammonia in the gas and particle phases. This project addresses current inadequacies in measurement technologies by evaluating novel methods that have not been deployed for ambient atmospheric measurements of ammonia concentrations. The improved measurement protocol and the data acquired are expected to significantly contribute to New York's effort to develop sound strategies to meet the NAAQS for $PM_{2.5}$.

APPENDIX E

Knowledge Synthesis Papers

NOTE: The information in these synthesis papers was drawn from project reports and has not necessarily been peer reviewed.

Appendix E: Synthesis of EMEP Research Findings

I. Air Quality and Related Health Research associated with Particulate Matter, Ozone, and Co-Pollutants

II. Ecosystem Response to Deposition of Sulfur, Nitrogen, and Mercury

III. Crosscutting Environmental Science, Energy, Technology and Policy Research

I. Summary of Findings From EMEP-Supported Projects Related to Air Quality and Health Research associated with the Particulate Matter, Ozone, and Co-Pollutants

Preface

This summary, which focuses on air quality and health effects, was prepared by NYSERDA staff to assist with program evaluation efforts and to facilitate discussions at the upcoming evaluation and planning meeting with EMEP Program Advisors and Science Advisors. Conclusions drawn from this effort will assist in determining research needs related to the EMEP program and help focus future research solicitations.

Introduction

In 1997, EPA set daily and annual standards for particulate matter in two size categories: PM_{10} (less than 10 um in diameter) and $PM_{2.5}$ (less than 2.5 um in diameter). For PM_{10}, the 24-hour standard is set at 150 ug/m^3, and the annual standard is 50 ug/m^3. For $PM_{2.5}$, the 24-hour standard is 65 ug/m^3, and the annual standard is 15 ug/m^3. The current standard for ozone (O_3) is based on a maximum concentration of 0.08 parts per million over an eight-hour period.

Atmospheric concentrations of ozone and fine particulate matter ($PM_{2.5}$) in parts of New York State and other regions of the northeastern United States continue to reach or exceed levels set in the National Ambient Air Quality Standards (NAAQS).

Recent $PM_{2.5}$ designations by EPA identify the New York City area (New York, Kings, Queens, Bronx, and Richmond counties), Long Island (Nassau and Suffolk counties), and Orange, Westchester, and Rockland counties as "non-attainment" for annual $PM_{2.5}$.

EPA has proposed new standards at the level of 35 ug/m^3 and 15 ug/m^3 for 24-hour and annual $PM_{2.5}$, respectively. They also propose removing fine $PM_{2.5}$ from the PM_{10} standard to create a "thoracic" coarse particle standard in the size range of $PM_{10-2.5}$. This new $PM_{10-2.5}$ standard would have a 24-hour limit of 70 ug/m^3.

The Environmental Monitoring, Evaluation, and Protection (EMEP) Program's multi-year plan (2002) identified ozone and $PM_{2.5}$ as important energy-related environmental management challenges facing New York State. It set general research objectives to:

1. develop and evaluate the effectiveness of pollution control strategies;
2. quantify local sources and regional transport of fine particles and their precursors to develop more equitable pollution control strategies; and
3. assess the relationships between health effects and $PM_{2.5}$, ozone, and co-pollutants to support development of control strategies to effectively mitigate health impacts.

Through a series of competitive solicitations targeted at critical research gaps identified in the EMEP research plan, 20 research projects focusing on ozone, $PM_{2.5}$, and co-pollutants were selected and funded by the EMEP Program. The total cost of this research was $20.2 million. The contribution of EMEP funds in these research projects was $9.2 million.

The EMEP approach to ozone, $PM_{2.5}$, and co-pollutant research can be simplified into several policy-relevant questions:

How can we improve measurement of $PM_{2.5}$ and its components?

What are the components of $PM_{2.5}$ in the New York region?

Where are the source regions and source types contributing to $PM_{2.5}$ in New York?

Are there specific components in the $PM_{2.5}$ /co-pollutant complex causing adverse health effects?

What are the implications for air-quality management of $PM_{2.5}$ and ozone?

1. How do we improve measurement of $PM_{2.5}$ and its components?

Ambient aerosols are heterogeneous, comprising particles from numerous sources that may then be modified by atmospheric or chemical processes, resulting in varying properties. For example, hygroscopic particles may adsorb water vapor if there is elevated relative humidity. Likewise, semivolatile compounds on a particle's surface may desorb during the heat of the day or condense at night. Understanding how temperature, pressure, and relative humidity affect particle behavior is important to designing particle samplers and interpreting aerosol measurement data.

Federal Reference Method (FRM)
The ambient air standard is based on measurement of $PM_{2.5}$ using a Federal Reference Method (FRM). Under the FRM procedure, a filter is preconditioned under a defined temperature and humidity and then weighed. Using hardware with well-defined specifications, a sample is collected on the filter over 24 hours at ambient temperature and humidity. The filter is then weighed under the same defined temperature and humidity conditions as during the preconditioning. The weight difference divided by the volume of sampled air yields the average 24-hour mass concentration. Due to the conditions of the FRM, it is only an indicator of $PM_{2.5}$ in the air. It does not precisely represent the mass of $PM_{2.5}$ as it exists and is breathed under ambient conditions.

1.1 Instrumentation Development
With EMEP support, Rupprecht & Patashnick Co. developed three instruments to improve continuous monitoring of ambient air, thereby addressing the limitations of the FRM noted above. These instruments are based on the use of the Tapered Element Oscillating Microbalance (TEOM) inertial mass measurement method. The goals of these efforts were 1) to increase correlation with measurements made using the FRM and 2) to develop a continuous measurement system that more closely represents the mass of fine particles found in ambient air.

To achieve the first goal, a sample equilibration system (SES) was developed to reduce the moisture content of the sampled ambient air stream, so that the temperature of the TEOM filter could be reduced from 50ºC to 30ºC, closer to the typical ambient collection temperature of the FRM. The SES retrofit to the TEOM allowed a lower operation temperature and retained a greater fraction of the collected semivolatile compounds, resulting in a greater degree of correlation with the non-temperature-constrained FRM samples.

To achieve the second goal, a new measurement concept – the Differential TEOM Mass Monitoring System, or Differential TEOM – was developed and tested. In this system, an electrostatic precipitator (ESP) is inserted between the sample inlet and the TEOM mass sensor. The ESP is cycled on and off to selectively remove particles from the sample stream. Mass measurements made with the ESP on are subtracted from those made with the ESP off, to track the gain or loss of semivolatile materials on the filter. This technology is able to resolve issues with measuring adsorption and evaporation of the sample collected by the monitor, providing a more detailed time-series record of $PM_{2.5}$ mass. As a follow-up to the Differential TEOM project, a simpler filter-based version of the monitor, the Filter Dynamics Measurement System (FDMS) was developed. Since its release, the FDMS has received approval from the California Air Resources Board for both PM_{10} and $PM_{2.5}$ sampling and is beginning to be used in sampling networks.

1.2 Instrument Comparison

The FDMS was designed to capture both the volatile and nonvolatile components of aerosol mass. The beta attenuation monitor (BAM) also measures both volatile and non-volatile $PM_{2.5}$ components. Schwab et al. (2006) made comparisons of the FDMS, TEOM, and BAM with the FRM in the field at Queens and Pinnacle State Park. The BAM and FDMS measurements were approximately 25% higher than the FRM measurements at Queens. The FDMS measurement was about 9% higher than the FRM at Pinnacle State Park. The FRM mass was higher than the standard TEOM measurements. The FRM captures a fraction, but not all, of the volatile components of the aerosol mass, raising serious questions about how representative are the FRM measurements of ambient PM.

Carbon

As part of a larger research effort on the source apportionment of organic particles, the Speciation Trends Network (STN) measurement of elemental carbon (EC) and organic carbon (OC) in PM will be compared to an independent analysis. This is another measurement in which the value is operationally defined by the sampler and analysis methodology rather than representing the species present in ambient air.

Particulate Mercury

New rules will soon be going into effect for Hg emissions, creating a need for both monitoring and research measurement to characterize and understand sources, sinks, and transformation processes of Hg. An added challenge is the various forms of Hg in the atmosphere: Hg, Hg (2+) or Reactive Gaseous Mercury (RGM), particulate mercury, and Hg in wet deposition. A comparison of manual measurements of gaseous mercury is being performed with an automated Tekran 2537A in the laboratory and at a field site in Postdam, NY. This project will likely be the basis of a Hg monitoring network in New York State. Based on the lessons learned in this project, the New York State Department of Environmental Conservation (NYSDEC) has submitted a proposal to EPA for expansion of Hg monitoring in New York State.

1.3 Stationary Source Testing: Oil- and Gas-Fired Combustion Systems

A dilution sampling technology and test method for $PM_{2.5}$ emissions and speciation measurements was developed for oil- and gas-fired combustion systems. A compact, lightweight dilution sampler was developed and tested in controlled and field conditions. Seven stationary sources were tested in a field program, including gas-fired boilers and steam generators, gas-fired combined cycle and cogeneration power plants, gas fired heaters, No. 6 oil-fired boilers, and diesel engines. The measurements were used to develop emissions factors and speciation profiles for PM, especially organic aerosols for use in source-receptor and source-apportionment analyses.

The study concluded that dilution source sampling can be an effective method of measuring PM2.5 emissions from stationary sources. Measurement of PM2.5 emissions is, however, highly method dependent. Emissions tests using different methodologies (e.g., dilution vs. filterable + condensable methods) can produce significantly different results and emission factors. In tests with gaseous fuels (refinery gas and natural gas), filterable + condensable methods yielded PM2.5 emission factors that were one to two orders of magnitude greater than determined using dilution methods. In field and pilot tests with No. 6 fuel oil, conventional stack sampling of filterable + condensable PM2.5 produced PM2.5 emission factors that were between 25% and 60% less than those determined using dilution sampling methods. These tests underscore the need for a consistent measurement method for PM2.5 – established at the national level – combined with a concerted effort to improve PM2.5 emissions inventories and emission factors. Specific findings are presented below.

$PM_{2.5}$ Mass
The $PM_{2.5}$ mass emission rates are extremely low. The $PM_{2.5}$ mass concentrations are near ambient levels in some cases, and these concentrations are very difficult to measure with conventional samplers and sampling techniques. However, the dilution sampler technique can achieve lower detection limits than traditional sampling methods and are more representative of gas-fired sources. The $PM_{2.5}$ emissions from No. 6 oil-fired sources and diesel engines are well above the minimum detection levels of this method.

$PM_{2.5}$ Speciation
For gas-fired sources, dilution sampling results indicate that the majority of $PM_{2.5}$ is OC. However, as a portion of the OC is volatile in nature, these measurements are highly uncertain. Sulfate, EC, NH_4^+, and other ions and elements are minor emissions components for gas-fired sources. Sulfate is the dominant $PM_{2.5}$ species for the oil-fired boiler tested, while EC dominates the diesel engine. The speciation profile for the oil-fired boiler also showed some elements, consistent with the ash content of the fuel, that may provide a distinctive signature.

Particle Size
The test results for gas-fired units indicate that nearly all of the $PM_{2.5}$ in the stack is smaller than 0.1 um. Exploratory ultrafine (0.1 um and smaller) particle measurements reveal peak number concentrations at a size of approximately 20 nm, indicating the predominance of particles formed by nucleation, and that ultrafine particles account for approximately one-third of the total mass for fine particles.

Particle size and composition measurements for the No. 6 oil-fired boiler test show that approximately 76% of the particle mass is represented by particles smaller than 0.32 um and that the majority of these are SO_4 related. This is reasonable, considering the elevated sulfur content of the fuel compared to the other sources tested in this program.

The diesel engine test was conducted with and without a diesel particulate filter (DPF). Ultrafine particle number concentration peaks at 60 and 80 nm, and both total PM and ultrafine particles were significantly reduced by the DPF. Studies by others have suggested that addition of a DPF may not reduce fine particles uniformly, but this was not observed in these tests.

<u>*Supporting EMEP Projects:*</u>
Development and Demonstration of a Continuous Ambient Particulate Monitor (R&P 6400 Series), Harvey Patashnick, No. 5060

Development and Demonstration of an Innovative Instrument for Ambient Particulate Matter Mass Measurement Standard, Patashnick, No. 6183

Enhanced Measurements of Oxidants, Fine Particles and Precursors, Demerjian et al., No. 4918

Chemical Composition of Fine Organic Particles from Urban Regional Background Locations in New York State, Monica Mazurek, No. 7616

Impact of In- and Out-of-State Power Plants on Semivolatile Pollutants in NYS, Hopke et al., No. 6083.

Fine/Ultrafine Particulate Emissions Profiles, Glen England et al. No. 6230.

2. What is in $PM_{2.5}$ in the New York region?

Particle composition information is necessary for several reasons. It is needed to identify the relationship between PM toxicity and health effects; to apportion PM primary and secondary mass to sources, thereby informing regulatory control strategies; and to evaluate air quality models.

Numerous research efforts funded through EMEP are working to identify and characterize the annual, seasonal, and diurnal composition of $PM_{2.5}$ in New York State. Figure 1 shows the location of nine sampling sites in New York State where aerosol and co-pollutant studies were conducted under EMEP. These locations include both urban (Queens, Bronx, and Manhattan (2 sites)) and non-urban sites (Stockton, Pinnacle, Sterling Forest, Whiteface Mountain, and Potsdam). In addition, some studies also use data from sites in adjacent states (Chester, NJ, Elizabeth, NJ, and Westport, CT), which represent locations upwind or downwind from New York City. By understanding the relationship of $PM_{2.5}$ composition to upwind source contributions and photochemical activity of precursor gases, PM mitigation strategies can be developed.

2.1. Composition

Annual Composition
The PM Technology Assessment and Characterization Study in New York (PMTACS-NY or "Supersite") research program was designed to address a series of policy-relevant questions. One of the objectives was to measure the temporal and spatial distribution of the $PM_{2.5}$/co-pollutant complex. Figure 2 shows the annual composition of $PM_{2.5}$ in New York City. The largest fraction is carbon based (36%), followed by sulfate (30%), nitrate (15%), and ammonium (15%), with 5% trace metals and water.

Spatial Variation of Composition
Composition of $PM_{2.5}$ at New York City (average of New York Botanical Garden, South Bronx, and Queens College measurements), Rochester, Pinnacle State Park, and Whiteface Mountain includes carbon, nitrate, sulfate, and ammonium at all of the sites, but there is a systematic change in the distribution of these components from the urban to the rural and remote locations (Schwab et al., 2004). Nitrate is highest in the large urban (NYC) and small urban (Rochester) sites, and significantly lower in the rural and remote locations. Sulfate is proportionately highest at Pinnacle State Park, presumably due to its proximity to the Ohio River Valley source region, and lowest in New York City.

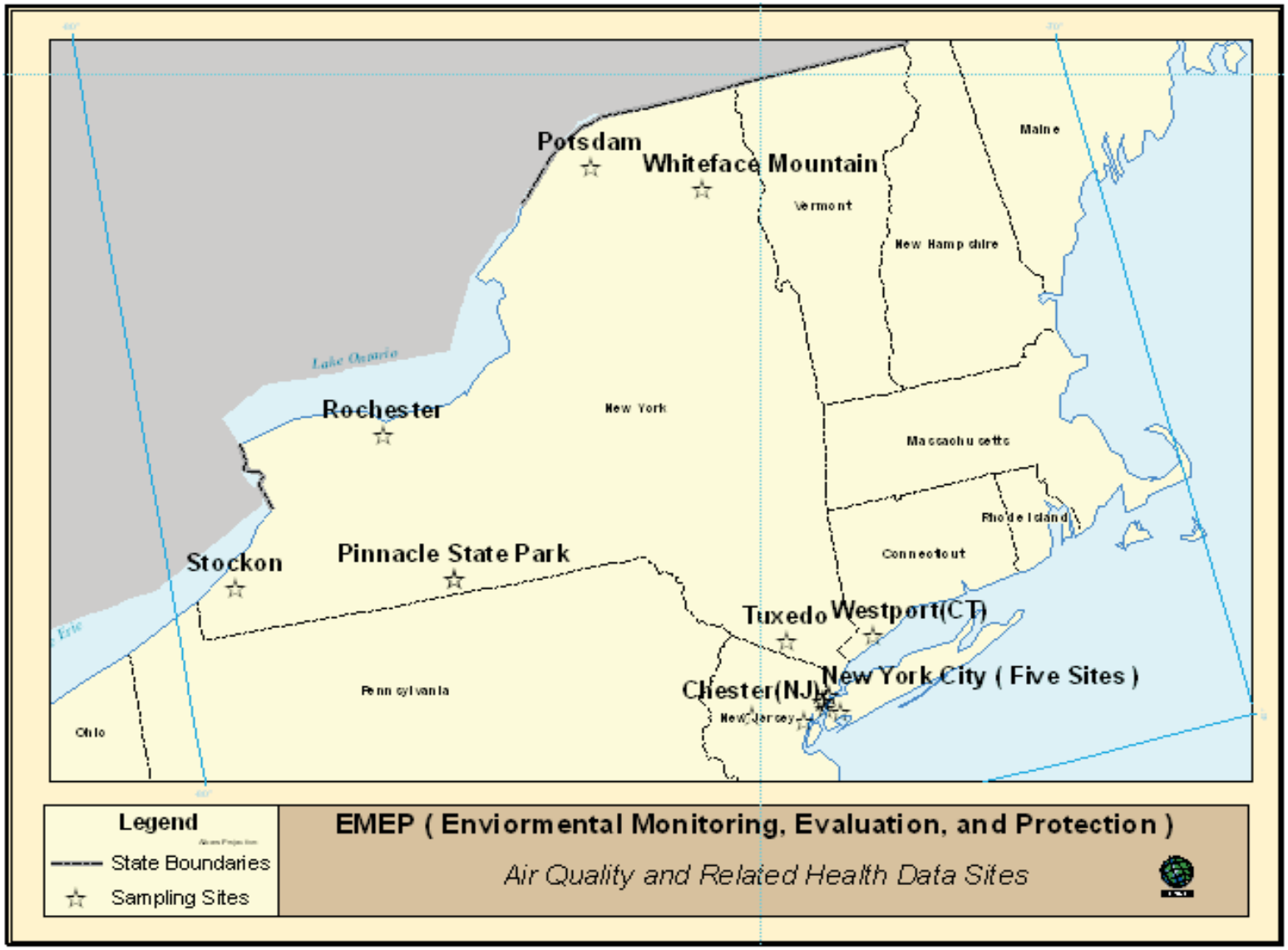

Figure 1. EMEP sampling sites.

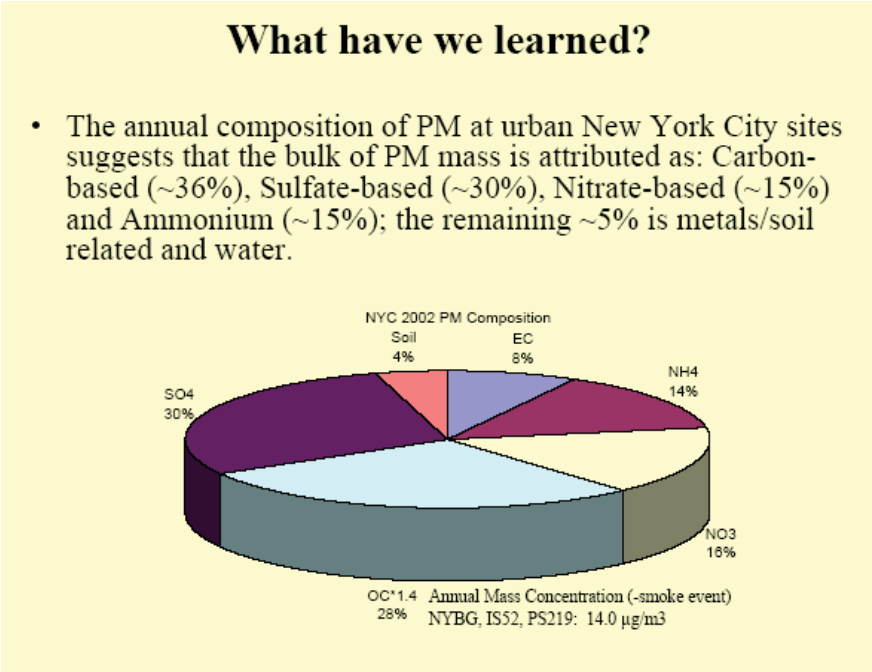

Figure 2. Annual composition of $PM_{2.5}$ in New York City.

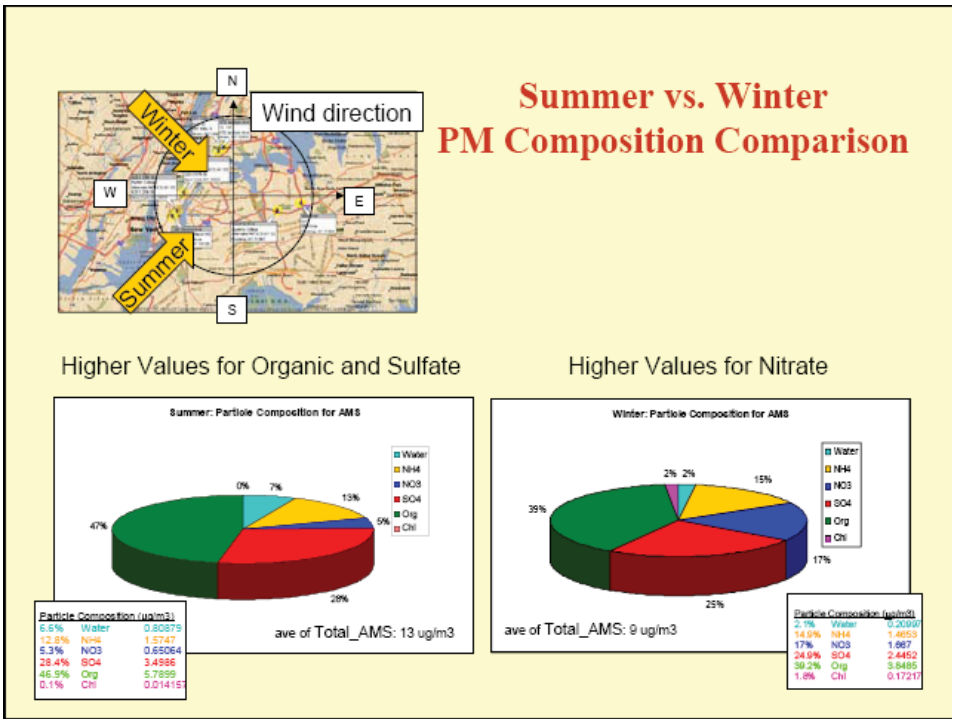

Figure 3. Composition of $PM_{2.5}$ by month, 9/00-10/02. (Demerjian et al., 2005)

Seasonal Composition
The composition of $PM_{2.5}$ changes with the seasons (Figure 3). During summer, wind is generally from the southwest, a region with many coal sources. $PM_{2.5}$ collected during summer has high amounts of sulfate (28%) and organic PM (45%), and fewer nitrates (5%).

In winter, there is less photochemistry and the wind is generally from the northeast, an area of fewer regional sources relative to the southwest. During this season, there is less $PM_{2.5}$ mass, but with a higher proportion of nitrate (17%) and higher mass of nitrate compared to summer.

2.2 Temporal Trends

Day of the Week
Luttinger et al. (2006) examined $PM_{2.5}$ components for day-of-week trends. They found a trend of lower mean concentrations on Sundays, increasing through the week to Thursdays for PM_{10}, elemental carbon (EC), and NOx. A day-of-week trend was not observed for $PM_{2.5}$, OC, or SO_2.

Diurnal Patterns
Three-hour sample averages of organic carbon showed little diurnal variation, possibly increasing slightly during the course of the day. Conversely, $PM_{2.5}$, PM_{10}, and, to a lesser degree, elemental carbon showed daily peaks in the morning hours (6-8 a.m.). These trends were consistent between the Bronx and Manhattan. The diurnal variation for average hourly $PM_{2.5}$ for two years of data collected in the Bronx and Manhattan is given in Figure 4 (Luttinger et al., 2006).

An aerosol mass spectrometer (AMS) was deployed in Queens during PMTACS-NY in summer 2001 (Drewnick et al., 2004). The AMS measures non-refractive mass only and so misses trace element species. It provided 10-minute mass concentration for sulfate, nitrate, ammonium, chloride, and total organics for a five-week period.

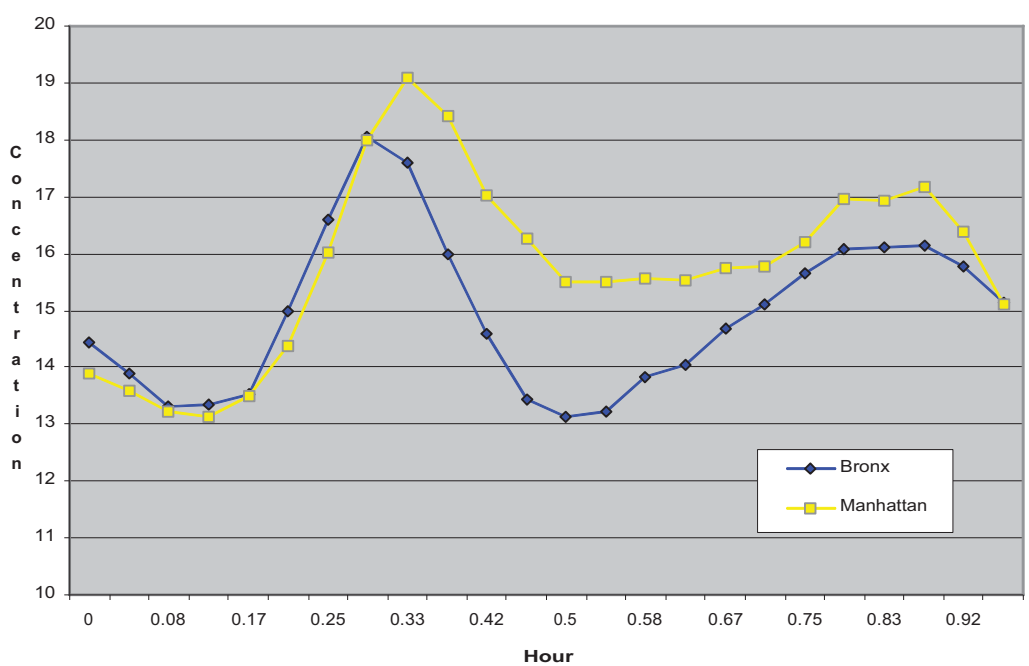

Figure 4. Diurnal Variation of $PM_{2.5}$ in the Bronx and Manhattan (Luttinger et al., 2006).

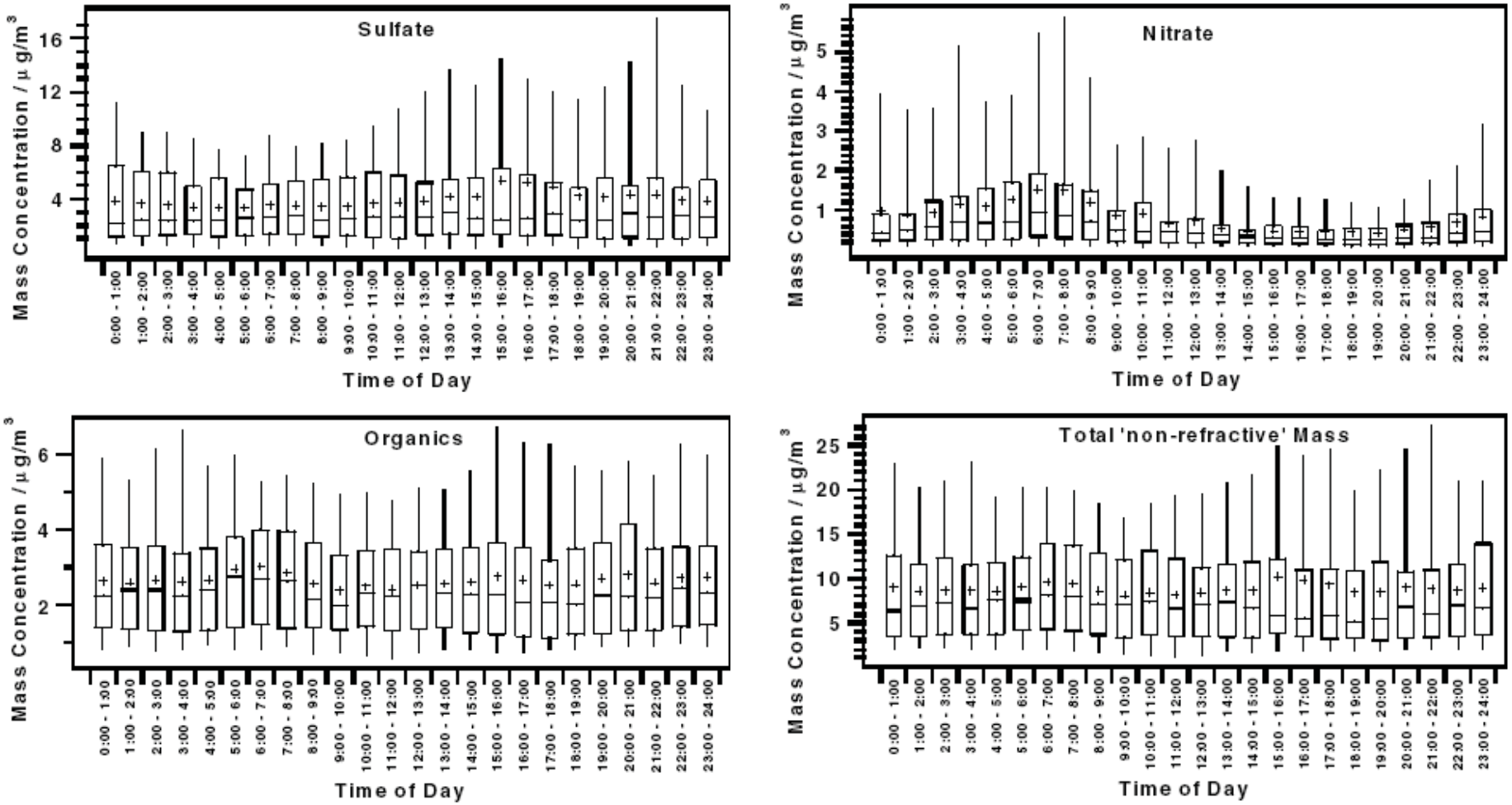

Figure 5. Average diurnal patterns for sulfate, nitrate, total organics, and total nonrefractory mass concentrations, measured during PMTACS-NY 2001. The boxes indicate the 25th percentile, the median, and the 75th percentile. The whiskers indicate the 5th and 95th percentiles. The means are printed as crosses.

Figure 5 shows the diurnal patterns for sulfate, organics, nitrate, and total non-refractive mass. The sulfate measurements show almost no diurnal pattern, indicating that observed sulfate was primarily due to regional transport rather than local production. In contrast, the nitrate particle concentration has a clear diurnal pattern peaking around 6-7 a.m. and decreasing to a minimum in the late afternoon. During the night it increases until early morning, with a small secondary maximum around midnight. The nighttime signal for nitrate is likely ammonium nitrate, formed by a very temperature-sensitive equilibrium. The observation is consistent with the observed summertime diurnal temperature pattern.

The mass concentration of total organic particulate shows a measurable diurnal pattern. There is a maximum from 5:00 to 8:00 a.m., again from 15:00 to 18:00, and later from 19:00 to 22:00. Using mass signals from the AMS to identify "fingerprint" markers, the organic aerosol particles were separated into photochemically generated aerosols and traffic-related hydrocarbons. Figure 6 shows the diurnal pattern for traffic-related particles and photochemical markers. The traffic-related particles have a maximum during the high-traffic periods. The photochemically generated particles show a maximum during the afternoon. From the data, it appears that organic particles measured in New York City are associated with both traffic and photochemical processes, although they are not yet resolved quantitatively.

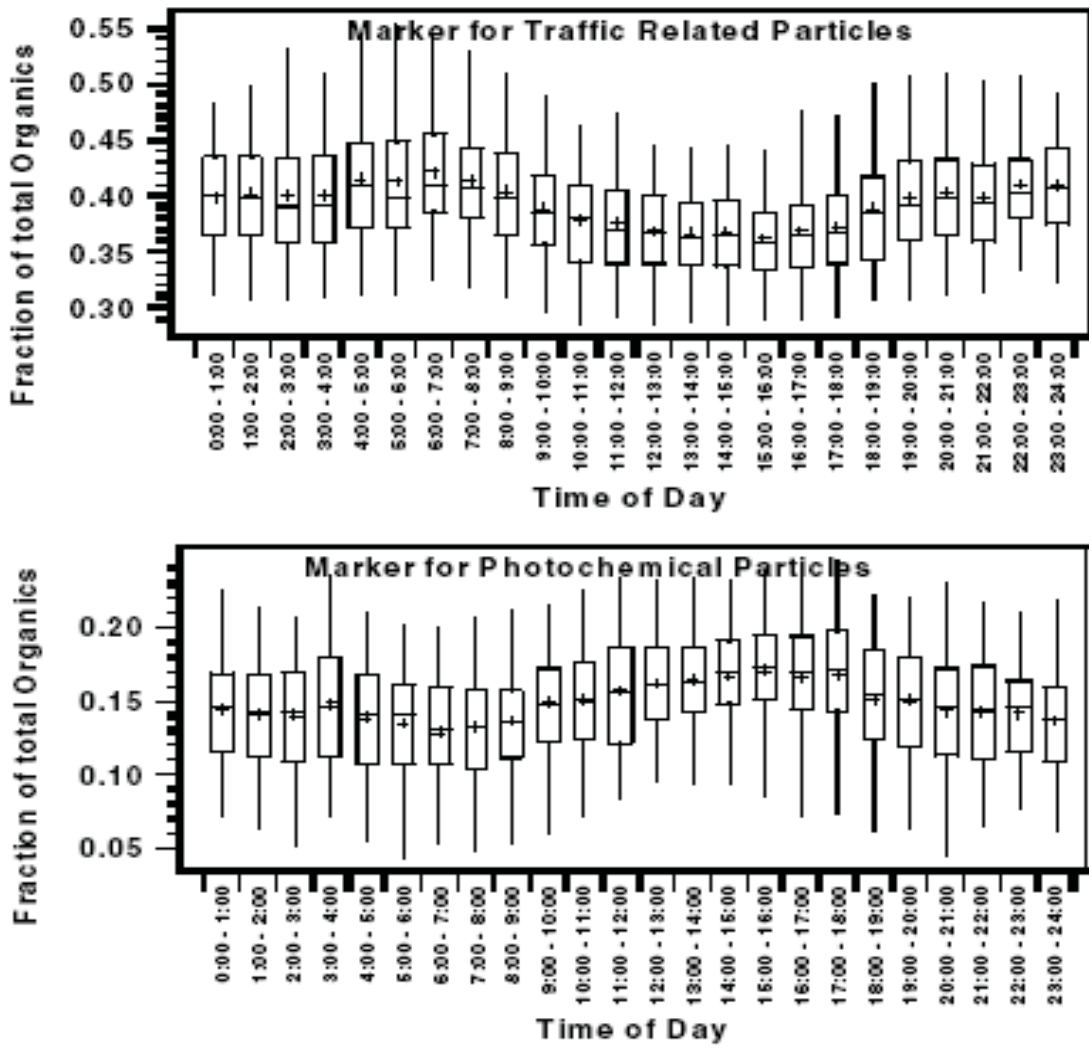

Figure 6. Average diurnal patterns of the fraction of organic particles, identified as markers for traffic aerosol and for photochemical aerosol. Unlike the diurnal pattern of the total organic mass concentration, these fractions both show a distinct diurnal pattern.

2.3 Co-Pollutants

Particulate matter results from both primary emissions of particles and secondary particle formation resulting from photochemical reaction or condensation of precursor gases such as SO_2. New York State is located downwind of major SO_2 sources in the Midwest and frequently receives transported SO_2 and aerosols containing sulfate (SO_4). Conversion of gaseous SO_2 to aerosol sulfate occurs during transport via a photochemical reaction. Figure 7 shows mean monthly SO_2 and sulfate concentrations measured in Manhattan (Bari et al., 2003). The SO_2 and sulfate show opposite seasonal patterns. The concentration of SO_2 is more than a factor of 2 higher in winter than in summer, while sulfate is approximately twice as high in summer as in winter. Bari et al. (2003) attribute the higher concentration of sulfate in summer to the increased rate of photochemical oxidation of SO_2 and to longer periods of meteorological stagnation in summer, allowing more time for reaction. The sum of gaseous SO_2 and particulate sulfate (in ppb) shows a maximum in winter. This may be due to increased SO_2 emissions from space heating in New York City or to meteorological conditions favoring lower mixing heights. Bari et al. also compared the percentage of total sulfur present as sulfate for each month (Figure 7b). The sulfate fraction is much higher in summer (19%) compared to winter (5-7%).

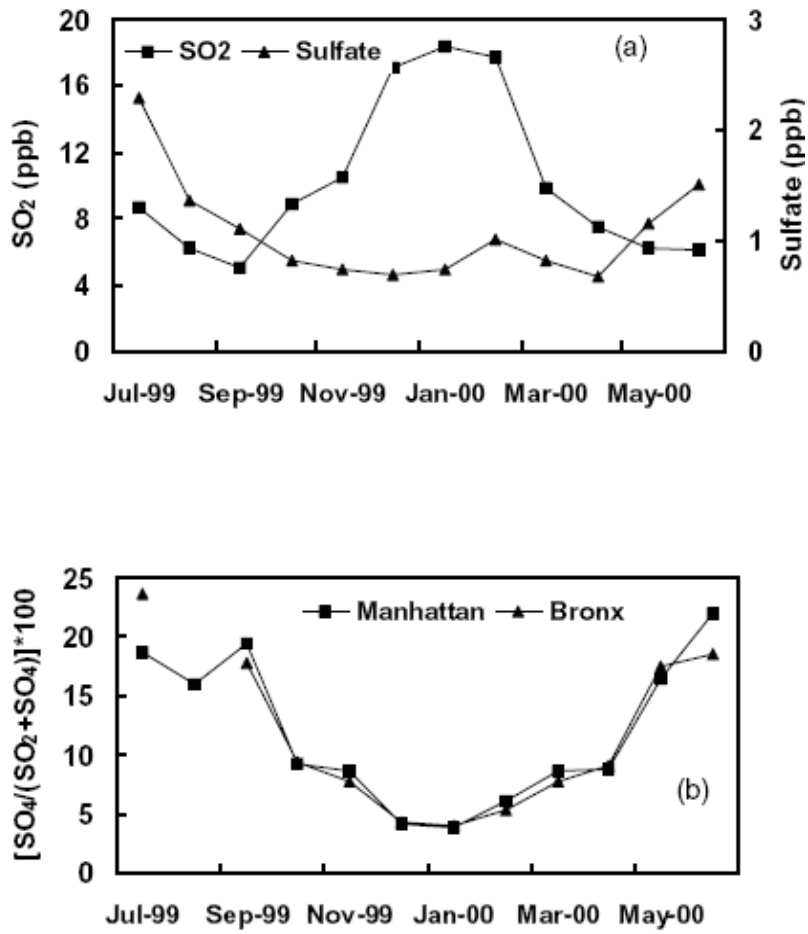

Figure 7. (a) Monthly mean concentration of SO_2 and sulfate; and (b) Monthly mean percentage of total sulfur present as sulfate.

The diurnal pattern for SO_2 (Figure 8) from two years of hourly data collected in Manhattan and at the Bronx shows an increase beginning at about 4 a.m. and peaking at 7 a.m., returning to overnight levels by noon. This pattern is the same for both locations, although SO_2 concentrations are slightly higher in Manhattan than at the Bronx location. This pattern likely reflects morning rush hour, increased use of home heating oil for domestic hot water and space heating, and atmospheric mixing from aloft.

<u>*Supporting EMEP Projects:*</u>
Enhanced Measurements of Oxidants, Fine Particles and their Precursors, Kenneth Demerjian et al., No. 4918

Fine Particle Constituents and Acute Asthma in Urban Areas, Daniel Luttinger et al., No. 6484

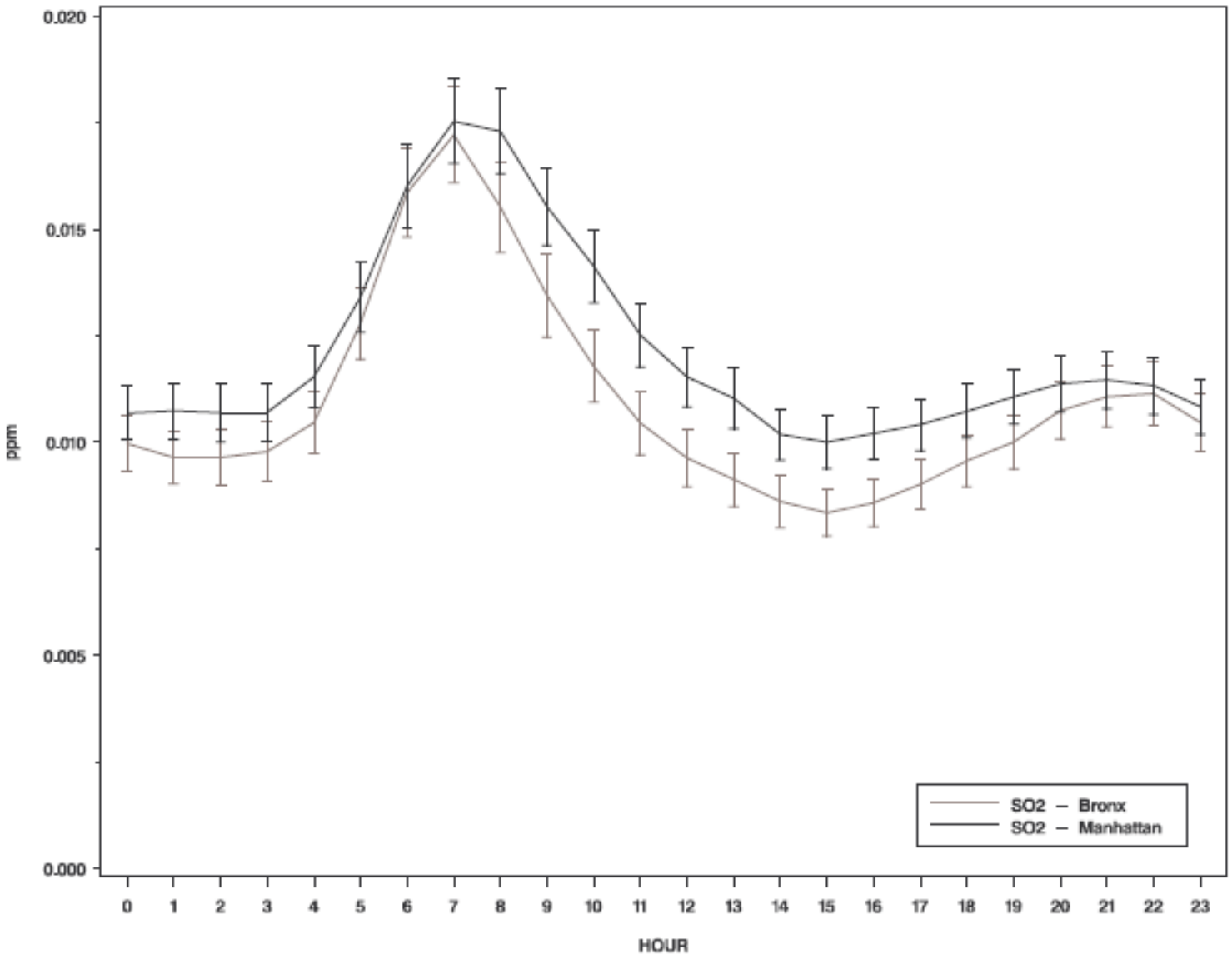

Figure 8. Averages by hour of day for sulfur dioxide. (Luttinger et al.)

3. What are the source regions and source types contributing to PM2.5 in New York?

Considerable effort has gone into understanding where the $PM_{2.5}$ components come from. The techniques described below range from sector analysis of mass concentrations with air trajectories to sophisticated source-apportionment modeling, to ambient real-time photochemistry intensives. Some methods can determine source types by markers, such as those from motor vehicles, soil, and sea salt, but cannot determine the source region. Other methods can identify whether components are of local origin or transported from a greater distance, but these methods have more difficulty identifying exact source types.

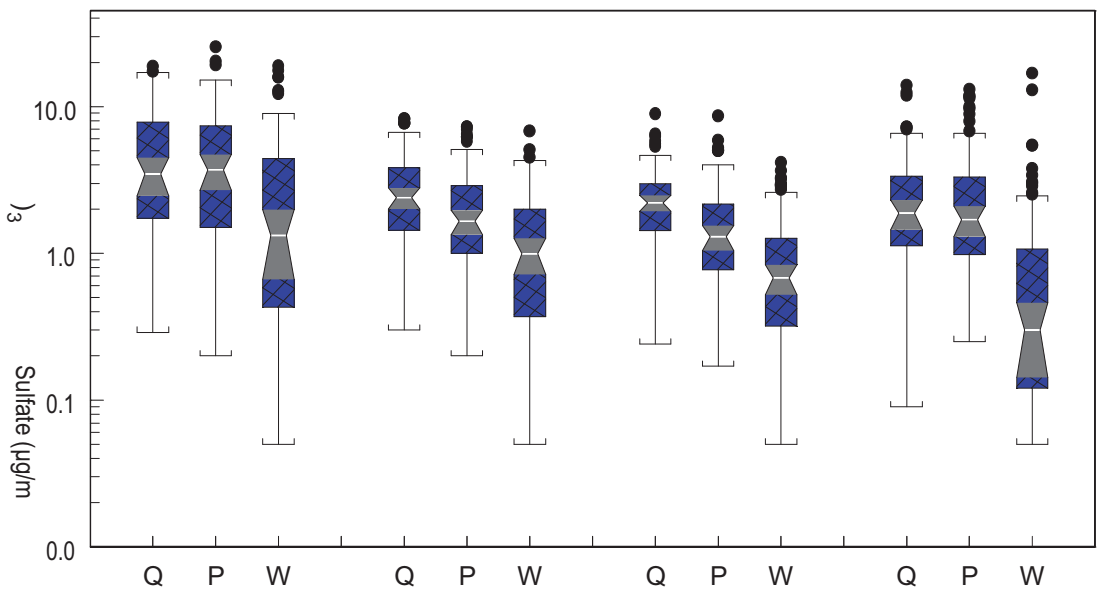

Figure 9. Box plots of daily sulfate at Queens, Pinnacle State Park, and Whiteface Mountain for quarters starting in the third quarter of 2001.

3.1 Local versus Transported Components

In order to develop effective air quality plans, it is necessary to know whether PM is transported from within a region or from a distant source. The Northeast is affected by local sources as well as transported aerosols and precursor gases from upwind sites in the Midwest. In summer, when winds are primarily from the west and southwest, SO_2 and $PM_{2.5}$ are transported into New York State.

Figure 9 shows box plots of the quarterly statistics of daily sulfate measurements at Whiteface Mountain, Pinnacle State Park, and Queens College (Dutkiewicz et al., 2004). Whiteface Mountain and Pinnacle State Park are in rural areas with few local sources. Conversely, the Queens site is in an urban location with many local sources. Although the sites are separated geographically, the concentrations of sulfate are similar due to long-range transport of aerosols impacting all three sites similarly.

Figure 10a shows a radial plot of sulfate as a function of the 12-sector directions superimposed on a map of the Northeast. Figure 10b is the same, but normalized to the frequency of the air masses and expressed as a percent. The radial plots illustrate the importance of source regions to the west and southwest. The highest sulfate at all three sites is focused toward the Ohio River Valley and the area around the Great Lakes. Moderately high concentrations at Pinnacle and Queens are also associated with air flow through the Mid-Atlantic states.

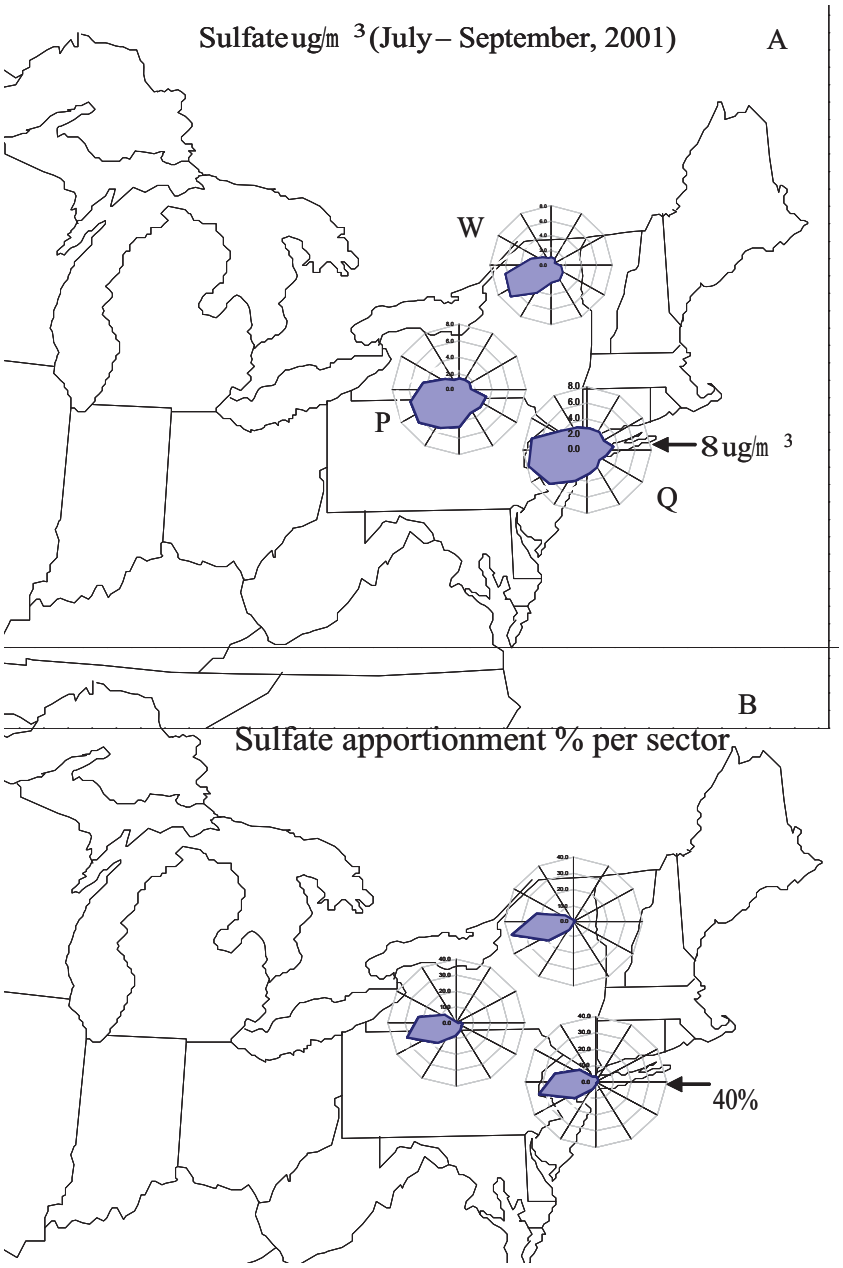

Figure 10. Radial plots of sulfate.

Bari et al. (2003) also used sector analysis to evaluate local and transported contributions to NYC aerosols at the Manhattan and Bronx sampling sites. In this method, "local" sources were considered to be those within 150 km of the sampling site. Sectors 12 through 4 on a clock, including any sources due north, in New England, and on Long Island, were assumed to be the background values. Because of this, local values should be considered as upper estimates. For all seasons, the majority of the transported component was from the Midwest. They found that 30% of annual $PM_{2.5}$ was transported to NYC from outside. The largest amount of transport occurred during summer. In addition, the annual amount of SO_4 transported from the Midwest was 43%, with the remaining 57% found to be of local origin. Conversely, they found that only 14% of SO_2 was transported into NYC, with 86% due to local sources (Figure 11).

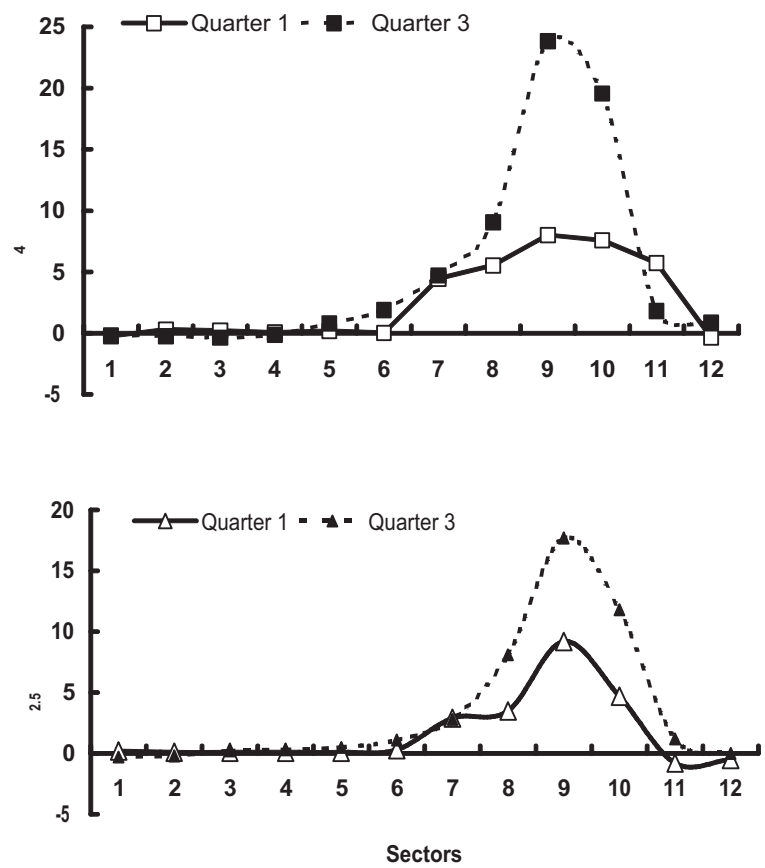

Figure 11. Quarterly transported component (%) after subtracting background for SO_4, SO_2, and $PM_{2.5}$ at Manhattan during first and third quarter 1999.

Dutkiewicz et al. (2004) evaluated the local versus transported components to New York City using the sector analysis approach, as well. Using data from Queens College (Supersite 2001-2002), the Bronx, and Manhattan (DOH, 1999-2000), they found sulfate concentration measured at the three sites to be highest when the wind was from the Midwest, and the effect was largest in summer. The same pattern for all three sites indicates a large effect from transported SO_4 (Figure 12). By separating the Queens data into warm and cold seasons, they estimated the local sulfate component in $PM_{2.5}$ to be 1.75 ug/m^3 during the cold season and 2.4 ug/m^3 during the warm season.

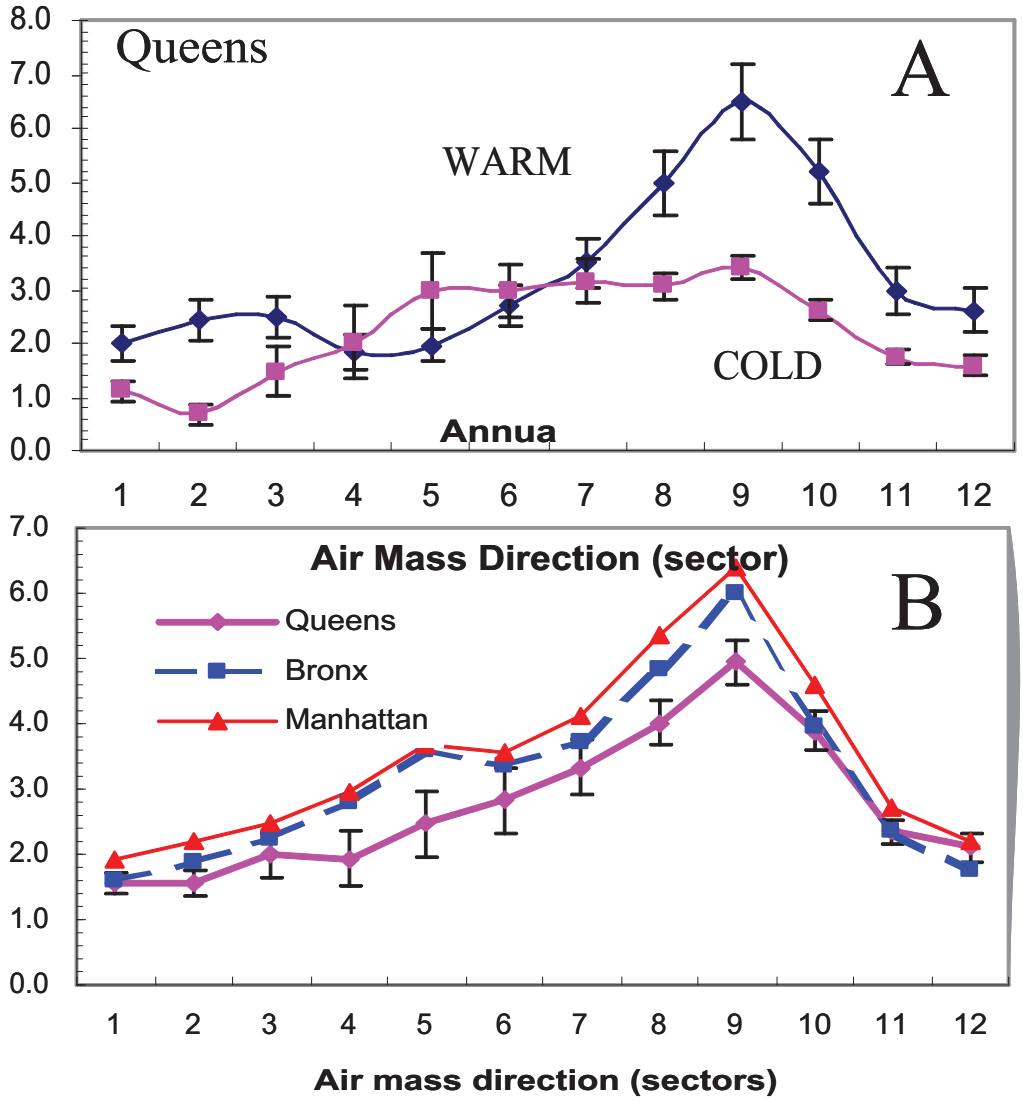

Figure 12. Top: Sulfate concentrations versus 12 sector directions for Queens in warm and cold (Oct.-Mar.) periods. Bottom: Annual sulfate concentrations versus the 12 sector directions for Queens, Manhattan, and Bronx. (Dutkiewicz et al., 2004)

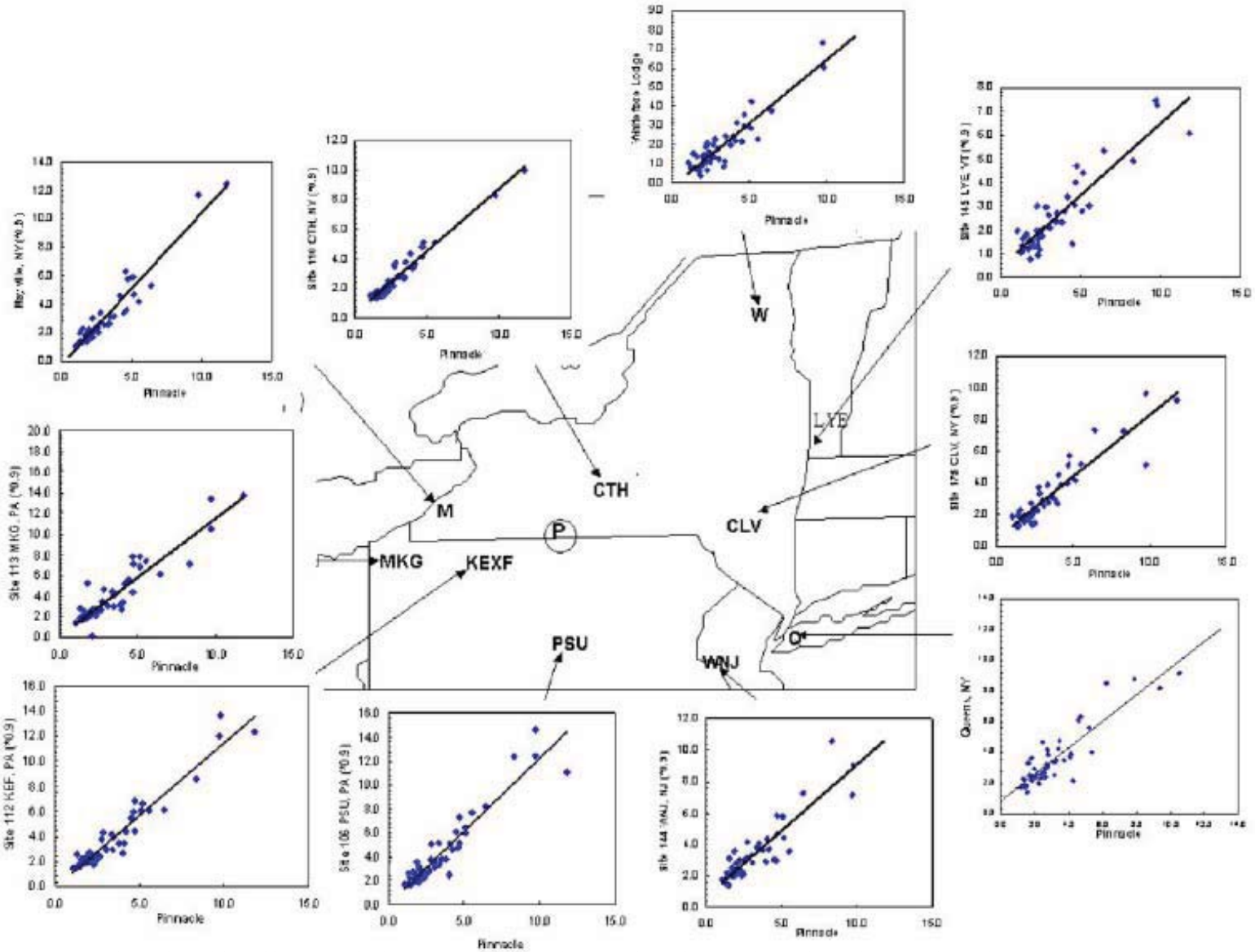

Figure 13. Scatter plots of weekly sulfate at each site versus concentrations at Pinnacle over the period July 2001 through June 2002. Lines are the result of linear regression fits to the data.

Dutkiewicz et al. (2004) determined local and transported sulfate using an alternative approach as well. Figure 13 shows scatter plots of sulfate measured in week-long CASTNet samples from 10 sites in and around New York State relative to sulfate measured at Pinnacle. The slopes of the sites west (upwind) of Pinnacle are greater than 1.0, indicating that they have a greater regional sulfate component than Pinnacle. Their intercept is close to zero, suggesting that their local sulfate is similar to Pinnacle. All of the sites east (downwind) of Pinnacle have slopes less than 1. This is consistent with a smaller regional sulfate component. The intercepts differ from site to site due to the local sulfate component. The lowest is at Claryville, NY (0.46), and the highest is in Queens (0.84), suggesting that the local sulfate component for Queens is 0.84 relative to that at Pinnacle. Adding this to the 0.8 ug/m^3 determined for Pinnacle based on air-mass trajectories yields a local sulfate concentration of 1.6 ug/m^3. This is comparable to the local background determined for Queens in the cold season (1.8 ug/m^3) but not for the warm season (2.4ug/m^3).

The nearest site to Queens is at Washington Crossing, NJ. This agricultural-urban site is in western NJ, 100 km southwest of Queens. The slope is similar to that for Queens, but the intercept is slightly lower at 0.64 ug/m^3. This local sulfate also affects the upwind Queens site.

Qin et al. (in press) also investigated local versus transported components of $PM_{2.5}$ in NYC. They used 2002–2003 Speciation Trends Network (STN) data for four urban sites: Elizabeth, NJ, the New York Botanical Gardens in the Bronx, IS52 in the Bronx, and Queens College. Comparison of the major $PM_{2.5}$ components were in good agreement, which is understandable since the $PM_{2.5}$ measured in NYC should have some common sources. The $PM_{2.5}$ at Chester, NJ, was reasonably well correlated with the NYC sites as well. Chester, NJ, approximately 100 km upwind of NYC, was selected as a background site. They found that 69-82% of PM $_{2.5}$ may be transported to New York City, with 18-31% from local sources. They also found that 93-100% of sulfate was transported, 54 to 65% of nitrate was transported, and 71-86% of NH_4^+ was transported.

Lall and Thurston (2005) used Sterling Forest, NY, a site 50 miles northwest of NYC, as a background site for the Hunter College site in Lower Manhattan. Using positive matrix factorization (PMF), they found that transported aerosols contributed more than 40% of the total $PM_{2.5}$ measured at Hunter College. In addition, more than 80% of the New York City sulfate mass and 30% of the OC was transported from outside. Conversely, the EC fraction in Manhattan is almost completely local (more than 90% of local origin).

Demerjian et al. (2005) estimated summer PM sulfate photochemical production using ambient measurements and reaction kinetics (OH + SO_2), which indicated a mean production rate of 0.14 ug/m^3/h, or 3.38 ug/m^3/day. These results indicate that 15-60% of observed PM sulfate at Queens College in July 2001 could have been generated by photochemical oxidation processes and was most likely of local origin.

Summary of Local versus Transported Components

A summary of the percent of transported $PM_{2.5}$ and aerosol sulfate is given in Table 1. The sulfate values range from approximately 40-100%. Those studies of seasonal transport found that 48-85% of sulfate was transported into New York City during summer. During winter, this value was lower, at 39-79%. The wide range of values is due to the various approaches taken in interpreting the aerosol measurement data. A careful analysis of these results and associated assumptions is necessary in order to apply findings to policy formulation.

The lowest values were determined using sector analysis. In this approach, sectors to the north and east (sectors 12-4) were assumed to be background. The observed SO_4 from these regions was subtracted from that measured in the other sectors to determine the transported component. Because this approach does not account for SO_2 sources in New England and Long Island, it minimizes the transported component. In addition, due to the six-hour trajectories used, this method assumed that all sources within 160 km were local.

In contrast, the methods that determined a higher percent of transported aerosols subtracted the sulfate measured at sites upwind, either Chester, NJ, or Sterling Forest, NY. These sites are 100 km and 80 km from New York City, respectively, well within the 160-km local radius used in the sector analysis. While they are frequently upwind sites, there may be times when they are affected by regional stagnation events and urban pollution to the east. These methods probably overestimate the amount of transported sulfate.

Despite the range of values, all of these studies suggest that a large fraction of aerosol sulfate and $PM_{2.5}$ in New York City is not from local sources and not under the control of New York State air-quality planners.

Table 1. EMEP estimates of $PM_{2.5}$ and sulfate transported into New York City.

Method Used	Estimated percent of PM2.5 transported into NYC(%)	Estimated percent of PM sulfate transported into NYC(%)	Citation
Sector analysis (local is within 160 km)	31 %	44-45 % annual	Bari et al. (2003)
Correlation of sites in northeast and sector analysis	--	48-65 % summer 39-44 % winter	Dutkiewicz et al. (2004)
Photochemical experiments	--	>50 %	Demerjian et al
Subtraction of upwind site and (Sterling Forest)	56 % summer 33 % winter	85 % summer 79 % winter	Lall and Thurston in press
Subtraction of upwind site (Chester)	69-82%	93-100 %	Qin et al. In press

<u>*Supporting EMEP Projects:*</u>
Enhanced Measurements of Oxidants, Fine Particles and their Precursors, Kenneth Demerjian et al., No. 4918

Fine Particle Constituents and Acute Asthma in Urban Areas, Daniel Luttinger et al., No. 6484

Analysis of PM Data in NY Using Advanced Source Apportionment Methods, Philip Hopke et al., No. 7919

Source Apportionment of Fine Particles in New York City, George Thurston et al., No. 6084

3.2 Identification of Source Types

Knowing whether important components of $PM_{2.5}$ are local or distant is only part of the information needed to develop air-quality management strategies. Knowing which source types are important and their relative contributions is also necessary.

New York City

Li et al. (2004) used the six-hour $PM_{2.5}$ data for SO_4 and trace metals; 10-minute aerosol mass spectrometer data for NO_3, NH_4, Cl, and OC; and 15-minute data for Na and K collected during the July 2001 intensive at the Queens College site to identify contributing sources by PMF. These sources and their relative contributions are summarized in Table 2.

Table 2. $PM_{2.5}$ sources identified at Queens College during July 2001 and relative contribution to PM mass determined by source apportionment analysis (Li et al., 2004).

Factor	Source	Major Constituents	Average Mass (ug/m3)	% Contribution to Total Mass
1	Secondary sulfate	SO_4, some OC	7.63	47
2	Secondary nitrate	NO3, some OC	1.28	8
3	Motor vehicles	OC, Zn, Pb	0.52	3
4	Road dust	Al, Ca, Fe, K	4.13	25
5	Sea salt	Cl, Na	1.73	11
6	Oil combustion	Ni, V	1.08	6

By far the largest contributor to $PM_{2.5}$ mass was secondary sulfate, contributing approximately 50% of the total. Road dust was next, comprising approximately 25% of the $PM_{2.5}$. However, due to an irregular pattern during the last two weeks of sampling, the authors suggest that this may have been affected by local construction activities.

Upstate New York

Some techniques can combine meteorology and aerosol data to give a better understanding of source locations. Aerosol data collected at Potsdam and Stockton during the summers of 2000 and 2001 include $PM_{2.5}$, BC, trace elements, and PAHs. The data were analyzed by PMF to identify possible source types (Liu et al., 2003). Six sources were identified as common to both sites: secondary sulfate, secondary nitrate, soil, wood smoke, zinc smelter, and copper smelter. A nickel smelter was also identified as a source for $PM_{2.5}$ at Potsdam (Figure 14). The results were also combined with potential source contribution function (PSCF) modeling, which includes air mass trajectories, to identify likely source regions. Results showed the Ohio River Valley to be the source region for secondary sulfate and secondary nitrate. The soil source region identified was the agricultural area in Ohio. Wood smoke was from the Great Lakes region. A copper source was located in Ontario, a zinc smelter was identified in Quebec, and nickel smelter sources were likely from Ontario and Quebec. Zhou et al. (2004) used the PMF results (Liu et al., 2003) to determine sources by two additional models: residence-time weighted concentrations (RTWC) and quantitative transport bias analysis (QTBA). The results of the methods were consistent with each other and located clearly defined sources well. As in the Liu et al. study (2003), the Midwest was identified as the potential source area for secondary sulfate.

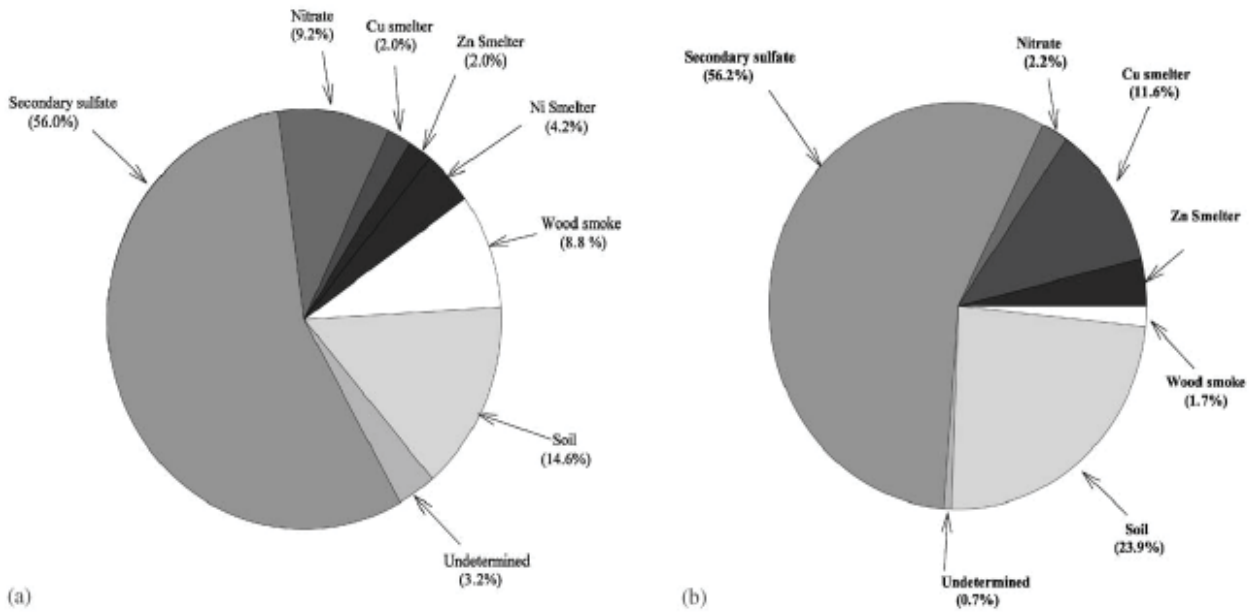

Figure 14. Source apportionment at Potsdam and Stockton. (Liu et al.)

Qin et al. (2005b) used data from four speciation trend network sites in the NYC metropolitan region and analyzed it by PMF to identify secondary sulfate, secondary nitrate, soil dust, aged sea salt, oil combustion, spark ignition, highway vehicle, and diesel as contributing to NYC aerosol (Table 3). A comparison of these findings to the EPA Emissions Inventory for primary $PM_{2.5}$ reveals some discrepancies. For example, the $PM_{2.5}$ source apportionment analysis did not identify a contribution from wood combustion, while it is estimated by the EPA Emissions Inventory to be 17% of primary PM emissions. This analysis also found soil to contribute 6-11% of the $PM_{2.5}$ in NYC, whereas the Emissions Inventory estimates 38-57% of primary $PM_{2.5}$ from fugitive dust. In addition, coal was not identified explicitly, but it is probably included in the secondary sulfate source. The receptor modeling analysis indicates that motor vehicle exhaust is a greater contributor to $PM_{2.5}$ (8-22%) than in the Emissions Inventory estimates. Finally, oil combustion was determined to contribute 4-11% of $PM_{2.5}$, much higher than the EPA Emissions Inventory estimate of 1.3-1.5%. A comparison is given in Table 3.

Table 3. Comparison of source apportionment identification of sources in NYC to those primary emissions in the EPA Emissions Inventory (adapted from Qin et al., in press).

Source Type	NYC Sites % of Total Mass Contribution by Source Category	EPA Emissions Inventory % of Total Mass
soil	6-11	38-57
oil combustion	4-11	1.3-1.5
spark ignition	8-22	3.9-5.3
diesel	approx. 3	approx. 14*
sea salt	3-7	3-5
wood burning	not identified	18

* combines both on-road and non-road

Hopke et al. (preliminary results) have also determined sources of $PM_{2.5}$ using PMF at Rochester, Buffalo, Pinnacle State Park, and Whiteface Mountain using 1-in-3- or 1-in-6-day data from STN or IMPROVE networks. The results are given in Table 4. At each location, secondary sulfate is the major contributor to $PM_{2.5}$, ranging from 36-58%.

Table 4. Average source contributions to $PM_{2.5}$ mass concentration determined by PMF source apportionment at Buffalo, Rochester, Pinnacle, and Whiteface Mountain, NY in ug/m3 and (%).

Sources	Buffalo	Rochester	Pinnacle	Whiteface Mountain
secondary sulfate	5.16 (36.1)	5.44 (43.8)	6.22 (58.2)	4.29 (53.4)
secondary nitrate	2.12 (14.8)	2.59 (20.8)	0.91 (8.5)	0.55 (6.8)
gasoline vehicle	2.76 (19.3)	1.64 (13.2)	1.81 (17.0)	1.55 (19.3)
highway/industry	1.60 (11.2)	--	--	0.47 (5.9)
road salt/sea salt	0.79 (5.5)	0.87 (7.0)	0.51 (4.8)	0.59 (7.3)
diesel emissions	0.68 (4.8)	1.37 (11.1)	0.57 (5.3)	0.35 (4.4)
highway/railroad	0.64 (4.5)	--	--	--
airborne soil	0.54 (3.8)	0.50 (4.0)	0.29 (2.7)	0.24 (3.0)
metal processing	--	--	0.37 (3.5)	--

Supporting EMEP Projects:
Enhanced Measurements of Oxidants, Fine Particles and their Precursors, Kenneth Demerjian et al., No. 4918

Analysis of PM Data in NY Using Advanced Source Apportionment Methods, Philip Hopke et al., No. 7919

Impact of In- and Out-of-State Power Plants on Semivolatile Pollutants in New York State, Philip Hopke et al., No. 6083.

3.3 Organic Components and Source Identification

The organic fraction of $PM_{2.5}$ in NYC is a substantial fraction (Figure 2), contributing 28% of the mass. This fraction is composed of many different compounds, only 15% of which have been identified (NARSTO, 2003). Identifying the various organic classes will be essential to determining sources and subsequent changes in the atmosphere. There is both a primary and secondary organic particle contribution.

Demerjian et al. (2005) compared OC:EC ratios by day of the week and found a higher ratio on the weekend on Canal Street (a major diesel truck route) due to decreased diesel traffic on the weekend. This was not observed at the Queens College site.

A study of the composition of the organic fraction in aerosols is being performed by Mazurek et al. using samples collected in and around New York City. The sites represent upwind and downwind sites as well as urban and rural sites. They were collected as part of the Speciation of Organics for Source Apportionment of $PM_{2.5}$ in the New York City Area (SOAP) project. This analysis identifies mass concentrations for 63 organic molecular marker compounds that will be used in new modeling for source apportionment. The findings for markers of motor vehicles, cooking oil, and photochemical oxidation products are given in Table 5.

Table 5. Preliminary results of organic marker spatial variability in the New York Metropolitan region.

Source Type	Marker	Spatial Variability	Seasonal Variation
motor vehicles	hopanes	highest in urban, lowest in rural	--
cooking oil	n-alkanoic acids C10-C30	highest in urban areas	highest in winter
photochemical oxidation product	C2-C10 diacids	highest in urban areas	highest spring and summer

The project results will be used in a chemical mass balance modeling effort with the EPA National Exposure Research Laboratory. However, initial model results indicate that more work is needed to improve the emissions inventory of fine PM in the NYC airshed, especially with respect to commercial and domestic food cooking.

As detailed in the recent NARSTO Emissions Inventory Assessment (NARSTO, 2005), there is a great need for more detailed inventories including fine particulates and their precursors. This study was able to identify three large classes of molecular markers.

<u>*Supporting EMEP Projects:*</u>
Enhanced Measurements of Oxidants, Fine Particles and their Precursors, Kenneth Demerjian et al., No. 4918

Chemical Composition of Fine Organic Particles from Urban Regional Background Locations in New York State, Monica Mazurek, No. 7616

3.4 Particle Size and Source Identification

Beyond total mass, the physical size of particles is important. Size determines whether a particle will settle out of the air or remain suspended. Size also gives important information about atmospheric processing and source types.

Hopke et al.(2005) measured particle number concentrations and size distributions in Rochester, NY, during 2002 (Figure 15). The Rochester ultrafine particulate data set is one of the longest records in the U.S. The smallest ultrafine particles (UFPs), from 11 to 50 nm, accounted for 70% of the total number concentration. The particles in the range of 50 to 100 nm accounted for approximately 20%. Hopke et al.(2005) found that the mean number concentration in winter months tended to be higher than values in summer. In addition, diurnal patterns emerged. Particles in the range of 11 to 50 nm typically had two peaks, one at about 8 a.m. that was associated with CO in the winter. The emissions were likely directly emitted from vehicles during the morning rush hour.

Nucleation and Growth

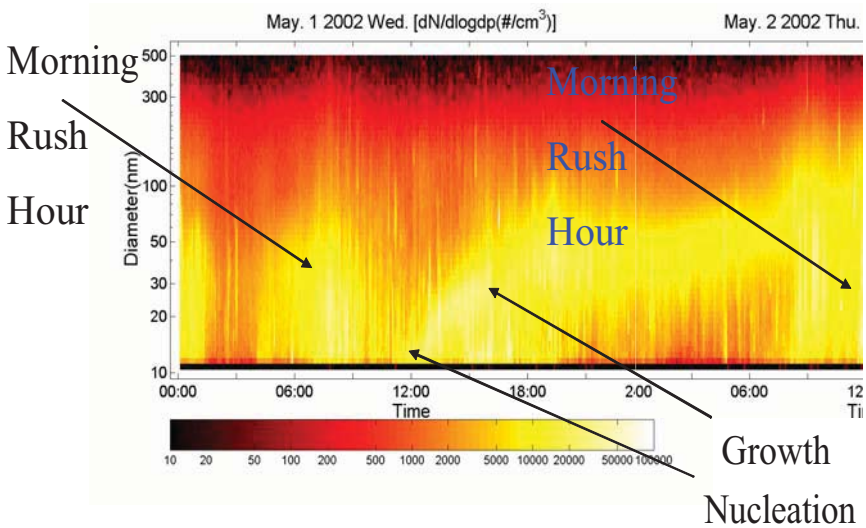

Figure 15. Particle number concentration and size distribution, Rochester, NY. (Hopke et al., 2005)

The second peak was between noon and 6 p.m. and was associated with nucleation events, which had a sharp increase of particles in the 11 to 50 nm range. This was most often observed in spring and summer, when photochemical activity is at its peak. In addition, peaks of SO_2 were observed during the nucleation events when the wind direction was from the northwest, where large local SO_2 emission sources are located. A subsequent study at this site (Jeong et al., 2006) also observed regional nucleation events. Ogulei et al. (in press) used receptor modeling to identify source types contributing to air quality in Rochester, NY. Using particle number concentrations, gaseous species, and meteorological variables, they identified ten different sources during three different seasons (Figure 16). Using this approach they were able to identify residential/commercial heating separately from other sources, such as diesel trucks. This is a significant advancement over other source apportionment techniques.

Particle counting and sizing measurements in the Supersite program showed little evidence of nucleation events in Queens, NY, suggesting preferential condensation of secondary semi-volatile products on existing aerosol surfaces. Only under very clean urban and rural aerosol background conditions, such as at Whiteface Mountain, was there some evidence of possible nucleation.

Drewnick et al. (2004) measured chemically speciated mass distributions during summer 2001 at Queens College. They found ammonium, nitrate, and sulfate particles consist primarily of a single mode at 400, 439, and 477 nm, respectively. In contrast, the organic particles typically had two modes (78 and 359 nm). The similar results for nitrate and sulfate indicate that they are internally mixed. In addition, this is supported by similar distributions even during hourly averages. The lower mode for ammonium indicates that it is associated not only with nitrate and sulfate particles but also with organic particles.

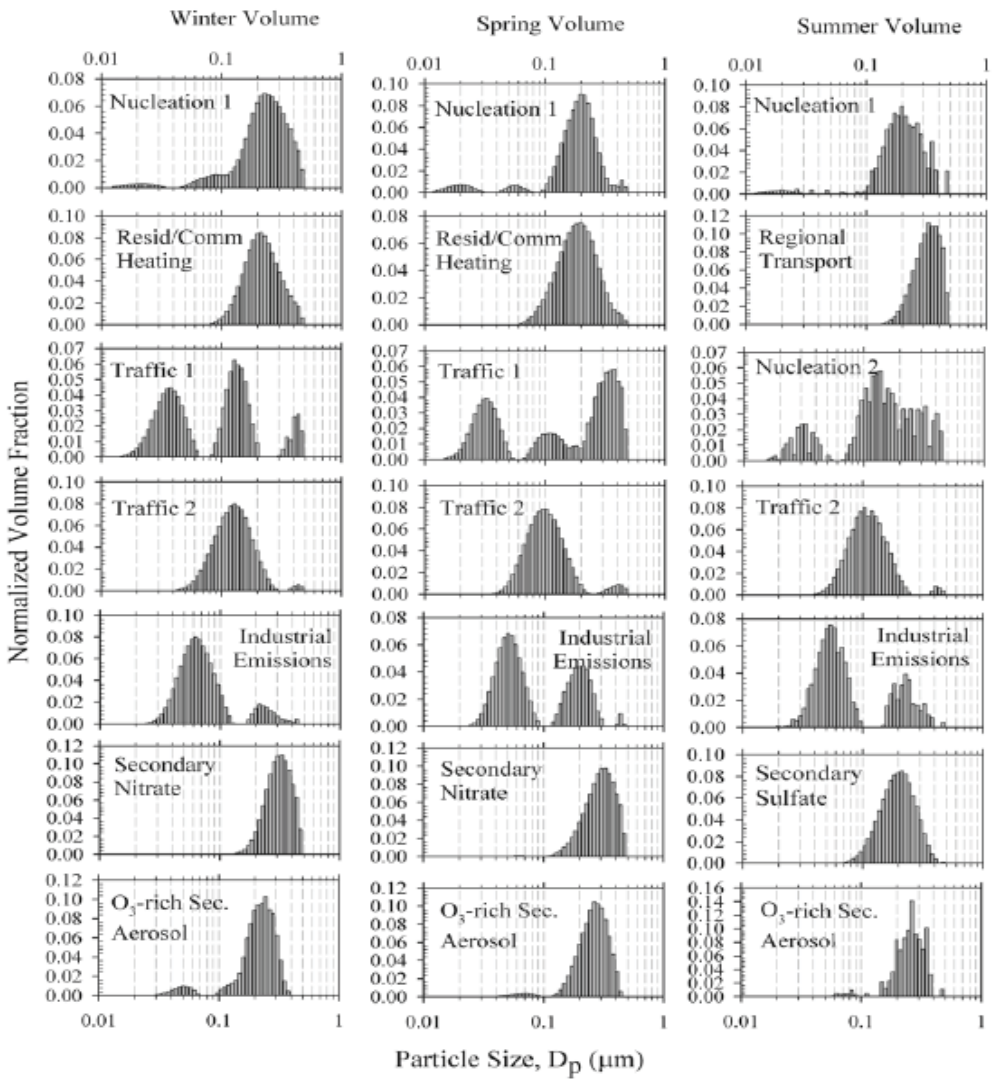

Figure 16. Particle volume profiles of resolved sources.

The organic-particle size distributions are substantially different. The accumulation mode diameter peak occurs at a significantly smaller particle diameter than nitrate, sulfate, and ammonium. In addition, during almost all time intervals, a smaller diameter mode is observed. This small mode and the relatively small diameter of the accumulation mode are indicative of relatively young aerosol, locally produced by the high volume of traffic in the area of the measurement site. This traffic-related organic aerosol is not internally mixed with the more aged ammonium sulfate and ammonium nitrate aerosol.

Research by Demerjian et al. (briefing) observed a seasonal variation in particle size. Figure 17 compares the summer and winter composition of UFP for measurements made in summer 2001 and winter 2004 at Queens College. In winter, there are smaller mean modes (200 nm), and the UFP bimodal distribution is masked. Once again, the organics are in greater abundance, but in winter the nitrate increases and is greater than the sulfate.

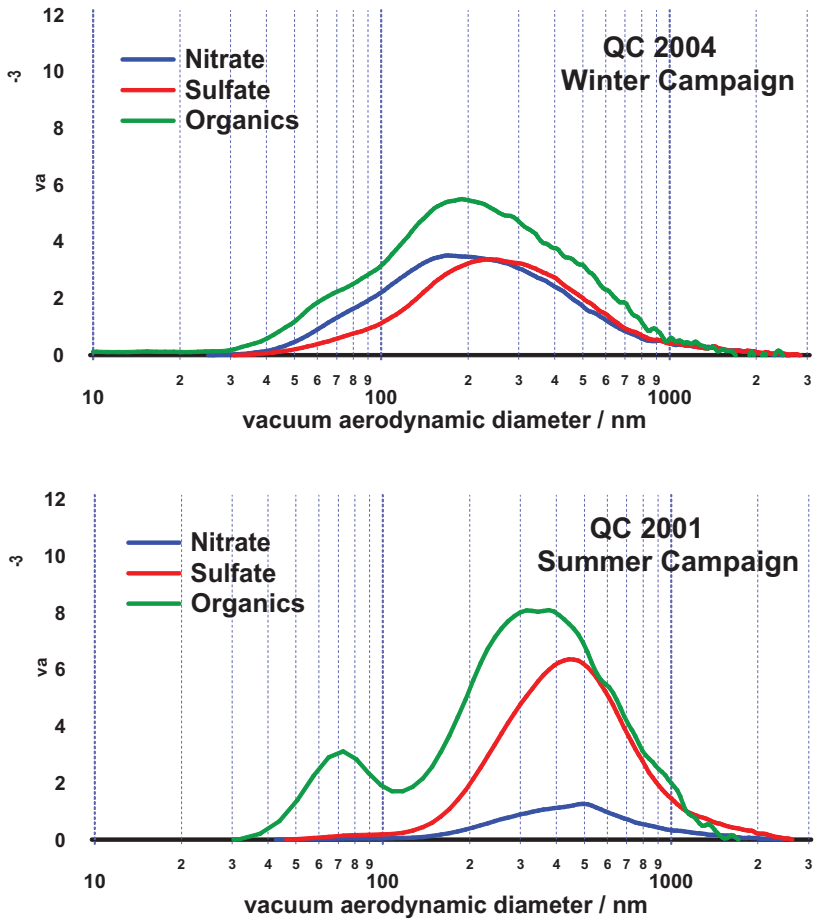

Figure 17. Summer and winter composition of UFP particle by size.

Diurnal patterns of size distributions of nitrate, sulfate, and organic PM were calculated by averaging all size distributions measured over each specific hour of the day (1:00, 7:00, 13:00, and 19:00) during the summer campaign (Figure 18; Drewnick et al., 2004). Diurnal patterns for sulfate, nitrate, and organic particle size distributions show little change of mode during the day, suggesting that most of this aerosol mass is transported to the measurement site from a different region. The most significant pattern was found in the small particle mode (less than 120 nm). This fraction showed a large maximum during the morning

rush hour, when the most traffic was experienced on the highways around the site. Smaller maxima were observed for the afternoon and evening traffic. These results suggest that the appearance of the intense small-particle mode in the size distribution of the organic particles is caused by heavy traffic on the highways.

Demerjian et al. (2005) further investigated summertime secondary organic aerosol (SOA) as a function of oxidant season. Estimates of photochemical production of SOA from direct measurement of OH and VOC are consistent with estimates from aerosol mass spectrometer analyses that attribute organic carbon $PM_{2.5}$ to hydrocarbon-based organic aerosol (HOA) and oxidized organic aerosol (OOA) species. The estimates suggest summertime contributions of SOA production from photochemical reactions in Queens can account for 40% of the observed organic carbon PM. Determining how much of the VOCs are of biogenic or anthropogenic origin will be important for estimating benefits of VOC controls such as diesel particulate filters. It also illustrates that reducing photochemical oxidants in general is important, not just with respect to ozone production but secondary PM formation as well, and that a multi-pollutant approach is needed in air-quality management considerations.

Supporting EMEP Projects:
Enhanced Measurements of Oxidants, Fine Particles and their Precursors, Kenneth Demerjian et al., No. 4918

Monitoring Particle Size Distribution in Rochester, Philip Hopke et al., No. 6820

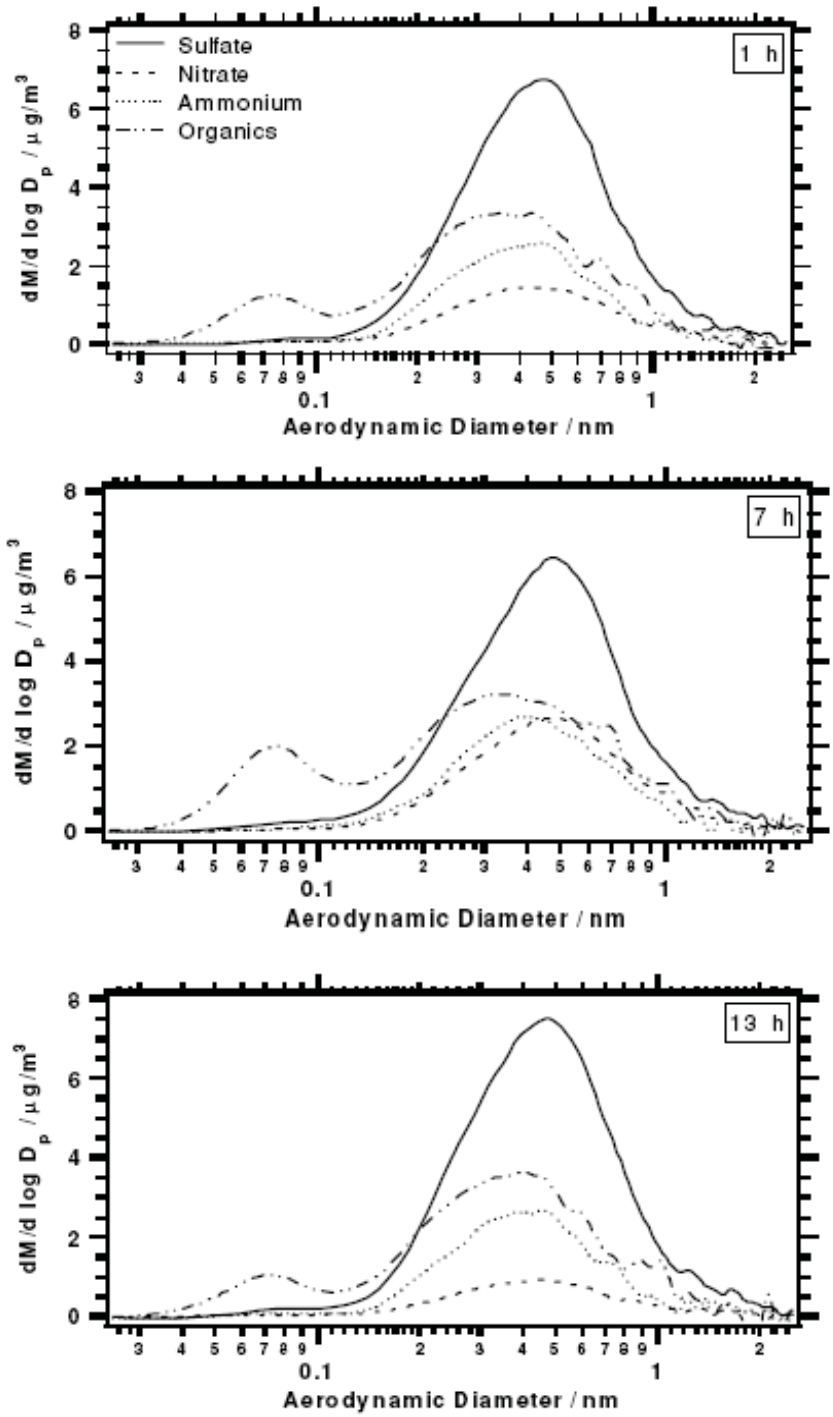

Figure 18. Diurnal patterns of the size distributions of sulfate, nitrate, and organics.

4. Are there specific components in the $PM_{2.5}$/co-pollutant complex causing adverse health effects?

Epidemiological studies have found associations between increasing PM mass concentrations and respiratory symptoms, respiratory and cardiovascular disease, and mortality. The National Ambient Air Quality Standard for PM is mass-based. The U.S. EPA has five PM Health Centers investigating the mechanisms by which PM causes adverse effects on human health. Among the hypotheses being tested are those focusing on particle size or composition. Larger particles can be removed in the nose, whereas smaller particles can travel deeper into the lungs. In addition, it is possible that PM components with different chemical composition have varying health effects. The bulk of the EMEP investment in health effects research has focused on exploring the role of UFPs. This has leveraged significant investment by EPA in a PM Health Effects Center at Rochester.

4.1 Ultrafine Particles

Research by Utell et al. investigated the effects of inhaling ultrafine particles in healthy subjects as part of the $8 million U.S. EPA PM Health Center program at the University of Rochester Medical Center. The researchers developed a UFP-exposure system that generated carbon particles that were diluted by filtered air and breathed through a mouthpiece by healthy subjects. Ultrafine-particle deposition was determined by the difference in numbers of particles exhaled from those inhaled. In addition, blood components were measured to monitor inflammation. The results showed that there were high pulmonary deposition rates, which increased with exercise. The smallest particles had the highest deposition rate. Blood oxygen saturation decreased in females after exposure to 25 ug/m^3 UFPs. There were a number of cardiac effects in addition to pulmonary effects, including signs of alteration of cardiac repolarization.

While these changes were small, they could affect heart function in people with severe cardiac disease. The Rochester PM Health Center will continue to investigate the effects of UFPs by monitoring a sensitive population's response to changes in ambient UFP concentration. Seventy-five subjects will be recruited from a cardiac rehabilitation program. These subjects will not be exposed to carbon particles generated in the exposure system described above; rather, they will simply breathe ambient air. There will be UFP monitors measuring the UFP concentration in the rehabilitation center as well as in ambient air of the general region where participants live. Some additional in-car and in-home measurements will also be performed. Ultrafine particles in Rochester, NY, were characterized by Hopke et al. (NYSERDA publication 05-04, 2006) who found traffic, coal-fired power plants, nucleation of particles from precursors, and particle growth as important influences on UFP number concentration.

Supporting EMEP Projects:
Clinical Studies of Exposure to Ultrafine Particles, Mark Utell et al., No. 4913

Ultrafine Particles and Cardiac Responses: Evaluation in a Cardiac Rehabilitation Center, Mark Utell et al. No. 8650.

4.2 Source Apportionment and Health Effects

In May of 2003, NYSERDA sponsored the "Workshop on Source-Apportionment of PM Health Effects," with the objectives: 1) to ascertain if quantitative relationships can be observed between apportioned source contributions and human mortality using particle composition and mortality data from two different cities; and 2) to ascertain if different receptor modeling methods significantly affect the contribution/mortality relationships.

Seven research groups participated and used various methods to apportion the $PM_{2.5}$ mass samples from Washington, D.C., and Phoenix, AZ. The methods ranged from simple mass regressions to more intricate factor analysis methods (Thurston et al., 2005; Hopke et al., 2005). The apportionments were then evaluated for their associations with daily mortality for each city (Mar et al., 2006; Ito et al., 2006).

The source apportionments by the various groups identified the same major source types with similar key tracers. The results of mortality-to-source-apportionment comparisons indicated that between-source variation in relative risk was statistically significant, while between-analysis variation was not. This indicates that variations in research group and/or choice of source apportionment method had only a relatively small effect on variations in the cardiac mortality relative-risk estimates derived for these cities. Across the two cities, the most consistently associated $PM_{2.5}$ source category with adverse health effects was sulfate-associated mass.

Although further research is needed in defining tracer profiles for sources with less-well-defined compositional characteristics in order to allow more exact quantitative source-specific mass toxicity evaluations, these results provide substantiation that present-day $PM_{2.5}$ source apportionment methods can provide valuable insights into the source components that contribute to $PM_{2.5}$–health-effects associations.

Supporting EMEP Projects:
Workshop on Incorporation of Receptor Models into PM and Adverse Health Effects Study, Philip Hopke et al., No. 7607.

4.3 Asthma in New York City

The New York State Department of Health, along with the New York State Department of Environmental Conservation, undertook a two-year sampling campaign (January 1999 through November 2000) of certain hazardous air pollutants, criteria pollutants, and bioaerosols in two New York City neighborhoods, located only five miles apart. The neighborhoods have different rates of hospital admissions for asthma and different socioeconomic status characteristics. The study was to assess whether ambient air quality differed in the two New York City locations and to evaluate the effects of various air contaminants on exacerbation of acute asthma symptoms.

The statistical analyses comparing ambient air between the Bronx and Manhattan sites were conducted using a paired t-test adjusted for autocorrelation. Comparisons were made on a seasonal basis (quarterly) and for the entire study period. Mean levels of fine PM, particulate acidity, particulate sulfate, particulate nickel, acid gases, ammonia, sulfur dioxide, and nitrogen oxides were significantly higher in Manhattan than in the Bronx over the entire study period. Mean levels of ozone, ragweed pollen, and grass pollen were significantly higher in the Bronx. For the most part, even when there were differences in concentrations between the two sites, the differences were small, less than 1.6-fold.

Using emergency department (ED) visit data and air quality parameters described above, the magnitude of the relationship between daily asthma ED visits and air pollution and bioaerosol concentrations across the two communities were compared. In addition, lag dependency of the asthma response, age and sex stratification, and whether effects were evident for control outcomes (i.e., ED visits for causes not likely to be related to air quality) were explored. The Poisson regression analysis was used to test effects of 14 key air contaminants on daily ED visits with control for temporal cycles, temperature, and day-of-the-week effects. The core analysis utilized the average exposure for the 0- to 4-day lags. Sensitivity analyses examined different lag effects.

Mean daily rates for asthma ED visits were over 8-fold higher in the Bronx study area than in the Manhattan area. The reason for this was beyond the scope of this study. Concentrations of pollutants were generally similar in the two communities with mean levels slightly higher in Manhattan in most cases. Among the 14 key pollutants examined individually in regression analyses, five had statistically significant effects on asthma ED visits in the Bronx, including daily 8-hour maximum ozone, mean daily nitrogen dioxide (NO_2), sulfur dioxide (SO_2), $PM_{2.5}$, and maximum one-hour $PM_{2.5}$. No statistically significant pollution effects were observed in the Manhattan community.

The findings of this study suggest that $PM_{2.5}$, SO_2, ozone, and NO_2 had statistically detectable impacts on acute asthma ED visits in a community with a relatively high baseline rate of acute asthma exacerbations. It is of particular interest that the more robust health impacts were observed with the daily maximum $PM_{2.5}$ concentrations compared to the 24-hour mean, suggesting that peak exposures may have larger health impacts. These associations with health effects in the Bronx occurred at ambient air levels that are below the current short-term NAAQS. Based on the results of this study, the New York State Department of Health has recommended that the U.S. EPA consider the findings in this study identifying respiratory health effects associated with SO_2 concentrations below current standards during their five-year review of the SO_2 NAAQS. It also gives evidence for considering the effects of short-term $PM_{2.5}$ excursions in future reviews of the $PM_{2.5}$ NAAQS. In addition, when community-based asthma interventions are planned with respect to air pollution messages, higher priority should be given to communities with larger asthma burdens.

Supporting EMEP Projects:
Fine Particle Constituents and Acute Asthma in Urban Areas, Daniel Luttinger et al., No. 6484

4.4 Water-Soluble Metals

The metals in PM are present only in trace amounts but may be bio-available when inhaled as small particles. No EMEP-funded health study is currently using this data, but the toxicity of water-soluble metals in ambient PM is a topic of current research nationally. Table 6 shows the solubility of various trace metals collected in daily samples at the Queens College site from July 2001-2002 (Dutkiewicz et al., unpublished). As anticipated, the anthropogenic elements are highly soluble, while the elements associated with the crustal components are insoluble.

Supporting EMEP Projects:
Enhanced Measurements of Oxidants, Fine Particles and their Precursors, Kenneth Demerjian et al., No. 4918

Table 6. Solubility of Trace Elements in $PM_{2.5}$ from Queens, NY.

element	mean solubility (%)	method*	regression coef. (r^2)	number
Zn	90 ±1.3	R	0.93	174
V	88 ±0.8	R	0.95	332
Pb	88 ±1.0	R	0.94	309
Mg	88 ±1.2	R	0.89	239
Mn	84 ±1.0	R	0.91	254
As	84 ±1.0	R	0.88	236
Co	73 ±1.2	R	0.90	156
Sb	71 ±0.8	R	0.91	298
Se	70 ±0.8	R	0.93	260
Ni	64 ±0.9	R	0.86	192
Fe	62 ±1.1	R	0.70	242
Ca	47 ±14	M	NA	12
Cd	12 ±7	M	NA	5
Al	11 ±8	M	NA	13
Cr	5 ±4	M	NA	6

* R = regression slope ; uncertainty= standard error
M = mean: uncertainty = standard deviation

5. What are the implications for air quality management of $PM_{2.5}$ and ozone?

To answer this, we must understand how particles form and evaluate the reliability of the emissions inventories that are used to determine major sources. These emissions inventories are key to air quality management. For $PM_{2.5}$ we need to know both primary composition and precursor emissions, as well as size distributions. For example, researchers lack detailed information on the carbon component, yet it makes up 36% of the PM mass in New York City.

5.1 Particle Formation in Vehicle Exhaust

Research by Yu et al. is investigating the possible mechanisms that determine how particles are formed and grow in motor vehicle exhaust. They are focusing on two theories: ion-mediated nucleation (chemiion theory) and H_2SO_4-H_2O binary homogeneous nucleation. They are also investigating the role of organic compounds in growing nucleated particles. Much of this work is being done by developing theoretical models, but some involves laboratory experiments with the NYSDEC's Automotive Emissions Laboratory.

Chemiions can be observed at high concentrations during vehicle acceleration but are much lower during idling or steady speed. Nucleated ions can explain some of the nucleated particles but do not address particle formation at very high concentrations. This study is investigating the role of binary nucleation, which can produce significant particle formation. It is also looking at the effect of particle formation when the S content of fuel is much lower, as with ULSD.

This study modeled particle formation and growth to investigate the role of organic compounds in a plume. Researchers found sulfuric acid vapor contributing to particle growth to about 3-4 nm, but organic compounds, such as from unburned fuel and lubrication oils, dominate the growth of the nucleated nanoparticles to around 10-20 nm.

Supporting EMEP Projects:
Formation and Transformation of Particles in Motor Engine Exhaust, Fangqun Yu, et al., No. 7618

5.2 Bus Technology Emissions Testing

Over the past 10 years, there has been an increase in the number of technologies available to improve emissions from heavy-duty vehicles. These strategies range from alternative-fuel technology to emissions-control technologies for use with existing diesel vehicles.

In 1996, the voters of New York State passed the Clean Air/Clean Water Environmental Bond. Among many resulting environmental programs was the Clean Fuel Bus Program, designed to provide financial incentives for public transportation authorities to begin procuring buses operating on alternative fuels. Such technologies included compressed natural gas (CNG), electric, and hybrid-electric buses. In 2000, the Metropolitan Transportation Authority began a year-long demonstration of diesel retrofits requiring ultra-low-sulfur diesel, a specialty fuel at the time that will be widespread in the fall of 2006.

The New York State Department of Environmental Conservation evaluated the durability and performance of these technologies in a chassis-dynamometer emissions test program. Performance evaluations of the particle filters showed they were durable and reduced CO, HC, and PM by more than 90% (Lanni, 2001). In addition, carbonyls were reduced by more than 99%, and more than 80% of PAH and N-PAH reduction was achieved (Lanni, 2001).

For CNG buses, the reduction of PM was approximately the same as a diesel bus with a continuously regenerative diesel particulate filter (CRDPF) using ultra-low-sulfur diesel (ULSD): more than 90% (Lanni et al., 2003). CO was higher for CNG buses than for buses with CRDPF. Similar SO_2 emissions were

observed from the two bus types; however, the buses with CRDPF had much higher SO_4-PM. The CRDPF emissions had a high NO_2/NOx ratio (50%) due to high NO_2 emissions. The ratio in emissions from CNG buses was equal to those from diesel buses without a CRDPF.

As part of the EMEP-funded PMTACS program, a mobile lab was set up for chase studies of the buses while in use. NOx emissions from diesel and CNG buses were comparable (Shorter et al., 2005), while the hybrid-electric buses produced about half the NOx emissions. In buses operating on ULSD and retrofitted with a CRDPF, NO_2 was approximately one-third of the NOx emitted, while for buses running on ULSD without a CRDPF, NO_2 was about 10% of the NOx. Researchers also found that SO_2 emissions from buses using ULSD were 16 times lower than those using conventional fuel (Herndon et al., 2005). Emissions of formaldehyde and methane from in-use CNG buses were approximately 15 times greater than those from diesel-powered buses (Herndon et al., 2005).

Characterization of Diesel Emissions
As part of the PMTACS bus-chase studies, an aerosol mass spectrometer (AMS) was used to study non-refractory PM_{10}. They found that the mass spectra of the non-refractory diesel aerosol components measured by AMS were dominated by lubricating-oil spectral signatures. The different processing of fuel and lubricating oil result in diesel fuel being enriched in n-alkanes, while the lubricating oil contains relatively more cycloalkanes and aromatics (Tobias et al., 2001).

Figure 19 shows the chemically resolved size distributions provided by the AMS during a chase event (Canagaratna et al., 2004). The in-plume versus background values were obtained using CO_2 as a tracer. In this figure, the in-plume sulfate distribution at 400 nm is dominated by ambient aerosols, but the smaller mode at 90 nm is dominated by vehicle emissions. The small mode is also prominent in the "in-plume" organic distribution, and comparison to the background organic distribution indicates that this mode is largely due to exhaust aerosol. Evaluation of the diesel chase data revealed that the small organic mode was always present between 80-100 nm. In their ambient measurements in Queens, other AMS measurements showed organic particles with modes at 80 and 360 nm (Drewnick et al., 2004a). The smaller mode was generally correlated with traffic activity levels, and when the small mode was more intense than the large mode, the measured ambient mass spectra resembled that of lubricating oil. The observations suggest that the small organic mode observed in ambient aerosol measurements is a signature of motor-vehicle-related aerosol.

Supporting EMEP Projects:
Enhanced Measurements of Oxidants, Fine Particles and their Precursors, Kenneth Demerjian et al., No. 4918

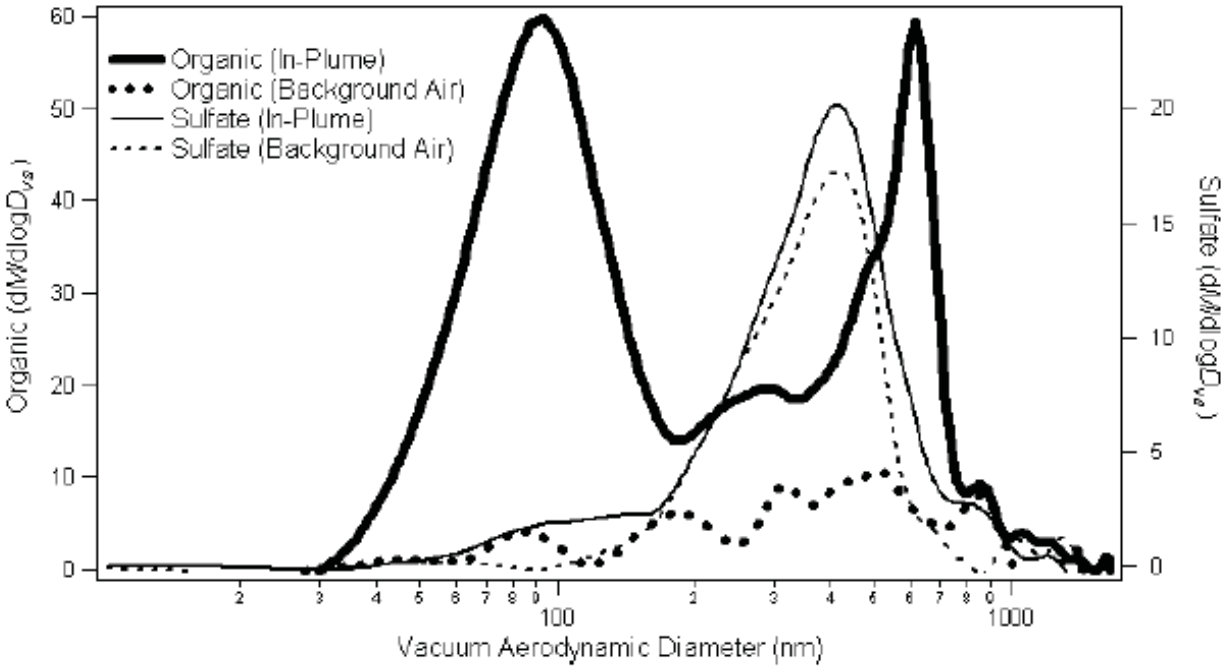

Figure 19. Chemically speciated size distributions measured for an individual vehicle during one chase event. The solid lines correspond to distributions averaged over time periods when the mobile laboratory was sampling the vehicle's exhaust plume. The dotted lines correspond to size distribution averages over time periods corresponding to ambient measurement conditions.

5.3 Ozone

EMEP O_3 research focused on increasing the understanding of long-range transport of O_3 and O_3 precursors. To improve our understanding of the problem of long-range transport of air pollution and source-receptor relationships for trace-level air contaminants, spatiotemporal features of pollutant observations were analyzed through a combination of statistical tools and back-trajectory analysis. Concentrations of O_3 and $PM_{2.5}$ are determined by a complex interplay of emissions (both anthropogenic and natural), chemical transformations (such as the formation of ozone from hydrocarbons and nitrogen oxides in the presence of sunlight), and physical processes (such as atmospheric transport and removal from the atmosphere by wet and dry deposition). To address the problem of attributing these products to specific sources, the concept of an "airshed" for O_3 and $PM_{2.5}$ was used to identify the spatial scale for these pollution problems and to delineate regions exhibiting similarities in their pollution characteristics.

The findings underscore that no state in the Northeast can adequately address pollutant problems alone until region-wide control strategies are implemented for O_3 and $PM_{2.5}$. The probabilistic framework recommended by these studies – aimed at integrating the spatiotemporal information of observations and model predictions and applied to ozone concentrations for demonstration purposes – should be expanded to address multipollutant problems within the "one atmosphere" approach (NYSERDA Report 03-02, 2003).

<u>*Supporting EMEP Projects:*</u>
Analysis of Ozone and Fine Particles in the Northeast, S.T. Rao et. al. No. 4914

Assessing the Effects of Transboundary Pollution on New York's Air Quality, S.T. Rao et. al. No. 6085

5.4 Sector-Specific Emission Control Initiatives

Although not sponsored through EMEP, NYSERDA has a number of emission-control testing and deployment programs designed to provide information on the efficacy of different control strategies and provide real-world improvements in air quality. These program are summarized in Table 7.

Table 7. Controls and emerging technologies: Activities at NYSERDA outside of EMEP.

NYSERDA Program	Description
Clean Air School Bus	**Incentive program for installation of diesel retrofit technology to reduce PM emissions.**
Ferry Emission Reduction	**Demonstration of emission control technologies for use in marine vessels operating in New York Harbor. Program also includes an incentive program for vessel retrofits and repowering.**
Clean Diesel Initiative	**Program will characterize the off-road fleet and range of equipment duty-cycles followed by a technology feasibility demonstration.**
Truck Stop Electrification	**Idle reduction technology demonstration.**
Low Sulfur Heating Oil	**Demonstration of performance and emissions characteristics of using low S heating oil in commercial and residential heating systems.**
Combined Heat and Power	**Emerging technology to improve facility energy efficiency by utilizing waste heat.**

6. Knowledge Gaps and Research Needs Identified Through EMEP Projects

The studies described above have greatly advanced the understanding of PM, ozone, and co-pollutants in New York State. Despite these advances, much more work is needed. The specific areas include better quantification of the local and transported component of PM. This will necessitate better trace-metals measurements than currently achieved through the Speciation Trends Network. Also, more speciation of organics will be needed to understand which sources are contributing to the largest component of PM. Currently, only 15% of this fraction can be resolved. Additional understanding of the real-time chemical transformations such as those obtained with the AMS is also needed.

The detailed atmospheric chemistry needs to be related to specific source types. This will require source profiling of many source types with both more species and better measurements than are currently in the EPA emissions inventory. Size distributions, in addition to detailed chemical speciation, will help resolve different combustion types using the same fuel, such as oil-fired boilers and diesel trucks. The change in sulfur in on-road diesel fuel should provide a tool to resolve these signatures.

Finally, improved use of more accurate emissions data and atmospheric and chemical processing are needed for air quality models. These need to be developed to reflect a probabilistic approach to air quality management.

More specific health research is needed to understand the mechanisms by which pollutants cause mortality and morbidity. This could help prevent unintended consequences as we move forward with air quality management strategies and product development of energy technologies.

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II. Summary of Findings from EMEP-Supported Projects Related to the Deposition of Sulfur, Nitrogen, and Mercury

Preface

This summary, which focuses on the deposition of sulfur, nitrogen, and mercury, and ecosystem response, was prepared by NYSERDA staff to assist with program evaluation efforts and facilitate discussions at the upcoming evaluation and planning meeting with EMEP Program Advisors and Science Advisors. Conclusions drawn from this effort will assist in determining research needs related to the EMEP program and help focus research solicitations.

Introduction

The EMEP multi-year plan (2002) identified acid deposition and mercury pollution as important energy-related environmental management challenges facing New York State. The general research objectives were to:

1. develop and evaluate the effectiveness of pollution control strategies for acid deposition and mercury;
2. quantify local sources versus regional transport of acid deposition precursors and mercury to develop more equitable pollution control strategies;
3. identify alternative environmental protection and mitigation strategies to reduce the impacts of acidification and exposure to mercury in New York; and
4. develop emerging multi-media/multi-pollutant environmental protection strategies.

Through a series of competitive solicitations targeted at critical research gaps identified in the EMEP research plan, approximately 20 research projects focusing on acid deposition and mercury were selected and funded by the EMEP Program. The total cost of this research was $20 million. The contribution of EMEP funds to these research projects was $9.5 million. The broad implications of each of these research projects are identified on the Project Update sheets [see Appendix D]. Below is a summary of knowledge created from the completed and ongoing projects.

1. Acid Deposition

Summary

With implementation of the Clean Air Act Amendments of 1990 (CAAA), it was expected that increases in precipitation pH would result in increases in pH and acid neutralizing capacity (ANC) in sensitive New York State surface waters, and decreases in sulfate (SO_4^{2-}), nitrate (NO^{3-}), and aluminum (Al) concentrations. This was expected to allow for the recovery of species diversity in biota affected by surface-water acidification during the 20th century. Adequate data on surface-water chemistry are now available to evaluate whether these intentions are being realized. The results of studies indicate that surface waters are slowly improving due to reduced levels of acid precipitation, but that additional improvements may require reductions in SO_2 and NO_X emissions greater than those mandated under the 1990 CAAA.

1.1 Adirondacks

Findings from the Adirondack Lakes Survey Corporation (ALSC) Long-Term Monitoring (ALTM) project indicate that when declines in emissions result in declines in acidic deposition, these improvements can translate into changes in water chemistry. Time-series analysis of water chemistry conducted from 1982-2000 show that improvements have occurred in a number of lakes, albeit slightly, as a result of changes in atmospheric deposition. More recently in 2005, another time-series analysis was conducted with four years of additional data. These results show that while a greater number of lakes are exhibiting positive trends, the slopes or the rates of those trends have slowed. The patterns and mechanisms for these changes are being further analyzed across lake types.

Although some recovery is evident, the Adirondack region continues to be at high risk from acidic deposition. Atmospheric deposition was the dominant source of acidity (>90%), while mineral weathering was the major source of improved acid neutralizing capacity for all study sites. Simulations indicated that these ecosystems would show little recovery after 2010 under the 1990 Clean Air Act Amendments. The effects of changes in atmospheric pollutant concentrations need to be placed in the context of other environmental influences, such as changes in climate and forest biota, in order for us to understand the major factors influencing the environmental health of the Adirondacks. These results, and continued monitoring, will not only provide critical information for assessments of forest and aquatic resources in the region, but also prove useful in predicting and evaluating the impact of policy options and future legislation on Adirondack air and water quality.

The following observations and conclusions were primarily drawn from EMEP research projects:

Deposition

Precipitation pH has increased an average of about 0.02 units in the Adirondacks and Catskills from 1984 to 2001; three-fourths of this increase has resulted from decreases in SO_4^{2-} concentrations and about one-fourth from decreases in NO^{3-} concentrations. These changes are paralleled by, and are assumed to result from, similar decreases in sulfur and nitrogen oxide emissions largely from power plants in the predominant source region of acidic precipitation for the state.

Sulfate

Sulfate concentrations in lake discharge markedly decreased in the 1990s, reflecting declining patterns in both wet and dry sulfur deposition. Despite decreases in atmospheric deposition and hydrologic losses, sulfate was still the dominant negatively charged ion in drainage water and was therefore a cause of declines in concentrations of positively charged ions. Declining surface water concentrations of base positively charged ions will have a great impact on future trends in surface water recovery from acidification.

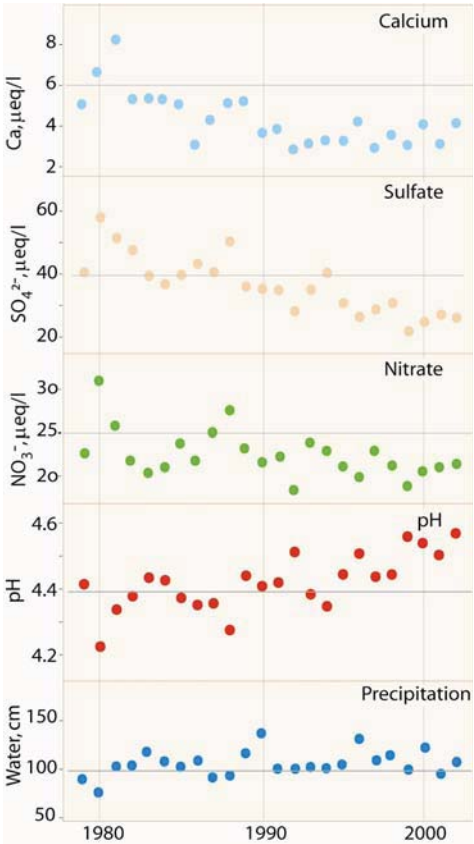

Figure 1. Wet deposition data from the National Trends Network station at Huntington Forest; the points give the annual volume-weighted averages of weekly observations. Sulfate has declined steadily and pH risen steadily. Calcium decreased in the 1980s and since then has been mostly constant; nitrate has perhaps declined, but the variability in the record makes it difficult to be sure.

Nitrate
In contrast to the case of sulfates, no long-term trend in nitrate concentrations in lake discharge was found in the 1990s. Patterns of nitrate cannot be attributed to changes in nitrate deposition or explained by nitrogen saturation models. However, nitrate concentrations were found to be correlated to interannual changes in air temperature (1983–2001). The strong relationship between air temperature and watershed nitrate loss (January–March) suggests that snowmelt responses to winter temperature fluctuations play a critical role in nitrate-loss variability in different years. The contrasting seasonal patterns that were observed might be explained by the high biological demand for nitrate and the microbial production of dissolved organic nitrogen (DON) during warm summer months. The close relationship observed between temperature and nitrate/DON loss suggests that the biotic and hydrological processes affecting nitrogen loss may be especially sensitive to changes in climate, as well as to changes in atmospheric nitrogen deposition. This response of watershed nitrogen to variations in climate and atmospheric deposition may determine the long-term patterns of nitrogen loss from the watershed.

The inclusion of both dry deposition and organic nitrogen substantially elevates estimates of nitrogen retention in Adirondack waters. This result, along with very low summer NO^{3-} concentrations in drainage water, suggests that there is a strong biological retention of both organic and inorganic nitrogen in Adirondack watersheds. In addition, the lowest NO^{3-} concentrations have been found in subcatchments with the highest proportion of wetlands, suggesting the importance of wetlands as sites of denitrification.

ANC
ANC improvement was detected in 29 out of 48 ALTM lakes. The rates of change are small and slow, suggesting it will take decades at current deposition rates to reach 50 meq/L, a level suitable for aquatic biota. Overall lake ANC levels remain a concern, with 34 lakes showing average ANC values of less than 50 meq/L, including 10 lakes with ANC levels below zero.

pH
Improvements (increased pH) were observed in 18 of the ALTM lakes, with two lakes declining. Overall averages were still critical to aquatic biota, with 23 lakes showing an annual mean pH of less than 5.5.

Aluminum
Episodic acidification is extremely damaging to Adirondack lake and stream ecosystems. High acidity during snowmelt and high-flow events causes aluminum levels to rise, which has been well documented to cause widespread fish mortality. An ongoing EMEP-funded study has found that over 50% of western Adirondack streams have aluminum levels during high-flow events that are sufficiently elevated to cause fish mortality. Of the 52 ALTM lakes, decreases in toxic forms of aluminum were detected in 28 lakes. While a shift was observed from toxic inorganic forms toward less toxic organic forms, toxic levels remain above those known to be toxic to juvenile forms of native Adirondack fish.

Significant Trends in 48 ALTM Lakes Values are Average Rates of Change							
	SO_4^{2-} ↓	NO_3^- ↓	C_B ↓	ANC ↑	pH ↑	Al_{im} ↓	DOC ↑
1992-2000	44 -2.57	15 -1.03	26 -3.33	29 1.60	18 0.04	28 -0.31	7 15.7
1992-2004	47 -2.11	22 -0.50	24 -1.62	37 1.13	29 0.02	40 -0.16	12 9.6

Table 1. Trends in selected analytes measured by the Adirondack Lakes Survey Corporation

Forest Species Composition
Species composition is a critical factor in forest nutrient dynamics, especially with respect to the processing of N. Thus, factors that change the forest community (e.g., pests, climate change) could have a dramatic impact on how New York forests respond to atmospheric pollutant deposition. The influence of species composition has been shown clearly in a study of subcatchments within the Arbutus Watershed (near Newcomb in the Adirondacks). A subcatchment with a large component of sugar maple and white ash (species that show high rates of nitrogen mineralization and nitrification) exhibited greater losses of nitrate than other subcatchments. While American beech and sugar maple were the predominant species in terms of biomass, red maple was the only species to increase in biomass. However, total aboveground biomass decreased during the period, while annual litter production remained constant.

Speckled Alder
Speckled alder fixes substantial quantities of nitrogen along the lake inlets. Wetlands with abundant alder had 6 times higher nitrate accumulation than reference wetlands without alder. Surface waters in alder-dominated wetlands contained approximately 3 times more nitrate than non-alder counterparts. In specific alder-dominated wetlands, nitrogen addition from alder exceeds atmospheric deposition by as much as 3 times. These findings highlight the importance of several factors that affect aquatic N concentrations, such as the biogeochemical attributes of the watershed and landscape, including the presence of alder-dominated wetlands. The effectiveness of measures to reduce nitrogen emissions and deposition will depend on these factors.

Fish Species Richness
Comparisons with earlier studies show that declines in species richness have stabilized and that the trend may be reversing. Future surveys could ascertain whether there is a pattern of biological recovery following decreases in acidic deposition and improvements in water chemistry.

Soils
More than 75% of the 1,320 Adirondack lakes in the target population studied receive surface water drainage from watershed soils that have low exchangeable calcium concentration (less than 0.52 $cmol_c$ kg^{-1}), base saturation (less than 10.3%; a measure of the soil's ability to neutralize acids), and pH (less than 4.5). Comparison of data developed in an EMEP study and data collected by the U.S. Environmental Protection Agency in the mid-1980s suggested that while lakewater chemistry was improving subsequent to large decreases in acid rain, Adirondack soil acid-base chemistry may have been continuing to

deteriorate in most of the acid-sensitive watersheds. It appears that this deterioration in soil condition may have occurred even while lake chemistry was getting better. Such an effect would be expected to restrict the extent to which lakes will be able to recover in the future from acidification and might contribute to future adverse impacts on forest vegetation. Watershed soil is clearly the key to determining the extent to which Adirondack lakes will recover.

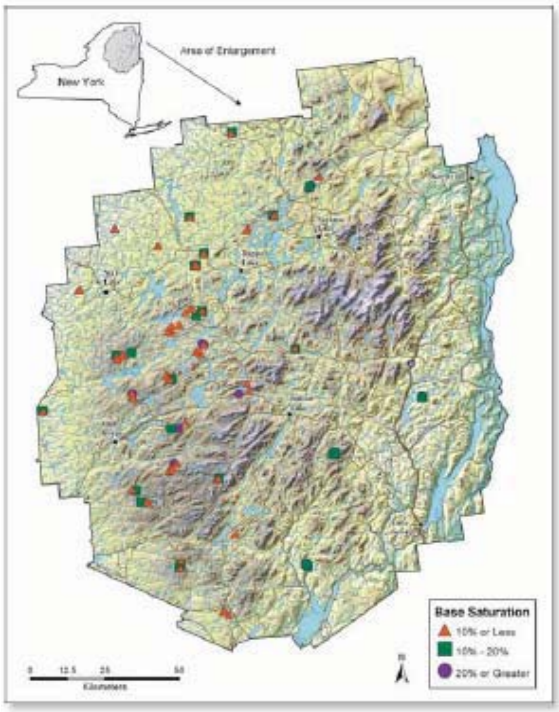

Figure 2. Soil base saturation for soil samples collected within the statistically-selected watersheds in the Adirondacks.

<u>Supporting EMEP Projects:</u>
Long-Term Monitoring Program for Evaluating Changes in Water Quality in Adirondack Lakes, Karen Roy, et al., No. 4915

Evaluation of the Recovery from Acidification of Surface Waters in the Adirondacks, Myron Mitchell, et al., No. 4917

Effects of Atmospheric Deposition of S, N, Hg on Adirondack Ecosystems, *Dudley Raynal, et al., No. 6806*

Assessment of Extent to Which Intensively-studied Lakes are Representative of the Adirondack Mountain Region, Tim Sullivan, et al., No. 7605

Assessment of Extent to Which Intensively-studied Lakes are Representative of the Adirondack Mountain Region

1.2 Catskill/Lower Hudson Valley Region

Atmospheric Deposition

This area has shown a decline in total (wet and dry) atmospheric deposition of both nitrogen and sulfur since 1988. Total sulfur deposition has declined substantially (1988–2000), as a result of reductions of regional SO_2 emissions. However, sulfur emissions from power plants in the Hudson Valley area have decreased much less than emissions from power plants in the Northeast as a whole. Statistical correlations indicate that deposition trends at the site were more influenced by regional than by local emissions. Atmospheric deposition of nitrogen has also generally declined in this area since 1988.

Sulfur
Sulfate concentrations in throughfall (water that falls to the ground following interaction with the forest canopy) and soil solution indicate a lower flux of sulfur through the ecosystem. Soil solution sulfur concentrations are much higher than throughfall concentrations and indicate a substantial internal source of sulfur in these forests, most likely from the weathering of the shale and slate bedrock in the area. Sulfate and calcium are highly correlated in throughfall and soil solution. The decline in atmospheric deposition of sulfur has decreased the leaching of calcium from the canopy and soil, despite the fact that mineral weathering adds a substantial amount of sulfur to this ecosystem.

Nitrogen
No decrease in inorganic nitrogen concentration in soil solution has been observed in the Catskill region. Under current nitrogen deposition conditions, there is minimal loss of nitrogen in Catskill drainage waters, suggesting almost complete retention of nitrogen. Nitrogen is strongly retained both in the forest canopy and in the soil, through complex plant, microbial, and abiotic processes. Overall, the nitrogen retention capacity for many forests in the Hudson Valley would be expected to be quite high because of the area's history of widespread burning and harvesting in the 19th century and the dominance of oaks, which tend to have low rates of nitrogen cycling and loss.

Forest Dynamics and Exotic Pests
These forests are affected by multiple biotic stresses, primarily owing to the introduction of exotic pests. The two most problematic, the gypsy moth and the hemlock woolly adelgid, have substantial effects on nitrogen cycling and retention. Gypsy moth defoliation can radically alter the forest nitrogen cycle. While this perturbation usually causes little nitrogen loss from the forest in drainage waters, under certain conditions, such as nitrogen saturation, nitrogen losses can be significant.

N Cycling Experiment
In the Hudson Valley region (specifically, the Institute of Ecosystem Studies forest in Millbrook), fertilized plots show signs of significant increases in foliar and litterfall nitrogen and in NO^{3-} leaching. The surprisingly high NO^{3-} leaching indicates that nitrogen saturation may occur at this site much earlier than expected based on other studies, suggesting that the ecosystem is susceptible to nitrogen saturation. This accelerated trend toward nitrogen saturation may result from characteristics of the site, which is an oak forest on thin soils in a ridgetop location. However, the site is representative of a major ecosystem type in southern New York State and is typical of sites attacked by the gypsy moth. This susceptibility to both nitrogen saturation and gypsy moth defoliation indicates that the interaction of these stresses should be further studied.

Catskill Streams
Data collected by the NYS Department of Environmental Conservation and U.S. Geological Survey in 1987 indicated that stream pH and ANC values are strongly related to the number of mayfly species in the Neversink River watershed. These data suggest that mayfly species diversity may be a good indicator of recovery following pH and ANC increases resulting from reduced levels of acidic deposition. Preliminary analysis of the 2003 data and comparisons with the 1987 data indicate a similar general pattern of downstream change in mayfly and fish species as pH increases in the Neversink River. There are, however, some differences between the two study years. In the process of comparing data from the two years and attributing any changes to reduced acidic deposition, the fact that 2003 was a very wet year has proven to be a challenge. Summer streamflow in 2003 in the Neversink River was the highest of any summer in the past 30 years. Current efforts are aimed at determining whether the primary cause of the subtle differences in stream chemistry and biota is, in fact, changes in acidic deposition, or simply the result of the very wet summer and the physical and chemical changes in stream habitat that accompany frequent high flows.

While the widespread recovery of streams in the Catskills is as yet unconfirmed, recent data do suggest that recovery may be underway in waters with ANC values in the range of 30–70 μeq/L. These potential early improvements in stream chemistry may eventually result in the recovery of acid-intolerant biota in affected streams. This project's comparison of 1987 and 2003 data from the Neversink River will contribute to our understanding of how reductions in the acidity of deposition affect water chemistry and biota. Additionally, the data accumulated by the project will provide a basis for comparison against which future changes in the acidity of precipitation and in the acid-base status of surface waters in the Neversink basin may be evaluated.

Supporting EMEP Projects:
Integrated Assessment of the Recovery of Surface Waters from Reduced Levels of Acid Deposition in the Catskills and Adirondacks, Burns, et al., No. 6486/6490

Monitoring Deposition and Effects of Air Pollution in the Hudson Valley, Lovett, et al. 6819

Potential Recovery of Water Chemistry and Stream Biota from Reduced Acid Deposition at a Sensitive Watershed in the Catskills, Burns, et al., No. 7606

1.3 Statewide Issues Related to Acid Deposition

Nitrogen

Reactive nitrogen originates from numerous sources and has complex relationships with other pollutants. It therefore requires integrated management strategies and policies addressing multiple rather than individual sources. The assessment of nitrogen pollution in the Northeast region shows that the current CAAA has not yet had a substantial effect on airborne nitrogen emissions. It is important to note that there is currently neither an air quality standard for ammonia nor a water quality standard that limits the total loading of reactive nitrogen to surface waters. Together with efforts to reduce SO_2, CO_2, and other pollutants, nitrogen in the Northeast can be further decreased through a number of strategies: reducing power-plant nitrogen emissions, improving wastewater treatment to remove nitrogen from effluent, reducing the use and increasing the efficiency of nitrogen fertilizers, and creating and restoring natural nitrogen sinks in wetlands and floodplains. A number of innovative nutrient management projects currently being implemented on farms throughout the region provide hopeful examples.

Modeling results offer insight into the relationship between different emissions reduction scenarios and ecosystem recovery. Appraisal of the rate of recovery of different Northeast ecosystems under a variety of policy scenarios indicates that:

- controls on vehicle and electric utility NOx emissions produce the largest reductions in airborne nitrogen pollution,
- nitrogen removal from wastewater at a basin-wide scale is the single most effective means of reducing nitrogen loading to estuaries in the Northeast.

The Role of Sugar Maple in the Nitrogen Cycle
In sugar maple stands, rates of nitrification and nitrate leaching are higher than in those of other common hardwood and softwood species. A number of factors may account for this phenomenon, including the rate at which leaf litter decomposes in the soil and soil chemistry in the stands. Although sugar maple is the most dominant species in northern hardwood forests of New York, conditions such as beech bark disease, climate change, soil calcium depletion, and pest infestations may affect the future abundance of sugar maple and consequently nitrogen cycling and ANC trends in these regions. Thus, future trends in

nitrate concentrations in surface waters may depend on changes in tree species composition, which is determined by multiple environmental factors.

Soils—Statewide

EMEP research studying soils statewide is still in its early stage. It is known that an accurate assessment of the threat of Ca depletion by acid rain and forest harvesting depends on understanding the contribution of apatite weathering to Ca cycling in forest soils. Apatite is important in granitoid parent materials (igneous rock) but not in sedimentary rocks. The soil parent materials derived from clastic sedimentary rocks averaged 80 ppm Ca from apatite, compared to 720 ppm in the parent materials derived from igneous rocks. Parent material is likely more important than glaciation in determining apatite availability in soils. Sugar maple decline has been observed to occur on unglaciated soils of the Allegheny Plateau; glaciers tend to rejuvenate reservoirs of fresh minerals available for weathering. Roots and fungi, including mycorrhizae, play a role in mineral weathering, and it has been suggested that apatite weathering is at least in part under biotic control.

Information concerning the distribution of sources of Ca and the ability of tree species to access Ca is essential for predicting the sensitivity of forests across New York State to Ca depletion. The data accumulated through EMEP-funded research will provide a more accurate assessment of the likelihood that New York State forests will be adversely affected by the depletion of calcium and other exchangeable cations as a result of acidic deposition. This information is vital for the development of sound policies for managing and protecting New York's forest resources. Additionally, carbon storage in forest soils is of increasing interest because of the need to account for C storage in soils when using forests to offset emissions of CO_2.

Supporting EMEP Projects:

Status and Effects of Nitrogen Pollution in North Eastern United States , Lambert, et al., No. 6487

Evaluation of the Recovery from Acidification of Surface Waters in the Adirondacks, Myron Mitchell, et al., No. 4917

Assessing the Sensitivity of New York Forests to Cation Depletion, Yanai, et al., No. 8649

2. Mercury

2.1 Ambient Measurement and Deposition

Historical Patterns of Mercury Deposition in the Adirondacks

Concentrations of total Hg were measured in sediment cores collected from eight Adirondack lakes. Historical profiles were determined for each lake showing changes in sediment Hg deposition over the past 200 years. Although there were lake-to-lake variations, on average sites showed a 5.8-fold increase in sediment Hg deposition from background values (before 1900) to peak values. Mercury deposition peaked from 1973 to 1995 and decreased in recent years. Conducting this analysis for pre-anthropogenic conditions, the deposition of Hg to the surface of a perched seepage lake (a lake that receives all of its inputs directly from precipitation, with no watershed inputs) was estimated to be 3.4 ± 1.1 $\mu g/m^2$-yr. For modern conditions, the deposition of Hg to the surface of a perched seepage lake was determined to be 8.6 ± 2.4 $\mu g/m^2$-yr; a value similar to current estimates of wet Hg deposition for the Adirondacks. Watershed Hg retention by year was estimated using sediment deposition data across the study lakes. It was observed that the retention of Hg in Adirondack lake-watersheds has decreased over the past 200 years. The mechanism responsible for this decline is unclear.

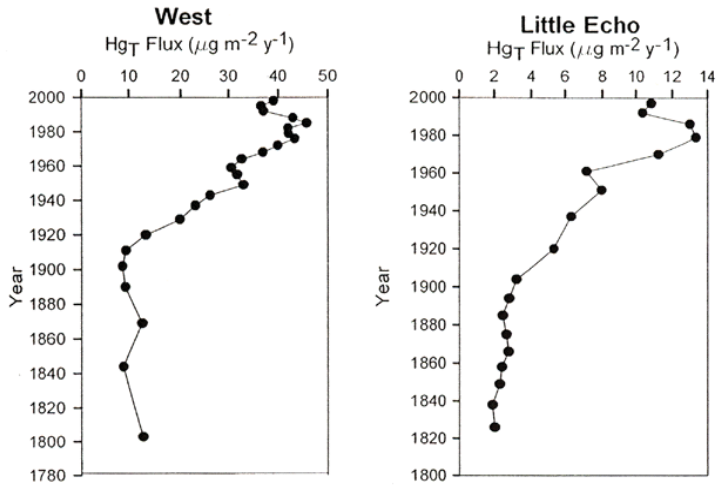

Figure 3. Sediment Hg deposition to West Pond and Little Echo Pond in the Adirondacks over time. Increases in sediment Hg deposition in the early 1900s have been followed by decreases in the latter portion of the century. Note Little Echo Pond is a perched seepage lake and is probably representative of direct changes in wet Hg deposition.

Mercury Deposition Network (MDN) Sites

The last complete year for which wet mercury data are available is 2004. The annual volume-weighted concentration of total mercury for Huntington Forest for 2004 is 6.7 ng/L, with values ranging from 0 to 27.7 ng/L. The annual wet deposition of mercury is 6.9 μg/m^2-yr, with weekly deposition ranging from 0 to 650 ng/m^2-wk. These values are similar to values reported in the network for other sites in eastern Northern America. The time-series of annual volume-weighted concentrations of mercury in wet deposition at Huntington Forest for the period the site has been in existence in shown in the figure below. These values are also compared to values at Biscuit Brook in the Catskills for 2004. There have been no significant trends in mercury deposition at the Huntington Forest since measurements were initiated at the site.

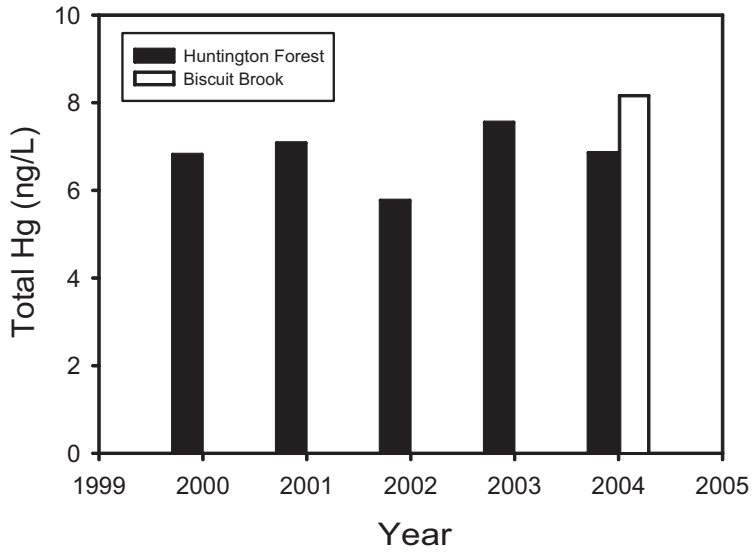

Figure 4. Time-series of annual volume-weighted concentrations of total mercury in wet deposition at Huntington Forest. The concentrations of total mercury at Huntington Forest are compared to values for Biscuit Brook for 2004.

Although the MDN site at the Huntington Forest has only been in existence for a short period, the data collected have been extremely valuable in the interpretation of mercury deposition for the region. Moreover, if there are additional reductions in atmospheric emissions of mercury, such as those proposed for electric utilities, data from this site could provide a reference from which it will be possible to detect changes in wet deposition if they occur.

Using information on wet deposition at Huntington Forest, and throughfall and litter deposition on mercury obtained from Sunday Lake and Huntington Forest, Dr. Charles Driscoll (Syracuse University) is developing maps of total mercury deposition for the entire Adirondack region.

The work performed at the MDN stations also benefits other studies of mercury in the region, such as the NYS Department of Environmental Conservation's extensive survey of mercury concentrations in fish in NYS waters. As part of the MDN, these sites will contribute to a national database of weekly concentrations of total mercury in precipitation and seasonal and annual fluxes of total mercury in wet deposition. Dry deposition of mercury is not currently measured at the New York State MDN sites.

Ambient Mercury Measurement

New rules will soon be going into effect for Hg emissions, creating a need for both monitoring and research measurement to characterize and understand sources, sinks, and transformation processes of Hg. An added challenge is the various forms of Hg in the atmosphere: Hg, Hg (2+) or Reactive Gaseous Mercury (RGM), particulate mercury, and Hg in wet deposition. A comparison of manual measurements of gaseous mercury is being performed with an automated Tekran 2537A in the laboratory and at a field site in Postdam, NY. This project will likely be the basis of a Hg monitoring network in New York State. Based on the lessons learned in this project, the New York State Department of Environmental Conservation (NYSDEC) has submitted a proposal to EPA for expansion of Hg monitoring in New York State.

2.2 Mercury Transport

Computer modeling conducted in 2001 showed U.S. emissions (non-NYS) to be the largest source of total Hg deposition in New York State. Overall, results from local deposition and long-range transport scenarios vary only slightly from those of the baseline scenario. U.S. emissions were the largest source of total Hg deposition at all three New York State sites in the model. Dry deposition was dominated at all sites by NYS and U.S. emissions, while wet deposition showed a much greater contribution from sources outside North America.

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.

Major sources of uncertainty include emissions (including Hg species), the dry deposition of Hg(II), and, for lake mercury cycling models, the sediment burial rate. Knowledge of atmospheric Hg chemistry is still incomplete; laboratory experiments are needed to identify and characterize the most important reactions. Finally, there is a great need for Hg measurements with which to evaluate the models, including ambient atmospheric concentrations of Hg(0), Hg(II), and Hg(p), and wet and dry deposition rates of mercury.

2.3 Cycling of Mercury in Watersheds

The Sunday Lake watershed is located in the western part of the Adirondack Park in New York State, just west of the Stillwater Reservoir. This lake-watershed system was selected for mass balance analysis. Sunday Lake is a small lake surrounded by a much larger watershed; therefore, water moves through the lake rapidly, resulting in a detention time on the order of two weeks. Wetlands cover approximately 20 percent of the Sunday Lake watershed, with most located adjacent to lakes and streams (riparian wetlands). Wetlands border 65 percent of all the stream channels and much of the lake shorelines.

The dynamics of Hg were studied within upland coniferous and deciduous forest plots at the Sunday Lake watershed. The flux of Hg to the forest ecosystem was dominated by dry deposition, which was estimated as throughfall plus litterfall. These inputs accounted for 70% of total deposition. (Note: we have very little state/national data of what appears to be a dominant mercury flux—dry deposition.)

Concentrations of total Hg attached to soil varied in depth but were similar among plots with highest concentrations in the surface organic layer, lowest in the leached layer immediately below the organic layer; concentrations rose again in the upper mineral soil, and lower values were found in the deeper mineral soil. Total mercury concentrations in soil porewaters were highest in waters draining the forest floor, decreasing through the mineral horizons. Concentrations of MeHg attached to soil were relatively uniform throughout both forest soil profiles, whereas porewater MeHg concentrations were highly variable.

Hydrology

During the period of study, precipitation averaged 126.5 cm, compared to an average of 77.4 cm of stream flow. Total stream runoff was thus 61% of precipitation, with the remaining 39% assumed to be lost to evapotranspiration (ET). High flows tended to occur in the fall and spring, while the lowest flows generally occurred in late summer.

Most of the soils in the Sunday Lake watershed have relatively high infiltration capacities, which means that the vast majority of water that enters streams and lakes first moves through watershed soils. Approximately 20% of the total groundwater input enters the streams through the riparian wetland areas.

Groundwater levels fluctuate through the interface between the organic horizon and the mineral horizons of the wetland soils. The riparian wetlands discharge water to the streams from surrounding soils throughout most of the year. During rain storms and snowmelt events, the groundwater flow direction in the riparian wetland can be reversed, with water from the stream mixing with the groundwater. This may have the effect of moving more active forms of mercury and organic matter into wetlands with very active microbial communities that methylate mercury.

Lake Watershed Mass Balance

Wet Hg deposition was 10.3 $\mu g/m^2$-yr, with 0.6 percent of Hg occurring as MeHg. Forest vegetation was important in mediating the inputs of Hg to the forest floor. For the watershed as a whole, we estimate total deposition of Hg to the forest floor to be 33.9 $\mu g/m^2$-yr. This flux of Hg is considerably greater than estimates of Hg lost from the forest floor by drainage water (13.9 $\mu g/m^2$-yr). This discrepancy in Hg mass balance suggests that Hg is accumulating in the forest floor and/or Hg is lost by volatilization. Fluxes of HgT decreased with depth in soil water, coinciding with decreases in DOC. This pattern suggests that Hg is immobilized in the mineral soil by the deposition of organic matter. Concentrations of Hg in surface waters ranged from 1.9 to 4.6 ng/L. Atmospheric Hg deposition was retained in the watershed, and Sunday Lake was a sink for inputs of total Hg.

Considerable enrichment in MeHg was evident in throughfall and litterfall when compared to the flux in wet deposition. As observed for total Hg, drainage fluxes of MeHg were lower than drainage losses from the forest floor. This pattern suggests that the forest floor is an active zone of demethylation. Fluxes of MeHg were elevated in waters draining riparian wetlands. This flux of MeHg can largely explain the MeHg input to Sunday Lake. MeHg concentrations in surface waters of the Sunday Lake watershed ranged from 0.2 to 2.53 ng/L. The mass balance indicates that the watershed, particularly riparian wetlands, and the lake were net sources of MeHg to downstream surface waters.

2.4 Biota

Determination of levels of abiotic and biotic mercury exposure will contribute to the assessment of the risks posed by mercury pollution to human and ecological health in NYS and the Northeast. Of the loons sampled in the Adirondacks, 18% are estimated to be at risk for harmful effects from mercury contamination. Additional results from sampling in 2005–2006 will augment the database that is being developed. Behavioral impacts are now being summarized. Results will be coordinated with related projects, with the aim of improving assessment of the impacts of mercury exposure on loons. Findings should prove useful in broader evaluations of the impact of mercury toxicity and the extent of mercury distribution in northeastern aquatic ecosystems in relation to deposition. The evaluation of mercury levels in prey fish will also aid in identifying Adirondack lakes that should be evaluated for fish consumption advisories to prevent human exposure to mercury.

Fish and water samples have been collected from 131 lakes across New York State. More than 1700 fish samples and over 100 water samples have been analyzed. The NYS Department of Health has recently added numerous waterbodies, including all waters of the Adirondacks and Catskills, to their fish consumption advisories based on this data.

<u>*Supporting EMEP Projects:*</u>
Mercury in Adirondack/Catskills Wetlands, Lakes and Terrestrial Systems, Munson, et al., No. 4916

Contributions of Global and Regional Sources to Mercury Deposition in New York State, Seigneur, et al., No. 6485

Atmospheric Transport and Fate of Mercury in New York State, Walcek, et al., No. 6488

Mercury Deposition Monitoring in the Catskills, McHale, No. 6818

Mercury Deposition Monitoring in the Adirondacks, Driscoll, No. 8152

Long-term Monitoring and Assessment of Mercury Based on Integrated Sampling using the Common Loon, Prey Fish, Water, and Sediment, Schoch, et al., No. 7608

Strategic Monitoring of Mercury in New York State Fish, Simonin, et al., No. 7612/7716

Impact of In- and Out-of-State Power Plants on Semivolatile Pollutants in New York State, Hopke et al., No. 6083

3. Knowledge Gaps/Research Needs Identified Through the EMEP Projects

A quantitative understanding of the factors other than acid precipitation that may affect surface-water pH and ANC is necessary to separate the effects of clean air laws and atmospheric deposition from natural variability and disturbance.

While the acidity of deposition has declined in New York over the past 20 years, insufficient data exist for determining whether the acidity of streams has decreased in response to these developments. More adequate baseline data will also be needed for identifying and evaluating future trends in the acidity of soils and streams. In the absence of sufficient information, policy efforts at restoring and protecting these natural resources will have to be made with a considerable degree of uncertainty.

Uncertainties remain in our understanding of the atmospheric fate and transport of mercury. Major sources of uncertainty include emissions (including Hg species), the dry deposition of Hg(II), and, for lake mercury cycling models, the sediment burial rate. Knowledge of atmospheric Hg chemistry is still incomplete; laboratory experiments are needed to identify and characterize the most important reactions. There is also a great need for Hg measurements with which to evaluate the models, including ambient atmospheric concentrations of Hg(0), Hg(II), and Hg(p), and wet and dry deposition rates of mercury. Other needs also related to Hg include the fate of soil Hg, soil re-emissions, and the response of fish to changes in Hg deposition and acid deposition. Also of note is that the available mercury-in-fish database currently includes information on fish for only ~5% of NYS lakes.

Peer-Reviewed Publications Supporting this Summary

2000

Inamdar, Mitchell, McDonnell. 2000. Topographic and riparian controls on hydrologic and biogeochemical response of forested catchments. In: Wigington, P. J., and R. L. Beschta (eds). American Water Resources Association, Middleburg, VA, TPS-00-2, pp.137-142

2001

Bischoff, J.M., P.Bukaveckas, K.Ohrui and M.J. Mitchell, 2001. Nitrogen storage and cycling in vegetation of a forested wetland: Implications for watershed N processing. *Water, Air and Soil Pollution* 128: 97-114.

Hurd, T.M., D.J. Raynal and C.R. Schwintzer, 2001. Symbiotic N-fixation of Alnus incana ssp. rugosa in shrub wetlands of the Adirondack Mountains. *Oecologia* 126: 94-103.

Mitchell, 2001. Linkages of nitrate losses in watersheds to hydrological processes. *Hydrological Processes*, 15: 3305-3307.

Mitchell, Driscoll, Owen, Schaefer, Michener, Raynal, 2001. Nitrogen biogeochemistry of three hardwood forest ecosystems in the Adirondack Mountains. *Biogeochemistry* 56: 93-133.

Mitchell, McHale, Inamdar and Raynal, 2001. Role of within lake processes and hydrobiogeochemical changes over 16 years in a watershed in the Adirondack Mountains in New York State, USA. *Hydrological Processes* 15: 1951-1965.

2002

Gbondo-Tugbawa, S.S., C.T. Driscoll, M. J. Mitchell, J.D. Aber, and G.E. Likens, 2002. A model to simulate the response of a northern hardwood forest ecosystem to changes in S deposition. *Ecological Applications* 12: 8-23.

Ito, M., M.J. Mitchell and C.T. Driscoll, 2002. Spatial patterns of precipitation quantity and chemistry and air temperature in the Adirondack Region of New York. *Atmospheric Environment* 36:1051-1062.

Ito, M., M.J. Mitchell, and C.T. Driscoll, 2002. Discussion on "Spatial patterns of precipitation quantity and chemistry and air temperature in the Adirondack region of New York." *Atmospheric Environment* 37: 135-138.

Kelly, Lovett, Weathers, and Likens, 2002. Trends in atmospheric concentration and deposition compared to regional and local pollutant emissions at a rural site in southeastern New York, USA. *Atmospheric Environment* 36(10): 1569-1575.

Lorey, P., and C.T. Driscoll, 2002. Historical trends of mercury deposition in Adirondack lakes. *Environmental Science and Technology* 33: 718-722.

Lorey, P., C.T. Driscoll, and D. Engstrom, 2002. Changes in the historical mercury deposition in Adirondack lake sediments and the role of lake watersheds. In preparation.

McHale, McDonnell, Mitchell, Cirmo, 2002. A field based study of soil and groundwater nitrate release in an Adirondack forested watershed. *Water Resources Research* 38(4): 1029/2000WR000102.

2003

Driscoll, C., K. Driscoll, M. Mitchell, and D. Raynal, 2003. Effects of acidic deposition on forest and aquatic ecosystems in New York and the Northeastern U.S. *Environmental Pollution* 123(3).

Driscoll, C.T., K.M. Driscoll, K.M. Roy, and M.J. Mitchell, 2003. Chemical response of lakes in the Adirondack region to declines in acidic deposition. *Environmental Science and Technology* 37: 2036-2042.

Ito, M., M.J. Mitchell and C.T. Driscoll, 2003. Response to discussion on "spatial patterns of precipitation quantity and chemistry and air temperature in the Adirondack region of New York. *Atmospheric Environment* 37: 135-138.

Kiernan, B.D., T.M. Hurd and D.J. Raynal, 2003. Abundance of Alnus incana spp. rugosa in Adirondack Mountain shrub wetlands and its influence on inorganic nitrogen. *Environmental Pollution* 123(3).

Mitchell, Driscoll, Inamdar, McGee, Mbila, and Raynal, 2003. Nitrogen biogeochemistry in the Adirondack mountains of New York: hardwood ecosystems and associated surface waters. *Environmental Pollution* 123(3).

Park, J., M. Mitchell, P. McHale, S. Christopher and T. Myers, 2003. Interactive effects of changing climate and atmospheric deposition on N and S biogeochemistry in a forested watershed of the Adirondack Mountains, New York State. *Environmental Pollution* 123: 355-364.

2004

Chen, L. and C.T. Driscoll, 2004. Modeling the response of soil and surface waters in the Adirondack and Catskill regions of New York to changes in atmospheric deposition and historical land disturbances. Submitted to *Atmospheric Environment* 38: 4099-4109.

Chen, L., C.T. Driscoll, S. Gbondo-Tugbawa, M. Mitchell, and P.S. Murdoch, 2004. The application of an Integrated Biogeochemistry Model (PnET-BGC) to five forested watersheds in the Adirondack and Catskill Regions of New York. *Hydrological Processes* 18: 2631-2650.

Hurd, T.M., D.J. Raynal, 2004. Comparison of nitrogen solute concentrations within alder (Alnus incana spp. rugosa) and non-alder dominated wetlands. *Hydrological Processes*, 18: 2681-2697.

Lawrence, G.B., B. Momen, and K. Roy, 2004. Use of Stream Chemistry for Monitoring Acidic Deposition Effects in the Adirondack Region of New York. *Journal of Environmental Quality* 33: 1002-1009.

Lovett, G. and M. Mitchell, 2004. Sugar Maple and nitrogen cycling in the forests of eastern North America. *Frontiers in Ecology and the Environment* 2(2): 81-88.

McHale, M.R., C.P. Cirmo, M.J. Mitchell, and J.J. McDonnell, 2004. Wetland nitrogen dynamics in an Adirondack forested watershed. *Hydrological Processes* 18: 1853-1870.

2005

Hurd, T.M., K. Gokkaya, B.D. Kiernan, and D.J. Raynal, 2005. Nitrogen sources in Adirondack wetlands dominated by nitrogen-fixing shrubs. *Wetlands* 25(1): 192-199.

Ito, M., M.J. Mitchell, C.T. Driscoll, and K.M. Roy, 2005. Nitrogen input-output budgets for lake-watersheds in the Adirondack region of New York. *Biogeochemistry* 72.

Mitchell, M.J, 2002. Episodic Acidification. In: Jay H. Lehr (ed), 2005. *Water Encyclopedia*, John Wiley and Sons Publishing.

Piatek, K., M. Mitchell, S. Silva, and C. Kendall, 2005. Sources of nitrate in Adirondack surface water during dissimilar snowmelt events. *Water, Air, & Soil Pollution*.

2006

Gokkaya, K., T. Hurd, and D. Raynal, 2006. Symbiont nitrogenase, alder growth, and soil nitrate response to phosphorus addition in alder (*Alnus incana* ssp. *rugosa*) wetlands of the Adirondack Mountains, New York State, USA. *Environmental and Experimental Botany* 55: 97-109.

NOTE: The information in these synthesis papers was drawn from project reports and was not necessarily peer reviewed

III. Summary of Findings from EMEP-Supported Projects Crosscutting the Topics of Air Quality, Health, Ecological Response, and Energy

Preface

This summary, which focuses on "crosscutting" research projects was prepared by NYSERDA staff to assist with program evaluation efforts and facilitate discussions at the upcoming evaluation and planning meeting with EMEP Program Advisors and Science Advisors. Conclusions drawn from this effort will assist in determining research needs related to the EMEP program and help focus future research solicitations.

Introduction

Research supported under this EMEP focus area cuts across a range of energy-related environmental issues. Projects included in this focus area may address pollutants associated with both fine particle pollution and acid rain impacts. Often these are multimedia studies or multi-pollutant studies. Several of these projects include an economic, technology, or policy analysis component.

1. Costs and Benefits of Reducing Emissions from the Electricity Sector

In 2004 an assessment was conducted of several proposed regional and national emission control strategies to reduce SO2, NOx, and mercury including: (i) the Clean Air Interstate Rule (CAIR) combined with a mercury cap; (ii) CAIR combined with a mercury cap and seasonal SIP NOx policy; (iii) CAIR plus a tighter mercury control using Maximum Achievable Control Technology (MACT); and (iv) CAIR plus a tighter mercury standard with trading.

A suite of models, including a model of capacity planning and operation for the U.S. electricity sector, an integrated assessment model of air transport and environmental effects, and a state-of-the-art air chemistry model for the eastern United States was used for a broad assessment of the costs and benefits of these proposed policies. In evaluating the potential environmental benefits of these proposals, researchers specifically analyzed how they would influence emissions from power plants that affect air quality in New York State and the nation.

This project resulted in several important findings, which are presented below.

- Benefits to the nation and to New York State significantly outweigh the costs associated with reductions in SO_2, NOx, and mercury, and all policies show dramatic net benefits.

- The manner in which mercury emissions are regulated will have important implications not only for the cost of the regulation, but also for emission levels and emission locations for SO_2 and NOx.

- Contrary to EPA's findings, CAIR as originally proposed by itself would not keep summer emissions of NOx from electricity generators in the SIP region below the current SIP seasonal NOx cap. In the final CAIR, EPA added a seasonal NOx cap to address seasonal ozone problems. CAIR with the seasonal NOx cap produces higher net benefits.

- The effect of the different policies on the mix of fuels used to supply electricity is fairly modest under scenarios similar to the EPA's final rules.

- A maximum achievable control technology (MACT) approach, compared to a trading approach as the way to achieve tighter mercury targets (beyond EPA's proposal), would preserve the role of coal in electricity generation.

- The evaluation of scenarios with tighter mercury emission controls shows that the net benefits of a maximum achievable control technology (MACT) approach exceed the net benefits of a cap and trade approach.

Supporting EMEP Project:
Multi-Pollutants Policies for the Electricity Sector and Environmental Quality in the Empire State, Palmer et al., No. 7610.

2. New York City Regional Heat Island Mitigation

New York City, like other large cities, is warmer than surrounding areas due to the urban heat island effect, which occurs when impervious built surfaces such as roads and buildings absorb solar radiation and re-radiate it in the form of heat. The development of a heat island has regional-scale impacts on energy demand, air quality, and public health. Heat island mitigation strategies, such as urban forestry, living (green) roofs, and light-colored surfaces, could be implemented at the community level within New York City, but their effects need to be tested with comparable methodologies. Although the heat island effect occurs throughout the year, its occurrence during the summer months is of particular public policy concern because of the association of higher temperatures with increases in electric demand due to air conditioning, elevated air pollution, and heat-stress-related mortality and illness.

This study used a regional climate model (MM5) in combination with observed meteorological, satellite, and GIS data to determine the impact of urban forestry, living roofs, and light surfaces on near-surface air temperature in New York City. Nine mitigation scenarios were evaluated city-wide and in six case-study areas. Temperature impacts were calculated on a per-unit-area basis, taking into account the available land area for implementation and other physical constraints. The scenarios were then evaluated based on their cost-effectiveness at reducing air temperature and consequent lower demand for electrical energy for air conditioning.

Results show that significant reductions in New York City's near-surface air temperature, generally defined as the air temperature 2 meters (6 feet) above the street or surface level, can be achieved by implementing heat island mitigation strategies. Effects vary in magnitude across scenarios, case-study areas, and heat-wave days. The city-wide simulated temperature impact of the mitigation scenarios ranged from 0.1ºF (<0.1ºC) for open space planting to 0.7ºF (0.4ºC) for

ecological infrastructure (a combined strategy of urban forestry and living roofs), if 100% of the available area is redeveloped, averaged over all heat-wave days and times.

Model results also indicate that the most effective mitigation strategy per unit area redeveloped is curbside planting. The average difference in simulated near-surface air temperature between impervious surfaces and trees was 3.5ºF (1.9ºC), which was higher than the differences between other surface-cover types. Therefore, street trees—which involve redevelopment of impervious surfaces—have the largest cooling potential per unit area, followed by living roofs, light-colored surfaces, and open-space planting.

A combined strategy that maximizes the amount of vegetation in New York City by planting trees along streets and in open spaces, as well as by building living roofs, offers more potential cooling than any individual strategy. The choice of a strategy should consider the characteristics and priorities of the neighborhood, including benefit/cost factors and the available area for implementation of each strategy.

Supporting EMEP Project:
New York City Regional Heat Island Mitigation, Rosenzweig et al., No. 6681

3. Combined Heat & Power (CHP) and Distributed Generation

3.1 Emission Reduction Credits and Emission Allowance Market Opportunities for Small CHP Projects in New York State

Combined heat and power (CHP), which involves the coincident production of heat and electrical/mechanical power from a single process and fuel source, may be a suitable option in industrial, institutional, commercial, municipal, and residential applications. CHP can be cleaner and more efficient and reliable than conventional methods of separately generating heat and power, as heat that is normally wasted in generating central-station electricity is instead used near the CHP system. By taking advantage of this otherwise wasted heat, CHP significantly increases overall energy efficiency. In addition, because CHP is located at the end-user's site, there are virtually no transmission and distribution line losses, which typically diminish the amount of power delivered from central power plants to the consumer by 5%-10%.

This policy study developed a guidebook for determining how an end user installing CHP can quantify and secure emissions reduction credits (ERCs) from the New York State Department of Environmental Conservation (NYSDEC). It also performed an evaluation of how existing NYSDEC allowance-based regulations can be interpreted and implemented to transform the general intent of program rules into a practical and effective mechanism to incentivize CHP projects. By receiving ERCs or set-aside allowances, CHP projects can obtain financial benefits that could help promote the installation of additional CHP systems, benefiting the environmental and economic health of New York State.

3.2 Quantifying the Environmental and Economic Benefits of Increased Deployment of Combined Heat and Power (CHP) Technologies

The goal of the ongoing project is to increase understanding of the positive and negative impacts of increased deployment of DG/CHP technologies throughout New York State. Increased deployment of DG/CHP systems in New York State can reduce emissions of greenhouse gases (CO_2) and criteria air pollutants (NOx, SOx, Hg, VOC, PM, and CO). Greenhouse gas emission reductions result from the fact that a DG/CHP system can satisfy overall on-site energy demand (electric and thermal) more efficiently than conventional alternatives (i.e., purchasing electricity and natural gas separately from the local utility). Less fuel is needed to satisfy the same demand, resulting in lower overall carbon dioxide emissions. Criteria air pollutants can be reduced when multiple DG/CHP systems collectively produce enough electric energy to partially/fully displace the operation of a "dirty" peaking plant. The price of electric energy in New York State's de-regulated market is determined by the operating cost of the power plant providing the marginal generation needed to satisfy peak demand. These marginal generating facilities are typically the least efficient and most expensive to operate, resulting in high wholesale market clearing prices. A collection of DG/CHP systems, with an aggregated power output equal to or greater than that of an expensive large-scale peaking plant, may reduce the amount of time throughout the year that these higher-cost units will need to operate. This project is using a variety of modeling tools to explore and quantify these potential impacts.

Supporting EMEP Projects:
Analysis of New Pollution Control Strategy Utilizing Emission Reduction Credits and Small-Scale Combined Heat and Power Units, No. 7615.

Quantifying the Environmental Benefits of Increased Deployment of Combined Heat and Power Technologies in New York State, No. 7617.

4. Measurement of Ambient Gaseous Ammonia

Gaseous ammonia is of increasing interest as an atmospheric gas due to its role in forming aerosol particles such as ammonium nitrate and ammonium sulfate. Ammonia is not measured routinely in any of the major sampling networks. The State University at Albany's Atmospheric Science Research Center is performing an evaluation of six different gas-phase ammonia analyzers to determine if any are suitable for routine deployment. The first step was a laboratory intercomparison of instruments including two commercial continuous low-level ammonia analyzers, one based on chemiluminescence and the other on ion mobility spectrometry along with three research-grade ammonia instruments and a third commercial analyzer on lone from another institution. Following the laboratory intercomparison, the ion mobility spectrometer was deployed for three months at Pinnacle State Park in order to obtain ambient-air ammonia measurements.

The preliminary findings indicate that measurement of gaseous ammonia continues to be a challenge. It is extremely sensitive to materials used in sample lines and the analyzer itself. With unlimited resources, the tunable diode laser has the fastest response, good sensitivity, and good accuracy. With respect to routine monitoring, the ion mobility spectrometer appears to have

sufficient accuracy, sensitivity and robustness to provide reliable field measurements. However, time response and absolute accuracy continue to be areas where more work is needed.

Supporting EMEP Projects:
Ambient Gaseous Ammonia: Evaluation of Continuous Measurement Methods Suitable for Routine Deployment. Schwab, No. 8642.

5. Novel Approach for Determining Sources of Atmospheric Nitrogen

Increasing inputs of reactive nitrogen (N) to ecosystems in the northeastern USA have been linked to many environmental concerns, including acidification of ecosystems, accumulation of N in groundwater, and eutrophication of waterways. The role of atmospheric N deposition is of particular interest to land managers and policy makers, as rates of atmospheric N deposition in the northeast are among the highest in the nation. The sources of atmospheric N deposition include industrial, automotive, and agricultural emissions, and data regarding the relative contributions of these sources are needed in order to develop sound strategies for managing and understanding the effects of these and other N inputs to the landscape.

This project uses novel isotopic tracer techniques to assess the importance of atmospheric nitrogen deposition in New York State. New methods are being refined to measure isotopes in the nitrate (NO_3^-) molecule including oxygen-17 ($\Delta^{17}O$), oxygen-18 ($\delta^{18}O$), and nitrogen-15 ($\delta^{15}N$). the project is exploring the feasibility of using this trio of isotope tracers to quantify: (1) the relative contributions of different sources of atmospheric N to precipitation (e.g., distinguishing between stationary, automotive, and agricultural sources), and (2) the relative contributions of different sources of atmospheric nitrate to several New York watersheds.

Isotopic compositions of the following are being analyzed: (1) wet and dry deposition samples collected within New York's airshed, (2) dry deposition samples collected from various emissions sources, (3) surface water samples from streams and rivers in a variety of environmental settings in New York watersheds, and (4) wet deposition from a national-scale network of sites.

Preliminary results show the following:

- $\delta^{15}N$ is spatially variable. A well-documented N deposition gradient exists across the Mid-western and Northeast U.S. $\delta^{15}N$ values are highest in the west and decrease eastward. This spatial gradient persists throughout the year.
- $\delta^{15}N$ is correlated with indicators of atmospheric deposition. $\delta^{15}N$ values are significantly correlated with nitrate concentration, sulfate concentration, and pH from precipitation collected at each of the NADP sites throughout the year. These results suggest that the spatial variability of $\delta^{15}N$ over the Northeastern region is source-related. In particular, the correlation between $\delta^{15}N$ and sulfate deposition suggests that the NO_x affecting $\delta^{15}N$ values is likely derived from stationary rather than mobile source emissions.
- Spatial and temporal analyses with electric generating unit emissions by county showed the strongest correlations between $\delta^{15}N$ and NO_x emissions within 300-400 mile radial areas of NADP sites, suggesting the source area for atmospheric deposition to this region is approximately 300-400 miles away.

- $\delta^{15}N$ values are lower in the summer than the winter. The seasonality is consistent across all sites.

The results of this national study are unprecedented in characterizing the spatial variability associated with the isotopic composition of precipitation nitrate. It is anticipated that isotopic tools will be a valuable asset for deciphering sources of atmospheric deposition in New York landscapes, as well as the fate of atmospheric N among multiple N sources in New York watersheds.

Supporting EMEP Project:
Quantifying Atmospheric Nitrogen Sources with New Stable Isotope Techniques, Kendall et al., No. 7609/8183

APPENDIX F

Program Communication Strategy

EMEP PROGRAM COMMUNICATION STRATEGY

Prepared in 2002 and updated periodically

EMEP targets three major audiences: the scientific community, policymaker, and the general public.

I. SCIENTIFIC COMMUNITY

Who is the Target Audience?: EMEP funds researchers active in the fields of environmental science, including geologists, chemists, meteorologists, ecologists, biologists; statisticians; health scientists; economists; and a variety of multidisciplinary scientists. Most of the scientists funded by EMEP work at institutions in New York State (refer to the EMEP fact sheet). We also seek to bring in a broader national perspective and reach out to scientists throughout the country as needed.

What are the Objectives of Our Communication Activities with the Scientific Community?:

- Provide a forum for the exchange of information on critical environmental topics in New York State. Bring together scientists active in key fields to help foster more collaborative research and make the most out of limited research dollars.
- Ensure that results from EMEP are used by the scientific community, so that we do not "reinvent the wheel."
- Ensure that EMEP produces information that is viewed as technically sound.

Current Communication Strategies:

- Work scope for each EMEP project requires a final technical report which can be distributed to other scientists.
- Work scope for each EMEP project requires that the Principal Investigator (PI) make data available electronically. This is a requirement before the PIs can receive final NYSERDA payment.
- Researchers publish findings in peer-reviewed journals and present project findings at technical conferences and at the EMEP conferences.
- EMEP uses a science advisory committee (comprised of nationally recognized experts in various disciplines) to periodically review projects to ensure that there is some buy-in from peers and to ensure that the research is credible.
- We've also pulled together Special Issue publications on key EMEP topics
- The EMEP web page contains project summaries as well as a list of analytes and site locations - keyed into a map, in addition to all final reports in PDF. The web site links to the PI's web-site, which will contain quality-checked data.
- List of EMEP journal articles is posted on our web page - to provide more detailed information for the scientific community.
- The EMEP page will not serve as a major data repository. It will point to available data sets required to be maintained by the Pis.

Other Approaches Under Development/Issues to Consider:

- We still need to resolve long-term data archiving.

II. Policy Makers and Policy Analysts

Who is the Target Audience?: State, National, and Regional policy makers and analysts involved in energy and environmental matters relating primarily to air emissions and the Clean Air Act. These include the Department of Environmental Conservation, Department of Health, Department of Public Service, key NYS legislative committees, the U.S. EPA, key U.S. legislative committees, Northeast States for Coordinated Air Use Management (NESCAUM), Midatlantic Regional Air Management Association (MARAMA), Association of State Air Pollution Control Officials. Other more cross-cutting topics such as nitrogen pollution touch many different legislative areas and related policy makers (e.g., farm bill, Clean Water Act, etc.). Also, resource managers such as Adirondack Park Agency may be the target for a few projects.

In general, we have tried to target the ***policy analyst*** in these key agencies/organizations, as opposed to elected officials or political appointees. Our assumption is that these policy makers will turn to their advisors/analysts for technical information.

What are the Objectives of Our Communication Activities with the Policy Community?:

- Provide credible technical information to inform the decision-making process, with the ultimate goal of helping to develop more effective, more equitable, and more economically efficient policies to benefit New York State.

Current Communication Strategies:

- Work scope for each EMEP project requires a comprehensive Executive summary written for a general audience. The summary is to be written in the tone of a "New York Times - Science Times" article. The summary is to underscore the policy implications of the research and provide charts, graphs, illustrations etc. When a topic is of broad interest, we may require that a stand-alone paper be written for the general public. [This is all in addition to the full technical/science report which is also required.]
- Researchers present project findings at the EMEP conferences, which are attended by many policy analysts at the State, National, and Regional level.
- Also at the EMEP conference we try to provide a few panels where the scientists can hear directly from policy makers/analysts as to their priorities and information needs.
- EMEP uses an active Program Advisory Group (PAG). This PAG has representatives from each of the key agencies (in the target audience above). The PAG is supposed to be representing the position of their agency and informing others in their agency on EMEP findings and directions.
- We also reach out extensively to Environmental Organizations (NGOs, public interest, etc) who are stakeholders in policy formulation in this arena. We have had several Environmental organizations on our PAG, and we meet with them at least annually to discuss programs and get feedback.
- We produce "translation papers" or "Special Communications" which integrate findings from one or more projects and present information to a more general audience, with a specific policy focus.
- We encourage and support "synthesis type projects" whereby the PIs use published

data/studies already available and try to interpret within a policy/modeling context.

- The improved web-page should help provide timely information to policy analysts.
- Project-fact sheets are produced for each EMEP project. Basic fact sheet information includes: the general environmental phenomenon (e.g. acid deposition, ozone, fine particulate), the focus of the specific research project and how it fits into the larger phenomenon, results or conclusions to date, picture of site or equipment, highlights of researcher/research team, links to PI's site, and other relevant sites.
- A biannual EMEP Newsletter is produced.
- An EMEP List server was developed.

Other Approaches Under Development/Issues to Consider:

- We need to continue to build a repore with *specific key policy contacts*, so that they come to EMEPs when they want information on a topic.
- We need to get each PI to identify specifically who is the audience of 10 or so people that need the information from their study.
- We need to continue to outline the policy timeline and upcoming policy decisions related to EMEP research topics so that we can be more pro-active.
- Despite a desire to communicate with policy makers, we still need to maintain our objectivity and avoid taking an "advocacy" position. This is a fine line.

III. General Public

Who is the Target Audience: Residents and Students in New York.

What are the Objectives of Our Communication Activities with the General Public:

- Provide a source of good environmental information as a service to residents in the State of New York (e.g., high-school, college students)
- Get some recognition for NYSERDA and NYS initiatives
- Increase the level of awareness of energy-environmental issues to result in a more informed and engaged community.

Current Communication Strategies:

- A few EMEP projects have received significant press/media coverage.
- The Web-site is the most public tool we have and as such should include not only the project fact sheets but basic summaries of the major areas of research being conducted by the EMEP program, and links to other sites (researcher, EPA, NESCAUM, NARSTO, DEC, ARB). In addition an introductory section on why NYSERDA is funding these projects and what the SBC is should be included. Also a glossary of terms and lots of visuals.
- We have also added some general information materials for teachers and students and linked to other useful sites.
- We have also sponsored videos for the general public (e.g., Mountain lake PBS Special on Mercury in Loons)

Issues to Consider:

- How much more than a good web site do we need for the general public?

IV. CROSSCUTTING

One of the goals of EMEP is to get scientists and policy makers together so that (1) policy makers have access to the latest technical information, (2) scientists get some more insight on the policy context of their research and can hopefully produce more policy relevant analyses.

Our conferences and occasional topical workshops, as well as annual program review meetings, help to accomplish this.

APPENDIX G

Peer-Reviewed Publications by Research Area

Publications Citation Analysis

Appendix G: Peer-Reviewed Publications, by Research Area

A. Air Quality and Related Health Research: Particulate Matter, Ozone and, Co-Pollutants

1999

Identifying pollution source regions using multiply-censored data. E. Brankov, S.T. Rao, and P.S. Porter. *Environmental Science & Technology* 33: 2273-2277, 1999.

The role of vertical mixing in the temporal evolution of ground-level ozone concentrations. J. Zhang and S.T. Rao. *Journal of Applied Meteorology* 38: 1674-1691, 1999.

Spatial and temporal variation in the mixing depth over the northeastern United States during the summer of 1995. S. Berman, J.-Y. Ku, and S.T. Rao. *Journal of Applied Meteorology* 38: 1661-1673, 1999.

2000

Airway and cardiovascular effects of inhaled ultrafine carbon particles in resting, healthy, nonsmoking adults. J.A. Boscia, D. Chalupa, M.J. Utell, W. Zareba, J.A. Konecki, P.E. Morrow, F.R. Gibb, G. Oberdörster, M. Azadniv, L.M. Frasier, D.M. Speers, and M.W. Frampton. *American Journal of Respiratory and Critical Care Medicine* 161: A239 (Abstract), 2000.

Characterizing PM 2.5 Emission Profiles for Stationary Sources: Comparison of Traditional and Dilution Sampling. G. England, B. Zielinska, and K. Loos. *Fuel Processing Technology* 65: 177-188, 2000.

Deposition of inhaled ultrafine carbon particles in resting healthy nonsmoking adults. M.W. Frampton, D. Chalupa, P.E. Morrow, F.R. Gibb, G. Oberdörster, J. Boscia, D.M. Speers, and M.J. Utell. *American Journal of Respiratory and Critical Care Medicine* 161: A257 (Abstract), 2000.

Development of a sample equilibration system for the TEOM continuous PM monitor. M.B. Meyer, H. Patashnick, J.L. Ambs, and E. Rupprecht. *Journal of the Air and Waste Mangement Association* 50: 1345-1349, 2000.

Effects of changes in data reporting practices on trend assessments. Henry, Rao, Zurbenko, and Porter. *Atmospheric Environment* 34: 2659-2662, 2000.

The effects of land use in meteorological modeling: implications for assessment of future air quality scenarios. Civerolo, Sistla, Rao, and Nowak. *Atmospheric Environment* 34: 1615-1621, 2000.

How should the photochemical modeling systems be used in guiding emissions management decisions? S.T. Rao, C. Hogrefe, H. Mao, J. Biswas, I. G. Zurbenko, P. S. Porter, P. Kasibhatla, and D. A. Hansen. In: *Air Pollution Modeling and Its Application XIV*, eds. S.E. Gryning and F. Schiermeier, pp. 25-34. New York: Kluwer Academic/Plenum, 2000.

Interpreting the information in ozone observations and model predictions relevant to regulatory policies in the eastern United States. C. Hogrefe, S.T. Rao, I.G. Zurbenko, and P.S. Porter. *Bulletin of the American Meteorological Society* 81: 2083-2106, 2000.

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Assessing the Impact of the Acid Deposition Control Program. K.L. Civerolo, E. Brankov, S.T. Rao, and I.G. Zurbenko. *Atmospheric Environment* 35: 4135-4148, 2001.

Blood leukocyte expression of LFA-1 and ICAM-1 after inhalation of ultrafine carbon particles. M.W. Frampton, M. Azadniv, D. Chalupa, P.E. Morrow, F.R. Gibb, G. Oberdörster, J. Boscia, and D.M. Speers. *American Journal of Respiratory and Critical Care Medicine* 163: A264 (Abstract), 2001.

A comparison of measured and simulated ozone concentrations in the rural areas of the eastern United States. G. Sistla, K. Civerolo, W. Hao, and S.T. Rao. *Journal of the Air and Waste Management Association* 51: 374-386, 2001.

Demonstrating Attainment of the Air Quality Standards: Integration of Observations and Model Predictions into the Probabilistic Framework. Hogrefe and Rao. *Journal of the Air & Waste Management Association* 51, 1060-1072, 2001.

Development of a reference standard for particulate matter mass in ambient air. H. Patashnick, G. Rupprecht, J.L. Ambs, and M.B. Meyer. *Aerosol Science and Technology* 34: 42-45, 2001.

Do We Understand Trends in Atmospheric Sulfur Species? Reid, Misra, Bloxam, Yap, Rao, Civerolo, Brankov, Mohapl, and Vet. *Journal of the Air & Waste Management Association* 51: 1561-1567, 2001.

Evaluating the performance of regional-scale photochemical modeling systems: Part I—Meteorological predictions. C. Hogrefe, S.T. Rao, R. Kasibhatla, G. Kallos, C.J. Tremback, W. Hao, D. Olerud, A. Xiu, J. McHenry, and K. Alapaty. *Atmopheric Environment* 35: 4159-4174, 2001.

Numerical Investigation of Boundary-Layer Evolution and Nocturnal Low-Level Jets: Local versus Non-Local PBL Schemes. Zhang, Mao, Civerolo, Berman, Ku,

Rao, Doddridge, Philbrick, and Clark. *Environmental Fluid Mechanics* 1: 171-208, 2001.

Numerical Investigation of the Effects of Boundary-Layer Evolution on the Predictions of Ozone and the Efficacy of Emission Control Options in the Northeastern United States. Ku, Mao, Zhang, Civerolo, Rao, Philbrick, Doddridge, and Clark. *Environmental Fluid Mechanics* 1: 209-233, 2001.

An operational evaluation of two regional-scale ozone air quality modeling systems over the eastern United States. G. Sistla, W. Hao, J.-Y. Ku, G. Kallos, K. Zhang, H. Mao, and S. T. Rao. *Bulletin of the American Meteorological Society* 82: 945-964, 2001.

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A facility for controlled human exposures to ultrafine particles. D.F. Chalupa, F.R. Gibb, P.E. Morrow, G. Oberdörster, E. Riesenfeld, R. Gelein, M.J. Utell, and M.W. Frampton. In: *Crucial Issues in Inhalation Research - Mechanistic. Clinical and Epidemiologic*, eds. U. Heinrich and U. Mohr, pp. 241-253. Stuttgart, Germany: INIS Monographs, Fraunhofer IRB Verlag, 2002.

An approach for the aggregation of aerodynamic surface parameters in calculating the turbulent fluxes over heterogeneous surfaces in atmospheric models. D.T. Mihailovic, S.T. Rao, C. Hogrefe, and R. Clark. *Environmental Fluid Mechanics* 2: 315-337, 2002.

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Deposition of ultrafine carbon particles in subjects with asthma. D.C. Chalupa, P.E. Morrow, B. Oberdörster, D. Speers, D. Daigle, M.J. Utell, and M.W. Frampton. *American Journal of Respiratory and Critical Care Medicine* 165: A829 (Abstract), 2002.

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Intercomparison and Evaluation of Four Semi-continuous PM-2.5 Sulfate Instruments. F. Drewnick, J. J. Schwab, O. Hogrefe, S. Peters, L. Husain, D. Diamond, R. Weber, and K. L. Demerjian. *Atmospheric Environment* 37: 3335-3350, 2003.

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PM source apportionment and health effects: 2. An investigation of intermethod variability in associations between source-apportioned fine particle mass and daily mortality in Washington, DC. K. Ito, W.F. Christensen, D.J. Eatough, R.C. Henry, E. Kim, F. Laden, R. Lall, T.V. Larson, L. Neas, P.K. Hopke, and G.D. Thurston. *Journal*

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PM source apportionment and health effects: 3. Investigation of intermethod variations in associations between estimated source contributions of $PM_{2.5}$ and daily mortality in Phoenix, AZ. T.F. Mar, K. Ito, J.Q. Koenig, T.V. Larson, D.J. Eatough, R.C. Henry, E. Kim, F. Laden, R. Lall, L. Neas, M. Stolzel, P. Paatero, P.K. Hopke, and G.D. Thurston. *Journal of Exposure Analysis and Environmental Epidemiology* 16: 311-320, 2006; advance online publication: November 2005.

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In Preparation

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Comparison of the space-time signatures of air quality data from different monitoring networks. E. Gego, C. Hogrefe, P. Porter, J. Irwin, and S.T. Rao. To be submitted to *Pure Applied Geophysics*. In preparation.

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In Review

Advances in Continuous Measurement Methods for PM-2.5 Mass: Part 1. Laboratory Studies of a 30C TEOM with Nafion Dryer and of a Self-correcting TEOM with Electrostatic Precipitator. J. Schwab, J. Ambs, O. Hogrefe, and K. Demerjian. Submitted to *Journal of the Air and Waste Management Association*, January 2003; reviewers comments received and revisions submitted December 2003.

Advances in Measurement Methods for PM-2.5 Mass: Part 2. Field Evaluations of the 30C TEOM Monitor with Nafion Dryer in Rural and Urban Locations, and Comparisons with 50C TEOM Monitor and FRM 24 Hour Integrated Filters. J. Schwab, J. Ambs, J. Spicer, D. Felton, and K. Demerjian. Submitted to *Journal of the Air and Waste Management Association*, January 2003; reviewers comments received and revisions submitted December 2003.

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Elemental Composition of PM2.5 Aerosols in Queens, New York: Evaluation of Sources of Fine- Particle Mass. V.A. Dutkiewicz, S. Qureshi, L. Husain, J. J. Schwab, and K. L. Demerjian. Submitted to Special Issue: *Atmospheric Environment*.

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Appendix G: EMEP Citations Analysis for 1999 to 2005

Program activities resulted in the publication of 138 papers. A citations analysis conducted by Thomson Scientific in 2006 found 98 papers in their citations database. The distribution of these papers by publication year is shown in Figure 1. These papers were cited in peer-reviewed journals 655 times between 1999 and 2005. The cumulative number of citations is shown in Figure 2.

Figure 1

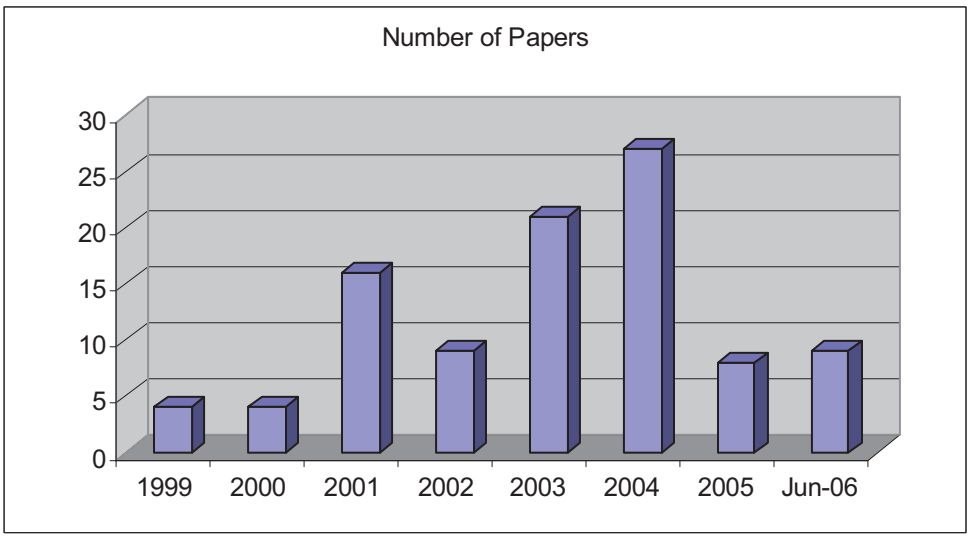

Figure 2

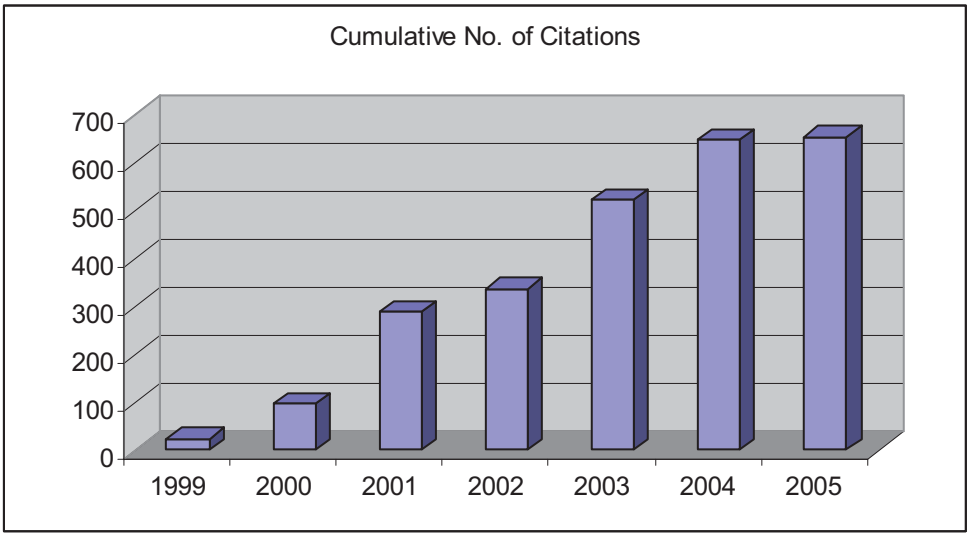

Table 1 presents the list of organizations represented in the 98 papers. Table 2 presents the list of journals and Table 3 lists the 14 countries represented.

Table 1. Organizations Represented in the 98 Papers

Acad Sinica	Meteorol Serv Canada	TAMS Consultants Inc
Aerodyne Res Inc	Mission Res Corp	TOFWERK AG
Aerosol Dynam Inc	N Carolina Supercomp Ctr	Tokyo Univ Agr & Technol
Alabama A&M Univ	New York State Adirondack Lakes Survey Corp	Univ Albany
Amer Petr Inst	New York State Dept Environm Conservat	Univ Athens
Arizona State Univ	New York State Dept Hlth	Univ Calif Berkeley
Boston Univ	NOAA	Univ Calif Los Angeles
Brigham Young Univ	Norwegian Meteorol Inst	Univ Colorado
Bur Air Qual Surveillance	NYS Dept Environm Conservat	Univ Florida
Bur Air Res	NYSDEC	Univ Helsinki
CESTM	NYU	Univ Idaho
Clarkson Univ	Ontario Minist Environm	Univ Louisville
Ctr Ecosyst	Oregon State Univ	Univ Maine
Ctr Environm Med & Lung Biol	Penn State Univ	Univ Manchester
Dept Chem & Biochem	Rupprecht & Patashinck Co Inc	Univ Maryland
Dept Environm Conservat	Rupprecht & Patashnick Co Inc	Univ N Carolina
Desert Res Inst	Seoul Natl Univ	Univ New Hampshire
Duke Univ	Shippensburg Univ	Univ Novi Sad
E&S Environm Chem Inc	Siena Coll	Univ Puerto Rico Rio Piedras
Exxon Res & Engn Co	SRKR Engn Coll	Univ Rochester
GE Energy & Environm Res Corp	State Univ New York	Univ So Calif
Georgia Inst Technol	SUNY Albany	Univ Toronto
GM Corp	SUNY Coll Buffalo	Univ Washington
GSF	SUNY Coll Cortland	US EPA
Harvard Univ	SUNY Coll Environm Sci & Forestry	US EPA
Hokkaido Univ	SUNY Coll Fredonia	US Forest Serv
Hubbard Brook Res Fdn	SUNY Coll Oneonta	US Geol Survey
Inst Ecosyst Studies	SUNY Coll Oswego	USDA Forest Serv
Kinki Univ	SUNY ESF	W Virginia Univ
Kyoto Univ	SUNY Syracuse	
Max Planck Inst Chem	Syracuse Univ	

Table 2. List of Journals Where Papers Appeared

Journal	Papers	No. of Citations
ATMOS ENVIRON	23	137
J AIR WASTE MANAGE	9	32
J GEOPHYS RES-ATMOS	8	11
AEROSOL SCI TECH	7	82
ENVIRON SCI TECHNOL	7	62
HYDROL PROCESS	6	26
ENVIRON POLLUT	5	26
WATER AIR SOIL POLL	4	23
J APPL METEOROL	3	51
B AM METEOROL SOC	2	47
INHAL TOXICOL	2	39
PURE APPL GEOPHYS	2	4
ENVIRON HEALTH PERSP	1	25
BIOSCIENCE	1	21
OECOLOGIA	1	16
ECOL APPL	1	13
BIOGEOCHEMISTRY	1	11
GLOBAL CHANGE BIOL	1	9
FUEL PROCESS TECHNOL	1	5
WATER RESOUR RES	1	5
FRONT ECOL ENVIRON	1	4
GEOPHYS RES LETT	1	4
J AEROSOL SCI	1	1
J ENVIRON QUAL	1	1
16TH CONFERENCE ON PROBABILITY AND STATISTICS IN THE ATMOSPHERIC SCIENCES	1	0
ENVIRON EXP BOT	1	0
ENVIRON FLUID MECH	1	0
ENVIRON MODELL SOFTW	1	0
FOURTH CONFERENCE ON ATMOSPHERIC CHEMISTRY: URBAN, REGIONAL AND GLOBAL SCALE IMPACTS OF AIR POLLUTANTS	1	0
J CHEM PHYS	1	0
J EXPO SCI ENV EPID	1	0
WETLANDS	1	0

Table 3. Countries Represented

Country	No. of Papers	No. of Citations
USA	98	655
Greece	2	46
Germany	4	24
England	1	23
Taiwan	1	11
Canada	2	5
South Korea	2	5
Japan	1	4
India	1	2
Switzerland	1	1
Finland	1	0
Norway	1	0
Yugoslavia	2	0

The papers were also assessed to determine the degree of impact measured as the expected number of citations divided by the actual number of citations. The expected number is the average number of citations for an article published in a particular journal. Across all articles, the ratio was 1.3 indicating that the papers were cited more than expected. Table 4 shows the papers with the highest impact ratios.

Table 4. Papers with the Highest Impact Ratio (Expected No. of Citations Versus Actual No. of Citations)

No. of Citations	Expected No. of Citations	Impact Ratio	Author	Journal	YR	Title
23	2.8	8.2	Canagaratna, MR	AEROSOL SCI TECH	2004	Chase studies of particulate emissions from in-use New York City vehicles
27	3.6	7.5	Daigle, CC	INHAL TOXICOL	2003	Ultrafine particle deposition in humans during rest and exercise
18	2.8	6.4	Drewnick, F	AEROSOL SCI TECH	2004	Measurement of ambient aerosol composition during the PMTACS-NY 2001 using an aerosol mass spectrometer. Part I: Mass concentrations
2	0.4	5.6	Chang, MCO	J AIR WASTE MANAGE	2004	Measurement of ultrafine particle size distributions from coal-, oil-, and gas-fired stationary combustion sources
5	1.0	4.8	Hogrefe, O	J AIR WASTE MANAGE	2004	Semicontinuous PM2.5 sulfate and nitrate measurements at an urban and a rural location in New York: PMTACS-NY summer 2001 and 2002 campaigns
13	2.8	4.6	Drewnick, F	AEROSOL SCI TECH	2004	Measurement of ambient aerosol composition during the PMTACS-NY 2001 using an aerosol mass spectrometer. Part II: Chemically speciated mass distributions
13	2.9	4.5	Bischoff, JM	WATER AIR SOIL POLL	2001	N storage and cycling in vegetation of a forested wetland: Implications for watershed N processing
10	2.8	3.6	Kim, E	J GEOPHYS RES-ATMOS	2004	Improving source identification of fine particles in a rural northeastern US area utilizing temperature-resolved carbon fractions
18	5.1	3.5	Ren, XR	ATMOS ENVIRON	2003	OH and HO2 chemistry in the urban atmosphere of New York City
12	3.6	3.4	Utell, MJ	INHAL TOXICOL	2002	Cardiovascular effects associated with air pollution: Potential mechanisms and methods of testing

APPENDIX H

Previous Evaluation of EMEP Instrument Development Projects

Appendix H: Previous Evaluation of EMEP Instrument Development Projects

The Section below is an excerpt from the **New York Energy $mart Program Evaluation and Status Report, Final Report, May 2005, Chapter 8 Research and Development Program Area.**

Continuous Ambient Particulate Monitor Development and Innovative Instrument for Ambient Air Particles Projects

NYSERDA's Environmental Monitoring, Evaluation, and Protection Program (EMEP) has recently supported two product developments to improve continuous monitoring of fine particulate matter (PM) mass in ambient air—the air that people breathe. These products are based on the use of the Tapered Element Oscillating Microbalance (TEOM®) inertial mass measurement method. The two goals of these efforts were (1) to increase correlation with measurements made using the Federal Reference Method (FRM), a 24-hour filter-based method; and (2) to develop a continuous measurement system that more closely represents the mass of fine particles found in ambient air, rather than that found following the techniques described in the FRM.

To achieve the first goal, a sample equilibration system (SES) was developed to reduce the moisture content of the sampled ambient air stream so that the temperature of the TEOM filter could be reduced from 50°C to 30°C, which is closer to the typical ambient collection temperature of the FRM. The lower temperature also reduces the loss of semivolatile components of PM mass. Performance of the SES-TEOM was assessed both under controlled laboratory conditions and in a year-long side-by-side field test by Atmospheric Sciences Research Center (ASRC) of the State University of New York at Albany.

To achieve the second goal, a new measurement concept—the Differential TEOM Mass Monitoring System, or Differential TEOM—was developed and tested. In this system, sharing SES components, an electrostatic precipitator (ESP) is inserted between the sample inlet and the TEOM mass sensor, operated at 30°C, but theoretically at ambient temperature. The ESP is regularly cycled on and off to selectively remove particles from the sample stream. The sampled ambient air stream first passes through a size-selective inlet that allows small particles to enter the monitoring system. Mass measurements made with the ESP on (when particles are trapped before reaching the sample filter-mass sensor), are subtracted from those made with the ESP off (when particles are collected on the filtermass sensor) to track gain or loss of semivolatile materials on the filter, providing a more detailed time-series record of PM mass.

The performance of the Differential TEOM was assessed at several research institutions through subcontracts and cooperative agreements:

- University of Duisburg, Germany, which used laboratory-generated aerosols to assess the effect of the SES dryer on particle measurement.

- Clarkson University, which, using a similar approach, assessed the efficiency of the ESP and its effect on particle measurement.
- University at Albany Institute of Materials, which focused on the ESP electrode performance relating to material buildup, wear, and cleaning methods.
- Atmospheric Sciences Research Center of the State University of New York at Albany, which conducted: (1) controlled laboratory aerosol testing using a variety of aerosols; (2) and ambient field measurements with the Differential TEOM, other co-located monitoring systems, and FRM PM samplers.

The Differential TEOM was deployed in Albany and Queens (New York City), as well as Claremont and Rubidoux in California. The devices were shown to have the potential to provide real-time fine particle mass data that can be used to improve the quality of health effect studies and verify the impact of state implementation plans for controlling PM, as well as to reduce monitoring costs.

These projects resulted in two major advances in real-time monitoring of fine particles. These include reducing the moisture content of the sampled ambient air so that the temperature of the device could be reduced from 50°C to 30°C, and developing an innovative approach to account for the loss of semivolatile materials on the filter surface. The devices have the potential to provide highly time resolved and accurate fine particle mass data that can be used to improve health effects studies, verify the impact of state implementation for controlling PM2.5, as well as to reduce monitoring costs.
As follow-on work to the Differential TEOM development, based on use of an ESP, the Filter Dynamics Measurement System (FDMS) was developed using a chilled-filter as a filter-based version of the Differential TEOM monitor. The FDMS is designed for agencies that need a routine monitoring network. The new Series 8500 FDMS has been approved by the Air Resources Board of California for both PM10 and PM2.5 sampling. The outlook for increasing use of this technology appears to be excellent. Sales of the SES and the FDMS (introduced in 2000 and 2002, respectively) are approaching multimillion-dollar levels as anticipated to arise over the product's life cycle. There is growing indication that the FDMS may become an accepted method by EPA for regulating ambient monitoring.

The following is a partial list of additional accomplishments that were achieved through the project:

- Three patents were granted to Rupprecht and Patashnick (R&P), the primary contractor
- More than a dozen documents were created and distributed to share the project results with key industry and government stakeholders
- The results were also shared at several conferences and workshops
- A successful business model was created for R&P

The following realized and potential economic and environmental benefits are attributable to this project:

*Realized Economic Benefit*s

- With earlier NYSERDA support for a carbon-in-ash stack monitor in 1981, R&P has grown from 5 people in 1981to more than a 100 employees in 2004 specializing in developing, manufacturing, and selling particulate mass measurement instruments.
- All manufacturing of the SES and FDMS products is carried out in NYS. As with most private corporations the specific dollars in labor income is proprietary information. However it can be stated that because of the SES and FDMS projects more sustained labor was necessary to meet the volume of production needs for these two commercial products while keeping up with production of other standard products. All of this production is performed currently in our East Greenbush, New York facility. Since production forecasts vary from month to month one cannot earmark the number of production units and support employees for these specific products.
- Approaching multimillion dollars in sales of SES-TEOM and FDMS monitors after 5 years in the market.

Potential Economic Benefits

- The potential economic benefit from these two commercial products can be estimated in multimillions of dollars over the anticipated production life cycle. The labor to support this sales level is commensurate, but the specific relationship cannot be provided.

Realized Environmental and Health Benefits

- The TEOM accurately provides greater time-series resolution of ambient data than the FRM. (non-quantifiable benefit)

Potential Environmental and Health Benefits

- Recent studies have shown that acute exposure to PM2.5 can cause more significant adverse health effects compared to chronic exposure, which underscores the importance of real-time measurement. The real-time measurement provided by the FDMS-TEOM could therefore be extremely valuable in assessing the impact of policies and regulations (should they be developed) on mitigating these exposures.